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PREFACE

The delay in bringing out this issue has partly been, the result of fiscal constraints which have affected the entire government machinery including the Department of Agriculture and Livestock. Problems in receiving reviewers' comments were also a contributing factor. It is hoped however, that an alleviation of the above problems would enable us to bring out the next issue on time.

Editor

PAPUA NEW GUINEA

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CONTENTS

LIMITATIONS TO SWEET POTATO GROWTH IN SMALL VOLUMES OF SOIL IMPOSED BY WATER AND NUTRIENT STRESS, ACIDITY AND SALINITY.

A.J. Dowling[1,4], F.P.C. Blamey[2] and T. Hoa[3]

ABSTRACT

Sweet potato (Ipomoea batatas *(L.) Lam.) is an important smallholder root crop in Papua New Guinea, and there is an increasing requirement for its use as a diagnostic test species in agricultural research programs. As a result, it was decided to investigate sweet potato growth under conditions of water and nutrient stress, soil acidity and soil salinity using procedures with a small volume (1.7 L) of potted soil. An Orthoxic Tropudult soil deficient in phosphorus (P) and sulfur (S) from the Highlands Agricultural Experiment Station at Aiyura was assessed. Well-defined growth responses were apparent from about 10 days after sowing. Water stress dramatically reduced growth. As water stress increased, vines decreased in length and had fewer leaves, lower whole plant (tops plus roots) fresh weights and lower dry top weights. Water stress also masked effects of nutrient stress. Nutrient stress (P and S deficiency) reduced whole plant fresh weight and dry top weight without affecting vine length or number of leaves. Phosphorus and S requirements for 90% of maximum yield were equivalent to 48 and 25 kg ha^{-1}, respectively. Sweet potato proved intolerant of soluble salts at the high level (electrical conductivity of 1:5 soil:water extract 1.87 dS m^{-1}) imposed. Application of lime raised pH (1:5 soil:water) from 5.0 to 5.8, but had little effect on growth. Limitations on plant size and period of growth imposed by a small volume of soil strongly suggest that soil water must be maintained between field capacity and 50% of field capacity if other factors (e.g. nutrition) are to be effectively assessed and extrapolated to the field.*

Key Words: *Sweet potato, Water stress, Phosphorus, Sulfur, Lime, Salinity*

INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam.) is the most important staple food crop throughout the Highlands of Papua New Guinea (Bourke 1985). At the village or smallholder level, sweet potato gardens are managed according to traditional shifting cultivation practices. These practices typically include a period of fallow where grass or woody regrowth is encouraged for the maintenance of soil physical and nutritional properties. Thus the effective life-span of a typical garden soil will depend, initially, upon its physical and nutritional status and, subsequently, upon its rate of physical and nutritional degradation under cropping. In parts of Enga, and Southern and Western Highlands Provinces of PNG, the productive life of a garden is often extended by the use of organic manures, and the interplanting and sequential harvesting of crops, but rarely by application of inorganic fertiliser or by use of soil amendments (e.g. mulch, lime). Also in the Aiyura area of the Eastern Highlands Province, legumes (usually peanut or winged bean) are planted in rotation with sweet potato (Bourke 1990).

Due to an increasing requirement for use of sweet potato as a diagnostic test species in experiments in the field (e.g. Wayi and Konabe 1993), in controlled environments (e.g. Bourke 1977) and in solution culture (e.g. O'Sullivan *et al.* 1993), it was decided to investigate the response of sweet potato to a variety of factors and amendments likely to modify its growth in small volumes of soil (i.e. in pots) under controlled conditions. Using an Orthoxic Tropudult soil, deficient in phosphorus (P) and sulfur (S) (Dowling *et al.* 1994), simple short-duration pot studies were conducted to describe sweet potato growth responses to: (1)

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combinations of water and nutrient stress, soil acidity and soil salinity; and (2) rates of applied P and S.

