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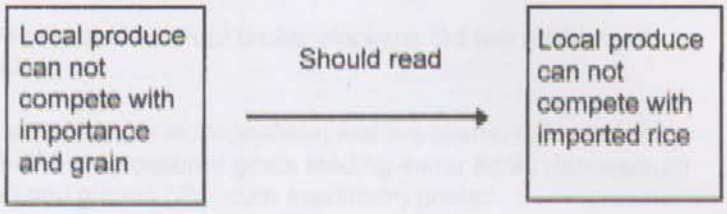
***Figure 1.* PROBLEM ANALYSIS**



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CONTENTS

PERFORMANCE AND ECONOMIC EVALUATION OF BROILER CHICKENS FED TWO CULTIVARS OF CASSAVA

Asifo O Ajuyah[1] and Mareko Tofinga

ABSTRACT

Two hundred and seventy broiler chickens were fed a sorghum-soybean meal control diet and two cassavas–soybean meal based test diets separately. The two cassava cultivars were the local white (LWCC) and local yellow (LYCC) cultivars. At weekly intervals and at slaughter age physical traits and economic performances of the birds were measured. Birds' fed the sorghum-soybean meal control diet performed better than the groups fed the two cassava cultivar based diets for live weight, feed conversion and weight gain. There were no significant differences between both cassava cultivars for the traits measured. Similarly, differences in chemical composition between the local white and local yellow cassava cultivars had no effect on all the production traits. However, taking into account the yield potentials of both cassava cultivars per hectare it can be calculated that the white cultivar would supply the feed requirements for 52% more broiler chickens than the yellow cultivar. The complete replacement of sorghum with either cassava cultivar did not impair broiler performance in terms of livability and feed intake. This observation is of significance to broiler producers involved in the production of their feed, and also as a marketing strategy for cassava farmers.

Key words: *Cassava, broiler chickens, physical and economic performances*

INTRODUCTION

In commercial broiler production feed constitutes approximately 60 to 80% the cost of producing broiler chicken meat. A major component of this cost (40 to 60%) is the energy-supplying ingredient of the feed. In developed countries such as USA, Canada, Australia and New Zealand, traditionally cereal grains (maize, wheat, barley or sorghum) supply the energy component of the chicken feed, as a result of which most local feed millers and animal nutritionists in the South Pacific region tend to formulate poultry feed using mostly imported cereal grains from as far as Canada and USA. However, a local feed energy substitute for imported cereal grains in the diet of broiler chickens in the region is cassava (*Manihot esculenta*). Cassava, or tapioca, is high in gross energy and is an important staple food in Fiji and also an alternative to taro, sweet potato, yam and plantain in Samoa, Tonga and the Cook Islands (FAO 1991).

Apart from its high water content, low and poor quality protein content, some of the major constraints in the use of cassava as poultry feed include, a long production cycle (9 to 18 months), hydrogen cyanide content and limited storage of the fresh tuber (4 to 5 days). This is in-addition to problems of drying at high humidity with constant rainfall. Research studies conducted in the South Pacific region have shown that raw, dried cassava flour supplemented with high quality protein rich in methionine, and fortified with adequate amount of minerals and vitamins, could replace up to 40% of maize, or up to half the cereal grains in a typical broiler diet. Ochetim (1987) observed no adverse effects on physical performance (weight gain and feed consumption), carcass yield and dressing percentage in his studies when 40% of dried-ground cassava was replaced with maize. However, Naidu (1988) reported that with 70% water content, cassava as an energy feed source for poultry on a dry matter basis is more expensive (F$0.54) than imported maize (F$0.27) for Fiji feed millers, even without any further processing. Recently, at the University of the South Pacific, School of Agriculture, Samoa, results from cassava evaluation trials have indicated significant differences in the yield, protein and water content of two local cultivars (Tofinga 1995; Hazelman 1997).

In this study, the physical performances of broiler chickens and the economics of producing broiler chicken meat were evaluated when 100% of imported sorghum was replaced by two cultivars (local white and local yellow) of cassava with different yield and chemical composition.

MATERIALS AND METHODS

Three hundred (300) day-old straight-run (mixed sex) Cobb broiler chicks were obtained from a hatchery

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in New Zealand. Thirty (30) chicks were randomly distributed into each of nine pens containing wood shavings as litter, two tube feeders and one automatic watering device. Three pens were placed on each of the following experimental diets:

- diet 1, ground sorghum-soybean meal as the control diet;
- diet 2, ground local white cassava cultivar-soybean meal based diet, and
- diet 3, ground local yellow cassava cultivar-soybean meal based diet (Table 1).

The two cultivars of cassava were obtained from the University plot of Dr. M. Tofinga and some selected local farmers. Fresh cassava tubers were cut into chips using a bush knife, dried by solar drying for 2 to 3 days and ground into fine powder with dry matter content of about 90.0%. The chemical composition and yield of the two cassava cultivars are shown in Figure 1 and Table 1. Crude protein analysis was based on spectrophotometric technique after digestion using the digesdahl apparatus (Hite 1996). Approximately 0.25 grams of ground dried cassava sample was weighed into a digestion flask, and 4.0 ml of concentrated sulfuric acid added. Digestion was facilitated at 440°C for 4 minutes, followed by the addition of 10-ml hydrogen peroxide. The digestate was allowed to cool and distilled water added to the 100-ml mark. The absorbance of a 1.0 ml aliquot containing 5 ml polyvinyl alcohol and 1.0 ml Nessler reagent was determined at 425 nm against a blank containing 1.0 ml of distilled water, 5 ml of polyvinyl alcohol and 1.0 ml of Nessler reagent. Percent crude protein in the cassava was calculated from a regression equation ($y = -1.31 + 28.4x$, where y = percent crude protein and x = absorbance.) obtained from primary standard set for Kjeldahl nitrogen as described by Hite (1996).

The diets were formulated to contain similar amounts of metabolisable energy (isocaloric), that is 3159 and 3082 Kcal/kg, respectively, by the inclusion of 7% animal tallow (Table 1). However, it was not possible to formulate an iso-nitrogenous diet because of the low levels of protein in cassava compared to sorghum, 3% and 8.9% respectively. The three diets were mixed using a cement mixer and diet preparation was done on a weekly basis. The experimental diets and water were provided for *ad libitum* consumption. The lighting program during the first three weeks of the experiment was continuous (24 light: 0 dark) and, thereafter, until slaughter natural daylight (14 light: 10 dark). Throughout the duration of the experiment the following records were kept on per pen basis, weekly feed intake, liveweight and daily mortality. The weights of all dead birds were recorded prior to post-mortem analysis and disposal. At 6 weeks of age, 5 birds per pen or 15 birds per treatment were randomly selected, slaughtered, processed and eviscerated according to standard commercial procedures (Ajuyah et al. 1991).

Table 1. Ingredient Composition of Broiler Diets (g/kg)

INGREDIENTS	Control	Cassava (whiteor yellow Cultivar)
Ground Sorghum	536	-
Ground Cassava	-	536
Soybean meal	330	330
Fish meal	20	20
Animal tallow	70	70
DiCal Phosphate	20	20
Limestone	10	10
[1]Broiler premix	5	5
Salt	3	3
Lysine	3	3
DL-Methionine	2	2
Calculated Analysis		
Energy ME, kcal/kg	3159	3082
Dry Matter (%)	90.05	90.59
Crude Protein (%)	20.1	17.0
Calcium (%)	0.98	1.14
Total Phosphorus (%)	0.77	0.65
Lysine (%)	1.45	1.36
Methionine& Cystine(%)	0.90	0.70

Economic evaluation of the treatments was based on the cost of feed per kilogram liveweight and yield of cassava per hectare.

The data were analyzed using one-way analysis of variance, and the estimate of error variation was pens within treatment (Steel and Torrie 1980). Significant differences between treatment means were tested using Least Significance Difference (LSD) at 5% probability level ($P<0.05$). Computation was done using the Pacific Regional Agricultural Biometrics Service.

RESULTS AND DISCUSSION

The economic feasibility of using cassava as the major source of energy in diets for broiler chickens depends on the cost of traditional energy ingredients such as maize and sorghum. In most cases it is usually cheaper to import maize for use in poultry feed as opposed to the use of locally grown cassava. However, there are different cultivars of cassava with different yield potentials (Table 3) and chemical composition (Figure 1). The data on weekly performance traits for the broiler chickens are presented in Table 2. The complete replacement of sorghum with either cassava cultivar had no significant effect on feed intake. It could be inferred that the linamarin and lotaustralin content (precursors of hydrogen cyanide) of the sun-dried cassava cultivars did not seem to interfere with feed consumption. The range of hydrogen cyanide in sweet cassava cultivars in Samoa has been shown to be within safe limits for the inclusion of 40-60% raw dried ground cassava flour in livestock feed (Udo *et al.* 1980). To reduce the level of hydrogen cyanide in raw cassava the following processing options have been recommended; maceration, soaking or fermentation, boiling, sun drying, roasting and dehydration. This is in-addition to adequate level of sulpur containing amino acids in the cassava-based diets that may be involved in the detoxification of free hydrogen cyanide. In contrast liveweight, weight gain and feed conversion ratio were significantly depressed amongst the groups of birds fed the cassava-based diets. This might be as a result of differences in dietary protein between the control (20.1% CP) and cassava based diets (17% CP). In previous studies Udo *et al.* (1980) and Ochetim (1986) attributed poor performance of birds to the low protein, vitamin and mineral contents and lack of sulfur-containing amino acids such as methionine in cassava based diets. Although there were slight differences between the two cultivars of cassava for protein and dry matter content (Figure 1), these differences were not reflected in the production traits measured (Table 2) to 42 days of age. However, at 35 - 42 days of age the group of birds fed the local white cultivar had significantly higher weight gain than the group fed the yellow cassava cultivar based diet. This difference could be attributed to slightly higher feed intake by the group fed the local white cultivar based diet.

The percent mortality from week 1 to slaughter (6 weeks) was 4, 6 and 5 for the control, white cultivar and yellow cultivar fed group respectively. The two major causes of death were sudden death syndrome and starvation of runts. The highest mortality for the cassava based diets were recorded on day 35, which might explain the reduced feed intake compared to

Figure 1. **Chemical composition (g/kg) of dietary cassava cultivars - the local white cassava cultivar (LWCC) and local yellow cassava the local white cassava cultivar (LYCC).**

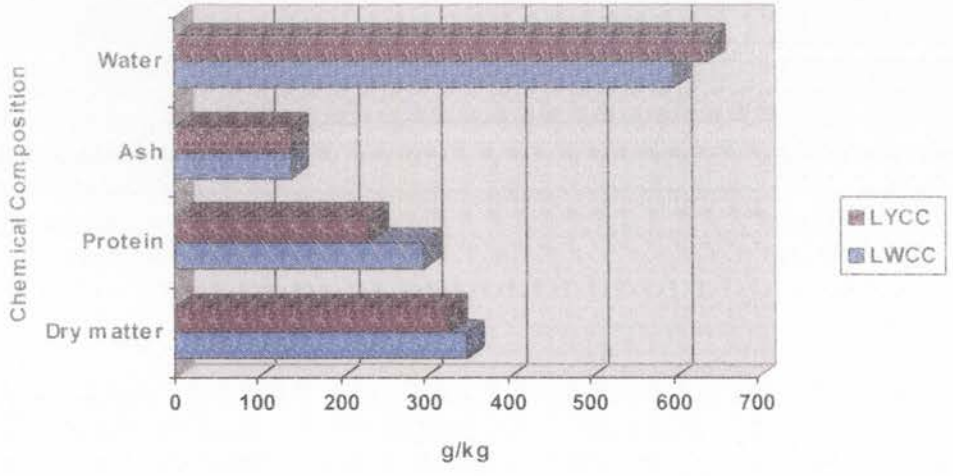

Table 2. **Weekly Performances of Broiler Chickens Fed the Test Diets**

[1]Diets	7	14	21	28	35	42
				Age in Days		
				Live Weight (g/bird)		
Control	147[a]	329[a]	665[a]	1046	1521[a]	2031[a]
LWCC	140[b]	295[b]	595[b]	974	1261[b]	1723[b]
LYCC	140[b]	291[b]	596[b]	965	1249[b]	1673[b]
SEM	1.5	6.7	12.4	16.6	46.9	58.1
				Feed Intake (g/bird/week)		
Control	136	274	589	731	990	1233
LWCC	130	267	568	852	753	1398
LYCC	129	265	602	851	751	1340
SEM	1.4	6.3	10.9	28.7	50.0	35.0
				Weight gain (g/bird/week)		
Control	107[a]	182[a]	336[a]	382	474[a]	511[a]
LWCC	100[b]	155[b]	300[b]	379	287[b]	463[b]
LYCC	100[b]	151[b]	305[b]	369	284[b]	424[c]
SEM	1.5	5.6	6.7	10.5	32.8	13.7
				Feed Conversion Ratio		
Control	1.3	1.5[b]	1.8[b]	1.9[b]	2.1[b]	2.4[b]
LWCC	1.3	1.7[a]	1.9[ab]	2.2[a]	2.6[a]	3.0[a]
LYCC	1.3	1.7[a]	2.0[a]	2.3[a]	2.6[a]	3.2[a]
SEM	0.0	0.0	0.0	0.1	0.1	0.1

[a-c] Means within a column with no common superscripts are significantly different (P<.05)
[1] LWCC = Local White Cassava Cultivar; LYCC = Local Yellow Cassava Cultivar.

day 28.

The economic feasibility of total replacement of sorghum with cassava is shown in Table 3. Although feed cost per bird was higher for the control group compared to birds on the cassava-based diets, cost per kilogram liveweight was cheapest for the control group. For the small-scale broiler farmer in the South Pacific region with 50 to 500 birds the difference between the white and yellow cultivars is of little significance. However, for a farmer that intends to plant his energy feed ingredient, the local yellow cultivar has the best potentials as a local feed resource. For example in terms of available feed resource, birds per hectare are approximately 4000 and 6000 for the white and yellow cassava based cultivars respectively. This is because with 33 and 35% dry matter content, the dry matter yield per hectare will be 13.2 and 8.75 tons for the yellow and white cultivar respectively. Fernando and Tofinga (1986), suggested that maize production on a large scale should be encouraged to meet current feed crisis in the region. However, Ainu'u (1986) reported that most countries in the region lack the capacity to produce maize solely as livestock feed. Instead, it was suggested that cassava, which is well adapted to many countries in the region, should be mass-produced.

[1]Broiler premix supplied the following nutrients per kilogram of diet. Vitamin A 1500IU, vitamin D 200ICU, vitamin E 10IU, vitamin K 0.5mg, riboflavin 3.6mg, pantothenic acid 10mg, niacin 27mg, vitamin B_{12} 0.009 mg, choline 1300mg, biotin 0.15mg, folacin 0.55mg, thiamin 1.8mg, pyridoxine 3.0mg, magnesium 600mg, manganese 60mg, zinc 40mg, iron 80mg, copper 8.0mg, iodine, 0.35mg and selenium. 0.15mg

Table 3. **Production Traits and Economics of Production of Broiler Chickens Prior to Slaughter.**

[1]Production traits	Control	LWCC	LYCC
Live weight (kg)	2.0[a]	1.6[b]	1.6[b]
Carcass wt. (kg)	1.3	1.0	1.0
Dressing (%)	64.7	64.7	65.4
Economics of Production			
Total feed intake (g)	3953	3968	3938
Cassava intake (g)	-	2127	2111
Feed cost $/kg DM	1.93	1.88	1.91
Feed cost $/bird	7.63	7.46	7.52
Cost of chick	2.50	2.50	2.50
Broiler cost at 6 wk.	10.13	9.96	10.02
Cost/kg live wt.	5.07	6.23	6.26
Yield/Hectare (tons)	-	25	40
DM/hectare (tons)	-	8.75	13.2
Fresh Wt. Cost/kg Cassava	-	$0.30	$0.30
Cost/kg Dry matter	-	$0.86	$0.91
[2]Number of Broilers per hectare	-	4114	6253

[a,b]Means within a row with no common superscripts are significantly different (P< 05).
[1]Production traits based on 15 birds per treatment
[2]Number of broilers per hectare based on total cassava yield (kg) /cassava intake (g) per bird.
LWCC = Local White Cassava Cultivar; LYCC = Local Yellow Cassava Cultivar
Cost based on Samoan tala 1 T$ = 0.288 US$

In summary, birds fed the sorghum-soybean meal control diet performed better than the groups fed either cassava cultivar. There were no differences to 42 days of age between the cassava fed group for all the traits measured. However, the economics of producing broiler meat could be affected by cassava yield per hectare, with high yielding cultivars reducing feed cost per unit area. This observation is of significance to broiler producers involved in the production of their feed and also as marketing strategy for cassava farmers in the region. In addition satisfactory performance traits were maintained when cassava completely replaced sorghum.

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We wish to express sincere gratitude to Mr. Steve Hazelman for the supply of data on cassava yield in Samoa, and Mr. David Hunter for statistical analysis. Also Miss Dorcas Olori, Miss May Pitakere and Mr. Uga Luaupu for care of the birds. The University of the South Pacific Research Committee provided financial support for this research.

REFERENCES

AJUYAH, A. O., LEE, K. H., HARDING, R. T., and SIM, J. S. (1991). ChangeS in the yield and in the fatty acid composition of whole carcass, and selected meat portions of broiler chickens fed full-fat oil seeds. Poultry Science 70:2304-2314.

AINU'U, H. I. (1986). The livestock industry in Western Samoa: Problems and prospects. Alafua Agric. Bull. 11:51-58.

FAO. (1991). Development of animal feed based on locally available ingredients in the South Pacific Region. RAPA Publication, 1991/13 pp.18.

FERNANDO, L. H., and TOFINGA M. P. (1986). Production of cereal grains and pulses as components of livestock feed. Alafua Agric. Bull. 11:39-44.

HAZELMAN, S. (1997). Cassava Evaluation: A trial program linking farmers, extensionists and researchers. Pacific Regional Agricultural Program; Project 1 farming systems in low lands. Published by USP/SOA

HITE, R. 1996. Chemical evaluation of local feed ingredients for pig and poultry production in Solomon Islands. AG:383 Student Research Project. The University of the South Pacific, School of Agriculture, Alafua campus, Samoa.

NAIDU, R. K. 1988. Status of the livestock industry in the South Pacific. In Proceedings: Using local feed resources for pigs and poultry. Sept. 5-9, 1988 at Fiji College of Agriculture Koronivia, Fiji.

OCHETIM, S. 1987. Efficacy of some alternative energy sources to maize in diets of broiler chickens in the South Pacific Region. Alafua Agric. Bull. 12:13-17.

OCHETIM, S. 1986. Nutritional and economic evaluation of substitute feeds for maize and soybean meal for growing pigs. Fiji Agric. J. 48:8-11.

UDO, H., FOULDS, J., and TAUOU A. 1980. Comparison of cassava and maize in commercially formulated poultry diets for Western Samoa. Alafua Agric. Bull. 5:18-26.

TOFINGA, M. 1995. Personal communication. Steel, R. G. D., and Torrie, J. H. 1980. Principles and procedures of statistics. Biometrical approach. 2nd edition. McGraw-Hill Book Company, New York, NY.

EFFECT OF FRESH LEUCAENA(*LEUCAENA LEUCOCAPHALA*) LEAF SUPPLEMENTATION ON THE GROWTH OF YOUNG ANGLO-NUBIAN CROSSBRED GOATS FEEDING EITHER BATIKI (*ISCHAEMUM ARISTATUM* VAR. *INDICUM*) AND GUINEA GRASS (*PANICUM MAXIMUM*)

Eroarome M. Aregheore[1] and Yahaya, M.S.[2]

ABSTRACT

A feeding trial was conducted at the University of the South Pacific, School of Agriculture in Samoa, to investigate the effect of leucaena fresh leaf supplementation on the growth of 7 – 9 months old Anglo-Nubian x Local Fiji goats stall fed with either batiki or guinea grass as basal diet. Leucaena leaves were supplemented at 0, 10, 30 and 50 % levels of the total daily forage allowances. 16 goats were divided into two groups of 8 each. Each group was further divided into 4 sub groups of two each while receiving the respective diets. The experimental design was a change-over with two feeding periods, each of 24 days separated by 7-day adaptation period. The parameters measured were voluntary feed intake and apparent nutrient digestibility and estimates of live weight changes. CP content of the two grass diets increased linearly with increase in the level of leucaena in the diet, which ranged from 5.3 -18.2 % for batiki and 7-19.1 % for guinea. DMI of grass only diets were significantly (P<0.05) lower than those supplemented with leucaena leaves, but there was no significant (P>0.05) difference between levels of supplementation. DM, CP and OM digestibilities improved with increasing levels of leucaena. LWG of goats without leucaena was significantly lower (P<0.05). Batiki at 10 % level of leucaena supplementation was significantly (P<0.05) lower than the two higher levels but in the case of guinea grass there was no significant (P>0.05) difference between levels of leucaena supplementation. At the same level of leucaena supplementation guinea grass consistently gave significantly (P<0.05) higher LWG. Maximum growth was attained at 30 % leucaena supplementation for batiki, while for guinea grass it was at 10 % level.

Keywords: *Leucaena, batiki, guinea grass, goats, DMI, growth, digestibility*

INTRODUCTION

In most Pacific Island countries (PICs) natural or unimproved pasture is the main source of feed for grazing ruminant livestock. The importance of natural pasture for ruminant livestock production in the tropics has been stressed by several researchers, (Olubajo and Oyenuga 1971; t'Mannetje 1978; Reynolds 1978; Gutteridge and Whiteman 1978; Adjei 1995; Aregheore 2001a). Batiki grass (*Ischaemum aristatum* var. *indicum*) which was introduced into Samoa from Fiji initially to compliment existing natural or unimproved pastures has now become the most commonly propagated pasture grass for ruminant livestock. However, other grass species such as guinea grass, (*Panicum maximum*) signal grass (*Brachiaria decumbens*) and elephant grass (*Pennisetum purpureum*) are also used. In Samoa, guinea and signal grass rank second and third in terms of availability of grass species for ruminant livestock grazing. In most cases they are used in zero grazing through the cut-and-carry system.

In the tropics, growth and performance of ruminant livestock are largely limited by forage quality, which results in low voluntary intake and digestibility (Minson 1971; Humphreys 1987; Aregheore 2001b). Adu and Adamu (1982) reported that the low productivity of ruminant animals in the tropics is a reflection of poor yields and low quality of natural grasslands. Season and species of grass have been observed to influence the nutritive value which in turn affects voluntary intake and digestibility of the herbage, (Aregheore 2001a,b).

Leaves, shoots and twigs of browse plants are cheap protein sources that can help to overcome the nutritional deficiencies of low quality feeds (roughage). Leaves from browse and fodder trees form major parts of livestock feed in many tropical countries (Woods *et al.* 1994; Mandal 1997) and play an important role in improving dietary protein (Kaitho *et al.* 1998).

Many indigenous and introduced browse species are found in Samoa, which include *Erythrina* spp.,

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Calliandra calothyrsus; *Gliricidia sepium*, *Sesbania grandiflora*, *Leucaena leucocephala* and *Spondias mombin*. Among these *Gliricidia sepium* and *Leucaena leucocephala* are widely used by smallholder farmers. It has been observed however, that animals take some time in accepting *Gliricidia sepium*, compared to *Leucaena leucocephala* which is often accepted immediately (Abdulrazak *et al.* 1996); Smith *et al.* 1995; Aregheore *et al.* 2001c). Based on this rejection factor most farmers prefer to supplement their grazing animals with *Leucaena leucocephala*. The objective of this trial, was to investigate the effect of *Leucaena* as a protein supplement, fed either with batiki grass or guinea grass based diet at 0, 10, 30 and 50 % levels, on performance of goats fed in the tropical environment of Samoa.

MATERIALS AND METHODS

Site

The experiment was conducted at the Goat Unit, School of Agriculture, The University of the South Pacific, Alafua Campus, Samoa (Latitude ~13.5° S, Longitude ~172.5° W).

Animals, Experimental procedure and design

Sixteen growing goats (Anglo-Nubian x Local Fiji) were used to measure voluntary feed intake, apparent nutrient digestibility, and growth rate and weight gain. The goats were 7-9 months old with the mean weight of 9.5 ± 0.42 kg. The goats were divided into two groups of eight animals each and each group was further sub-divided into four sub-groups of two goats per diet. Each group represented either batiki grass or guinea grass while the sub-groups differ in treatments. The design of the experiment was a change-over with two periods, each of 24 days in length, separated by a 7-day adaptation period (Gill and Magee, 1976). The treatment groups were balanced for body weight gain and age.

The goats were drenched with an anthelminthic (Albendazole) at the start of the experiment at a rate of 1 ml/10 kg bodyweight. All the goats were allowed access to mineral blocks and ample drinking water. The mineral/vitamin block contained salt (NaCl), 120 g/kg calcium, 60 g/kg phosphorus, 60 g/kg manganese, 150 mg/kg copper, 1.5 mg/kg colbalt, 7.5 mg/kg iodine, 600 mg/kg manganese, 750 m/kg iron, 600 mg/kg zinc, 1.5 mg/kg selenium; Vit. A, D and E with copra meal and molasses added.