METHODS

Experimental Soil

The experimental soil was collected from the north-facing slope of the International Board of Soil Research and Management (IBSRAM) project site on the Highlands Agricultural Experiment Station (HAES) (6° 19' S, 145° 55' E) at an altitude of 1650 m in the Aiyura valley near Kainantu, Eastern Highlands Province, PNG. Wayi and Konabe (1993) have classified this soil as an Orthoxic Tropudult (after Soil Survey Staff 1990).

A composite surface (0 to 0.15 m) soil sample of six 80 kg subsamples was collected, and then air dried and sieved <5 mm. Dowling *et al.* (1994) described this surface soil as being strongly acid (pH 5.4 in 1:5 soil:water), containing allophane and active Al (pH 7.9 in 1:50 soil:NaF solution), and being strongly P-fixing (P retention 73%) with low P availability (3.8 mg kg^{-1} Olsen-P). Maize (*Zea mays* L.) growth was reduced by P and S deficiency. A 2 kg subsample of soil was retained for determination of air dry field capacity (FC) and saturated soil water contents, and assessment of plant available water content.

Air dry and saturation gravimetric soil water contents were determined using procedures given by Rayment and Higginson (1992). Gravimetric water content at FC was determined after packing approximately 200 g of air dry soil into a 300 mm column. Water was applied uniformly to the top of the column, allowed to infiltrate and redistribute for 24 h, and FC in the top 50 mm was assumed. After discarding the surface 10 mm, the 10 to 20 mm layer was placed in a tared dish, weighed, dried at 105° C for 48 h, reweighed, and gravimetric water content at FC determined.

Pot trials utilised shadehouse and laboratory facilities of the Department of Agriculture, PNG University of Technology, Lae. All pot trials involved the use of 165 mm diameter (1.7 L) PVC pots, each lined with a plastic bag and containing 1.9 kg air-dry soil packed to a density of 1.1 g cm^{-3}.

Assessment of water and nutrient stress, soil acidity and soil salinity

Treatments were imposed to reflect a range of PAW contents, soil nutrient levels, soil acidity levels and salt contents. Water stress (W) treatments were: (1) limited water (W_L), in which the soil was watered to FC twice weekly; (2) adequate water (W_A), in which the soil was watered to FC daily; and (3) excess water (W_E), in which the soil was watered to saturation daily. Nutrients (Nutr), lime (Lime) and salt were either applied or not applied. These factors were then combined to result in the following treatments: (1) W_L; (2)W_L + Nutr; (3)W_L + Nutr + Lime; (4)W_A; (5)W_A + Nutr; (6)W_A + Nutr + Lime; (7) W_A + Nutr + Salt; (8)W_E; and (9)W_E + Nutr. Treatments were arranged in a completely randomised experimental design with four replications.

Fertiliser grade nutrients were applied (kg ha^{-1}) as follows: mixed NPK (as 6% N, 6% P, 5% K) at 160 N, 160 P and 130 K; Ca and N (calcium nitrate with 12% N, 17% Ca) at 40 N and 50 Ca; elemental S (100% S) at 75 S. After being thoroughly mixed, lime ($CaCO_3$, 2.3 t ha^{-1}) or salt (NaCl, 6.5 t ha^{-1}) were added to the appropriate treatments. After mixing, pots were wet to FC with distilled water and sealed. After a 10 day incubation period, two sweet potato (cv. Wanmun) vine cuttings were planted in each pot. Each vine cutting consisted of a growing tip and three nodes (leaves removed), and was approximately 150 mm in length. The base of the cutting was placed horizontally against the wall of the pot at a depth of approximately 40 mm, and the growing tip allowed to protrude 20 to 50 mm above the soil. A granular plastic mulch (depth 10 mm; Hostalen®, Hoeschst, Australia) was added to minimise evaporative losses from the soil surface 7 days after sowing (DAS). To facilitate pot movement for watering to FC, a stake was placed in the centre of each pot. Vines would be later tied to this stake. Pots were then watered to weight with distilled water as required; twice weekly to FC for W_L, daily to FC for W_A, and daily to saturation for W_E. Vines were grown for 42 days until well-defined growth responses were evident. Individual vine lengths and leaf numbers were recorded prior to harvest. Plants tops were cut at ground level and fresh weights immediately recorded. Plant tops were then dried (70° C for 72 hours) and reweighed. A 25 mm diameter soil core was then taken from each pot, dried at 40° C for 48 hours and sieved <2 mm, and pH (1:5 soil:water) and salinity (electrical conductivity of 1:5 soil:water suspension) determined using procedures given in Rayment and Higginson (1992). Roots were carefully removed from the soil under a stream of water, and root fresh weights recorded. Whole plant fresh weights were than calculated as the sum of top and root fresh weights.

Analysis of variance was used to test effects of treatments on vine length, number of leaves, whole plant fresh weight and dry top weight. Pairwise comparisons of treatment means were performed by the protected least significant difference (l.s.d.) test at P<0.05.

Assessment of P and S requirements

Treatments consisted of seven P and seven S rates (0, 20, 40, 80, 160, 320 and 640 kg ha^{-1}), applied as $Ca(H_2PO_4)_2H_2O$ and $CaSO_4 2H_2O$, respectively. Basal S (160 kg ha^{-1}) was applied to pots amended with P, and basal P (160 kg^{-1}) to pots amended with S; no other basal nutrients were applied since this soil was shown by Dowling *et al.* (1994) to be deficient only in P and S. Treatments were arranged in a completely randomised experimental design with three replications. After mixing, pots were wet to FC with distilled water and sealed. After a 10 day incubation period, two sweet potato (cv Wanmun) vines were planted in each pot as described previously. These were thinned to one vine per pot, 7 DAS and a granular plastic mulch (10 mm depth) added to minimise evaporative losses from the soil surface. Each vine was tied to a stake placed in the centre of its pot to facilitate watering and vine extesion. Pots were watered (to weight) daily to FC with distilled water. Vines were grown for 28 days when well-defined growth responses were evident. Individual vine lengths and number of leaves were recorded prior to harvest, and the vines harvested as described prevoiusly.

Analysis of variance was used to test effects of applied P and S. Pairwise comparisons of treatment means were performed by the protected least significant difference (l.s.d.) test at P<0.05. Mitscherlich relations of the form $y = a - be^{-kx}$ were fitted to data describing dry matter yield of plant tops (y) and applied P or S (x). Maximum yield (a, Y_{MAX}) was calculated, and absolute yields converted to relative yields. Mitscherlich relations were fitted to relative yield and applied P or S to remove the effect of differences in Y_{MAX} on the curvature co-efficient (k). The P and S requirements for 90% Y_{MAX} were then calculated.

RESULTS AND DISCUSSION

For this Orthoxic Tropudult soil, the air-dry water content was 16%, the water content at FC was 42%, and the water content at saturation was 55%. With pots containing 1900 g of air-dry soil, oven dry (105°C) soil mass was 1650 g. Water added to air-dry soil for FC and saturation were calculated as 440 and 650 g, but for convenience, pot mass at FC and at saturation was rounded to 2400 and 2600 g, respectively.