Diets, Feeding and management

Batiki and guinea grasses were harvested daily and chopped with a bush knife into pieces (6-8 mm) in order to limit preferential selection of forage components. *Leucaena* was harvested in the morning for feeding in the afternoon, with some allowed to wilt overnight for feeding in the morning. Stems were removed to ensure that the fodder composition was uniform. An adaptation period of 7 days was allowed for the goats to get used to the diets.

Basal diets of either batiki or guinea were supplemented at 0, 10, 30 and 50 % of the total daily forage allowance levels with fresh *Leucaena* leaves and fed to the goats. The basal and supplementary components of the diets were mixed thoroughly to avoid selection, and offered as a whole diet. There were a total of eight diets; and batiki or guinea grasses only diets were used as controls. The level of supplementation used was calculated as percentage of total *ad libitum* daily forage allowance of the growing goats. The diets were fed on an *ad libitum* basis to allow about 10 – 20 % refusal.

The diets were offered three to four times daily to ensure constant availability. Batiki and guinea grass and *leucaena* were sampled once a week for dry matter determination. Feeds offered and refused were recorded on a daily basis to estimate voluntary dry matter intake. The pens were cleaned and leftovers from the previous day removed, weighed and sampled daily before supplying each day's diet. The live weights recorded at the end of each week of the experiment were used to calculate the amount of the feed to be offered during the subsequent week.

Digestibility study

At the end of the growth trial, all the animals in each diet group were used for metabolic studies. The total daily faecal output from each animal was collected, weighed and a 25 % sample removed for nutrient content analysis. The samples were later dried in a forced-air oven at 70° C for 24 hours. The daily samples of faeces and diets were then bulked separately and milled with a simple laboratory mill, and stored in air tight bottles until required for analysis.

Analytical Methods

The nutrient contents were analyzed following AOAC (1995) method. All analyses were done in triplicate. Dry matter was determined by drying at constant weight at 70° C for 24 hours in a forced-air oven, ash by incineration at 600° C for 4 hours, protein by the micro-Kjeldahl procedure (N x 6.25). Neutral detergent fibre (NDF) analysis was according to Goering and Van Soest (1970).

Statistical analysis

The observations from the feeding trial (voluntary feed intake, growth rate, feed efficiency and apparent nutrient digestibility coefficients) were analyzed using ANOVA procedures with individual goat as a replicate, period and treatment as mean effects.

RESULTS AND DISCUSSION

Chemical composition

Chemical composition of Leucaena, batiki and guinea grasses, and supplemented diets is presented in table 1. Nutrient composition (DM, CP, NDF and OM) of the Leucaena used in this study are 43.8 %; 31.2 %; 38.6 % and 85 % respectively and are consistent with values reported by Abdulrazak *et al.* (1997); Kaitho *et al.* (1998); Tjandraatmadja *et al.* (1993). Nutrient contents of batiki and guinea grasses are comparable to values reported earlier by Kumar (2000) and Aregheore and Cawa (2000).

The mean value of DM and NDF of batiki grass were significantly ($P<0.05$) higher than those of guinea grass while the opposite was true for OM. There was no significant difference ($P>0.05$) between CP of both grasses that increases linearly with increase in the levels of leucaena leaves in the diets (Table 1). The increase ranged from 5.3 – 18.2 % CP (mean 11.3±4.9) and 7 – 19.1 % CP (mean 12.5±4.7) for batiki and guinea grass based diets, respectively. Inclusion of leucaena in both batiki and guinea grass at the various supplementary levels (0-50 %) had effects on the nitrogen content of the diets offered to the goats. The data obtained are consistent with the findings of Bamualim *et al.* (1984); Tjandraatmadja *et al.* (1993); Abdulrazak *et al.* (1997) and Aregheore *et al.* (2002). They reported that the usage of the leaves of browses and multipurpose trees as supplements contribute to improve the nutrient quality of diets based on low quality roughage or tropical grasses.

Dry matter intake

Dry matter intake (DMI) by goats on the batiki (378 g/day) and guinea (385 g/day) sole diets were both lower ($p<0.05$) than those goats on the diets supplemented with *leucaena* leaves (Table 2). However, the goats on guinea grass had higher ($p<0.05$) DMI than the goats on batiki grass and the result obtained confirmed the earlier report of Aregheore (2001b).

The inclusion of *leucaena* leaves increased DMI in both batiki and guinea grass based diets (Table 2), which demonstrates the relevance and importance of supplementation of low quality forages with leaves of browses as means of improving their nutritive values. It has been reported that the leaves of browses play an important role in improving dietary protein (Woods *et al.* 1994; Mandal 1997; Kaitho *et al.* 1998). The inclusion of *leucaena* leaves improved

Table 1. Proximate chemical composition of grass and *Leucaena*-grass mixtures (analysis of DM, %)

		Diets					
Nutrients (%)	Grass	Grass + 0 % Leu.	Grass + 10% Leu.	Grass + 30% Leu.	Grass + 50% Leu.	Mean	± SEM
DM	Batiki	37.3[1]	37.3[1]	39.3	40.6	38.6	1.4
	Guinea	44.2[2]	44.2[2]	44.1	44.0	44.1	0.08
CP	Batiki	5.3[a]	8.4[a]	13.1[b]	18.2[c]	11.3	4.9
	Guinea	7.0[a]	9.4[a]	14.3[b]	19.1[c]	12.5	4.7
NDF	Batiki	39.7	39.6	39.4	39.2	39.5	0.2
	Guinea	36.0	36.3	36.8	37.3	36.6	0.5
OM	Batiki	82.4[1]	82.7[1]	83.2	83.7	83.0	0.5
	Guinea	89.0[2]	88.7[2]	86.2	86.0	87.7	1.2

* Four (4) diets four each grass species
+ % Leu. - *Leucaena*, DM, dry matter; CP, crude protein; NDF, Neutral detergent fibre; OM, organic matter.
± SEM, standard error of mean
[a,b,c] Means within row with different superscript differ ($p<0.05$)
[1,2] Means within each treatment (% of *Leucaena*) for each variable of different superscript differ ($p<0.05$).

Table 2. **Effects of *Leucaena* supplementation on voluntary feed intake and growth of goats**

		Diets: + Leucaena (%)					
Parameter	**Grass**	**0**	**10**	**30**	**50**	**Mean**	**± SEM**
Av. Daily DMI (g)	Batiki	378[1]	412	419	412	405.3	15.9
	Guinea	385[2]	416	415	410	406.5	12.6
Initial live-weight (kg)	Batiki	12.3	12.3	12.3	12.2	12.3	0.04
	Guinea	12.3	12.3	12.3	12.3	12.3	0.00
Final live-weight (kg)	Batiki	15.2	16.4	17.1	16.8	16.4	0.7
	Guinea	15.6	16.7	17.8	17.1	16.5	0.8
Body weight gain/loss (kg)	Batiki	2.9	4.1	4.8	4.6	4.1	0.7
	Guinea	3.3	4.4	5.5	4.8	4.5	0.8
Ave. daily LWG (g/d)	Batiki	60[c]	86[b1]	100[a1]	96[a]	86	0.02
	Guinea	69[b]	92[a2]	115[a2]	100[a]	94	0.02
Feed efficiency (feed/gain)	Batiki	6.3	4.8	4.2	4.3	4.9	0.8
	Guinea	5.6	4.5	3.6	4.1	4.4	0.8
Dry matter intake (g/kg $BW^{0.75}$)	Batiki	40.9[1]	44.6	43.3	39.4	42.1[1]	2.0
	Guinea	47.1[2]	48.7	48.8	46.1	47.7[2]	1.1

+ Leu. (%), with *Leucaena*
± SEM, standard error of mean
[a,b,c] Means within row with different superscript differ ($p<0.05$)
[1,2] Means within each treatment (% of *Leucaena*) for each variable of different superscript differ ($p<0.05$)

the nutritive value of the diets and subsequently increased DMI by the goats.

Another possible reason for the improved total DMI in the *leucaena* diets might be associated with faster outflow rate of particulate matter due to reduction in retention time of particulate matter (Bamualim *et al.* 1984) and/or the nature of the legume protein (Abdulrazak *et al.* 1996).

Live weight gains

There was no significant ($P>0.05$) difference between goats that received sole grass diets. Average daily live weight gain (LWG) of goats on grass only diet was significantly ($P<0.05$) lower than those of goats on diets supplemented with *leucaena*. Supplementation with leucaena leaves significantly ($P<0.05$) increased LWG reaching the maximum growth rate at 30 % supplementation for batiki, least at 10 % for guinea grass. At the same level of supplementation, LWG of guinea grass based diet was significantly ($P<0.05$) higher than that of batiki based diet except at the 50 % level. However, LWG of the goats supplemented with *leucaena* leaves at the 10 % and 50 % levels were significantly better ($p<0.05$) than those on the of batiki and guinea sole diets (no supplementation with *leucaena*). The improvement in LWG was reflected by a similar improvement in feed efficiency with increasing level of *leucaena* in the diets in both grasses.

One important aspect of legume supplementation is to identify the optimum level of its inclusion in the diet. It has been suggested that the optimum level of shrub and tree leaf supplements are in the range of 30 – 50 % of the diet on a dry matter basis. Kaitho (1997) suggested that the optimum level of browse supplements to low-quality diets fed to sheep was 45 % for *Leuceana leucocephala*. In this experiment *Leucaena* leaves were included up to 50 % of the total daily forage allowance of the goats and there were observed improvements in LWG.

Apparent nutrient digestibility coefficients

Table 3 presents data on apparent nutrient digestibility coefficients by the goats fed the batiki or guinea grass and diets with *leucaena* leaves supplementation. DM, CP and OM digestibilities improved with increase in the levels of *leucaena* supplementation. The goats on batiki or guinea sole diets were significantly lower ($p<0.05$) in the digestibility of DM, CP, NDF and OM than those of the goats on diets supplemented with *leucaena*.

However, the goats on guinea grass with *leucaena* leaves at the 10 – 50 % levels of supplementation were better ($p<0.05$) in the digestion of CP, NDF and OM than the goats on batiki grass at similar levels of supplementation with *leucaena*. The implication of these data is that the goats on guinea grass had better response than those goats on batiki grass even when supplemented with *leucaena* leaves at the same levels (10 – 50 %).

The goats that had higher OM digestibility had higher LWG. The goats that had 30 % and 50 % *leucaena* leaves diets had higher OM digestibility. It has been observed that the higher the OM digestibility, the

Table 3. **Apparent nutrient digestibility coefficients of mixtures of *Leucaena* leaves with either batiki or guinea grasses at four levels (0, 10, 30 and 50 %) of supplementation**

		Diets: % Leucaena					
Nutrients	**Grass**	**0**	**10**	**30**	**50**	**Mean**	**± SEM**
DM	Batiki	44.4^{d}	57.8^{b}	63.0^{b}	68.0^{a}	58.4	8.9
	Guinea	48.0^{c}	58.2^{b}	64.7^{a}	66.4^{a}	59.6	7.5
CP	Batiki	48.3^{c}	58.0^{ab1}	62.9^{a1}	65.8^{a1}	58.8	6.6
	Guinea	49.6^{c}	68.3^{b2}	72.0^{a2}	74.3^{a2}	66.1	9.7
NDF	Batiki	48.9^{c}	64.9^{a}	60.9^{a1}	58.6^{ab}	58.3	5.9
	Guinea	50.4^{c}	63.4^{b}	68.6^{a2}	61.8^{b}	61.1	6.6
OM	Batiki	46.7^{c}	64.5^{b}	70.0^{a1}	67.6^{ab1}	65.1	4.4
	Guinea	51.2^{c}	65.8^{b}	74.8^{a2}	70.2^{a2}	65.5	8.8

% *Leucaena*,
DM, dry matter; CP, crude protein; NDF, Neutral detergent fibre; OM, organic matter.
± SEM, standard error of mean
^{a,b,c} Means within row with different superscript differ ($p<0.05$)
^{1,2} Means within each treatment (% of *Leucaena*) for each variable of different superscript differ ($p<0.05$).

higher the expected metabolizable energy (ME); and the feed with higher OMD is expected to provide more energy and therefore more production i.e. high live weight gain. This was the trend in this experiment with respect to LWG.

CONCLUSION

This study clearly demonstrates that inclusion of fresh *leuceana* leaves, up to 50 % of total daily forage allowance in the diets of goats offered either batiki grass or guinea grass improved their DMI and growth performance. It also shows that the levels of *leucaena* used may not cause any detrimental toxicity effects if goats are feed for a short period similar to that in this study. Such practices may be more appropriate for short-term feeding as in fattening program with cut-and-carry or semi-intensive system where goats could be fed controlled levels of *leucaena*. Finally, the goats on guinea grass had better response than those goats on batiki grass even when supplemented with *leucaena* leaves at the same levels. Maximum growth was attained at 30 % leucaena supplementation for batiki, while for guinea grass it was at 10 % level. *Leucaena* supplementation is therefore recommended for cut-and-carry or semi-intensive system of production.

REFERENCES

ABDULRAZAK, S.A., R.M. MUINGA, W. THORPE and E.R. ORSKOV (1996). The effect of supplementation with *Gliricidia sepium* and *Leucaena leucocephala* forage on intake, digestibility, and live-weight gains of *Bos taurus x Bos indicus* steers offered napier grass. *Animal Science,* 63:381-388.

ABDULRAZAK, S.A., R.M. MUINGA, W. THORPE and E.R. ORSKOV (1997) Supplementation with *Gliricidia sepium* and *Leucaena leucocephala* on voluntary food intake, digestibility, rumen fermentation and live-weight of crossbred steers offered *Zea mays* stover. *Livestock Production Science*, 49:53-62.

ADJEI, M.B (1995). Component forage yield and quality of grass-legume cropping systems in the Caribbean. *Tropical grasslands,* 29:142-149.

ADU, I.F. and ADAMU, A.M. (1982). The nutritive value and utilization of three tropical grass hays by sheep. *Tropical grasslands,* 16(1):29-33.

AOAC (1995). *Official Methods of Analysis*, 16th ed. (Association of Official Analytical Chemists, Arlington, VA).

AREGHEORE, E.M (2001a). The effect of supplements of crop residues based diets on the performance of steers grazed on natural pasture during the dry season. *African Journal of Range and Forage Science,* 18:25-29.

AREGHEORE, E.M (2001b). Nutritive value and utilization of three grass species by crossbred Anglo-Nubian goats in Samoa. *Asian-Australasian Journal of Animal Sciences*, 14(10):1389-1393.

AREGHEORE E.M. and CAWA, K. (2000). Voluntary intake by crossbred Anglo-Nubian goats of water hyacinth (*Eichhornia crassipes*) fed in two states plus guinea grass (*Panicum maximum*) in confinement. *Scientia Agriculturae Bohemica*, 31(4) 261-271.

AREGHEORE, E. M.; PERERA, D. and YAHAYA, M.S. (2002). Effect of nutritive value of batiki grass (*Ischaemum aristatum* var. *indicum*) supplemented with leaves of browses (*Gliricidia sepium* and *Leucaena leucocephala*) on performance of goats. *Scientia Agriculturae Bohemica*, Vol. 33. (2): 63-70.

BAMUALIM, A., STACHIW, S., JONES, R.J. and MURRAY, R.M. (1984). The effect of fresh leucaena leucocephala as supplement on the utilisation of pasture hay by goats. *Proceedings of the Australian Society of Aniaml Production*, 15:259-262.

GUTTERIDGE, R.C. and WHITEMAN, P.C. (1978). Pasture species evaluation in the Solomon Islands. *Tropical Grasslands*, 12(2):113-126.

GILL, J.L. and MAGEE, W.I. (1976). Balanced two-period changes over designs for several treatments. *Journal of Animal Science*, 42:775-777.

GOERING, H.K and VAN SOEST, P.J. (1970) Forage fibre analysis (Apparatus, Procedures and some applications) Agriculture Handbook No. 379. ARS, USDA, Washington, D.C. 20 pp.

HUMPHREYS, L.R. (1987). Tropical pastures and fodder crops. 2nd Ed. Intermediate Tropical Agriculture Series. Longman Scientific & Technical, John Wiley and Sons Inc: New York.

KAITHO, R.J., I.V. NSAHLAI, B.A. WILLIAMS, N.N. UMUNNA, S. TAMMINGA and VAN BRUCHEM, J. (1998). Relationship between preference, rumen degradability, gas production and chemical composition of browses. *Agroforestry Systems*, 39:129-144.

KUMAR, A. (2000) Energy and protein requirement of growing crossbred Anglo-Nubian goats in Samoa. B.Agric. Project. School of Agriculture, The University of the South Pacific, Apia, Samoa. 26 pp.

MANDAL, L. (1997) Nutritive value of tree leaves of some tropical species for goats. *Small Ruminant Research*, 24:95-105.

MANNETJE, L.t'. (1978). The role of improved pastures for beef production in the tropics. *Tropical Grasslands*, 12(2):1-9.

MINSON, D.J. (1971). The nutritive value of tropical pastures. *Journal of Australia Institute of Agricultural Science*, 37:255-263.

OLUBAJO, F.O. and OYENUGA, V.A. (1971). The measurement of yield, voluntary intake and animal production of tropical pasture mixtures. *Journal of Agricultural Science* (Cambridge), 77:1-7.

REYNOLDS, S.G. (1978). Evaluation of pasture grasses under coconuts in Western Samoa. *Tropical grasslands*, 12(3):146-151.

SMITH, J.W., LARBI, A., JABBAR, M.A. and AKINLADE, J. (1995) Voluntary intake of sheep and goats fed three states and at three levels of supplementation to a basal diet of *Panicum maximum*. *Agroforestry Systems*, 32;287-295.

TJANDRAATMADJA, M., I.C. MACRAE and NORTON, B.W. (1993). Effect of inclusion of tropical tree legumes, *Gliricidia sepium* and *Leucaena leucocephala*, on the nutritive value of silages prepared from tropical grasses. *Journal of Agricultural Science* (Cambridge), 120:394-406.

WOODS, C. D., TIWARI, B. N., PLUMB, V.E., POWELL, C. J., ROBERTS, B.T., SIRIMANE, V. D. P., ROSITER J. T., and GILL, M. (1994). Interspecies differences and variability with time of protein precipitation activity of extractable tannins, crude protein, ash and dry matter contents of leaves from 13 species of Nepalese fodder trees. *Journal of Chemistry Ecology*, 20:3149-3162.

GROWTH, LITTER YIELD AND LITTER NUTRIENT COMPOSITION OF *CASUARINA OLIGODON* IN THE PAPUA NEW GUINEA HIGHLANDS

B. Bino[1] and M.B. Kanua[2]

ABSTRACT

Casuarina Oligodon *is the most common planted tree species in Papua New Guinea Highlands. A growth study of* C. oligodon *was carried out at the three sites at different altitudes (2000, 1750 and 1300 m above sea level). Another unreplicated observation study examined litter yield and nutrient composition of* C. Oligodon *using a three year old stand (4444 trees/ha) over a three year period. At the 2000 m site, the height and diameter growth was slower initially but reached 4.5 m and 47 mm respectively at 33 months. The site also recorded 100% survival of seedlings. At the 1750 m site, the height growth slowed after 12 months which was mainly due to the continuous die back of growing apical tips. The diameter showed almost positive linear growth. About 69% of the plants had dead apical growing tips with 6% mortality. At the site at 1300 m, height and diameter at 12 months were 3.0 m and 34 mm respectively. The results of the litter yield study show that monthly average ranges between 200 and 400 kg/ha (dry matter) from a three-year-old plot. Although the nutrient content in dry leaf litter was low, it returned to the topsoil 45.6, 2.4 and 9.6kg/ha of N, P and K respectively.*

Keywords: Casuarina oligodon, *litter yield, nutrient composition, agroforestry, multipurpose tree.*

INTRODUCTION

Casuarina oligodon (L. Johnson) is endemic to New Guinea. It is found mostly in the upland valleys over an altitudinal range of 700-2600 meters above sea level (m.a.s.l.), occasionally as high as 2820 m.a.s.l., and is most common at 1400 to 2100 m above sea level in Papua New Guinea (PNG) (Bourke 2000). Since the arrival of Europeans in the early 20th century, both the government agencies and non-government organisations have played a major role in encouraging adoption and spread of this species. *C. oligodon* is now the most common tree species in the highlands and is planted as a fallow species, to provide shade for coffee, for rehabilitation of grasslands and for various wood products). Casuarina has been well accepted into the traditional farming systems and since habitation and cultivation of crops is found up to an altitude of 2850 m.a.s.l. (Ghodaka 1994), this species may play a vital role in the higher altitude farming systems. Between 1400 and 2000 m.a.s.l. is where most of the indigenous agroforestry systems using *C. ologodon* are found (Bourke 1985).

The Highlands Agriculture Experiment Station (HAES) under its agroforestry research program has a mandate to develop low input sustainable farming systems for subsistence farming. One part of the program includes collection and evaluation of different multipurpose tree species (MPTS) under varying agro-ecological conditions. *C. oligodon* was included in seveal such studies. The broad objective was to identify the best performing MPTS with desirable attributes for use in agroforestry systems.

The first part of this paper reports the growth performance of *C. oligodon* at three sites at different altitudes. The second part reports a study of *C. oligodon* leaf litter production and nutrient turnover at Aiyura.

MATERIALS & METHODS

Study Sites

Trials assessing the growth performance of *C.oligodon* together with other MPTS were carried out at 2000 m.a.s.l. at Gumine, Simbu Province, 1750 m.a.s.l. at Aiyura, Eastern Highlands Province (EHP) and 1300 m.a.s.l. at Tabibuga in Western Highlands Province (WHP).

The site at Gumine (6° 14' S, 144° 59' E) was located on a 40-50% slope with a NE-SW aspect. The top soil depth is about 30-50 cm and is mostly made up of volcanic ash. The subsoil is made up of moderately drained, dark yellowish clay. The mean annual rainfall is about 2100 mm. The land was previously used to grow sweet potato and was under *Imperata cylindrica* dominated grass and shrubs.

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The Aiyura site (6° 19' S, 145° 35' E) has a mean annual rainfall of 2100 mm. The tiral was established on 25-30% slope. The top soil is about 15-25 cm in depth and the subsoil is mostly made up of poorly drained heavy clay.

The trial site at Tabiguba (5° 50' S, 145° 50' E), is wetter with a mean rainfall of about 3000 mm/year. The trial was laid out on a 50-60% slope. The top soil is quite shallow probably as a rresult of soil erosion which resulted from frequent cultivation of the site. The subsoil is a moderately drained light orange clay.

All seedlings were raised in a central nursery. Seedlings were transported to the Growth measurement trial sites for planting when they were four mouths old and about 30-50 cm high. *The trials were planted using a randomized complete block design and were replicated three, four and three times respectively.* At the 2000 m.a.s.l. and 1300 m.a.s.l. sites, there were 15 seedlings *per replicate* planted at 1.5 m x 1.5 m spacing (three seedlings per row by five seedlings per column in a rectangular block) with nine measurable plants excluding the border plants. At the 1750 m.a.s.l. site, there were 20 seedlings *per replicate* planted at 1.5 m x 1.5 m spacing (two seedlings per row by 10 seedlings per column rectangular block) with 16 measurable plants excluding border plants. Growth data (height and diameter) were recorded at three monthly intervals.

The study of litter yield and nutrient composition was carried out at Highlands Agricultural Experiment station at Aiyura. It used a three year old plot of *C. oligodon* planted at 1.5 m x 1.5 m (4444 trees/ha) triangular spacing. The total area of the stand is 7.5 m x 9.0 m (67.5m^2). The trees were on a moderate slope of about 30%. The top soil is about 30 cm deep and the subsoil is a moderately drained light to heavy clay.

Twelve litter traps each measuring 1.5 m x 1.5 m were randomly placed under the plot of *C. oligodon*. This was an unreplicated observation study due to the small size of the casuarina plot. The litter traps were made with 1 mm mesh shade cloth and supported off the ground, to retain fine litter fraction and allow free drainage of water. Litter was collected every four weeks starting November 1990 for three years. The samples were oven dried to constant weight and sub samples were sent to the Department of Agriculture and Livestock chemistry laboratory for analysis.