Water and nutrient stress, soil acidity and soil salinity

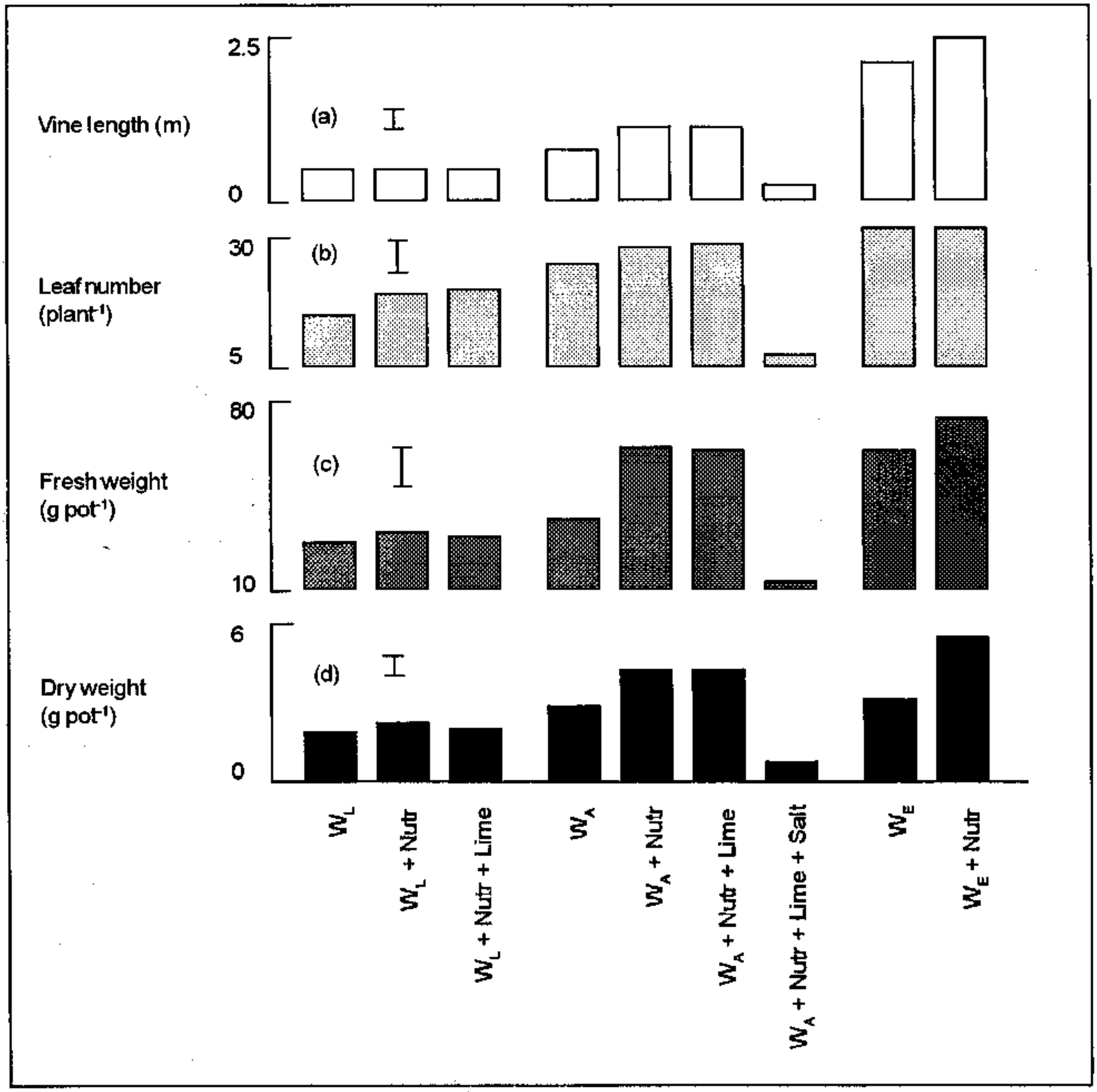
Visible growth responses to treatments were apparent from about 10 DAS. Vines in W_E pots were the longest and greenest, whereas those in W_A+Salt and W_L pots were the shortest and displayed a mild purple discolouration of leaf veins and underside of the leaf. Water stress appeared to limit vine growth more severely than did nutrient stress (P and S deficiency) or soil acidity. The presence of a high level of salt (NaCl)

Table 1. **Treatment effect on soil pH (1:5 soil:water) and electrical conductivity (1:5 soil:water) where WLA = adequate water supply, WE = excess water supply, Nutr = added nutrients, Lime = added lime and Salt = added NaCl following harvest of sweet potato grown in an Orthoxic Tropudult soil.**

Treatment	pH (1:5)	Electrical Conductivity (dS m-1)
WL	5.3 a[1]	0.03 a
WL+Nutr	5.3 a	0.24 b
WL+Nutr+Lime	5.7 b	0.32 b
WA	5.3 a	0.02 a
WA+Nutr	5.3 a	0.37 b
WA+Nutr+Lime	5.8 b	0.43 b
WA+Nutr+Salt	5.3 a	1.87 c
WE	5.3 a	0.03 a
WE+Nutr	5.3 a	0.36 b
l.s.d. (p=0.05)	0.1	0.19

[1] *Means followed by a common letter are not significantly different (P<0.05).*

Figure 1. **Treatment effects on (a) vine length, (b) number of leaves, (c) whole plant fresh weight, and (d) dry top weight with water where W_L = limited water supply, W_A = adequate water supply, W_E = excess water supply, Nutr = added nutrients. Lime = added lime and salt = added NaCl for sweet poptato grown in an Orthoxic Tropult soil from the Highlands Agricultural Experiment Station, Aiyura. Vertical bars show l.s.d. at p=0.05**



dramatically reduced growth. Visible symptoms of P and S deficiency, as described by O'Sullivan *et al.* (1993), were not observed.

At harvest, vine length ranged from 0.22 to 3.64 m, leaf number from 4 to 40 plant^{-1}, whole plant fresh weight from 10 to 102 g pot^{-1}, and top dry weight from 0.50 to 6.72 g pot^{-1}. Variations in these variables were highly inter-correlated ($r>0.77$), and similarly affected ($P<0.05$) by treatment (Figure 1). Treatment also had significant effects on soil pH which ranged from 5.3 to 5.8, and on soil salinity where electrical conductivity (EC) meas-

Table 2. **Effects of applied phosphorus and sulfur on vine length, number of leaves, whole plant fresh weight, and dry weight of plant tops for sweet potato grown in an Orthoxic Tropudult soil.**

Application rate (kg ha^{-1})	Vine length (m)	Number of leaves ($plant^{-1}$)	Whole plant fresh weight (g pot^{-1})	Dry weight of plant tops (g pot^{-1})
		(a) Phosphorus		
0	0.43 a[1]	12 a	24 a	1.53 a
20	0.93 b	16 b	34 b	2.44 b
40	0.97 bc	19 bc	43 cd	2.88 bcd
80	1.09 bcd	19 cd	46 de	3.07 cde
160	1.24 cd	22 cd	54 e	3.53 e
320	1.26 cd	21 cd	47 de	3.14 cde
640	1.38 d	21 cd	44 c	2.94 bcde
		(b) Sulfur		
0	0.50 a	13 a	25 a	1.51 a
20	1.21 bcd	21 cd	42 cd	2.94 bcde
80	1.13 bcd	21 cd	49 de	3.59 e
160	1.37 d	23 d	45 cd	3.25 de
320	1.38 d	21 cd	45 d	3.29 de
640	0.98 b	18 bc	37 bc	2.57 bc

[1] Means followed by a common letter are not significantly different ($p<0.05$).

ures ranged from 0.02 to 1.87 dS m^{-1} (Table 1). Only lime (2.3 t ha^{-1}) increased pH, but salinity was increased by application of nutrients and especially by application of NaCl (6.5 t ha^{-1}).

Water stress. The degree of water stress was quantified as the range in plant available water (PAW) between irrigations. After each irrigation, PAW was assumed to be 100% at saturation and 0% at 'air dry', and calculated to be 71% at FC. Water used between irrigations was recorded on two occasions, *viz.* at 21 and 35 DAS. At 21 DAS, W_L pots used 100 to 130 mL over 3 days, W_A pots 80 to 100 mL per day and WE pots 100 to 160 mL per day between irrigations. Corresponding values at 35 DAS were: W_L pots 150 to 200 mL; W_A pots 130 to 160 mL; and W_E pots 180 to 240 mL. With W_E pots wet to saturation and W_A and W_L pots wet to FC, these water use data suggest W_E pots were maintained at >66% PAW, W_A pots at 49 to 71% PAW, and W_L pots at 43 to 71% PAW. Thus, water stress increased with irrigation treatment ($W_E < W_A < W_L$) as PAW decreased from >66% under W_E to between 43 to 71% under W_L.