RESULTS AND DISCUSSIONS

Growth measurements

There was 100% survival of *C. oligodon* at 2000 m.a.s.l. and 1300 m.a.s.l. sites while at 1750 m.a.s.l. site, 6% (1) of the seedlings died and 69% (11) had dead apical growing tips. The height at 1750 m showed steady growht for the first 12 months but slowed down to 21st month, and gradually picked up to the 33rd month. (Figure 1). This may be due to the thick layer of iron/manganese concretions found at the depth of 30 cm which impeded root penetration. The root network of some plants uprooted from the

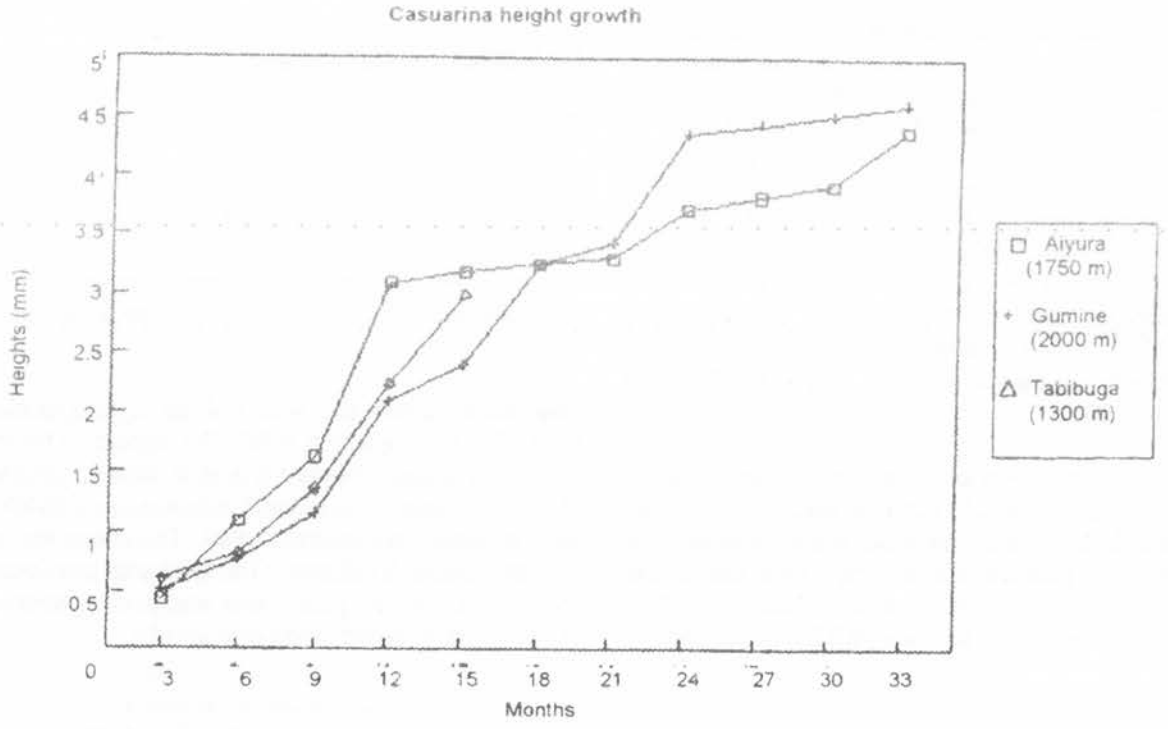

***Figure 1.* Growth rate (height) of casuarinas at three sites in the PNG highlands.**

adjacent areas showed the taproot and lateral roots were growing in a horizontal fashion to find a space to penetrate the lower soil horizons. Meanwhile the diameter growth (Figure 2) of these trees was unaffected and reached more than 50 mm by 33 months.

At the highest site, the height growth rate (Figure 1) was less initially but reached more that 4 m in 33 months while the diameter (Figure 2) grew at a slower rate. This growth rate was much higher than other MPTS tested as observed on the same site. Altitude may be limiting growth of other multi-purpose tree species. At the 1300 m.a.s.l. site, the height and diameter growth (Figure 1 and 2) at 12 months was slow but rapidly increased after that.

At the 2000 m.a.s.l. site, *C. oligodon* was able to achieve growth comparable to the other MPTS at the site at 33 months. At 1300 m, where more tree species are suited to the altitude, the climate, humidity and other enviornmental factors, other MPTS were able to compete with *C. oligodon*, decreasing its

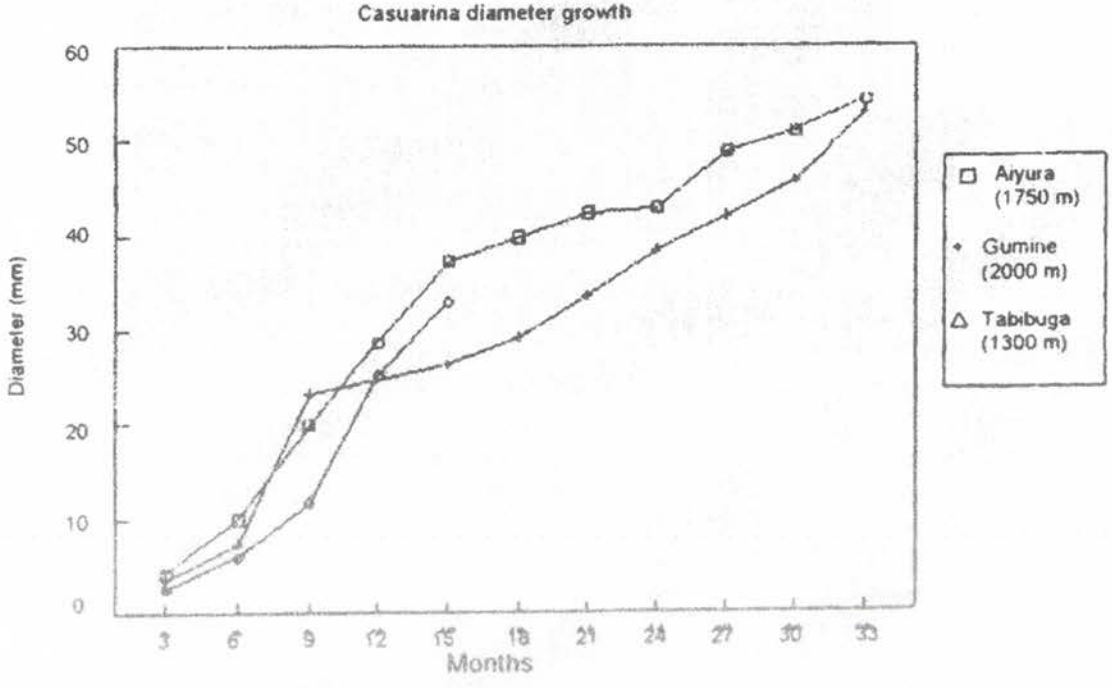

Figure 2. Growth rate (diameter) of casuarinas at three sites in the PNG

growth rate

Litter yield and nutrient composition

The mean monthly leaf litter yield of *C. oligodon* based on three years of data is depicted in Figure 3. There was no relationship between litter yield and month of the year. The mean monthly yield ranged between 200 and 400 kg/ha (dry matter). Harding (1994) reported, from a similar study using *C. oligodon* as coffee shade and planted at 5x5 m (400 trees/ha) in the Kainantu area, that higher litter yields were obtained in the wetter months between October and February. He found a *C. oligodon* litter yield of 7000 - 8000 kg (dry matter) ha/yr from 10-15 year old stand. This is two to three times higher than that reported in this study. This may indicate that older stands produce more litter than the younger stands. The enviornmental factors that influence the growth of the trees may also determine the performance of the trees and hence the litter production.

The *Casuarina oligodon* litter had an average N content of 1.2% (Table 1) which corresponds well to that reported by Harding (1994) of 1.0-1.4%. The N, P and K contents in *C. oligodon* leaf litter are low. This could be due to the translocation of plant nutrients to the actively growing areas of the tree before leaf fall.

The monthly means litter yield (274 kg/ha) and data from Table 1 were used to estimate mean montly nutrient inputs in *C. oligodon* leaf litter (Table 2). It shows *C. Oligodon* can return 39, 3 and 10 kg of N, P and K per ha per year of the respective nutrients. The N is about half the amount reported by Harding (1994) who estimated it to range between 84 to 123 kg/ha/year in *C. oligodon* leaf litter. This could largely be due to the age of the stand. It is possible that, as the trees grow older, the litter production of the trees also increases. In addition, the density of the stand may also have some influence on the litter production, that is, the widely planted trees may have wider

Figure 3. **Average monthly *C. oligodon* litter yield (dry matter) based on three year data.**

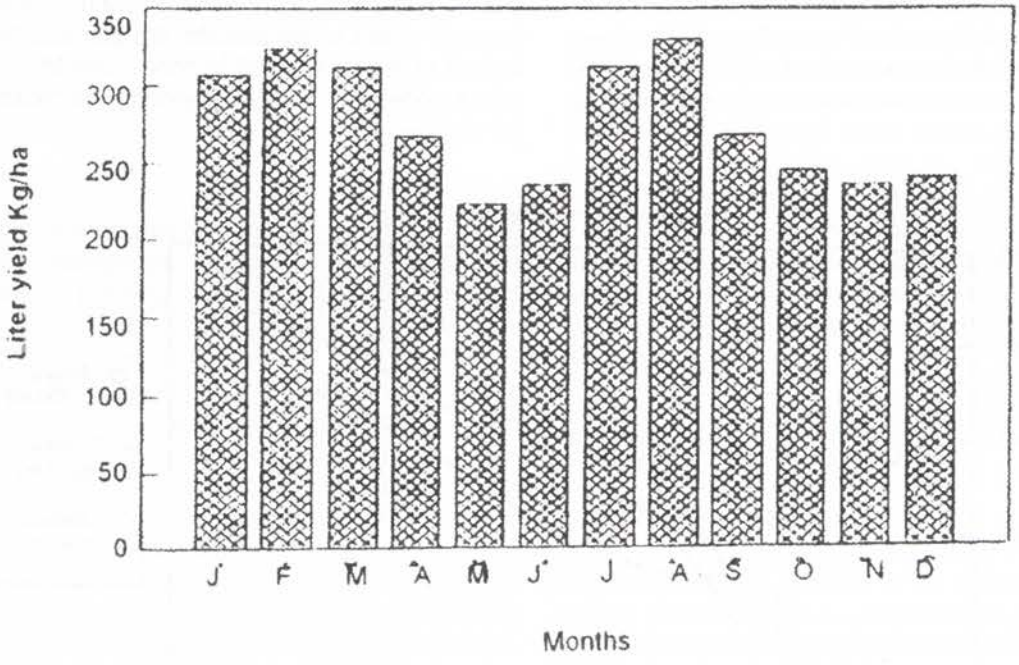

Table 1. **Average nutrient content of *Casuarina oligodon* leaf litter**

% of dry matter					
N 1.2	P 0.1	K 0.3	Ca 1.2	Mg 0.2	S 0.2
Microgram/g of dry matter					
Mn 370	Fe 184	Zn 34.0	Cu 7.0	B 32.0	

Table 2. **Mean annual nutrient inputs Kg/ha in *Casuarina oligodon* leaf litter**

N 39	P 3	K 10	Ca 39	Mg 7	S 7
Mn 1.37	Fe 0.68	Zn 0.13	Cu 0.03	B 0.12	

and larger canopy with the capacity to produce more litter than closely spaced trees with narrow canopy.

CONCLUSION

C. oligodon is likely to remain the most important multipurpose tree in the traditional farming systems at altitudes of 2000 m.a.s.l. and above. This was demonstrated when it had a 100% survival at 2000 m.a.s.l. However, when comparing its performance at three different sites at different altitudes, it achieved the best growth at 1750 m.a.s.l. The most suitable altitudinal range for best performance of *C. oiigodon* is possibly between 1400 and 2000 m.a.s.l.

The litter yield study from a stand of *C. oligodon* when it was three, four and five years old shows that it can return 200-400 kg (dry matter) /ha/month of litter. The results did not show clear evidence of a relationship between litter yield and month of the year, although this may be due to the disruptions in the normal weather pattern. The nutrient content of *C. oligodon* leaf litter apperars to be low with average N, P and K contents of 1.2%, 0.1% and 0.3% respectively. However, the nutrient contribution in leaf litter is 39, 3 and 10 kg/ha/yr for N, P and K respectively. It is possible that the litter yield and nutrient contribution would increase as the stand grows older.

RECOMMENDATIONS

It would be useful to know the nutrient content of fresh *C. oligodon* leaf litte to assess its potential as green manure. According to Thiagalingam (1983), soil nutrients under *C. oligodon* increase with the age of the trees. However, there is no information on the actual amount of nitrogen fixed by *C. oligodon*. Also it would be useful to know the rate of *C. oligodon* litter breakdown in the soil to understand the process of soil nutrient contribution by this species.

The following is recommended:

- The biological nitrogen fixation ability of *C. oligodon* should be quantified;
- The nutrient content of fresh *C. oligodon* leaves should be determined;
- The break down rate of both fresh and dry *C. oligodon* litter should be studied;
- The effect of *C. oligodon* on the soil fertility maintenance and its effect on crop production should be studied;
- Management of *C. oligodon* in agroforestry systems should be described; and
- Some of the wood and non-wood properties should be studied.

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REFERENCES

BOURKE, R.M. (1985). Food, coffee and casuarina: an agroforestry system from the Papua New Guinea highlands. Agroforestry Systems 2 (4): 273-279.

BOURKE, R.M. (2000). Managing the species composition of fallows in Papua New Guinea by planting trees. In *Voices from the Forest: Farmer Solutions Towards Improved Fallow Husbandry in Southeast Asia. Proceedings of a Regional Conference on Indigenous Strategies for Intensification of Shifting Cultivation in Southeast Asia.* M.F. Cairns (ed.) International Centre for Research in Agriforestry, Bogor.

GHODAKE, R.D. (1994). Adjustments in the highlands agriculture of Papua New Guinea. Paper presented at the International workshop on evolution of mountain farming systems, Pokhara, Nepal.

HARDING, P.E. (1994). A comparison of the nitrogen requirement of two coffee (*Coffee arabica L.*) management systems in Papua New Guinea. Unpublished PhD thesis. Department of Soil Science, University of Reading.

THIAGALINGAM, K. (1993). Role of casuarina in agroforestry. In: Midgley, S.J., Turnbull, J.W. and Johnston, R.D. (eds.). Casuarina Ecology, Management and Utilization. CSIRO, Melbourne. pp 175-179.

HOST PLANTS OF *AMBLYPELTA* STåL (COREIDAE: HETEROPTERA) IN PAPUA NEW GUINEA

Mark M. Ero

ABSTRACT

Most Amblypelta species are polyphagous feeders, including some commercial and food crops causing considerable damage of economic importance. They attack the growing tips, stem, petiole, fruits and nuts of plants by piercing and sucking the sap. Twenty species/subspecies are known to occur throughout the South Pacific and some parts of South East Asia. The host plants of Amblypelta in Papua New Guinea is reviewed here.

Key words: *damage, symptoms, die back, salivary enzymes.*

INTRODUCTION

The genus *Amblypelta* comprises a total of 20 described species and subspecies. The species are distributed throughout the Pacific and part of South East Asia. Eight species are known to occur in Papua New Guinea (PNG), four being represented by subspecies. They include *A. ardleyi* Brown, *A. bukharii* Ghauri, *A. madagana* Brown and Ghauri, *A. theobromae* Brown, *A. cocophaga cocophaga* China, *A. costalis szentivanyi* Brown, *A. gallegonis bougainvillensis* Brown and *A. lutescens papuensis* Brown. The species are widely distributed throughout the lowlands.

Amblypelta is a polyphagous pest of a wide range of plants. Several species have been recorded as serious pests of fruit, nut or tree crops, forest trees and ornamental plants in the regions where they are found (Brown 1958a, Bigger 1982, Donaldson 1983, Smith 1984 and Szent-Ivany and Catley 1960). Peng *et al.* (2002) listed *A.cocophaga*, *A. cristobalensis*, *A. theobromae*, *A. lutescens papuensis*, *A. lutescens lutescens* Distant and *A. nitida* Stål to be the most important economic species. Of these, *A. cocophaga cocophaga*, *A. theobromae* and *A. lutescens papuensis* are the most common pests in PNG. Most host plants of *Amblypelta* species in PNG are introduced and cultivated plants. *Manihot esculenta* Crantz (cassava), *Theobroma cacao* L. (cocoa), *Psidium guajava* L. (guava), *Abelmoschus manihot* (L.) Medik (aibika), *Hevea brasiliensis* Muell. Arg. (rubber), *Anacardium occidentale* L. (cashew), *Carica papaya* L. (pawpaw) and *Cocos nucifera* L. (coconut) are the most common cultivated host plants of *Amblypelta*, recording the highest number of *Amblypelta* species feeding and breeding on them. Table 1 presents a comprehensive list of the host plants of *Amblypelta*.

Amblypelta species have piercing and sucking mouth-parts, with an elongated rostrum which is used to pierce through the plant parts and absorb the nutrients. Both adults and nymphs feed from plant parenchyma, secreting salivary enzyme which facilitates the uptake of cell contents from both the feeding site and the surrounding area (Miles 1987). They attack fruit, nuts, stems, petioles and growing shoots. The symptoms of attack by this pest are very characteristic and include wilting and dieback of growing tips, premature nut and fruit fall, and the development of sclerotic lesions in plants that survive the damage, thus reducing production and quality.

This paper reviews the host plants of *Amblypelta* in PNG, and a comprehensive list dating back to 1958 is provided.

RESULTS AND DISCUSSION

1. Nature of damage

Amblypelta spp. attack plants by damaging four distinct parts:

a. *Growing tip*. The soft tender growing tips of the host plants are most susceptible to attack by this pest. The attack to growing tips occurs at the early stages of growth. The pest habitually inserts its elongate stylet through the tender portion of the young growing tip and sucks in the nutrients from the plant. The attack in such manner results in irregular scar formation, sometimes resulting in splits

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and cracks and thus reducing the quality and quantity of production.

b. *Stem*: The attack to stems is often at the tender terminal end where they are softer and it is easier for the stylet to penetrate. The pest inserts its stylet through the soft skin of the terminal portion of the stem and thus absorbs the nutrients from the plant. The initial effect of feeding can result in the wilting of the shoots. Those shoots surviving the attack later develop cancerous swellings and cracks.

c. *Petiole*: Some host plants such as pawpaw and aibika have soft petioles that are susceptible to attack by certain species of *Amblypelta*. A few species attack plants in such a manner.

d. *Fruits and Nuts*: The attacks on fruits and nuts occur especially at early stages when they are soft and it is easy for the stylet to penetrate. The pests use their stylets to pierce the fruits and nuts and absorb the juices from them. Attack in such manner can result in inhibition of fruit growth and, in severe cases, result in premature fruit fall. Coconuts, cocoa pods and vanilla pods are attacked in this manner.

2. Crops attacked

Amblypelta species have been recorded to attack a number of commercial and food crops causing severe damage. The major host crops include: cocoa (*Theobroma cacao* L.), coconut (*Cocos nucifera* L.), rubber (*Hevea brasiliensis* Muell. Arg.), cassava (*Manihot esculenta* Crantz), aibika (*Abelmoschus manihot* (L.) Medik), cashew (*Anacardium occidentale* L.), pawpaw (*Carica papaya* L.) and guava (*Psidium guajava* L.). Table 1 presents a full listing of the recorded host plants of *Amblypelta* species in PNG. It also indicates the pest status of the respective species.

1.1. *Theobroma cacao* L. (cocoa)

The major species of *Amblypelta* attacking cocoa are *A. theobromae*, *A. lutescens papuensis* and *A. cocophaga cocophaga*. Both adults and nymphs attack the growing tips and the pods. They damage pods by causing circular brown scars that eventually result in malformations or inhibition of growth of fruits, especially in severe cases at early stages. The damage to the terminal shoots is often at the extreme tender tip where they are much softer. The attack results in dieback of the shoots and, in severe cases, the development of multiple terminal branches (Brown 1958b).

A. ardleyi, *A. bukharii*, *A. gallegonis bougainvillensis* and *A. madagana* are also known to attack cocoa but are not serious pests. *A. costalis szentivanyi* has been sighted on cocoa but has not been seen feeding (Kumar 2001). Further feeding trials are required to see if this particular species is also a pest of cocoa. All species and subspecies of *Amblypelta* in PNG have been recorded on cocoa (Table 1).

1.2. *Cocos nucifera* L. (coconut)

Two species have been recorded as pests of coconut. They are *A. cocophaga cocophaga* and *A. lutescens papuensis* both causing similar characteristic damage; however, the former is regarded as causing more serious damage than the latter. These species mainly attack the nuts, resulting in premature nut fall in serious cases. Kumar (2001) highlighted *A. cocophaga cocophaga* as attacking the flowers as well. He noted that both the adults and nymphs pierce the flowers and young nuts with their long stylets, sucking in juices and injecting toxic saliva. Attacks in such manner kill flowers, cause young nuts to dry up, produce feeding scars and result in early fall of nuts. Consequently, only a few nuts are produced. Coconuts damaged in this way only produce about 65-96% of the copra that they would have produced if undamaged (Brown 1958b).

2.3. *Hevea brasiliensis* Muell. Arg. (rubber)

Three species are known to be pests of rubber. They are *A. lutescens papuensis*, *A. costalis szentivanyi* and *A. theobromae*. They attack the plant mainly by feeding on the growing tips, sometimes causing leaves near the growing tips to wilt and fall. In severe cases they cause distortion of flush tissue and proliferation of side shoots (Brown 1958b).

2.4. *Manihot esculenta* Crantz (cassava)

A large number of *Amblypelta* species have been recorded attacking and breeding on cassava, second only to cocoa (Table 1). They include *A. lutescens papuensis*, *A. theobromae*, *A. costalis szentivanyi*, *A. cocophaga cocophaga* and *A. gallegonis bougainvillensis*. The pests mainly attack the tender terminal portion of the stem. They insert their long stylets through the stems and absorb the nutrients. Post attack symptoms are the wilting of shoots and later development of swellings and longitudinal cracks. In severe cases, the growing tips eventually die, sometimes causing the stem to develop multiple lateral branches. Dori (1998) reported a 40% tuber loss in cassava due to *A. lutescens papuensis* attack in the Central Province.

Despite cassava being the common host for *Amblypelta* species along with cocoa, it cannot be an ancestral host as the plant was introduced into the Pacific from South America (Brown 1958b) and it is not native to the regions where *Amblypelta*

species are found. However, the pest was readily able to colonize the plant when it was first introduced.

5.5 *Abelmoschus manihot* (L.) Medik (aibika)

A. lutescens papuensis has been recorded as a serious pest of aibika. Both the adults and nymphs cause the damage, attacking both stems and petioles. The initial sign of attack by *A. lutescens papuensis* is the development of watery lesions on the tissues surrounding the attack site that later develop into longitudinal cracks when dry. The damage can cause dieback of the growing tips. In severe cases the plant may suffer desiccation and loss of foliage resulting in stunted growth and sometimes death. Dori (1989) reported some varietal differences in resistance to the pest, where some varieties of aibika are more susceptible to *A. lutescens papuensis* attack than others.

2.6. *Carica papaya* L. (pawpaw)

Szent-Ivany and Catley (1960) recorded *A. lutescens papuensis* from pawpaw. The authors noted that the pest attacks the plant by feeding on the growing tips and the soft petioles. Attacks on the growing tips and stems are usually more serious than those on the soft petioles. Brown (1958b) further highlighted the same pest as causing young pawpaw plants to die when attacked at the stem.

2.7. *Anacardium occidentale* L. (cashew)

A. lutescens papuensis is also a serious pest of cashew (Peng *et al*, 2002). Both nymphs and adults attack the crop. Feeding sites include foliar tissue, floral growing tips and fruits. The feeding sites later develop necrotic lesions. The characteristic symptom on the growing tip following feeding is the development of an elongated, blackened and sunken lesion. The growing tip, when hardened, develops elongated depressed lesions, sometimes with cracks. Peng *et al* (2002) further highlighted that the damage to foliar tissue and flushing shoots is much higher (10-40%) on trees without red ants (*Oecophylla smaragdina* F.). The damage is very low (1%) on trees with red ants and. Peng *et al* (2002) further suggest that *O. smaragdina* F. can be a good biological control agent for *A. lutescens papuensis*.

8.8. *Psidium guajava* L. (guava)

Dori (1993, unpublished) reports that *A. lutescens papuensis* is also a serious pest of guava, especially in the Central Province. The species attacks both the flushing shoots and the fruits. The symptoms are characteristic on fruits, with feeding lesions appearing as round brown scars. Excessive feeding sometimes causes the distortion of the fruits. The sites of attack are often sites for entry of pathogens and infections.

Apart from the crops listed above, several species of *Amblypelta* also feed on a wide range of other crops of unrelated families, without their pest status being known (Table 1).