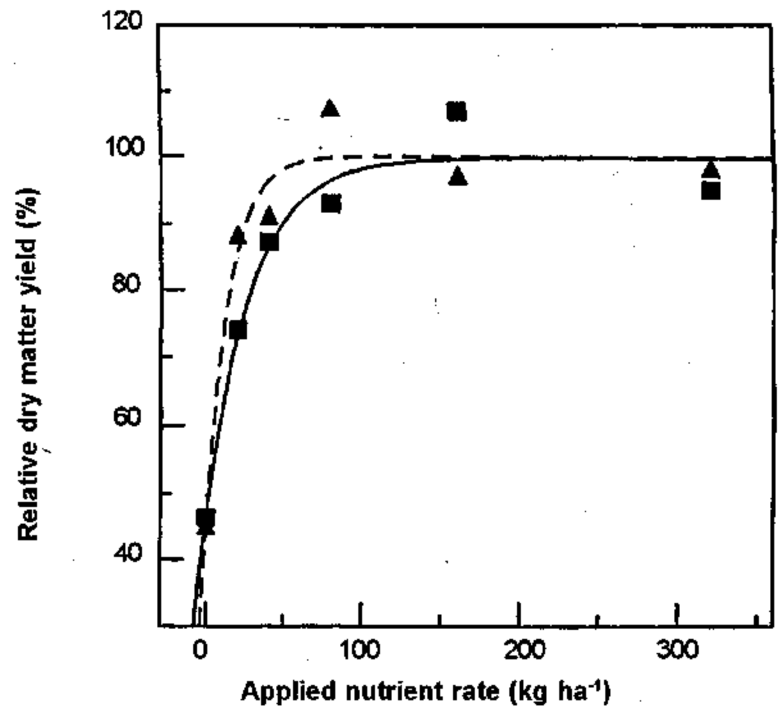
The impact of water stress on vine growth and dry matter production was dramatic (Figure 1). As water stress increased (other stresses not limiting *viz.* W_E+Nutr < W_A+Nutr < W_L+Nutr), vine length decreased from 2.49 to 0.59 m, leaf number decreased from 32 to 19 $plant^{-1}$, whole plant fresh weight decreased from 76 to 32 g pot^{-1} and dry top weight decreased from 5.33 to 2.20 g pot^{-1}. Similar patterns of decrease were apparent when nutrients (viz. $W_E < W_A < W_L$) and soil acidity (viz. W_E+Nutr+Lime < W_A+Nutr+Lime < W_L +Nutr+Lime) may have been limiting.

Nutrient stress. Nutrient stress was minimised by application (kg ha^{-1}) of 200 N, 160 P, 130 K, 50 Ca and 75 S. As nutrient stress increased, whole plant fresh weight decreased from 62 to 37 g pot^{-1} (W_A+Nutr > W_A) and dry top weight decreased (WE+Nutr > WE) from 5.33 to 4.43 g pot^{-1} and 4.30 to 2.80 g pot^{-1} (WA+Nutr >W_A). In contrast, vine length and number of leaves were little affected (Figure 1). As water stress increased, the impact of nutrient stress on dry matter production became less apparent.

Figure 2. **Mitscherlich fits to data describing the relationship between relative yield of dry tops and applied P (■ , solid line) and applied S (▲ , dashed line) for sweet potato grown in an Orthoxic Tropudult soil from the Highlands Agricultural Experiment Station, Aiyura. Fitted Equations are:**

For P, $RY = 100 - 53\ e^{-0.035x}$ ($n = 6$, $R^2 = 0.96$)
For S, $RY = 100 - 55\ e^{-0.067x}$ ($n = 6$. $R^2 = 0.96$)

(For convenience, data for 640 kg ha^{-1} additions of P and S are not included.)



Soil acidity. This soil was strongly acidic (pH 5.3). Although the addition of lime (2.3 t ha^{-1}) raised soil pH levels from 5.3 to 5.8 (Table 1), liming had little effect on plant growth and dry matter production (Figure 1).