A.lutescens papuensis has been noted to be a serious pest of *Delonix regia* (Hook) (flame tree) (Waite and Huwer 1998). Some other plants on which *A. lutescens papuensis* has been recorded include: *Phaseolus mungo* L. (black gram), *Urena robata* L. (pink Chinese burr), *Abroma augusta* (L.) L.f (devil's cotton), *Ipomoea batatas* (L.) Lam (sweet potato), *Magnifera indica* L. (mango), *Plumeria rubra* L. (frangipani), *Sechium edule* (Jacq.) Schwartz (choko), *Artocarpus communis* Forster and Forster (breadfruit), *Dioscorea* sp. (yam), *Citrus* sp. (citrus) and *Areca catechu* (beetle nut). *A. theobromae* has been recorded from *Vigna unquiculata sesquipedalis* (L.) Verdc. (snake bean), *Vigna radiata* (L.) R. Wilcezek (mung bean), and *Psophocarpus tetragonolobus* (L.) DC (winged bean) while *A. gallegonis bougainvillensis* has been recorded from *Cocos nucifera* L. (coconut), *Pueraria phaseoloides* (Roxb.) Berth (tropical kudzu) and *Ipomoea batatas* (L.) Lam (sweet potato) as well. The pest status of these records are not known (Table 1). This author is of the view that the species concerned can be serious pests to some of the food crops mentioned here under adverse environmental conditions such as prolonged dry periods when their major host plants are scarce. These records are also of isolated cases and more thorough research is needed to fully confirm the pest status on the food crops concerned. Host plant choices by such polyphagous species may be flexible, depending on the changing quality of plants and environmental conditions (Leps *et. al* 2001).

A. lutescens papuensis and *A. theobromae* are the two most common and serious pest species on wide range of crops in PNG. They cause severe damage to this wide range of crops. The Australian species, *A. lutescens lutescens* (Distant) and *A. nitida* Stål have been recorded as serious pests of avocado (*Persea americana* Mill.) in Queensland (Waite and Huwer 1998), however, there are no records of *Amblypelta* attacking avocado in PNG. Wiles (2002, unpublished) highlighted *Amblypelta* spp. as also attacking vanilla in the East Sepik Province. None of the species of this pest have been recorded as serious pests of mango. This author was also unable to find any *Amblypelta* species feeding on mango during a mango pest survey in the Central Province, even during the dry season.

Table 1. **Host plants of *Amblypelta* spp. in Papua New Guinea[1].**

Amblypelta spp.	Host Plants		Locality	Source
	Species	Family		
A. lutescens papuensis Brown	*Abelmoschus manihot* (L.) Medik (++)	Malvaceae	Boroko, NCD, Gulf Province; Oro Province, Milne Bay Province.	Szent-Ivany & Catley, 1960;Dori, 1998; Preston, 1998
	Sechium edule (Jacq.) Schwartz. (*)	Cucurbitaceae	Locality unknown	Szent-Ivany,1959; Waite & Huwer, 1998
	Hevea brasiliensis Muell. Arg. (++)	Euphorbiaceae	Aroa & Bisianumu, Girinumu Estate, Central Province.	Szent-Ivany & Catley, 1960; Bourke *et al.*, 1973
	Cocos nucifera L. (++)	Palmae	Petoi, Gulf Province; Goodenough Is., Milne Bay Province; Popondetta, Oro Province.	Szent-Ivany & Catley, 1960
	Manihot esculenta Crantz (++)	Euphorbiaceae	Laloki, Diamond Valley & Aroa Estate, Central Province.	Brown, 1958b; Present work; Szent-Ivany, 1959
	Anacardium occidentale L. (++)	Anacardiaceae	Launakalana, Central Province.	Peng, 2002 (unpublished).
	Phaseolus mungo L. (*)	Euphorbiaceae	Central Province.	Brown, 1958b
	Urena lobata L. (*)	Malvaceae	Central Province.	Brown, 1958b
	Abroma augusta (L.) L.f (*)	Sterculiaceae	Central Province.	Szent-Ivany & Catley, 1960;Szent-Ivany 1959
	Carica papaya L. (+)	Caricaceae	Central Province.	Szent-Ivany & Catley, 1960
	Ipomoea batatas (L.) Lam. (*)	Convolvulaceae	Central Province.	Szent-Ivany & Catley, 1960;Szent-Ivany, 1959
	Magnifera indica L. (*)	Anacadiaceae	Central Province.	Szent-Ivany & Catley, 1960;Szent-Ivany, 1959
	Plumeria rubra L. (*)	Apocynaceae	Locality unknown	Waite & Huwer, 1998
	Psidium guajava L. (++)	Myrtaceae	Locality unknown Central Province	Waite & Huwer, 1998Dori, 1993 (unpublished)
	Artocarpus communis Foster & Foster (*)	Moraceae	Locality unknown	Waite & Huwer, 1998
	Dioscorea sp. (*)	Diocoreaceae	Locality unknown	Waite & Huwer, 1998
	Areca catechu	Palmae	Locality unknown.	Dori, 1993 (unpublished)
	Delonix regia (Hook) (++)	Caesalpindaceae	Locality unknown	Waite & Huwer, 1998
	Theobroma cacao L. (++)	Sterculiaceae	Central province.	Present work
A. theobromae Brown	*Hevea brasiliensis* Muell. Arg. (++)	Euphorbiaceae	Oro Province.	Brown, 1958b
	Theobroma cacao L. (++)	Euphorbiaceae	Jerarota, Sangara, Kokoda Pltn. Oro Province; Normanby & Fergusson Is.,	Brown, 1958b; Bourke *et al.*, 1973

[1] Present work refers to information gathered from the collection labels in the National Agricultural Insect Collection at the time of this study.

Contd. from pg.28

			Naura, Milne Bay Province.	
	Manihot esculenta Crantz (++)	Euphorbiaceae	Oro Province; PAU, Central Province.	Brown, 1958b
	Cocos nucifera L. (+)	Palmae	Locality unknown Milne Bay Province	Waite & Huwer, 1998;Smith,1984
	Vigna unguiculata sesquipedalis (L.) Verdc. (*)	Fabaceae	Locality unknown	Waite & Huwer, 1998
	Vigna radiata (L.) R. Wilezek (*)	Fabaceae	Locality unknown	Waite & Huwer, 1998
	Anacardium occidentale L. (+)	Anacardiaceae	Milne Bay Province	Smith, 1984
	Psophocarpus tatragonolobus (L.) DC (*)	Fabaceae	Locality unknown	Waite & Huwer, 1998
A. ardleyi Brown	*Theobroma cacao* L. (*)	Sterculiaceae	Lae, Morobe Province; Amele Village. Pltn., Madang Province.	Present work
A. costalis szentivanyi Brown	*Manihot esculenta* Crantz (+)	Euphorbiaceae	Rabaul, ENBP;Pirive Village, Oro Province, Central Province.	Brown,1958b;Present work
	Hevea brasiliensis Muel. Arg (*)	Euphorbiaceae	Central Province	Brown, 1958b; Szent-Ivany & Catley, 1960
	Theobroma cacao L. (+)	Sterculiaceae	Rabaul, ENBP; Bougainville, BP	Present work
A. cocophaga cocophaga China	*Theobroma cacao* L. (+)	Sterculiaceae	Keravat, ENBP; Tanaboia Pltn., BP	Present work
	Cocos nucifera L. (+)	Palmae	Bougainville, BP	Brown, 1958b
A. gallegonis bougainvillensis Brown	*Manihot esculenta* Crantz (+)	Euphorbiaceae	Bougainville, BP;	Present work
	Piper sp. (*)	Piperaceae	Locality unknown	Brown, 1958b
	Cocos nucifera L. (*)	Palmae	Locality unknown	Brown, 1958b
	Pueraria phaseoloides (Roxb.) Berth. (*)	Leguminosae	Locality unknown	Brown, 1958b
	Ipomoea batatas (L.) Lam. (*)	Convolvulaceae	Locality unknown	Brown, 1958b
	Theobroma cacao L. (*)	Sterculiaceae	Tanaboia Pltn., Bougainville, BP	Present work
A. madagana Brown & Ghauri	*Theobroma cacao* L. (+)	Sterculiaceae	Magafin, Dagua., ESP; Parer Pltn., WSP; Mamoo Pltn., Oro Province; Amele Village, Bogadjim Pltn., Madang Province	Present work
A. bukharii Ghauri	*Theobroma cacao* L. (++)	Sterculiaceae	Brown River, Central Province.	Ghauri, 1984

++ major pest, + minor pest and * pest status not known.

Abbreviations: NCD, National Capital District
PAU, Pacific Adventist University
ENBP, East New Britain Province
BP, Bougainville Province
ESP, East Sepik Province
WSP, West Sepik Province

The extent of damage has been seen to vary between the nymphs and the adults. Preston (1998) has noted that nymphs cause more damage than the adults as they are wingless and concentrate their feeding on the same fruits, petioles, shoots or lateral branches for longer periods. The adults are good fliers and change sites while the nymphs fall to the ground when they are disturbed (Preston 1998).

The degree of damage varies from plant to plant and also from species to species. The most serious damage is caused by *A. lutescens papuensis,* especially within the Central Province. The non-economic species are *A. ardleyi* and *A. gallegonis bougainvillensis* which cause no serious damage to crops on which they feed. The other species rank in between with the degree of damage varying among the crops.

A number of reasons contribute towards *A. lutescens papuensis* being a serious pest in Central Province. The obvious one is that it is mostly dry throughout the year in this region, accompanied by continuous burning of dry vegetation by humans. This promotes the occurrence of damage to crops since when bushes are burned, pests aggregate in places with fresh, young, planted crops and feed on the young tissue, thus causing the damage. For instance, this author observed the species to be a very serious pest of cassava during the dry season in Port Moresby, in serious cases killing whole plants. The species is also prevalent in most parts of Central Province. In most other parts of the country where *Amblypelta* is found, it is often humid whole the year around and the pest thrives in the forests and abandoned gardens. Indeed, the pest is found everywhere, but relatively in low abundance and does not often cause major damage.

The genus is generally confined to lower altitudes about of 300 - 400 m above sea level. There are no species recorded from the highlands. Specific species are restricted to certain areas with only a few species overlapping. *A. lutescens papuensis* is confined to Central, Gulf, Oro and Milne Bay provinces, *A. theobromae* to Central, Oro, Milne Bay and Morobe (Smith 1984) provinces, *A. ardleyi* to Morobe and Madang provinces, *A. costalis szentivanyi* to Central, East New Britain, Bougainville and Oro provinces, *A.cocophaga cocophaga* to East New Britain and Bougainville provinces. *A. gallegonis bougainvillensis* is restricted to the Bougainville Province, *A. madagana* to East Sepik, West Sepik and Madang provinces, while *A. bukharii* is restricted to the Central Province.

This author is doubtful concerning the absence of records from the West New Britain and New Ireland provinces since a number of species are available in the neighboring East New Britain Province. It is therefore recommended that further surveys be conducted to confirm their absence or otherwise.

SUMMARY

Amblypelta is a polyphagous pest and attacks wide range of crops causing characteristic damage. This paper presents a comprehensive list of host plants of *Amblypelta* species in PNG. No specific effective control measures have been developed so far; however, Integrated Pest Management (IPM) is seen as the ideal approach.

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REFERENCES

BIGGER M. 1982. The Effect by *Amblypelta cocophaga cocophaga* China (Hemiptera: Coreidae) on growth of *Eucalyptus deglupta* in the Solomon Islands. *Bulletin of Entomological Research* **75:** 595-608

BOURKE T.V., FENNER T.L., STIBICK J.N.L., BAKER G.L., HASSAN E., O'SULLIVIAN D.F. and LI C.S., 1973. Insect pest for the year ending 30th June 1969. *Department of Agriculture and Fisheries.* Port Moresby 57 pp.

BROWN E.S. 1958a. Revision of the genus *Amblypelta* Stål (Hemiptera: Coreidae). *Bull. Ent. Res* **49** (3): 509-541.

BROWN E.S. 1958b. Injury to cacao by *Amblypelta* Stål (Hemiptera: Coreidae) with a summary of food plants of species of this genus. *Bull. Ent. Res.* **49**: 543-554.

DONALDSON J.F.1983. The Australian species of *Amblypelta* Stål (Hemiptera: Coreidae). *Journal of Australian Entomological Society* **22**, 47-52.

DORI F.M. 1989. Selection for varietal resistance to tip-wilt bug in aibika. Annual Research Report. Agriculture Research Division, Department of Agriculture and Livestock, Papua New Guinea.

DORI F.M. 1998. Investigation of the pest complex and beneficial species on aibika: a base for Integrated Pest Management studies on aibika. Laloki Agricultural Research Station, Papua New Guinea.

GHAURI M.S.K. 1984. Two new species of *Amblypelta* Stål, attacking cacao in Papua New Guinea and Irian Jaya (West New Guinea) , with a key to each species (Heteroptera: Coreidae). *Reichenbachia*, **22** (6): 51-64.

KUMAR R. 2001. Insect Pests of Agriculture in Papua New Guinea, Part 1. *Principles and Practice, Pests of Tree Crops and Stored Products*, Science in New Guinea, University of Papua New Guinea, Papua New Guinea. 723 pp.

LEPS J., NOVOTNY V., and BASSETT Y. 2001. Habitat and successional status of plants in relation to the communities of their leaf-chewing herbivores in Papua New Guinea, *Journal of Ecology*, **89**, 186-199.

MILES P.W. 1987. Plant-sucking bugs can remove the contents of cells without mechanical damage. *Experientia*, **43**: 937-939.

PRESTON S.R. 1998. Aibika / Bele. *Abelmoschus manihot* (L.) Medik. Promoting the conservation and use of underutilized and neglected crops. Institute of Plant Genetics and Crop Plant Research, Gatersleben / International Plant Genetic Resources Institute, Rome, Italy.

SMITH E.S. 1984. Studies on *Amblypelta theobromae* Brown (Heteroptera: Coreidae) in Papua New Guinea-descriptions of the immature and adult stages. *Bull. Ent. Res.*, **74**: 541-547.

SZENT-IVANY J.J.H. 1959. Host plants and distribution records of some insects in New Guinea, *Pacific Insects*, **1**(4): 423-429.

SZENT-IVANY J.J.H. & CATLEY A. 1960. Notes on the distribution and economic importance of the Papuan tip-wilt bug *Amblypelta lutescens papuensis* Brown (Heteroptera: Coreidae), *Papua New Guinea Agri. Jorn.*, **13** (2): 59-65.

WAITE G.K & HUWER R.K. (1998). Host plants and their role in the ecology of the fruitspotting bugs *Amblypelta nitida* Stål and *Amblypelta lutescens lutescens* (Distant) (Hemiptera: Coreidae), *Australian Journal of Entomology*, **37**: 340-349.

A REVIEW OF TARO (*COLOCASIA ESCULENTA* (L.) SCHOTT) GENETIC RESOURCES OF PAPUA NEW GUINEA

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ABSTRACT

The status of taro (Colocasia esculenta (L.) Schott) genetic resources and the efforts of the National Agricultural Research Institute, together with several regional networks, in the acquisition, conservation, evaluation and utilization of the germplasm are reviewed. Wild and cultivated genotypes show enormous genetic variation suggesting Papua New Guinea is a centre of diversity. However, traditional varieties are being displaced due to biotic and abiotic factors. A representative sample of the genetic diversity of taro in Papua New Guinea has been collected and is maintained ex situ. The need to develop alternative conservation strategies for efficient management and utilization are considered.

Keywords: *Taro,* Colocasia esculenta, *genetic resources, germsplasm, genotypes, vegetable propagation*

INTRODUCTION

Taro, *Colocasia esculenta* (L.) Schott, is an edible aroid belonging to the Araceae family. It is a historical staple root crop in Papua New Guinea (PNG) and taro cultivation at Kuk in the Western Highlands Province, for example, has been dated to 9, 000 BC (Golson 1977). It has been suggested that it was the principal crop in the highlands prior to the introduction of sweet potato (*Ipomoea batatas*) 300-500 years ago (Clarke 1977; Bayliss-Smith 1982, 1985). With a long history of association with human society, taro has emerged as symbolic in traditional beliefs and rituals among many ethnic groups (Barrau 1965; Panoff 1972; Barth 1975; Morren and Hyndman 1987).

Taro is cultivated as an important staple up to an altitude of 2, 200 m (Bourke *et al.* 1998). It is grown as a minor food crop as high as 2, 740 m (Bourke 1982). It is primarily grown for its edible corm. However, leaves, inflorescences, and tender inner layers of petiole sheaths may also be used as vegetables. It is now being cultivated as a semi-commercial crop with surplus produce sold at markets. (Anonymous 2001). Annual production of taro is estimated at 170, 000 tonnes from an area of 31, 000 ha (FAO 2001).

Taro production, however, has been declining in the recent past as reported by Wagih *et al.* (1994). Taro leaf blight (TLB), caused by *Phytophthora colocasiae* Racib., taro beetles (*Papuana* spp.), the Alomae – Bobone virus complex (ABVC) and declining soil fertility all affect yield and have contributed to the declining production (Sar *et al.* 1998). Changing dietary habits and preferences for exotic foods, and the introduction of other crop species with better comparative advantages such as Chinese taro (*Xanthosoma sagittifolium)* and sweet potato have also had a negative influence on taro production (Waddell 1972; Bourke 1982; Joughin and Kalit 1986). The impact of these factors on production has unfortunately led to loss of traditional cultivars in some parts of PNG (Wagih *et al.* 1994).

This paper reviews efforts to preserve the existing taro genetic diversity by collecting and conserving farmers' varieties and evaluation and utilization of the genetic resources to improve production in PNG. Past efforts, current status and future prospects are discussed, highlighting collaboration with regional networks.

TARO DIVERSITY

Taro is believed to have originated in the Indo-Malayan region, either between Eastern India and Bangladesh (Plucknett 1983; Purseglove 1988) or in Southern China (Cable 1984). The origins of wild taros and their domesticated relatives, and the directions of dispersal remain debatable (Matthews and Terauchi 1994) *cited by* Yen 1995). Three hypotheses have been proposed for PNG taro germplasm. Firstly, it may be an eastward extension of the Indo-Malayan flora suggesting a single centre of origin in South Asia (Plucknett *et al.* 1970; Leon 1977; Yen 1982; Coates *et al.* 1988). Secondly, it may have been dispersed by early migrants and other seed vectors (Okada and Hambali 1989; Pawley and Green 1973). Thirdly, it may have

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resulted from an independent origin in PNG suggesting multiple origins of the crop (Matthews 1990, 1991; Lebot 1999), and PNG is considered as a centre of diversity (Leon 1977).

Three botanical varieties of *C. esculenta* are prevalent in PNG. Variety *aquatilis* is the commonly occurring wild type (Matthews 1991, 1987) whereas variety *esculenta* (dasheen type) and variety *antiquorum* (eddoe type) are cultivated in gardens, either in swiddens or irrigated plots. A third cultivated form expresses intermediate traits between the dasheen and eddoe types and is believed to be a hybrid (Lebot *et al.* 2000). The distribution of the cultivated forms depend on their status as a component of the cropping system practised, where taro is cultivated either as a dominant or co-dominant staple (Figure 1).

Numerous varieties exist in gardens (Panoff 1972; Rangai 1982; Morren and Hyndman 1987). The variability may be attributed to sexual recombination and perhaps somatic mutation, associated with continuous vegetative propagation and the subsequent selection by farmers based on adaptability and culinary qualities from exotic and novel varieties. Taro flowers and sets seed naturally. Protogyny and self-incompatibility systems in the inflorescence facilitate cross-fertilisation, which usually results in variable progenies (Shaw 1975; Okpul and Ivancic 1996; Johnston and Gendua 1998). Farmers have developed practices to identify, evaluate and select new varieties from natural crosses. Such practices have been observed in Pomio in West New Britain Province (Panoff 1972) and in Manus, Morobe and the Western Highlands provinces. On Manus Island after the rainy season, farmers search for seedlings of new varieties in ant nests on small trees, in bamboo patches, and in soils shifted by landslides. Similarly, in Morobe and the Western Highlands provinces, seedlings germinating in drains or ditches and alongside creeks and streams are nursed and culinary qualities assessed at maturity.

Continuous vegetative propagation has been observed to complicate colour or pigment patterns, resulting in the creation of numerous morphotypes. Exchange of such variants between communities may have resulted in new identities. A general indication of variability within the genepool can be traced from vernacular names. Novel varieties are usually named after the founder or are given names relating to culinary qualities such as texture and aroma, or even names that are analogous to human anatomy relating to the shape or pigmentation of plant parts, while introduced varieties are given the names of their place of acquisition. Clonal variants (or even unidentified but morphologically similar varieties), on the other hand, are given additional names that describe the phenotypic variation. For example, in the Morobe Province, a popular variety, Numkowec, has three variants: Numkowec-koko, Numkowec-sisip and Numkowec-yangyang, which are distinguished by their red, white and green basal ring colours, respectively.

The variability has been indicated in diversity studies based on quantitative traits (Ivancic *et al.* 1995), isozyme variations (Lebot and Aradhya 1991), variations in ribosomal and mitochondrial DNA restriction sites (Matthews 1990), Randomly Amplified Polymorphic DNA (Irwin *et al.* 1998), Amplified Fragment Length Polymorphisms (AFLP) (van Eck *et al.* 1998) and microsatellites (Mace and Godwin 2000; Godwin *et al.* In press). These studies have shown that a high level of genetic diversity exists in PNG as compared to neighbouring Pacific Islands. Nevertheless, and as exemplified by Waddell (1972), the displacement of taro is a growing concern (Wagih *et al.* 1994; Kesavan and Aburu 1982). During 1998, the present authors observed villagers in Lababia (population of >1000), Morobe Province, abandon taro cultivation in favor of sweet potato as a result of high infestation by taro beetle and epidemics of TLB. Consequently, all traditional varieties (estimated to be over 40) selected over the years under a taro-based farming system are now displaced. Such a situation raises the need to explore, collect and safeguard the existing genetic diversity for potential use.

ACQUISITION AND CONSERVATION

Collection of germplasm representing the genetic diversity is a prerequisite for its effective study, conservation and utilization for crop improvement. Past collections of cultivated and wild taros were conducted on an *ad hoc* basis by various researchers in the Department of Agriculture and Livestock (whose research functions are now under the National Agricultural Research Institute (NARI)) and the PNG University of Technology (UniTech). A total of 461 accessions were collected and maintained at the Highlands Agricultural Experiment Station (48), the Lowlands Agricultural Experiment Station (120), Laloki Research Station (135), Saramandi Research Station (28), Kuk Agricultural Research Station (10) and UniTech (120) (Aburu 1980; Jackson 1994; Levett *et al.* 1985). Amalgamation of the remnants of these collections at Bubia Agricultural Research Centre, now the Wet Lowlands Mainland Programme (WLMP) of NARI, formed the basis for the national taro germplasm collection (Arura 1985; Kambuou 1995).

Other institutions were involved on a number of occasions. The International Plant Genetic Resources Institute (IPGRI), formerly the

International Board for Plant Genetic Resources (IBPGR), funded several collection missions in the 1980s. Additional explorations resulted in the collection accruing 602 entries by 1989 (Akus *et al.* 1989) which were maintained in an *ex situ* collection at Bubia. A lot of accessions were lost before being characterized and evaluated. The losses are mainly attributed to inadequate husbandry in terms of weed control, and insect pest and disease management. Natural calamities such as floods and prolonged dry periods also had impacts on the field genebank, which was reduced to 437 accessions by 1995. Frequent staff turnover resulted in the loss of the passport data and field plans, which eventually invalidated the remaining entries and impeded efforts to re-collect (Kambuou 1998). Such errors have proved expensive and made maintenance of large *ex situ* collections unsustainable (Godden 1999).

From these experiences, the concept of a core collection and the use of complementary conservation strategies, especially *in vitro* techniques, for efficient conservation and utilization of taro germplasm were necessitated. Recently, local cultivars were re-collected throughout the country under the auspices of several regional networks: the Pacific Regional Agricultural Program (PRAP) of the Secretariat of the Pacific Community (SPC), the European Commission–funded Taro Network for Southeast Asia and Oceania (TANSAO) and the Taro Genetic Resources: Conservation and Utilization project (TaroGen) funded by the Australian Agency for International Development (AusAID). A total of 859 accessions from 16 provinces (Figure 1) have been collected, maintained *ex situ* in an augmented block design, and characterized. A core collection has been developed and a duplicate is being conserved *in vitro* in the Regional Germplasm Centre (RGC), Fiji (TaroGen 2001a).

International germplasm exchange can play an important role in broadening genetic diversity. This is an approach being emphasized by the TaroGen and TANSAO networks. The current germplasm collection also holds several exotic accessions from the Asia-Pacific region (Table 1). Recently, 134 accessions included in the TANSAO regional core collection were acquired. This set of lines is currently being maintained in tissue culture under quarar and will be virus-indexed and cleaned before ac to the field collection (Gunua *et al.* 2001).

VARIETY IDENTIFICATION AND EVALUATION

Agro-morphological characterization

Taro exhibits a wide array of agro-morphological polymorphism. Numerous variable but clonally stable traits are being used as markers for varietal identification and assessment of genetic diversity. The first descriptor list for taro, developed by IBPGR (IBPGR 1980), was used in earlier attempts to characterize the germplasm (Levett *et al.* 1985; Akus *et al.* 1989). An edited version, developed by IPGRI in collaboration with TaroGen (IPGRI 1999), is currently being used. Additionally, the TANSAO network developed a descriptor list using major agro-morphological markers for use in all of the partner countries for selection of national core samples to form a regional core collection (TANSAO 1998). A PNG core sample comprised of thirty-one varieties (Table 2) was selected based on the principal component score strategy from an initial collection of 279 accessions.

All accessions collected and maintained *ex situ* have now been characterized using the selected descriptors from the IPGRI descriptor list under TaroGen. The selected core sample from the TANSAO project has also been included. The data matrix was subjected to diversity analysis for the selection of a tentative core collection comprising the 20 per cent with the most diverse varieties. This work was conducted with assistance from IPGRI.

Molecular characterization

Lebot and Aradhya (1991) evaluated a total of 452 PNG accessions using isozyme markers. However, the information was not used to rationalize the collection due to loss of passport data and the field map. Although numerous diversity studies included PNG accessions (Matthews 1990; Irwin *et al.* 1998; Mace and Godwin 2000; Godwin *et al.* In press), the germplasm was not systematically characterized for varietal identification to rationalize the collection and to enable thorough assessment of the extent of genetic diversity.

The national core sample developed under TANSAO has been fingerprinted using AFLP at Wageningen Agricultural University and the information was used to compare genetic diversity among the accessions of the region (TANSAO, 1999, 2000). The core collection developed by TaroGen was fingerprinted at the University of Queensland using molecular markers under the ACIAR project No. CS2/94/43. Finally, 10 per cent of the whole collection comprising 83 varieties was selected to form the national core collection (Mace *et al.* 2001; TaroGen 2001a, 2001b).

Agronomic evaluation

Limited evaluation work has been conducted on yield and screening for disease resistance. Evaluations of varietal yields were, in most cases, preliminary and were sometimes inconclusive with respect to making recommendations of promising varieties for farmer adoption (Levett *et al.* 1985; Akus *et al.* 1989).

In exploiting the germplasm for disease resistance, Hicks (1967) screened for resistance against *P.*

Figure 1. **Map showing the number of accessions collected and status of taro as a staple crop in various provinces of Papua New Guinea.**

The map was produced using Mapping Agricultural Systems Project database (Bourke *et al.* 1998)

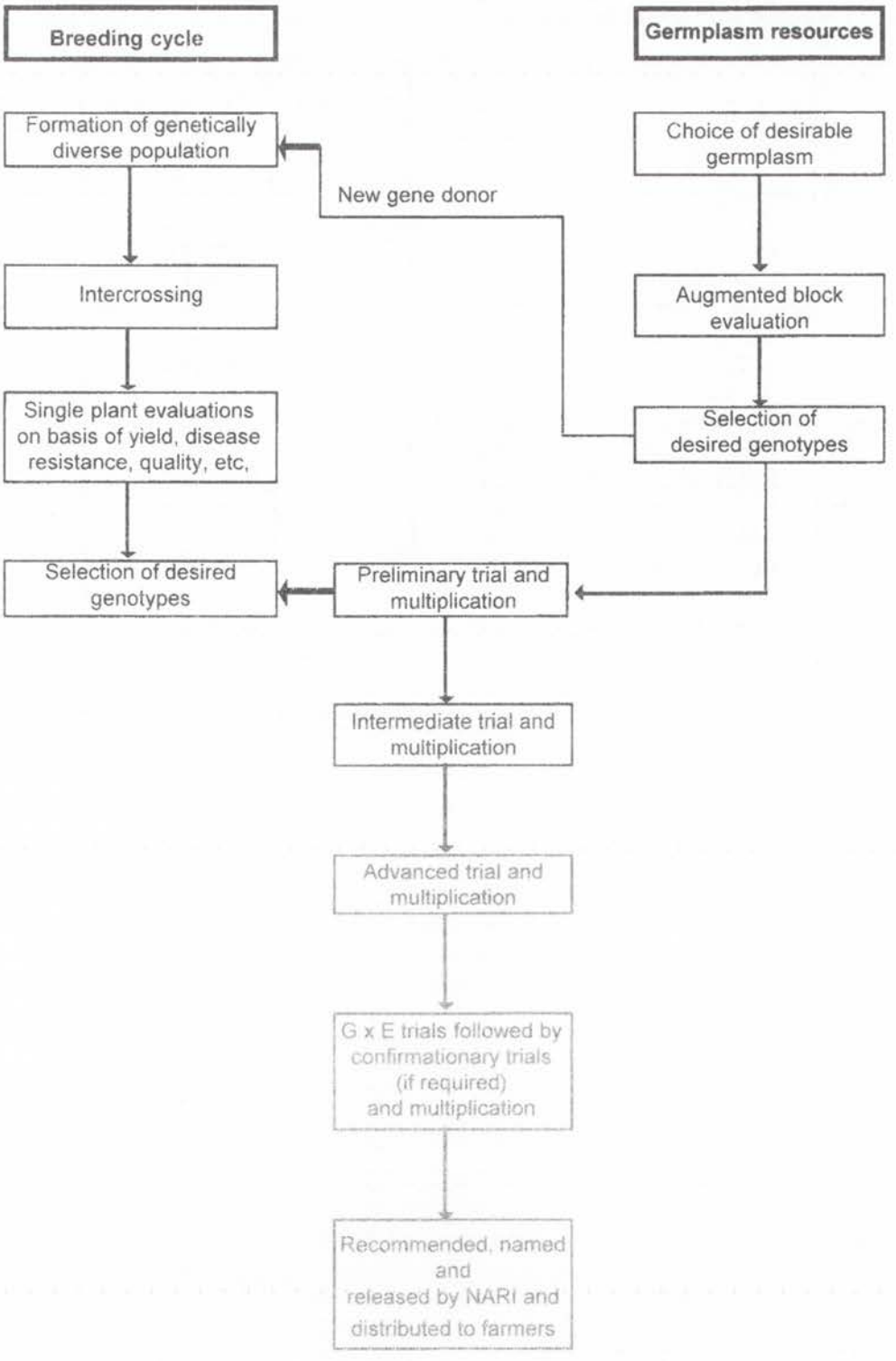

Figure 2. **Schematic representation of evaluation, development and release process for promising taro varieties**

Table 1. **Acquired exotic germplasm maintained in the National Agricultural Research Institute taro breeding working collection**

Country of origin1	Source	Acquisition date	Number of accessions	Type of sample	Current number of accessions
Cook Islands	IRETA, Samoa	1994	2	Cultivar	1
Fiji	IRETA, Samoa	1994	2	Cultivar	2
FSM	IRETA, Samoa	1994	2	Cultivar	1
Hawaii	IRETA, Samoa	1994	2	Cultivar	1
Indonesia	LIPI, Bogor	1998	10	Unknown	9
	LIPI, Bogor	2000	11	Cultivar	11
New Caledonia	IRETA, Samoa	1994	1	Cultivar	1
Niue	IRETA, Samoa	1994	2	Cultivar	1
Samoa	IRETA, Samoa	1994	2	Cultivar	1
Solomon Islands	DCRS, Solomon Islands	1993	Seeds	Semi-wide type	2
Thailand	DCRS, Solomon Islands	1993	1	Wild type	1
Vanuatu	IRETA, Samoa	1994	2	Cultivar	1

[1]FSM = Federated States of Micronesia; [2]IRETA = Institute for Research, Extension and Training in Agriculture; LIPI = Research and Development Centre for Biotechnology; DCRS = Dodo Creek Research Centre.

Table 2. **Taro cultivars forming the Papua New Guinea core sample selected for the Taro Network for Southeast Asia and Oceania regional core collection**

Assession number	Provincial Origin	Accession number	Provincial origin
BC1 643	Eastern Highlands	BC 793	Morobe
BC 646	Eastern Highlands	BC 798	Morobe
BC 656	Simbu	BC 810	Morobe
BC 661	Simbu	BC 813	Morobe
BC 674	Western Highlands	BC 818	Morobe
BC 677	Western Highlands	BC 835	Morobe
BC 680	Oro	BC 844	Morobe
BC 691	Oro	BC 846	Morobe
BC 734	West Sepik	BC 853	Morobe
BC 740	West Sepik	BC 859	Morobe
BC 749	Milne Bay	BC 874	Morobe
BC 759	Morobe	BC 885	Morobe
BC 769	Morobe	BC 887	Morobe
BC 770	Morobe	BC 894	Western
BC 773	Morobe	BC 902	Morobe
BC 786	Morobe		

[1]BC = Bubia collection number

colocasiae Racib. and noted varying levels of resistance among tested accessions. However, no further work was pursued until recently, when Kokoa and Darie (1994) screened for and identified three resistant genotypes, namely Ph-15, Ph-17, and Ph-21 as possible donors for resistance against *P. colocasiae*.

The collection is currently being systematically evaluated under the breeding program for other agronomic traits. Initial evaluations are based on the augmented block design in which performance of accessions within the collection are compared prior to formal testing and release for use (Figure 2). The selected TANSAO core sample is also being evaluated for agronomic traits and quality in formal trials (Gunua *et al.* 2001).

UTILIZATION OF CONSERVED GERMPLASM

Germplasm can be utilized directly in the form of better performing landraces or farmer varieties, or indirectly as donors of useful genes for the development of novel varieties. The germplasm has not been systematically evaluated for its direct use. Genetic improvement, on the other hand, was attempted over the years. Earlier taro breeding work was conducted at LAES. The Department of Agriculture (Anonymous 1941) reported on single plant selections that developed two high yielding varieties, 'Utility' and 'King', yielding up to 17.6 t/ha. No further improvement work was conducted until the 1980s when breeding for resistance to TLB was first attempted. A resistant Thai wild type identified as 'Bangkok' was used in crosses involving promising cultivars. This program was, in fact, an extension of Dr. G. V. H. Jackson's work in the Solomon Islands. However, no improved lines were released from LAES (Gunawardhana 1984).

Recently, three resistant genotypes, Ph-15, Ph-17 and Ph-21 from PNG, together with the genotype 'Bangkok' were used as donor parents in the base population of a modified recurrent selection procedure adopted for taro improvement at WLMP. Several cultivars (both indigenous and exotic) were used as recurrent parents in selection for yield and culinary qualities (Ivancic and Okpul 1996, 1997). The breeding work is currently in its fourth cycle (or generation). In the first cycle, selection was directed towards TLB resistance because of the strong influence of wild germplasm on yield and culinary quality (Okpul *et al.* 1997). A set of 12 lines was finally selected for intermediate trials, which resulted in the recommendation of seven lines for evaluation in national multi-location trials (Singh and Okpul 2000). These lines were evaluated in seven different sites throughout PNG (TaroGen 2000). Three lines (C2-E3, C2-E4 and C2-E8) were released as varieties under the names NT 01, NT 02 and NT 03, respectively (Okpul *et al.* 2002). The salient features of these varieties are highlighted in Table 3. Further, multi-character selection in the third cycle population has resulted in the selection of 6 lines, which are being bulked for multi-location trials. The fourth cycle population is currently being evaluated on a single plant basis and 237 superior lines have been identified.

The genebank has also provided a means for interested farmers to recover their lost varieties and many farmers have used the opportunity to diversify the number of varieties planted in their gardens. International students and researchers have also accessed the germplasm (Table 4). The regional approach to germplasm conservation being undertaken will ensure easier access by scientists and other bonafide users.

FUTURE PROSPECTS

Despite waning production, taro is still a staple of high market value in PNG. This highlights its potential as a commodity on which to base economic development in rural areas. However, taro is a difficult crop to grow because of its high requirements for soil nutrients, moisture and labour. It is also affected by numerous pests and diseases, which can have a drastic impact on yield. These factors have, cumulatively, caused farmers to lose interest in taro farming. As observed, the abandonment of taro cultivation is a serious threat to traditional varieties. In order to renew farmers' interest and prevent genetic erosion, more research needs to be conducted in developing options to circumvent production constraints. Major factors limiting production are TLB, taro beetle, declining soil fertility and ABVC together with its vectors, particularly *Tarophagus* spp. and *Aphis gossypii*. Other pests and diseases of some concern to growers include the dasheen mosaic virus, leaf defoliators (especially *Hippotion celeria* L. and *Spodoptera litura)* and the nematode *Hirschmaniella miticausa*.

Several leaf blight resistant lines have been developed and released as recommended varieties to farmers. Nevertheless, ABVC and taro beetle still remain as major constraints to production. Jackson and Gollifer (1975) have reported on varieties expressing varying levels of resistance to ABVC. The study identified varieties of the 'male types' (no relation to sexuality but generally larger plant forms) to be susceptible while the smaller 'female types' express some level of resistance. These observations need to be further investigated, although the situation is complicated by the fact that

Table 3. **Description of released taro varieties and a popular standard cultivar Numkowec***

Character	Variety			
	NT 01 (C2-E3)	**NT 02 (C2-E4)**	**NT 03 (C2-E8)**	**Numkowec (control)**
Yield	10.49 t/ha	7.68 t/ha	7.65 t/ha	5.89 t/ha
Average corm weight (g)	525 g	380 g	380 g	300 g
Yield stability	Stable	Stable	Unstable	Stable
Taro leaf blight (TLB)	Resistant	Resistant	Resistant	Susceptible
TLB diseased leaf area (%)	8.24	7.34	7.19	15.76
Taro beetle	Susceptible	Susceptible	Susceptible	Susceptible
Taro beetle damage (%)	19.70	19.04	18.74	19.53
Eating Quality	Good	Good	Good	Good
Eating Quality Score	2.64	2.59	2.54	2.52
Time to maturity (months)	6	6	6	6
Sucker production	3-4	2-3	5-6	6-8
Growth habit	Erect	Erect	Erect	Erect
Plant height	Tall	Tall	Tall	Tall
Leaf lamina	Light green	Dark green	Dark green	Dark green
Petiole colour	Light green	Purple green	Purple	Light green
Petiole junction	Purple	Purple	Purple	Purple
Flowering	Rare	Rare	Frequent	Frequent
Corm shape	Cylindrical	Elliptical	Conical	Conical
Corm skin	Smooth	Smooth	Smooth	Smooth
Flesh colour	Pink	Pink	Pink	Pink
Corm dry matter content (%)	35	41	41	38

* Source (Okpul *et al* 2002)

Table 4. **Papua New Guinea germplasm accessed by international institutions[1]**

Country	Institution[2]	Date of acquisition	Number of accessions[3]	Type of sample
Australia	ANU	1957-63, 1990-98	Unknown	Unknown
Australia	RBG	Unknown	1	Unknown
France	CIRAD	1995-1996	NA	Seed
Japan	KNAES	1986-1987	Unknown	Cultivar
Japan	OU, CU, TBG	1986-1988	9	Cultivar
Japan	NIVOT	1982, 1987	>30	Cultivar
Malaysia	SU	1989	Unknown	Unknown
Palau	PCAA	Unknown	1	Cultivar
The Netherlands	WAU	1999	40	Cultivar
United Kingdom	HRI	1986, 1994	15	Cultivar and seed
United States	UH	1994	3	Breeding line

[1]Table modified from Kambuou (1998); [2]ANU = Australian National University; CIRAD = Centre de Cooperation Internationale en Recherche Agronomique pour le Development; CU = Chiba University; HRI = Horticultural Research Institute; KAES = Kyushu Agricultural Experiment Station; NIVOT = National Research Institute of Vegetables, Ornament plants and Tea; Ou = Okayama University; PCAA = Palau Community Action Agency; RBG = Royal Botanical Gardens; SU = Selangor University; TBG = Tsukuba Botanical Gardens; UH = University of Hawaii; WAU = Wageningen Agricultural University. [3]NA = Not applicable.

several viral particles are involved whose combinations are usually manifested in varying symptoms (Rodoni *et al.* 1994).

Active search for satisfactory control measures for taro beetle has been concentrated in the last decade and is still continuing. Several biological control agents and chemicals have been identified in laboratory studies but their practical relevance is yet to be established (Thistleton *et al.* In press). Although the beetle has a wide host range, and varietal resistance does not seem to exist in taro as it attacks all varieties, it does not attack taro cultivated in flooded fields. This indicates the potential for using permanent flooding to circumvent beetle damage. Flooded or paddy culture may be an effective control measure, but it is not feasible in most areas of the ruggedly undulating terrain of PNG. Besides, cultivars in PNG are mostly adapted to rain-fed cropping systems and usually do not tolerate moisture levels above saturation point. Hence, genotypes tolerant to flooded conditions would need to be identified from the germplasm collection.

Taro breeding, as with other crop species, is strongly dependent on the availability of genetic resources. Collection and conservation of germplasm is therefore vital and a fair representation of the diversity has been collected from most provinces. A core collection of maximal diversity has been selected. In essence, the core collection was developed to ease management of the conserved genetic diversity and access to it. However, the germplasm is conserved *ex situ* where it is continuously exposed to biotic and abiotic stresses. Hence, complementary conservation strategies need to be developed to avoid the costly errors of the past. Medium to long-term storage *in vitro* should be considered. Although a duplicate of the core collection will be maintained *in vitro* in the RGC (Fiji), it is imperative to adopt such a complementary strategy nationally in PNG for ease of domestic access. Additionally, the feasibility of other options such as *in situ*, on-farm, conservation needs to be investigated.

Development of efficient screening methods and evaluation of the germplasm for varietal resistance against the main pests and diseases and for adaptability, particularly to permanent flooding, is of high priority. Long-term strategies have to be developed for pragmatic exploitation of the germplasm.

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REFERENCES

ABURU, K. (1980). Germplasm at Lowlands Agricultural Experimental Station, Keravat, Papua New Guinea. *International Board on Plant Genetic Resources South East Asia Newsletter* 4(3): 6-9.

AKUS, W.L., PISEA, T., ARURA, M., OSOSO, E. and BOKOSOU, J. (1989). Taro germplasm collection and maintenance. In: *Bubia Agricultural Research Centre, Annual Report*. Department of Agriculture and Livestock, Lae, Papua New Guinea.

ANONYMOUS (1941). Department of Agriculture Annual Report. *New Guinea Agriculture Gazette*. 7(2): 76-116.

ANONYMOUS (2001). Market Prices. *Fresh Produce News*. 150: 14-29.

ARURA, M. (1985). Taro germplasm collection. In: *Bubia Agricultural Research Centre, Annual Report 1984*. Department of Agriculture and Livestock, Lae, Papua New Guinea.

BARRAU, J. (1965). L'humide et le sec. *Journal of Polynesian Society*. 74: 329-346.

BARTH, F. (1975). *Rituals and knowledge among the Baktaman of New Guinea*. Yale University Press, New Haven.

BAYLISS-SMITH, T.P. (1982). Taro (*Colocasia esculenta*) in the New Guinea highlands. In: *Proceedings of the Second Papua New Guinea Food Crops Conference, Part One*. R. M. Bourke and V. Kesavan (eds). pp. 134-147. Department of Primary Industry, Port Moresby, Papua New Guinea.

BAYLISS-SMITH, T.P. (1985). Pre-ipomoean agriculture in the New Guinea highland above 2000 metres: some experimental data on taro cultivation. In: *Prehistoric Subsistence Agriculture in the Tropics*. E. S. Farrington (ed). pp. 285-320. BAR International Series 232, Oxford, United Kingdom.

BOURKE, R.M. (1982). Root crops in Papua New Guinea. In: *Proceedings of the Second Papua*

New Guinea Food Crops Conference, Part One. R. M. Bourke and V. Kesavan (eds). pp. 51-63. Department of Primary Industry, Port Moresby, Papua New Guinea.

BOURKE, R.M., ALLEN, B.J., HOBSBAWN, P. and CONWAY, J. (1998). In: *Agricultural Systems of Papua New Guinea. Working paper No. 1*. Australian National University, Canberra, Australia.

CABLE, W.J. (1984). Spread of taro (*Colocasia* sp.) in the Pacific. In: *Edible Aroids*. S. Chandra (ed). pp. 28-31. Oxford University Press, Oxford, United Kingdom.

CLARKE, W.C. (1977). A change of subsistence staple in pre-historic Papua New Guinea. In: *Proceedings of the Third International Symposium on Tropical Root Crops*. C. L. A. Leaky (ed). pp. 159-163. International Society for Tropical Root Crops and International Institute for Tropical Agriculture, Ibadan, Nigeria.

COATES, D.J., YEN, D.E. and GAFFY, P.M. (1988). Chromosome variation in taro, *Colocasiaesculenta*: implications for origin in the Pacific. *Cytologia*. 53: 551-560.

FAO (2001). FAO Statistical (FAOSTAT) database. http://apps1.fao.org

GODDEN, D. (1999). Economic rationale for cooperation in germplasm conservation. In: *Plant Genetic Resources in the Pacific: towards regional cooperation in conservation and management. ACIAR Monograph*. 76: 59-60.

GODWIN, I.D., MACE, E.S. and NURZUHAIRAWAITY. (In press). Genotyping Pacific Island taro (*Colocasia esculenta* (L.) Schott) germplasm. *In* Plant Genotyping - the DNA Fingerprinting of Plants. R. Henry (ed). CAB International.

GOLSON, J. (1977). The making of the New Guinea Highlands. In: *The Melanesian Environment*. J. H. Winslow (ed). pp. 45-56. The Australian National University Press, Canberra, Australia.

GUNAWARDHANA, S.A. (1984). A review of taro breeding, pests and diseases. In: Food Crops Advisory Meeting (2/3rd October 1984) Report. J. George and D. Moles (eds). Bubia Agricultural Research Centre, Lae, Papua New Guinea.

GUNUA, T.G., OKPUL, T. AND SINGH, D. (2001). Activities of TANSAO in Papua New Guinea. 2000 *Annual Report*. WLMP, National Agricultural Research Institute, Lae, Papua New Guinea.

HICKS, P.G. (1967). Resistance of *Colocasia esculenta* to leaf blight caused by *Phytophthora colocasiae*. *Papua New Guinea Agriculture Journal*. 19(1): 1-4.

IBPGR (1980). Descriptors for taro (*Colocasia esculenta*). International Plant Genetic Resources Institute, Rome, Italy.

IPGRI (1999). Descriptors for taro (*Colocasia esculenta*). International Plant Genetic Resources Institute, Rome, Italy.

IRWIN, S. V., KAUFUSI, P., BANKS, K., DE LA PENA, R. and CHO, J. (1998). Molecular characterization of taro (*Colocasia esculenta*) using RAPD markers. *Euphytica*. 99: 183-189.

IVANCIC, A. and OKPUL, T. (1996). A new mutation of taro (*Colocasia esculenta*) observed at Bubia Agricultural Research Centre. *Papua New Guinea Journal of Agriculture Forestry and Fisheries*. 39(2): 6-9.

IVANCIC, A. and OKPUL, T. (1997). Importance of wild germplasm in taro (*Colocasia esculenta*) breeding. In: *Proceedings of the 1st Congress of the Genetics Society of Slovenia* (September 2-5, 1997). Pp. 83-84. Ljubljana, Slovenia.

IVANCIC, A., SIMIN, A., OSOSO, E. and OKPUL, T. (1995). Wild taro (*Colocasia esculenta* (L.) Schott) populations in Papua New Guinea. *Papua New Guinea Journal of Agriculture, Forestry and Fisheries*. 38(1): 31-45.

JACKSON, G.V.H. (1994). Taro and Yam genetic resources in the Pacific and Asia. A report for ACIAR and IPGRI. ANUTECH Pty Ltd, Canberra, Australia.

JACKSON, G.V.H. and GOLLIFER, D.E. (1975). Disease and pest problems of taro (*Colocasia esculenta* (L.) Schott) in the British Solomon Islands. *PANS*. 21(1): 45-53.

JOHNSTON, M. and GENDUA, P. (1998). The growth performance of taro (*Colocasia esculenta*) grown from true seed. *Tropical Agriculture (Trinidad)*. 75(1): 13-17.

JOUGHIN, J. and KALIT, K. (1986). The changing cost of food in Papua New Guinea-an analysis of five urban markets. *Technical Report No. 14*. Department of Primary Industry, Port Moresby, Papua New Guinea.

KAMBOU, R.N. (1995). The current status and prospects of plant genetic resources in Papua New Guinea. *Harvest*. 18 (1 & 2): 26-70.

KAMBUOU, R.N. (1998). Status of taro collection in Papua New Guinea: Country Report. Paper presented at AusAID/SPC taro collection strategy workshop (December 7 – 11), Lae, Papua New Guinea.

KESAVAN, V. and ABURU, K. (1982). Conservation of plant genetic resources. In: *Traditional conservation in Papua New Guinea: implications for today. Monograph 16*. L. Morauta, J. Pernatta and W. Heaney (eds). pp. 379-384. Institute of Applied Social and Economic Research, Port Moresby, Papua New Guinea.

KOKOA , P. and DARIE, A. (1994). Field screening of taro (*Colocasia esculenta* (L.) Schott) for resistance to taro leaf blight (*Phytophthora colocasiae*). In: Proceedings of the Second Taro Symposium. G.V.H. Jackson and M. E. Wagih (eds). pp. 127. PNG University of Technology, Lae, Papua New Guinea.

LEBOT, V. (1999). Biomolecular evidence for plant domestication in Sahul. *Genetic Resources and Crop Evolution*. 46: 619-628.