Salinty. The impact of salt (6.5 t ha^{-1} NaCl), which increased soil EC from <0.03 to 1.87 dS m^{-1} (Table 1), on plant growth and dry matter production was dramatic, and perhaps more pronounced than for water stress (Figure 1). With adequate water and nutrition, salinity markedly depressed growth and dry matter production (W_A+Nutr > W_A+Nutr+Salt), vine length decreased from 1.37 to 0.30 m, leaf number decreased from 28 to 6 per plant, fresh weight decreased from 62 to 11 g pot^{-1} and dry weight decreased from 4.3 to 0.74 g pot^{-1}. Clearly, sweet potato was unable to tolerate this high level of soil salinity, and further work in this regard is warranted.

P and S requirements

With applied P, vine length ranged from 0.35 to 1.80 m, leaf number from 10 to 25 per plant, whole plant fresh weight from 20 to 57 g pot^{-1}, and dry top weight from 0.99 to 4.03 g pot^{-1}. For applied S, vine length ranged from 0.36 to 1.77 m, number of leaves from 11 to 25, whole plant fresh weight from 20 to 63 g pot^{-1}, and top dry weight from 1.12 to 4.37g pot^{-1}. Plant growth variables were inter-correlated ($r>0.81$), and were similarly influenced ($P<0.05$) by the rate of P or S application (Table 2).

Using data describing the weight of dry tops, separate Mitscherlich relations were developed to describe sweet potato growth responses to appled P and S, and Y_{MAX} (with approximate SE) estimated. For applied P, Y_{MAX} was 3.30 (± 0.12) g pot^{-1}; and for applied S, Y_{Max} was 3.34 (± 0.11) g pot^{-1}. Using these estimates of Y_{MAX}, separate relative growth responses to applied P and S were developed (Figure 2), and equivalent P and S requirements for 90% of Y_{MAX} calculated as 48 kg P ha^{-1} and 25 kg S ha^{-1}.

CONCLUSIONS

For this Othoxic Tropudult, sweet potato growth was depressed by water and nutritient stress and by soil salinity, but not by soil acidity. Simple procedures were used to grow vines in small volumes (1.7 L) of soil. However, considerable care was necessary at planting due to the mass of the planting material and its immediate requirement for water. Water requirements were minimised firstly, by removing as many leaves as possible and, secondly, by placing as much of the planting material in contact with wet soil as possible. Daily watering was essential. Senescing leaves were also removed during early growth.

Water stress dramatically reduced sweet potato growth, a result with great implications in pot experimentation. As water stress increased, vines became shorter with fewer leaves and lower whole plant fresh weights and dry top weights. Water stress also masked effects of nutrient stress. Nutrient stress acted to reduce plant growth, but had little effect on vine length or number of leaves. Given P and S deficiency in this soil, P and S requirements for 90% Y_{MAX} were equivalent to 48 and 25 kg ha^{-1}, respectively. Sweet potato proved intolerant of soluble salts at the high level (EC 1.87 dS m^{-1}) imposed in this experiment. Soil acidity was unlikely to limit sweet potato growth, and by inference, tuber yield on this soil. Further, the application of lime did not appear to induce potential micronutrient deficiency (e.g. Fe, Mn, Cu or Zn) or cation imbalance.

The results from this study suggest that sweet potato has great potential as a test species in short duration glasshouse studies. Although not exhibiting nutritional disorders as given by O'Sullivan *et al.* (1993), the value of sweet potato as a test species for tropical soils was recognised and its use is to be encouraged. However, with the limitations on plant size and period of growth that are imposed by a small volume of soil, it will be crucial to control and maintain soil water contents within defined limits (e.g. FC to 50% of FC) if other factors (e.g. nutrition, acidity and salinity) are to be effectively assessed and extrapolated to the field. The qualitative extrapolation of any response to the field must be questioned if the factor being examined (e.g. nutrition) does not clearly dominate all others (e.g. water, acidity and salinity) (De Vries 1980).