LEBOT, V. and ARADHYA, K.M. (1991). Isozyme variation in taro *Colocasia esculenta* (L.) Schott from Asia and Oceania. *Euphytica*. 56: 55-66.

LEBOT , V., HARTATI, S., HUE, N.T., VIET, N.V., NGHIA, N.H., OKPUL, T., PARDALES, J., PRANA, M.S., THONGJIEM, M., KRIEKE, C.M., VAN ECK, H., YAP, T.C and IVANCIC, A. (2000). Genetic variation of taro (*Colocasia esculenta*) in South East Asia and Oceania. In: *2000 Annual Report. Taro Network for South East Asia and Oceania: Evaluation and breeding for rain-fed cropping systems in South East Asia and Oceania*. Pp. 98-114. CIRAD Office, Port Vila, Vanuatu.

LEON, J. (1977). Origin, evolution and early dispersal of root and tuber crops. In: *Proceedings of the 4th Symposium (1-7 August 1976) of the International Society for Tropical Root Crops*. J. Cook, R. MacIntyre and M. Graham (eds). Pp. 20-36. International Development Research Centre, Ottawa, Canada.

LEVETT, M.P., KURIKA, L. and TAKAGI, H. (1985). Germplasm collection, description and preliminary evaluation of the major root crops in Papua New Guinea. *Technical Report 85/2*. Department of Primary Industry, Port Moresby, Papua New Guinea.

MACE, E.S. and GODWIN, I.D. (2000). Using SSRs to determine genetic diversity in taro. *The Satellite*. 3(1): 4-6.

MACE, E., GODWIN, I. and MATHUR, P. (2001). Development of recommended taro core collection based on molecular characterization. In: *Taro Conservation Strategy Workshop (September 2001) Report*. pp. 19-24. AusAID/SPC Taro Genetic Resources: Conservation and Utilization. Secretariat of the Pacific Community, Noumea, New Caledonia.

MATTHEWS, P. (1987). Wild taros and the context of cultivation. *Aroideana* 10(1): 9-13.

MATTHEWS, P.J. (1990). The origins, domestication and dispersal of taro. PhD Thesis. Australian National University, Canberra, Australia.

MATTHEWS, P.J. (1991). A possible wildtype taro: *Colocasia esculenta* var. *aquatilis*. *Indo-Pacific Prehistory Association Bulletin* 11: 69-81.

MATTHEWS, P.J. and TERAUCHI, R. (1994). The genetics of agriculture: DNA variation in taro and yams. In: *Tropical Archaeobotany: Applications and New Developments*. J. G. Hather (ed). pp. 251-262. Routledge, London, United Kingdom.

MORREN, G.E.B., and HYNDMAN, D.C. (1987). The taro monoculture of Central New Guinea. *Human Ecology*. 15(3): 301-315.

OKADA, H. and HAMBALI, G.G. (1989). Chromosome behaviors in meiosis of the interspecific hybrid between *Colocasia esculenta* (L.) Schott and *C. gigantea* Hook. F. *Cytologia*. 54: 389-393.

OKPUL, T. and IVANCIC, A. (1996). Hybridization of taro (*Colocasia esculenta* (L.) Schott): floral development and stigma receptivity. *Papua New Guinea Journal of Agriculture, Forestry and Fisheries*. 39(1): 12-18.

OKPUL, T., IVANCIC, A. and SIMIN, A. (1997). Evaluation of 35 leaf blight resistant taro lines for Bubia, Morobe Province, Papua New Guinea. *Papua New Guinea Journal of Agriculture, Forestry and Fisheries*. 40(1&2): 13-18.

OKPUL, T., SINGH, D., WAGIH, M. WILES, G. and HUNTER, D. (2002). Improved taro varieties with resistance to taro leaf blight for Papua New Guinea farmers. *NARI Technical Bulletin Series*. No. 3.

PANOFF, F. (1972). Maenge taro and cordyline: Elements of Melanesian key. *Journal of Polynesian Society*. 81: 375-390.

PAWLEY, A.K. and GREEN, R.C. (1973). Dating the dispersal of oceanic languages. *Oceanic Linguist*. 12: 1-67.

PLUCKNETT, D.L. (1983). Taxonomy of the genus *Colocasia*. In: Taro: A Review of *Colocasia esculenta* and its Potentials. Pp. 61-66. J. K. Wang and S. Higa (eds). Hawaii University Press, Honolulu.

PLUCKNETT, D. L., DE LA PENA, R.S. and OBRERO, F. (1970). Taro (*Colocasia esculenta*). *Field Crops Abstracts*. 23: 413-426.

PURSEGLOVE J.W. (1988). *Tropical crops: Monocotyledons*. Longman Press, Essex, United Kingdom.

RANGAI, S.S. (1982). Preliminary results of a survey of taro cultivation in the Gazelle Peninsula of New Britain. In: *Proceedings of the Second Papua New Guinea Food Crops Conference, Part One*. R.M. Bourke and V. Kesavan (eds). pp. 123-133. Department of Primary Industry, Port Moresby, Papua New Guinea.

RODONI, B.C., DALE, J.L. and HARDING, R.M. (1994). Review of Alomae disease of taro. *Papua New Guinea Journal of Agriculture, Forestry and Fisheries*. 37(2): 14-18.

SAR, S., WAYI, B.M. and GHODAKE, R.D. (1998). Review of research in Papua New Guinea for sustainable production of taro (Colocasia esculenta). *Tropical Agriculture (Trinidad)*. 75(1): 134-138.

SHAW, D.E. (1975). Illustrated notes on flowering, flowers, seeds and germination in taro (*Colocasia esculenta*). In: *Research Bulletin 13*. pp. 39-59. Department of Agriculture Stock and Fisheries, Port Moresby, Papua New Guinea.

SINGH, D. and OKPUL, T. (2000). Evaluation of 12 taro (*Colocasia esculenta* (L.) Schott) leaf blight resistant lines for yield and eating quality in Papua New Guinea. *SABRAO Journal of Breeding and Genetics*. 32(1): 39-45.

TANSAO (1998). 1998 Annual Report. Taro Network for South East Asia and Oceania: Evaluation and breeding for rain-fed cropping systems in South East Asia and Oceania, Port Vila, Vanuatu.

TANSAO (1999). 1999 Annual Report. Taro Network for South East Asia and Oceania: Evaluation and breeding for rain-fed cropping systems in South East Asia and Oceania, Port Vila, Vanuatu.

TANSAO (2000). 2000 Annual Report. Taro Network for South East Asia and Oceania: Evaluation and breeding for rain-fed cropping systems in South East Asia and Oceania, Port Vila, Vanuatu.

TAROGEN (2000). 1999/2000 Annual Report. AusAID/SPC Taro Genetic Resources: Conservation and Utilization. Secretariat of the Pacific Community, Noumea, New Caledonia.

TAROGEN (2001a). 2000/2001 Annual Report. AusAID/SPC Taro Genetic Resources: Conservation and Utilization. Secretariat of the Pacific Community, Noumea, New Caledonia.

TAROGEN (2001b). Taro Conservation Strategy Workshop (September 2001) Report. AusAID/SPC Taro Genetic Resources: Conservation and Utilization. Secretariat of the Pacific Community, Noumea, New Caledonia.

THISTLETON, B.M., MASAMDU, R., THEUNIS, W., ALOALI'I, I., TAISAU, P. and SIMBIKEN, N. (In press). A summary of studies on the taxonomy, biology and ecology of taro beetles *Papuana* spp. and *Eucopidocaulus* spp. (Coleotera: Scarabaeidae) from the South Pacific and evaluation of measures for their control. Secretariat of the Pacific Community, Noumea, New Caledonia.

VAN ECK, H.J., HAN, T. and JACOBSEN, E. (1998). Evaluation of the genetic diversity in taro (*Colocasia esculenta*) using AFLP fingerprinting. In: 1998 Annual Report, Taro Network for Southeast Asia and Oceania (TANSAO). pp. 78-82. CIRAD Office, Port Vila, Vanuatu.

WADDELL, E. (1972). The mound builders: Agriculture practices, environment and society in the Central Highlands of New Guinea. University of Washington Press, Seattle, USA.

WAGIH, M.E., SIAGURU, P. and MOUSA, N. (1994). The missing role of biotechnology in the conservation and use of floral diversity in Papua New Guinea. *Science in New Guinea.* 22(2): 51-60.

WILLS, R.B.H., LIM, J.S.K. and BAYLISS-SMITH, T. (1983). Nutrient composition of taro (*Colocasia esculenta*) cultivars from the Papua New Guinea Highlands. *Journal of Food Science and Agriculture.* 34: 1137-1142.

YEN, D.E. (1982). The history of cultivated plants. In: *Melanesia: Beyond diversity.* Volume One. R.J. May and H. Nelson (eds). Pp. 281-295. Research School of Pacific Studies, Australian National University, Canberra.

YEN, D.E. (1995). The development of Sahul agriculture with Australia as bystander. *Antiquity.* 69: 831-847.

ALTERNARIA STEM AND LEAF BLIGHT OF SWEET POTATO (*IPOMOEA BATATAS* (L.) LAM.): A NEW DISEASE IN THE HIGHLANDS OF PAPUA NEW GUINEA

Pere Kokoa[1]

ABSTRACT

A new disease on sweet potato (Ipomoea batatas) (*L.) Lam.*) *causing black lesions on stems and petioles that eventually lead to dieback of vines was reported in the Western Highlands Province of Papua New Guinea in early 1987. Isolations from necrotic lesions on stems and petioles yielded the fungi* Alternaria alternata, Phoma exigua, Phomopsis ipomoeae, Fusarium oxysporum, F. solani, F. subglutinans, F. lateritium *and the bacteria* Bacillus sp. *and* Pseudomonas cichorii. *Pathogenicity tests on isolates of* A. alternata, P. ipomoea, F. oxysporum, F. solani, F. subglutinans, F. lateritium *and a* Colletorichum sp. *at Kuk Agricultural Research Station in 1987 and 1988 conformed that* A. alternata *was the causal agent of stem and leaf blight of sweet potato.*

Keywords: *Pathogenicity, lesions, disease symptoms, hyphae, fungi.*

INTRODUCTION

Species of the fungus *Alternaria* have been reported as causing or being associated with leaf spot and, leaf and stem blight of sweet potato from India, Malaysia, Senegal, Ethiopia, New Caledonia, Rwanda, South Africa and Bazil (Waller 1984, Clark and Moyer 1988, Lenne 1991, Lopes and Boiteux 1994). *Alternaria* leaf spot of sweet potato has a worldwide distribution, while *Alternaria* stem and leaf blight has only been reported in Ethiopia (Clark and Moyer 1988). Lenne (1991) cited *Alternaria alternata* (Fr.) Keissler, *A. capsici-annui* Savul and Sandu-ville, *A. solani* Sorauer and *A. tenuissima* (Pers.) as the causal agents for leaf and stem blight on sweet potato. Waller (1984) identified *Alternaria bataticola* Tamamoto as the cause of leaf spot in the Southern Highlands of Papua New Guinea (PNG) and Clark and Moyer (1988) reported a species of *Alternaria* causing rot of stored sweet potato tubes. Storage rot is neither common nor important. Lenne (1991) also reported *A. alternata, A. capsici-annui, A. sesami* (Kaw.) Moh. and Ben., *A. solani* and *A. tenuissima* occurring on wild species of *Ipomoea*.

Leaf spot and stem blight are the two main *Alternaria* diseases of sweet potato, where stem blight is considered as the more severe disease (Clark and Moyer 1988). Symptoms of leaf spots only occur on older leaves. The lesions are light brown with dark-brown concentric rings and well-defined margins.

Stem blight causes small, gray to black, oval lesions on stems and petioles. Under humid conditions, the lesions enlarge and eventually girdle the stems and petioles and in dry weather conditions the lesions become bleached and cracked.

There are no reports of cultural or chemical control of either leaf spots and leaf and stem blight of sweet potato. However, some varieties of sweet potato are resistant to *Alternaria* (Clark and Moyer 1988, Lenne 1991).

This paper presents the results of pathogenicity tests following an outbreak of an unknown disease on sweet potato at Kamuga village in the Western Highlands Province, PNG in February 1987.

MATERIALS AND METHODS

Isolation and identity of pathogens

Diseased stems and petiole pieces collected from the field at Kuk Agricultural Research Station (KARS) and Kamuga village were soaked separately in running water under a tap for 1 hour. The samples were rinsed in deionised water, then transferred to a laminar flow cabinet where they were surface sterilised by immersion in 70% ethanol for 5-10 seconds, followed by flaming or immersion in 70% ethanol for

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60 seconds. The samples were rinsed three times in sterile water and blot dried with clean paper tissues. Thin sections of diseased stem and petiole were cut out aseptically using a pair of forceps and a sharp scalpel blade and plated onto potato dextrose agar (PDA) or water agar (WA).

Necrotic lesions were also incubated in moist chambers for 24 h to induce sporulation and spores and external hyphae were transferred with a sterile needle to plates containing PDA or WA. No antibiotics were used in the culture medium.

All isolated fungi from each media were subcultured using a hyphal-tip placed onto fresh PDA and WA until a pure culture was obtained. Isolates of *Fusarium* were subcultured onto carnation leaf agar (CLA) using single spores (Burgess *et al.* 1981, Burgess and Liddell 1988). Bacterial isolates were subcultured onto PDA. All cultures were incubated at room temperature under 9 h light provided by two fluorescent tubes.

Cultures of *Alternaria*, other fungi and bacterial isolates were identified by the International Mycological Institute, U.K. while the *Fusarium* isolates were identified by the Fusarium Research Laboratory, University of Sydney.

Plants

Six highly susceptible varieties: Mond Amb (Kuk 962), Langapin (Kuk 867), Karuku (Kuk 537), Teka (Kuk 787), Gorokagi (Kuk 546) and an unnamed variety (Kuk 469) were selected for inoculation tests. Mond Amb and Langapin were from the Kuk sweet potato collection while Karuku and Teka were local varieties from Kamuga village where stem and leaf blight was first reported.

The plants were raised in a field nursery. Clean and disease-free terminal vines were collected and washed in tap water to remove soil and plant debris. The bottom-end of a 30 cm long terminal shoot was placed in a 250 ml conical flask containing 200 ml of deionised water for about 14 days to allow roots to develop from the node submerged in the water. Vines with vigorous or healthy growth were selected and transplanted into 13.5 cm diameter plastic pots containing steam-sterilised soil. Each vine was staked with a small wooden stick and allowed to grow for 7 days before pathogenicity tests were conducted. Twelve plants of each variety were used for stem and petiole inoculations; four for treatments with the fungal inoculum and two as control (one for each treatment - wounded or non-wounded).

Inoculation

Two week old isolates of *A. alternata*, *Phomopsis ipomoeae*, *F. oxysporum*, *F. solani*, *F. subglutinans* and *F. lateritium* and a *Colletotrichum* species grown on PDA were used as primary inoculum. A single agar block containing hyphae of each fungus was cut out and placed directly on the surface of the stem or petiole (either wounded or non-wounded) with a sterile scalpel blade. The agar and inoculum were held in position by a piece of moist absorbent cotton wool wrapped around the stem and petioles. Control or check plants were inoculated with agar alone. Each test plant was covered with a clean and moist plastic bag for 24 h after which the plastic bag and cotton wool were removed. The plants were watered twice daily using a fine mist atomizer to keep the inoculated tissues moist and were observed throughout the trial.

RESULTS

Disease symptoms

The initial symptoms in the field was the appearance of small, black, oval or circular lesions about 1 mm in diameter on the stems and petioles. The lesions became irregular when they coalesced. Under favourable weather conditions, the lesions continued to enlarge and completely girdled the stem (Plate 1) and petiole. Under stress conditions, severe infections eventually resulted in the death of the whole terminal shoot or individual leaves. The lesions were initially superficial and became depressed as they increased in size. An individual lesion on the stem could enlarge to 5 cm in length.

Affected leaves initially showed general yellowing and eventually drying off the whole leaf blade or lamina. Infection on the lower surface of the leaf would also lead to uneven chlorosis of the leaf blade. Occasionally, death of leaves on one side of the stem above the lesion was observed. This occurred when a lesion did not completely girdle the stem, especially with varieties that had thicker stems. Shoot or tip die-back was also another symptom associated with the disease. It was uncommon in wet weather except on varieties with thinner stems and petioles. Die-back was usually common in dry weather conditions when the lesions completely girdled stems and petioles and had become bleached and cracked.

Organisms associated with the symptoms

Alternaria sp. was isolated more frequently from stem and petiole lesions on sweet potato varieties from Kamuga and Kuk Agricultural Research Station. The isolates were identified as *Alternaria alternate* (IMI 13066b, 13066e), *Phomopsis ipomoea* (IMI 13066c), *Phoma exigua*, *F. oxysporum* (FRL 9818) *F. solani* (FRL 9826), *F. subglutinans* (FRL 9827) and *F. lateirtium* (FRL 9820), *Bacillus* sp. (IMI 13066i),

Figure 1. A black lesion on stem caused by *A. alternata*.

Psedomonas cichorii (IMI 13066h) and unidentified specie of *Colletotrichum*.

Pathogenicity tests

***Alternaria alternata* (IMI 13066b, 13066e)**

The isolate of *A. alternata* was highly virulent when inoculated on unwounded and wounded stems and petioles of all test varieties. Black-brownish, water soaked lesions measuring 10-15 mm in length and 5 mm in width developed on stems and petioles within 2-3 days. In general, the lesions were black in colour and developed up to 15-35 mm within 16 days (Table 1). Most petioles had been girdled by then. Lesions were about 40 mm long and had completely girdled most stems by 31 days. One of the stem lesions on injured plants developed up to 60 mm long. Longitudinal cracks were observed on some lesions after 10 days. Disease symptoms did not develop on control plants.

***Phomopsis Ipomoeae* (IMI 13066c)**

P. ipomoeae fungus caused necrosis of stems and petioles of most treated plants while check plants remained normal. It appeared that necrosis was more evident on injured tissues but only became apparent after 5 days. The lesions were slightly depressed and black-brown in colour, up to 5 mm long and 3 mm wide, and ceased growing after 10 days. The isolate, *P. ipomoeae* appeared to be non-pathogenic under the test conditions.

***Fusarium* spp. (FRL 9818, FRL 9826, FRL 9827, FRL 9820)**

The isolates of *F. oxyxporum, F. solani* and *F. subglutinans* caused similar disease symptoms on both wounded and non-wounded stems and petioles. Slight necrosis (black) or bleaching was observed, particularly on injured stems and petioles. Necrotic lesions did not develop and cause severe symptoms like that observed in the field. It appeared that *F. oxysporum, F. solani* and *F. subglutinans* are weak or secondary pathogens.

The isolate of *F. lateritium* was highly virulent compared with the other *Fusarium* isolates. Black lesions up to 40 mm long were produced with whitish sporodochia in the centres on old necrotic stems and petioles. In some instances, stems and petioles were completely girdled by the lesions and this subsequently led to the collapse of the whole leaf or stem. The fungus caused similar disease symptoms to that caused by *A. alternata* except there was no production of spore masses in the centers of old or more advanced lesions.

***Colletorichum* sp.**

This isolate initially produced small, water-soaked dark-brown dot-like lesions on surfaces of both wounded and non-wounded stems and petioles. The lesions on surfaces of both wounded and non-wounded stems and petioles. The lesions differed in numbers from a few to many and did not appear to increase or enlarge in size from the time the cotton wool was removed. However, necrosis of tissue around the point of injury (up to 3 mm in thickness)

Table 1. **Development of symptoms on petiole and stem of a sweet potato inoculated with an isolate of *Alternaria alternata*.**

Test Isolate	Test Variety	Days Inoculation	Treated				Control	
			Petiole Wounded	Petiole Non-wounded	Stem wounded	Stem Non-wounded	Petiole Wounded	Stem wounded
Alternaria Alternata (IMI 13066b)	Mond Amb (Kuk 962)	3	Water-soaked, black-brown lesion, 15 mm x 5 mm	Water-soaked, black-brown lesion, 10 mm x 6 mm	Water-soaked, black-brown lesion, 12 mm x 5 mm	Water soaked, black-brown lesion, 10 mm x 5 mm	No symptom	No symptom
		6	Black lesion, 17 mm long, girdled three quarters of the petiole	Black lesion, 20 mm long, almost girdled the petiole.	Black lesion, 25 mm long, girdled half the stem	Black lesion, 14 mm x 7 mm	"	"
		9	Black lesion, 19 mm long, girdled three quarters of the petiole.	Yellowing of the leaf blade and petiole. The petiole had collapsed.	Black lesion, 33 mm long. Bleachin effect on the lesion.	Black lesion, 17 mm x 7 mm, with slight cracking.	"	"
		16	Black lesion, 20 mm long and almost girdled the petiole.		Black lesion, 37 mm long, girdled three quarters of the stem.	Black lesion, 18 mm long, girdled three quarters the stem.		
		31	Black lesion, 30 mm long completely girdled the petiole		Black lesion, 40 mm long, almost girdled the stem.	Black lesion, 18 mm long, girdled three quarters of the stem		

did occur, particularly on injured petioles of some varieties. The isolate appeared to be either a very weak pathogen or non-pathogenic under the test conditions.

DISCUSSION AND CONCLUSION

The results showed that *A. alternata* isolates (IMI 13066b, 13066e) readily caused infection and produced disease symptoms on stems and leaves. It appeared that lesion development and expansion were much faster on most treated plants as compared to that observed in the field. This is usually encountered in pathogenicity tests because the primary inoculum and environmental conditions in the screenhouse are different from that in the field. Despite this, the characteristic symptoms of *Alternaria* stem and leaf blight was evident on most stems and petioles inoculated with the fungus.

Except for *F. lateritium* the other fungi tested failed to produce typical symptoms of stem and leaf blight and are probably weak pathogens or saprophytes colonizing necrotic tissues of the stems and petioles. There was no infection observed on control plants. The isolate of *F. lateritium* was highly virulent and caused similar disease symptoms as that caused by *A. alternata*. The only significant difference was that *F. lateritium* produced masses of spores in the centres of old or more advanced lesions in the screenhouse and field conditions. Initially the spore

masses were whitist-orange in colour but turned black as it aged or dried up. The fungus has been reported (Kokoa unpublished) as the causal agent of a new disease (stem rot) on sweet potato in certain parts of the PNG highlands.

A. alternata isolates (IMI 13066b, 13066e) were shown to be the primary causal agent of stem and leaf blight on sweet potato in the highlands of PNG. This is the first time the disease has been reported and confirmed in PNG. It was initially thought that the disease would be confined to parts of the Western Highlands Province where the disease was originally reported. However, disease surveys carried out in 1988 and 1989 showed that the disease had spread to other parts of the Western Highalnds and to Simbu Province. It was found that infected vines used for planting material was the primary means by which the disease had spread over long distances within a short period of time. Although the source of the intial infection is not known, *A. alternata* has a wide host range and further pathogencity tests are required to identify which other hosts are susceptible to the isolate from sweet potato.

Alternaria stem and leaf blight has been considered by Clark and Moyer (1988) as a serious foliar disease on sweet potato. Field observations made during field surveys conducted by the plant pathology section of the Highlands Food Crops Team (HFCRT) in 1988 and 1989 showed that *Alternaria* stem and leaf blight could be a serious disease problem in the highlands provinces particularly, in association with other diseases (*Phomopsis* die-back, scab, viruses) and stress factors (dry weather, low soil fertility) (unpublished HFCRT papers). Serious blight or die-back was evident particularly on varieties with thin stems in prolonged dry weather conditions. There is very little information available on many aspects of the disease such as yield loss and disease control. Further follow-up surveys of 1988 and 1989 should establish the distribution and effect of the disease on sweet potato production in the highlands, and to recommend possible areas of research.

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REFERENCES

BURGESS, L.W. AND **LIDDELL, C.M.** (1988). Laboratory manual for Fusarium Research (2nd edition). Fusarium Research Laboratory, Department of Plant Pathology and Agricultural Entomology, The University of Sydney, Australia.

BURGESS, L.W., NELSON, P.E. AND **TOUSSOUND, T.A.** (1981). Laboratory manual for Fusarium studies. Fusarium Workshop, University of Sydney, Australia. 50 pp.

CLARK, C.A. AND **MOYER, J.W.** (1988). Compendium of sweet potato diseases. *The American Phytopathological Society*, U.S.A. 74. pp.

LENNE, J.M. (1991). Diseases and pests of sweet potato: South-East Asia, the Pacific and East Africa. *Natural Resources Institute Bulletin* No. 46. 115 pp.

LOPES, C.A. AND **BOITEUX, L.S.** (1994). Leaf spot and stem blight of sweet potato caused by *alternaria bataticola*: a new record in South America. *Plant Disease* **78**(11): 1107-1109.

WALLER, J.M. (1984). Diseases of small-holder food crops in the Southern Highlands Province of Papua New Guinea. Commonwealth Mycological Institute, England.

EVALUATING HIGH AND LOW NUTRIENT DENSITY FEED FOR THE FINISHING STAGES OF MUSCOVY BROILER DUCKS

Saun Ignatius and Alan Quartermain[1]

ABSTRACT

Since growing ducks are less efficient converters of feed than chickens, there could be economic advantage if duck feeds can be of lower nutrient density and cheaper than chicken feeds. Low nutrient density feeds are mainly formulated from cheaper feed resources. This study aimed to evaluate the performance of broiler Muscovy ducks during the finishing stage on a high nutrient density broiler chicken feed and a low density commercial feed formulated from locally available agro-industrial by-products such as copra meal and wheat mill-run for feeding rabbits. The results show that ducks on the high nutrient density feed have a higher weight gain than those on rabbit feed. However, costs per kilogram of liveweight gain show no significant difference between feeds. Break-even or threshold ratios at which low intensity feeds can be competitive with the high intensity feed were determined. The commercial rabbit feed proved as economic as broiler finisher but it will take a longer time for ducks to reach marketable weight. If a low nutrient density feed equivalent to the rabbit pellet can be developed to feed ducks during the finishing stage, the ratio of prices (commercial broiler finisher: low density feed) must be higher than the threshold of 1.72 for males and 1.67 for females to make it economical.

Key Words: *Muscovy ducks; cost of growth; low intensity feeding*

INTRODUCTION

Domestic ducks are not native to Papua New Guinea (PNG) but were introduced by early missionaries at the turn of the century. The popular breed in PNG is the Muscovy duck (*Cairina moschata*), although other breeds such as the Khaki Campbell (*Anas platyrhynchos*) exist in limited quantities. The spread of ducks around the country was more recent than for chickens with the first recorded organized distribution of Muscovy ducks by the Department of Agriculture, Stock and Fisheries (DASF) in 1974 (Quartermain 2000a). Only the Muscovy ducks have been adopted into the subsistence farming system. Muscovy ducks are being promoted by the National Agricultural Research Institute (NARI), Salvation Army in Eastern Highlands and other NGOs, the Food Security Branch of the Department of Agriculture and Livestock (DAL) and several provincial governments. These ducks are widely promoted as dual purpose birds for rural farming communities to keep under semi-intensive systems. In these systems, ducks for meat can be eaten at around four months of age, while breeders can be kept for about two years.

Reports from consultations with farmers and extension officers have shown that duck keeping and interest in keeping ducks is increasing among smallholder farmers in rural and peri-urban areas (Quartermain 2000b and NARI Nius 2002). With the need to improve production of Muscovy ducks, many duck farmers are utilizing commercial feeds. For growing Muscovy ducks for meat, some farmers are using broiler chicken feeds to raise them to around 12 weeks, when they are sold (NARI Nius 2002). These commercial poultry feeds are expensive. Most of the raw materials like grains and soybean meal for poultry feeds are imported, with only small amounts of maize and sorghum and low quality fishmeal and wheat milling by-products (millrun) available locally. Hence the cost of producing these feeds is high.

The commercial poultry feeds used to feed ducks are of high nutrient density. Since ducks eat more feed than chickens for the same growth, it can be uneconomical to feed high nutrient density feeds to ducks. It would be appropriate if suitable feeding systems based on increased content of available and cheaper feed resources such as agro-industrial by-products be developed. Although some farmers have raised their ducks under free-ranging systems with supplementary feeding, it takes a long time for these ducks to reach marketable size. It takes nearly 20 weeks to raise a duck to marketable size under a free-ranging system with supplementary feeds of kitchen wastes, surplus food crops and waste fruits. This makes it necessary to develop low nutrient density commercial feeds for duck farmers in peri-urban areas or homemade ration mixes for duck farmers in rural areas. With this development, more

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farmers will be encouraged to venture into duck keeping activities in rural and peri-urban areas leading to food security, adequate supply of household protein and cash income. This research, as part of the NARI livestock programme to develop low cost poultry feeding systems, aimed to test a low nutrient density feed against the standard commercial broiler feed during the finishing stage of Muscovy broiler duck production. It was expected that the recommendations from this research would lead to subsequent development and field-testing of a low intensity commercial feed or home made rations based on agro-industrial by-products (copra meal, wheat millrun, palm kernel meal and pyrethrum marc) for ducks.

Muscovy duck feeding

Although much poultry feed and nutrition information is available locally for chickens, very limited information is available for Muscovy ducks. Local duck feeding studies include Abdelsamie (*unpublished*) on protein and energy requirements of Muscovy ducks in the PNG environment, Bilong (1981) on the performance of Muscovy ducks on sweet potato, and Bakau and Tom (1996) on *yawa* banana in feeding Muscovy ducks. Effective feeding and management systems for duck keeping under subsistence and semi-subsistence systems are described by Abdelsamie (1979) and Bauer (1980). Overseas studies include Leclercq and Carville (1986a) and Leclercq and Carville (1986b) describing the growth and body composition of Muscovy ducks in France and dietary energy, protein and phosphorus requirements of Muscovy ducks. The review of nutrient requirements for meat type ducks by Dean (1986), with his recommended nutrient levels in diets, provides useful information for developing duck feeds.

Studies by Abdelsamie (*unpublished*) on Muscovy ducks during the first six weeks of life showed that growth rate and feed conversion of males and females were similar during the first and second week, but then males started to grow much faster and converted their feed more efficiently than females. The same study on the effects of varying energy and protein levels in diets showed that the fastest growth rate by males and females was achieved with a diet of 20 percent crude protein and metabolizable energy of 10.46 MJ/kg. It was reported that ducks have higher weight gains on the low energy diet compared to other diets of 11.72 MJ/kg and 12.56 MJ/kg, while low protein diets of 15 percent did not give good growth rates and feed conversion. It was also reported that increased protein level in the diet for male Muscovy ducks seemed to be producing faster growth rates, while female Muscovy ducks seemed to tolerate low protein levels better than males.

Bilong (1981) studied the performance of Muscovy ducks from 45 days old on cooked and mashed sweet potato (*Ipomoea batatas* L. Lam) supplemented with meat and bone meal. Sweet potato was chosen because it is an important food crop in PNG, the leaves can be fed for supplementary vitamins and it is available in large quantities. Male and female ducklings were kept separate, fed broiler starter for 45 days *ad lib* and then fed four different diets of broiler finisher and sweet potato. The diets were broiler finisher (18% crude protein) and different levels of sweet potato and meat and bone meal with protein levels of 16, 18 and 20 percent. Results showed that males had faster growth rates than females (50g/day vs 35g/day), with a higher body weight at 45 days (2361g vs 1652g) on broiler starter. After 45 days, the performance of ducks on broiler finisher was better than that on sweet potato based diets with a growth rate of 28g/day compared to ducks on sweet potato with 17g/day, 16g/day and 23g/day for 16, 18 and 20 percent protein diets respectively. Corresponding body weights at slaughter were 3500g, 2920g, 2950g and 3360g respectively for the diets.

Growth of Muscovy ducks is characterized by very pronounced sexual dimorphism and slower development than in Pekin ducks (Leclercq and Carville 1986a). Sexual dimorphism appears after two or three weeks of age as shown by Abdelsamie (unpublished), Bilong (1981) and Leclercq and Carville (1986a). In France, the maximum live weight of male and female Muscovy ducks is reached at 12 and 10 weeks respectively (Leclercq and Carville 1986a). The maximum daily gain of 80g/day in males occurs at seven weeks of age and falls rapidly afterwards. In females, the maximum daily weight gain is considerably less (a little more than 50g/day) and occurs at six weeks of age. Muscovy ducks are slaughtered at 10 weeks of age for females and 11 – 12 weeks of age for males when their growth rate has fallen almost to zero. Leclercq and Carville (1986a) highlighted that this was very different from other poultry species such as chickens or turkeys.

MATERIALS AND METHODS

The research trial was conducted at the NARI Labu Livestock Research Center situated at latitude 06° 40′ South and longitude 146° 54′ East and receiving an average annual rainfall of about 2900 mm.

The trial design was a factorial experiment using a completely randomized design with two factors, feed and sex, each at two levels. The two feed types were commercial rabbit pellets (RP) (Grant *et al.* 1996) and broiler finisher pellets (BF) from the Lae Feed Mills (Goodman Fielder Limited). A total of 48 ducklings with equal numbers of males and females

were sexed immediately after hatching and randomly allocated to small brooder pens (1 x 1 m) with males and females reared separately for five weeks on commercial broiler starter. After five weeks, the ducklings were weighed again and allocated into 16 experimental pens (3 x 4 m) with three birds of the same sex randomly selected for each pen. There were eight pens on each side of the growing shed.

Ducklings were fed *ad libitum* broiler starter feed for the five weeks before starting the experimental phase. In the experimental phase (6 -12 weeks), rabbit pellets and broiler finisher feed were fed *ad libitum* with daily weighing of feed given and uneaten residuals and weekly weighing of birds. The three birds in each pen were tagged with different coloured rubber bands to monitor individual growth. Statistical analyses were done on the final weight, weight gain and weekly weights on an individual basis while other variables were analysed on a pen mean basis.

It was assumed that standard broiler commercial feed would give better growth rates than the low density feed in terms of intake and hence the latter ducks would eat more to compensate their requirements. It was decided to determine the price (or cost of feed) ratio between the high intensity (high nutrient density) feed and the lower intensity feed such that the feed cost of producing a kilogram of liveweight during the finishing period of a bird would be equal. This can be considered as the break-even or threshold ratio. Any value of the ratio of actual feed prices above the threshold would indicate an economic advantage in favour of the lower intensity system. An increase in the actual ratio could occur if the high intensity feed price rose or the cost of lower intensity feed can be reduced relatively.

The threshold ratio is calculated as follows and is independent of the actual feed prices.

Cost of 1 kg of liveweight gain on the high intensity feed = $\frac{\text{(Intake H) (Price H)}}{\text{(Gain H)}}$

Cost of 1kg of liveweight gain on the low intensity feed = $\frac{\text{(Intake L) (Price L)}}{\text{(Gain L)}}$

At the threshold,

$$\frac{\text{(Intake H) (Price H)}}{\text{(Gain H)}} = \frac{\text{(Intake L) (Price L)}}{\text{(Gain L)}}$$

And the Threshold Ratio of Feed Costs (TRFC),

$$\frac{\text{(Price H)}}{\text{(Price L)}} = \frac{\text{(Intake L) (Gain H)}}{\text{(Intake H) (Gain L)}}$$

Table 1. **Average weekly weights (grams) from five weeks to 11 weeks for the four treatment groups**

Feed (F)	Sex (S)	Wk 5	Wk 6	Wk 7	Wk 8	Wk 9	Wk 10	Wk 11
Boiler Finisher Pellet	Male	1165	1600	2016	2365	2630	2872	3091
Boiler Finisher Pellet	Female	996	1274	1539	1720	1849	1922	1999
Rabbit Pellet	Male	1197	1462	1816	2029	2311	2579	2759
Rabbit Pellet	Female	963	1148	1343	1475	1523	1655	1731
Significant effects (p<0.05)		S	F, S	F, S	F*S	F, S	F, S	F, S
Lsd (p=0.05)		51	43	58	59	138	82	77

Table 2. **Average final weight (FW), weight gain (WG), feed conversion ration (FCR), feed intake (FI), and cost per kilogram gain (CKG) for the four treatments.**

Feed (F)	Sex (S)	Final weight (g)	Weight gain (g)	Feed conversion ration (pen basis)	Feed! Intake (pen basis) (kg)	Cost per Kilogram (K)
Boiler Finisher Pellet	Male	3165	1999	3.72	22.34	3.53
Boiler Finisher Pellet	Female	2014	1018	4.88	14.88	4.63
Rabbit Pellet	Male	2816	1618	6.38	30.93	3.50
Rabbit Pellet	Female	1796	834	8.22	19.90	4.46
Significant effects (p<0.05)		F*S	F*S	F, S	F*S	S
Lsd (p=0.05)		89	111	0.81	0.94	0.47

RESULTS

Results of the analyses are presented in Tables 1 and 2, while growth curves across the 12 weeks are depicted in Figure 1.

The week five weights are prior to the feeding of the two treatment diets. These initial weights show a significant sex difference ($p<0.05$) in weights, while the consecutive weeks also show significant differences ($p<0.05$). From week six to week 11, there are also significant differences between feeds ($p<0.05$). At week 8, there was significant ($p<0.05$) interaction between sex and feed.

For final weight, weight gain and feed intake, there are significant differences ($p<0.05$) in main effects of sex and feed and also significant ($p<0.05$) interactions. For the feed conversion ratio, there are significant differences ($p<0.05$) for sex and feed. For cost per kilogram of liveweight gain there are no significant differences ($p>0.05$) for feed but there are significant differences ($p<0.05$) for sex.

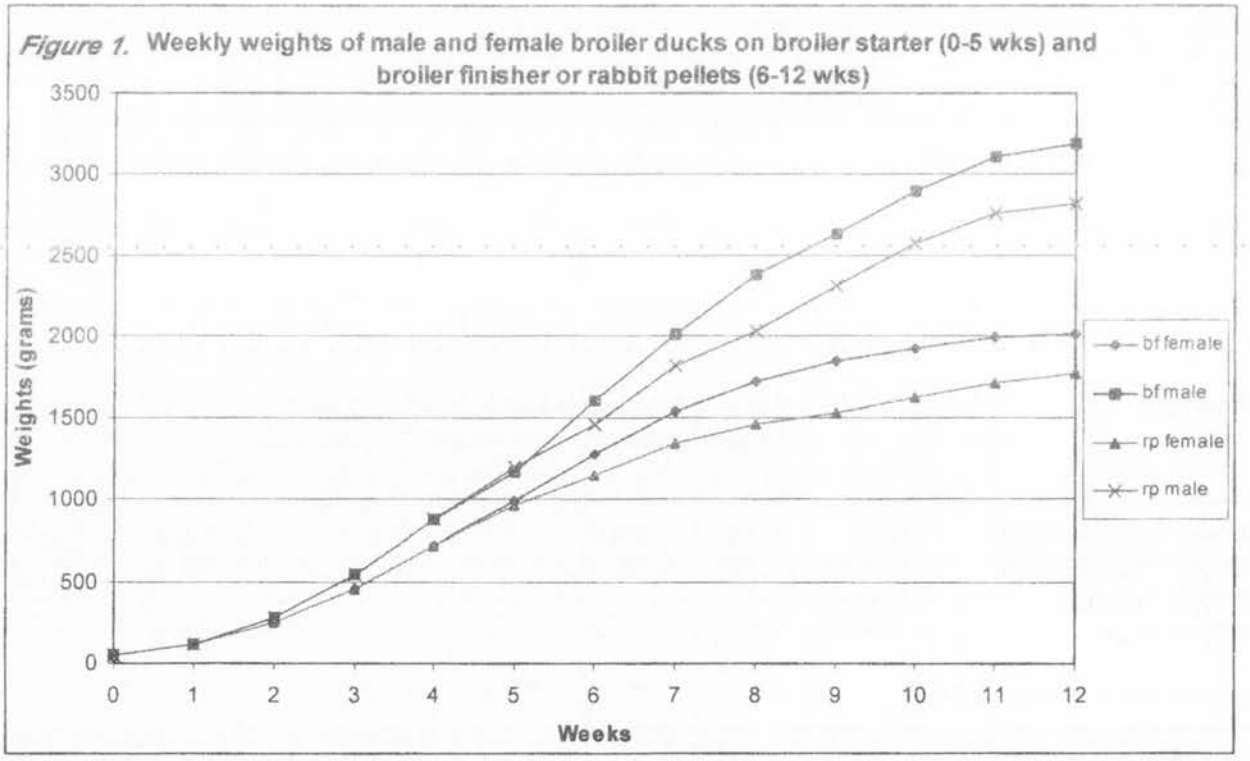
The TRFC (Threshold Ratio of Feed Costs) values are 1.72 for male and 1.67 for female Muscovy broiler ducks. With the cost of BF and RP at PNG Kina 0.95 and Kina 0.55 respectively, the actual cost ratio of the feeds at the time of the study was 1.73, meaning that for males the cost of producing one kilogram of gain was about equal for the two feeds. There could be a slight advantage in feeding females on the lower priced feed.

DISCUSSION AND CONCLUSION

Male ducks are heavier than females with higher weight gains, better feed conversion and higher intakes over 12 weeks. Sexual dimorphism is as reported by Abdelsamie (*unpublished*), Bilong (1981) and Leclercq and Carville (1986a). As shown in Table 1 and Figure 1, males are heavier than females at least as early as three weeks of age and were heavier than females when the treatment diets were introduced at five weeks.

From the evaluation of the two feeds, ducks on high nutrient density broiler finisher have higher weight gains, better feed conversion and lower feed intakes than those on the lower intensity rabbit feed. The broiler finisher has more nutrients to meet their requirements compared to the same amount of the low intensity rabbit feed. Therefore, on rabbit pellets the ducks consume more of the feed to meet their requirements. Comparison of the two feeds in terms of the cost of a kilogram of weight gain shows that the low intensity and cheaper rabbit pellet is competitive with but not better than the high intensity broiler finisher. At the prices current at the time of the study, the cost of producing a kilogram of weight gain for broiler Muscovy ducks is similar for either feed. Males are cheaper to produce since they have a higher growth rate than females. TRFC value for males and females (1.72 vs 1.67) shows that the cost of producing a kilogram of gain was equal for males on the two feeds while females may have a slight advantage on the lower priced feed.

Figure 1. **Weekly weights of male and female broiler ducks on broiler starter (0-5 wks) and broiler finisher or rabbit pellets (6-12 wks)**



Studies by Abdelsamie (*unpublished*) have shown that under lowland conditions, a low energy diet of 10.46 MJ/kg gives adequate growth rates. Since there is less demand by ducks for energy compared to broiler chickens, commercial broiler starter and finisher feed may not be the most economical for feeding ducks. Even with commercial rabbit pellets having high fibre and lower energy density compared to broiler finisher, we could not assume that ducks would not grow properly on this feed. In this study, broiler ducks grew well on broiler finisher and were heavier at 12 weeks of age. However, in terms of the cost of a kilogram of liveweight, there was no difference between the two feeds. If the price of the broiler finisher increases at a faster rate than that of rabbit pellets giving a ratio greater than the TRFC, low nutrient density feed can be profitably fed to ducks despite the longer time to reach marketable size.

This study shows that the low nutrient density rabbit feed is as good as broiler finisher. The TRFC values found are 1.72 for males and 1.67 for females. If low nutrient density feeds based on copra meal, wheat millrun or other by-products and having a similar nutrient value to rabbit pellet can be formulated to feed ducks at a low enough price to give a price ratio with broiler finisher greater than the TRFC values, then the cost of production can be considerably reduced. It is very important that minimal cost rations for ducks should be developed using locally available agro-industrial by-products such as copra meal and wheat millrun.

REFERENCES

ABDELSAMIE , R. E. (unpublished) *Protein and Energy Requirements of Muscovie ducks under PNG Environment.* Department of Primary Industry, Port Moresby.

ABDELSAMIE, R. E. (1979) Performance of ducks under semi-intensive management in Papua New Guinea. *Papua New Guinea Agricultural Journal* 30 (4): 43 – 51.

BAKAU, B. J. K. and TOM, M. (1996) The *yawa* banana: a potential feed for livestock. Livestock Development Note: No. 5. *Harvest* 18: 3 – 4.

BAUER, F. (1980) Muscovy ducks. *Rural Development Series Handbook No. 75.* Department of Primary Industries, Port Moresby.

BILONG, G. (1981) A study on the performance of Muscovy ducks on sweet potato (*Ipomoea batatas* L. Lam) feeding. *BSc Agric Hons Thesis,* University of Papua New Guinea, Port Moresby.

DEAN W. F. (1986) Nutrient requirements of meat-type ducks. In: *Duck Production Science and World Practice.* D.J. Farrel and P. Stapleton (Ed.) University of New England, Australia. pp. 31 – 37.

GRANT, I. MCL., ASKIN, D.C. and LOW, S.G. (1996) Rabbit production in Papua New Guinea. *Proceedings of the 6th World Rabbit Congress, 9 - 12 July 1996,* Toulouse, France.

LECLERCQ, B. and De CARVILLE, H. (1986a) Growth and body composition of Muscovy ducks. In: *Duck Production Science and World Practice.* D.J. Farrel and P. Stapleton (Ed.) University of New England, Australia. pp. 102 – 109.

LECLERCQ, B. and De CARVILLE, H. (1986b) Dietary energy, protein and phosphorus requirements of Muscovy ducks. In: *Duck Production Science and World Practice.* D.J. Farrel and P. Stapleton (Ed.) University of New England, Australia. pp. 58 –69.

NARI NIUS (2002) On-farm duck survey around Lae and Markham Valley. *NARI Nius* Oct - Dec 2002, Vol. 5, No. 4.

QUARTERMAIN, A. R. (2000a) Non-commercial poultry production in Papua New Guinea. *Asian-Australasian Journal of Animal Sciences.* 13th Supplement July 2000 c: 304 – 307.

QUARTERMAIN, A. R. (Ed) (2000b) *Proceedings of the NARI Poultry Workshop held at the Forest Research institute, 26th August 1999.* NARI Proceedings No. 1, National Agricultural Research Institute, Lae.

INTRODUCTION AND DISTRIBUTION OF *BACTROCERA MUSAE* (TRYON) (DIPTERA: TEPHRITIDAE) IN EAST NEW BRITAIN, PAPUA NEW GUINEA.

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ABSTRACT

Bactrocera musae *(Tryon), the banana fruit fly, is a pest of bananas and plantains on the Papua New Guinea mainland. In East New Britain Province (E.N.B.) trapping and host fruit surveying prior to mid 1999 indicated the absence of this fly, despite literature records to the contrary. In mid 1999, the possibility of an incursion of banana fruit fly into the Gazelle Peninsula of E.N.B. was reported. Three trapping surveys were carried out from late 1999 to mid-2000 on the north-east tip of the Gazelle and confirmed the presence of well established banana fruit fly populations. In December 2000, a delimiting survey was carried out to map the then distribution of the fly. The fly was shown to be widespread over the Gazelle, with population foci around Rabaul and Kokopo. Market surveys of banana fruit and field assessments were also done to support the trapping surveys. Although banana finger infestation by banana fly was found to be well below 10 percent, these results confirm that* B. musae *populations are established and causing damage. Banana fly appears to be absent in West New Britain and Bougainville, but very low level populations have been detected in Manus and New Ireland. We speculate that the incursion of* B. musae *into E.N.B. may be an indirect result of relief food supplies shipped to the Gazelle following the 1994 Rabaul volcanic eruptions.*

Key words: *banana, incursion, quarantine, banana fruit fly, Dacinae*

INTRODUCTION

Fruit flies (Diptera: Tephritidae) are major pests of fruit and vegetables in most tropical and subtropical regions of the world (White and Elson-Harris 1994) and are the number one agricultural pest in Papua New Guinea (PNG) (Waterhouse 1997). Female fruit flies lay eggs into fruit and vegetables with the subsequent larvae, or maggots, feeding on the flesh of the fruit. This causes breakdown of the fruit and may promote premature fruit drop.

Drew (1989) recorded 180 species of fruit flies in PNG, of which 12 are considered pests (Dori *et al.* 1993, Leblanc *et al.* 2001). One of the most important of these pest species is the banana fruit fly, *Bactrocera musae* (Tryon). Adult banana fruit flies oviposit into hands of green bananas, where subsequent larval feeding is highly destructive to the banana flesh (Drew *et al.* 1982). Infestation of PNG bananas by banana fly averages approximately 20 percent (Leblanc *et al.* 2001). Given the role of bananas as a primary staple food and economic crop for many agricultural communities in PNG, this loss to fruit flies is highly significant. Tenakanai (1997) reported that all banana varieties are susceptible, but field observations suggest that there is varietal resistance among bananas to fruit fly attack (authors' pers. obs.). In Provinces such as Morobe, Madang and others, where banana fruit fly is common, the wrapping of developing bunches in banana leaves is a traditional technique that improves the quality of the bananas, in large part through the exclusion of fruit fly.

Drew (1989) and Tenakanai (1997) reported *B. musae* as being widespread throughout PNG *and its islands* [our emphasis]. However, Tenakanai was simply repeating Drew's claim, while it is not clear how many *B. musae* specimens from the islands, or their precise localities, were seen by Drew. From 334 individual bananas of 14 varieties collected at Kerevat (04°19'S, 150°01'E), East New Britain Province (ENB), prior to late 1999, Leblanc and Mararuai failed to rear any banana fruit flies (unpublished data). Similarly, an extensive fruit fly trapping network in ENB running from mid 1997 through to mid 1999, failed to produce any *B. musae* (with a few exceptions: see Results). These findings, plus the lack of any traditional control techniques against banana fruit fly on the islands, cast doubt on the stated claims that *B. musae* is widespread in the PNG islands, or at least in ENB.

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In September 1999, possible cases of banana fruit fly infestation in bananas in the Raluana district of the Gazelle Peninsula were detected when two boiled 'Kiakiau' banana fingers were found to have brown spots severely infested with fruit fly maggots. Bananas are the primary staple of the Gazelle Peninsular and the estimated value of bananas to the economy of the Gazelle is in excess of K15 million (S. Ivahupa, NARI internal documentation). Because of the value of bananas to the people of the Gazelle, it was important to investigate the reports of an incursion and, if true, quantify the abundance of banana fruit fly in the area. We did this through a series of intensive, short-term trapping programmes and through fruit fly rearing from banana samples. This paper documents the results of these surveys.

MATERIALS & METHODS

Trapping surveys

Three sets of trapping surveys were carried out to identify the distribution and population levels of banana fruit fly. These surveys included: (i) an initial set of surveys in the Rabaul and Kokopo areas to identify and confirm incursion; (ii) a second, intensive delimiting survey; and (iii) an extensive survey to map the fly distribution across the island provinces. All trapping was done with modified Steiner traps (Drew *et al.* 1982) that contained the male fruit fly attractant methyl-eugenol (ME), mixed with the insecticide malathion. Banana fruit fly responds strongly and positively to ME (Drew 1989) and can be reliably sampled using this technique. Trapped flies were sorted to species level by the authors at NARI's Lowlands Agricultural Experiment Station, Kerevat, and then sent for confirmation of identity to Prof. R.A.I. Drew, Griffith University, Brisbane. Additional material was screened in the genetics laboratory of Prof J. Hughes, Griffith University, and confirmed to be genetically similar to known material of *B. musae* from North Queensland.

Confirmation of incursion surveys

Three surveys were carried out from late 1999 to mid 2000 covering the coast and hinterland of the Gazelle Peninsular from the Cocoa and Coconut Research Institute station at Tavilo (04°17'S, 152°01'E) on the north coast to Takubar (04°20'S, 152°19'E) and the Gelagela resettlement area about 8 km southwest of Kokopo. Survey one ran from November 24 to December 9, 1999, and covered the Kokopo town road from Malapau road junction to Takubar. Traps were established at 23 locations covering both residential and commercial areas of Kokopo. Survey two ran from May 26 to June 6, 2000, and covered the North Coast road from Tavilo to Namanula hill outside Rabaul. Traps were set at 11 locations covering village residential areas and vegetable gardens. Survey three ran from June 19 to July 4, 2000, and covered the Malmaluan, Nangananga and Burma roads. Traps were established at 13 locations covering village residential areas with many areas under vegetable cultivation.

Delimiting survey

An intensive survey of the Gazelle Peninsula was run during December 1-8, 2000. The aim of the survey was to determine, as far as possible, the distribution of banana fruit fly at that time. Sixty-one traps were distributed, covering the major road networks of the Gazelle Peninsular at approximately 10km intervals. The trap network extended along the north coast to Lasul (04°13'S, 151°43'E), along the east coast to Sum Sum Bay (04°42'S, 151°21'E) and inland as far as Riet (04°34'S, 152°05'E) at the base of the Baining Mountains.

Extensive surveys across the island provinces

This set of surveys covered both an extensive trapping array placed before the recognition of the ENB incursion and two smaller, targeted surveys placed after the incursion to confirm or deny the presence of banana fly in key regional localities. The extensive, regional survey covered the following areas and times: West New Britain Province (WNB)(September, 19-98 - April 1999, Hoskins, Kimbe town, Silanga area, maximum of 6 traps); ENB (July-19-98 - November 1999, predominantly around the Gazelle Peninsular and Bainings Mountains, maximum of 22 traps); Manus Province (September 1998 - May 1999, Lorengau town and district, maximum of 4 traps); New Ireland Province (NIP)(August 1998 - September 1999, Kavieng town, Lugagon village between Kavieng and Namatanai and Lihir Island, maximum of 5 traps). The targeted surveys covered the Namatanai (03°39'S, 152°26'E) district of NIP (November 28 to December 1, 2000, Namatanai town, Saraha, Pire, Burabalbango and Napanta villages, 5 traps) and the Silanga (05°33'S, 150°50'E) district of WNB (December 25, 2000 to January 6, 2001, 6 traps).

Rearing from Fruit

To measure the level of infestation being caused by the banana fly incursion, bananas were purchased from local roadside markets and collected from the Lowlands Agricultural Experiment Station banana plots and from gardens in the Rabaul and Kokopo areas. Fruit were set in individual containers and kept to assess the level of fruit fly infestation as described in Leblanc *et al.* (2001). Rearing occurred at intervals over a twelve-month period from June 2000 onwards. All reared flies were identified by Drew.

RESULTS

Trapping Surveys

Confirmation of incursion surveys

Banana fruit fly was confirmed as present throughout nearly all areas surveyed (Fig 1). The pest appeared to be well established throughout and between the Rabaul (04°11'S, 152°10'E) and Kokopo (04°20'S, 152°16'E) town areas. To the west and south-east of the these centers, respectively, banana fly populations decreased. The large numbers of flies in traps around the center of the infestation (Table 1) suggested that the population had been present for some time.

Delimiting survey

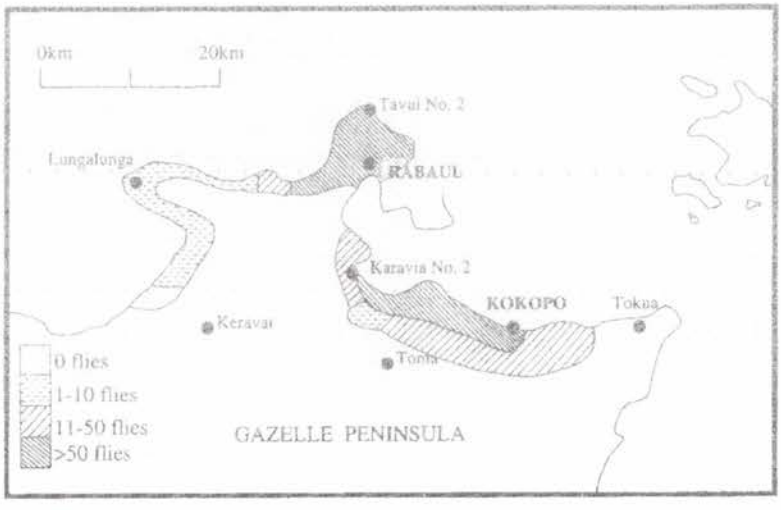
By December 2000, banana fruit fly was shown to be present over most of the north-east corner of the Gazelle Peninsula (Fig 2) and the Duke of York Islands. Population densities were highest around Rabaul, Kokopo and the heavily populated areas near these towns (including the villages and districts of Tavui, Nonga, Kuraip, Raluan, Rakunai, Nangananga, Toma, Ramale, Tokua, Rainau, Korai, Gelagela, Viviren, Reit, Dadul, Vunabaur and Ganai). However, fly populations declined with distance away from the north-east corner and became rare or absent in areas such as Kabaira, Kerevat, Warangoi, Maranagi, Lemingi, Wusing, Simbum and Warabu. The spatial distribution of fly populations suggests that the initial incursion occurred somewhere in the Rabaul or Kokopo districts and from there flies have been subsequently breeding and spreading.

Extensive Survey

Bactrocera musae was rarely collected in the extensive surveys (Fig 3). On Manus, 15 banana fruit flies were collected in comparison to 35,000 *Bactrocera umbrosa* (F.), a well established local pest species. There were no *B. musae* collected from West New Britain in either the extensive survey or the Silanga snapshot survey. In New Ireland, no banana fruit fly specimens were collected in the extensive survey, but two *B. musae* were detected in the Namatanai snapshot survey. This suggests the fly may be present in NIP but not yet established. No banana flies were collected from fruit fly traps set up on Bougainville

During the ENB extensive sampling program (October 1997 - November 1999), 83 *B. musae* were collected, all after October 1998. These flies were not recognized as *B. musae* until after the outbreak had occurred and *post hoc* re-examination occurred. In the survey database they were initially identified (by R.A.I. Drew) as a new sibling species near *B. musae*, rather than true *B. musae*. - *Bactrocera musae* is part of a species complex and is regarded as taxonomically difficult (Drew 1989). These flies thus represent the earliest positive identification of *B. musae* in ENB. The majority of these flies were collected from sites just behind Kokopo (e.g. 40 flies from 15 clearances of a trap hanging at the Vunamami Farmer Training Centre (04°21'S, 152°13'E)), but isolated individuals were trapped at more distant localities, such as Keravat and these

Figure 1. **Distribution and population density of *Bactrocera musae* on the north-east tip of the Gazelle Peninsula, East New Britain Province, as determined by local strapping from November 1999 to June 2000.***

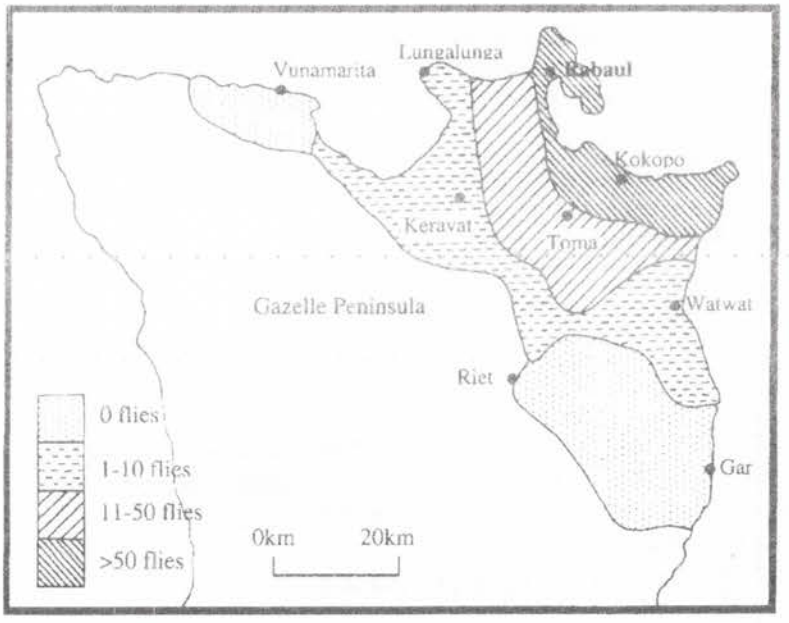


Footnote.
* Absence of flies outside the areas marked represent a lack of trapping data rather than the absence of flies, unless otherwise marked Population density contours are estimated by extrapolation between sampling points.

Table 1. **Daily catch of Bactrocera musae in selected traps during fruit fly incursion surveys of the Gazelle Peninsular, East New Britain.**

Trap location	Trapping period	No. of *B. musae*/day
Balanataman Village	1-15 Dec, 1999	67.9
Malapau Road Junction	1-15 Dec, 1999	72.5
Dalmaine Construction	1-15 Dec, 1999	72.7
Butuwin	1-15 Dec, 1999	47.3
Kokopo High School	3-15 Dec, 1999	65.8
Talina Cocoa Fermentory	1-15 Dec, 1999	34.2
Kokopo Village Resort	1-15 Dec, 1999	29.8
Ralum Police Station	1-15 Dec, 1999	61.2
Rural Dev. Bank, Kokopo	3-15 Dec, 1999	13.4
Coka Cola Depot, Kokopo	3-15 Dec, 1999	17.0
Timbur	1-15 Dec, 1999	11.8
Kinabot	3-15 Dec, 1999	59.4
Gelagela Junction, Kokopo	1-17 Dec, 1999	19.8
Gelagela	6-21 Dec, 1999	0.7

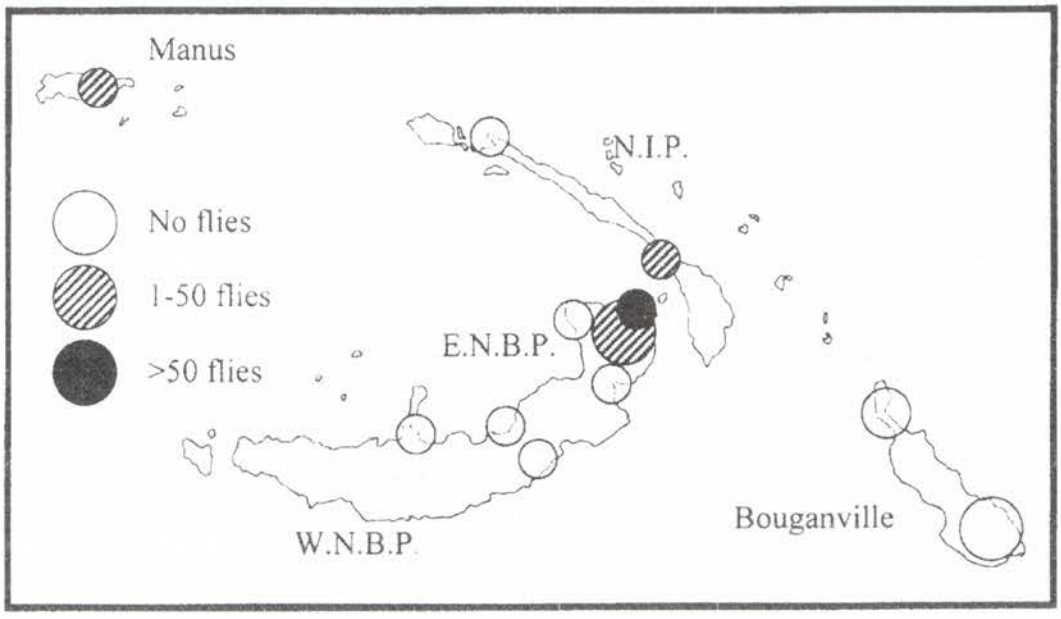
Figure 2. **Distribution and population density of *Bactrocera musae* on the north-east tip of the Gazelle Peninsula, East New Britain Province, as deter mined by local trapping during December 2000.***



Footnote:

* Absence of flies outside the areas marked represent a lack of trapping data rather than the absence of flies, unless otherwise marked. Population density contours are estimated by extrapolation between sampling points

Figure 3. **Distribution of *Bactrocera musae* in the island provinces of Papua New Guinea.**



probably represent dispersing flies.

Rearing from Fruit

Infestation rates of banana fruit collected from both markets and gardens were much lower than the average rate of around 20 percent reported for mainland PNG (Leblanc *et al.* 2001). From fruit collected from 28 roadside markets along the north and south coasts of the Gazelle, six percent infestation was recorded, caused equally by *B. musae* and *Bactrocera frauenfeldi* (Schiner). Fruit collected from 18 field locations in May and June 2001 yielded even fewer flies, with less than one percent infestation rate (Table 2). However, comments from village farmers during this collection are pertinent, for example: "*Bananas have to be harvested earlier than usual to prevent them getting damaged*". When infested fruit was collected, infestation of individual fingers was found to be heavy. One sample of seven ripe fingers, weighing 1.76 kg and collected from Tavui No 3 village (behind Rabaul town) on 12 April 2000, yielded 418 *B. musae* pupae. *Bactrocera frauenfeldi* is an abundant and wide-spread polyphagous pest species, but attacks on bananas are uncommon and are unlikely to increase above the base levels recorded. We anticipate banana fly infestation rates will climb as the *B. musae* fly population increases.

DISCUSSION

This report confirms the presence of *B. musae* on the Gazelle Peninsula of ENB and its distribution at the end of 2000: it is likely to have spread further since. In contrast to earlier literature (Drew 1989), we consider it unlikely that the species is endemic in the island provinces. This is based on the absence or rarity of the fly in trapping and fruit-rearing surveys throughout the islands prior to the ENB incursion and the absence of traditional control techniques. This contrasts markedly with the endemic banana fly populations of the PNG mainland, where trap-catch numbers are overwhelming and cultural control techniques exist.

All evidence suggests that the *B. musae* population on ENB is a relatively new incursion. If the population had been established for some time (i.e. greater than a decade) then it might be expected to occur throughout the Gazelle as its host plant, bananas, are grown all over the Peninsula. However, the population appears to be still spreading as there is a significant declining gradient in population density away from the major population foci around Rabaul and Kokopo. In addition to natural fly dispersal, it must be considered that the continual transportation of bananas is slowly spreading populations and, aiding their establishment. A lack of control measures for *B. musae* damage further increases

Table 2. **Tephritid fruit flies reared from bananas purchased from markets (March-June, 2000) or collected from gardens (May-June, 2001) in the Gazelle Peninsula, East New Britain Province.**

	Market Surveys	Garden Surveys
Number of banana varieties sampled	15	11
Number of markets/gardens visited	28	18
Fruit fly species collected *Bactrocera frauenfeldi Bactrocera musae*	*Bactrocera frauenfeldi*	*Bactrocera musae*
% infestation by both fruit fly species	6%	0.8%
% infestation by *Bactrocera musae*	3%	0.2%
Most common varieties sampled Tukuru, Katkatur, Chinese Tall.	Yawa	Kiakiau, Yawa,
Total weight of banana sampled	19.6 kg	36.8 kg
Number of banana fingers set-up	Not recorded ?	393
Average development stage of bananas sampled	mature green	mature green

the spread of the pest fruit fly.

If the incursion of *B. musae* is recent, then when or how did it arrive? Volcanic eruptions were experienced in ENB in September 1994. Extreme and widespread devastation prompted relief supplies from other parts of PNG, with fruit and vegetables being transported to the province in huge amounts. *Bactrocera musae* is present on the PNG mainland, especially in Morobe Province, where much of these food supplies were initially collected. It is thus possible that the fly was accidentally imported as an indirect consequence of the volcanic eruptions. This interpretation implies that flies were present on the Gazelle for two to four years before detection and this seems likely given the size of banana fly populations when first detected (Table 1), plus unprompted comments from local landholders suggesting maggots had been in their bananas since 1996 (authors' unpublished field records). The failure to detect the incursion until the resident fly population was large is very disturbing from a quarantine perspective, but reflects the difficulties of detecting low-density populations of fruit flies (Zalucki and Maelzer 1999). An alternative explanation for the incursion is that the fly may have been introduced in infested fruits carried by an air or sea-passengers, as there are no domestic quarantine restrictions in place to control fruit movement. Bananas are carried by 10% of passengers on PNG domestic airline flights –Putulan *et al.* in review and pose a high quarantine risk.

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REFEENCES

DORI, F., TENAKANA, D. AND KURIKI, K. (1993). The current status of fruit flies (Tephritidae) in Papua New Guinea. *Harvest* 15: 22-25.

DREW, R.A.I. (1989). The tropical fruit flies (Diptera: Tephritidae: Dacinae) of the Australasian and Oceanian regions. Memoir Queensland Museum No 26. 521 pp.

DREW, R.A.I., HOOPER, G.H.S. AND BATEMAN, M.A. (1982). *Economic Fruit Flies of the South Pacific Region*, 2nd Ed. Queensland Department of Primary Industries, Brisbane. X + 139pp.

LEBLANC, L. AND ALLWOOD, A.J. (1997). Mango fruit fly. SPC Pest Advisory Leaflet. 4pp.

LEBLANC, L, BALAGAWI, S., MARARUAI, A., PUTULAN, D. AND CLARKE, A.R. (2001). Fruit Flies in Papua New Guinea. Pest Advisory Leaflet No. 37, Secretariat of the Pacific Community- Plant Protection Service.

TENAKANAI, D. (1997). Fruit fly fauna in Papua New Guinea. Pp. 95-101 in: Management of Fruit flies in the Pacific. ACIAR Proceedings No. 76. A.J. Allwood and R.A.I. Drew (eds). ACIAR, Canberra.

WATERHOUSE, D.F. (1997). *The Major Invertebrate Pests and Weeds of Agriculture and Plantation Forestry in the Southern and Western Pacific*. ACIAR Monograph No. 44. ACIAR, Canberra.

WHITE, I.M., ELSON-HARRIS, M.M. (1994). *Fruit Flies of Economic Significance: Their Identification and Bionomics*. C.A.B. International, Wallingford. 604pp.

ZALUCKI, M.P., MAELZER, D. (1999). Pushing the limits of interpretation – sampling, trap networks and species incursions; what are the research needs? Pp 135-142 in: *Plant health in the new Global Trading Environment: Managing exotic insects, weeds and pathogens*. C.F. McRae, S.M. Dempsey (eds). DAFF – Australia National Office of Animal and Plant Health, Canberra.

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7. Text - Papers should be concise. Extensive introductions referring to the work of earlier authors should be avoided. Lengthy discussions and detailed descriptions should be reduced by the use of tables and diagrams. The text should not repeat in detail what is apparent from a table or diagram.

Names of countries or organizations may be abbreviated to capitals without full stops but must be given in full at the first mention.

Numbers under 11 should be spelt out unless qualifying a unit of measurement. If a number over 10 and a number under 11 appear in the same sentence, both are written as numerals. Do not begin a sentence with a numeral. Fractions should be given as decimals or spelt out. All decimal numbers less than unity should have a zero before the decimal marker, e.g. 0.25. All units should be in the S.I. System.

All scientific names of animals and plants must be underline to indicate that they should be set in italic type or written in italics. The authority should be cited in full on the first occasion a scientific name is used. Where the same name is used repeatedly, the genus may be abbreviated to a capital letter after the first citation. For example, use *Homo sapiens* Linnaeus on the first occasion and *H. sapiens* thereafter.

Common or local names may be used but the scientific name should be quoted on the first occasion. An agricultural chemical must be referred to by its generic or common name when it is first quoted.

8. Tables - Numerical results should be displayed as means with relevant standard errors rather than as detailed data. Standard errors should be given to one place of decimals more than the means to which they refer and the number of degrees of freedom should also be quoted. Tables should be complete in themselves so that they can be understood without reference ot accompanying text. Each table should have a brief and self explanatory title. The presentation of the same data in tabular and graphic form is not permitted.

9. Figures and photographs - Line drawings should

be drawn in black water-proof ink on smooth tough paper. Labeling should be clear and always produced with stencils using black water-proof ink and should be legible when reduced. No alterations or additions to artwork can be made by the editors. Figures should be no larger than an A3 page, and no smaller than final published size. Photographs should be glossy prints of good quality and must make a definite contribution to the value of the paper. Indicate the top of the figures and photographs on the back: the plate number of each figure and photographs, the author's name, and the title of the paper. Do not write on the back of photographs: use an adhesive label with the data previously written on it. Artwork should be of appropriate proportions for the final dimensions.

10. Acknowledgements - The names, initials and place of work of those the author wishes to mention may be included. It is unnecessary to mention everyone who has been marginally involved in the work.

11. References - These should be cited in the text by the author's name and data as follows:

"Moran and Brown (1965) showed or "Various works" (Miller and Smith 1956; Adams *et al.* 1960; Wilson 1978, 1979 a) found ..." The term *et al.* should be used when there are more than two authors. The letters a,b,c, should be used to distinguish several papers by the same author in one year.

All references in the bibliography should be given in full and in alphabetical order. For a journal the reference should include surname and initials of all author(s), (year), title of paper, full title of the journal, volume, (part) and full page numbers. For a book the reference should include author(s) surnames and initials, (year), title of chapter and page numbers if appropriate, full title of book, published and city and total page numbers. Conference proceedings should include the year and place of the conference. The title of the journal or book is underlined to be printed in italics. Examples:

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

Internal reports, communications and memoranda are not valid references. The criteria for valid publications (in the scientific world) are that publications are distributed widely among those interested in the subject and are available to the international public in major libraries and from the publisher. This therefore excludes reports circulated only within a department and to a few outsiders and conference documents available only to those who attended the conference and the like.

Work that has not been accepted for publication (unpublished data) and personal communications are not included in the list of references buy may be refereed to in the text. References cited in an appendix should be included in the list of references at the end of the paper.

Special care should be take to see that every reference in the text is included in the list of references and vice versa, and that there is consistency in the spelling of author's names and the citation of the dates throughout the paper.

12. Review of papers - All papers will be submitted to suitable professional referees. Major changes will be referred to the author for consideration. Minor editorial changes will be made without consultation but will be presented to the author(s) at proof stage. The final decision to accept or reject a paper, rests with the Editor.

13 Offprints - Twenty-five free off-prints are given to the author. Where there are several authors, the first author will be sent the off-prints. Extra off-prints may be ordered at the time the galley proofs are returned to the editor. Costs will be determined at the time of printing.

14. Recognised abbreviations in this journal are:

g	-	gram
kg	-	kilogram
t	-	tonne
l	-	litre
ml	-	millilitre
ha	-	hectare
mm	-	millimetre
cm	-	centimeter
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
* - $0.01 \leq p < 0.05$
** - $0.001 \leq p < 0.01$
*** - $p < 0.001$

Either kg/ha or kg.ha is acceptable, but large combinations of units should be in the form kg.ha to avoid possible mathematical ambiguity.

15. Submission of manuscripts - All correspondence should be addressed to: Editor, PNG Journal of Agriculture, Forestry and Fisheries, Agricultural Information Branch, Publication Section, Department of Agriculture and Livestock, P.O Box 417, Konedobu, Papua New Guinea.