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EVALUATION OF TWENTY FIVE VEGETABLE VARIETIES AT AIYURA, EASTERN HIGHLANDS PROVINCE.

W. L. Akus[1] and R. K. Nema[2]

ABSTRACT

Two trials were conducted to compare 25 species of traditional and introduced vegetables. The object of the trials was to provide the basis for making recommendations to highland institutional farmers for suitable vegetable species to grow. Fresh and dry weight yield from first to final harvest are presented. The following species recorded yields of over 5 t/ha (fresh weight) and 1 t/ha (dry weight): Pumpkin (Cucurbita moschata), *choko* (Sechium edule), *silverbeet* (Beta vulgaris), Oenanthe javanica, *cabbage* (Brassica oleracea), *Russian comfrey* (Symphytum asperrimum), Rungia klossii *and* Dicliptera papuana. *Based on yield, nutritional value, acceptability to the consumer, ease of cultivation and period of harvest, the following vegetables are recommended to institutional farmers: Pumpkin, silverbeet, oenanthe and rungia. Cabbage is recommended with reservations.*

Key words: *vegetable species, nutritionally superior, high yielding.*

INTRODUCTION

Vegetables such as leafy greens and beans constitute a significant portion of people's diet in the Papua New Guinea highlands. Several species are generally grown by villagers in their gardens. Some of these species are recent introductions to Papua New Guinea (PNG), but many are traditional. Vegetables are also an important source of cash income for many people in the highlands. This is confirmed by the fact that vegetables constitute a significant proportion of produce offered for sale in the markets. The nutritional value of many of the traditional species has not been assessed adequately. The limited data available suggest that they are nutritionally superior to many of the introduced species.

Research work on vegetables has been done by staff of the Department of Agriculture and Livestock, University of Papua New Guinea and various Christian missions. This has mainly consisted of variety trials on introduced species. Results are presented in papers by Aldous (1976), Anon (1975), Blackburn (1976), Dever and Voigt (1976), Dodd (1977), Fowler (1976), Kemp (1976), Kesavan (1977a, b, 1980), Lambert (1975), Powell (1982), Rose (1980) and Westwood and Kesavan (1982). A complete listing of 250 agronomic field trials done on vegetables up to 1978 is given by Bourke (1982).

At institutions, such as high schools and corrective institutions, introduced vegetables are mainly grown in the gardens and the traditional PNG species are overlooked. We suspected that at least some of the traditional species would prove as productive as the introduced ones being grown. Between 1979 and 1982 two formal trials were conducted by the authors to compare yields and periods of production of 25 traditional and introduced vegetable species. The main purpose of the trials was to determine which species should be recommended to institutional farmers.

MATERIALS AND METHODS

Two trials were conducted at the Highlands Agricultural Experiment Station at Aiyura in the Eastern Highlands (6° 19' S; 146° E; 1600-1850 m alt.; 2200 mm mean annual rainfall). The trials were done at an altitude of 1610 m. Trial 1 was located on a heavy clay soil and Trial 2 on a dark clay loam rich in organic matter.

Twenty five species were compared. These are listed in Table 1. A randomized block design was used with four replications. Plots were 4 m x 4 m in size. Each

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Table 1. **Vegetable species entered in Trials 1 and 2.**

Botanical name	Common name
Abelmoschus manihot	Aibika
Amaranthus tricolor	Aupa
Basella alba	Ceylon spinach
Brassica oleracea var. *capitata*	Cabbage
Brassica chinensis	Pak choi
Cucurbita moschata	Pumpkin
Cyanotis moluccana	-
Dicliptera papuana	Dicliptera
Lagenaria siceraria	Bottle gourd
Nasturtium schlechteri	-
Oenanthe javanica	Oenanthe
Phaseolus lunatus	Lima bean
Phaseolus vulgaris	Climbing bean
Phaseolus vulgaris	Dwarf bean
Pisum sativum	Peas
Psophocarpus tetragonolobus	Winged bean
Rungia klossii	Rungia
Saccharum edule	Lowland pitpit
Sechium edule	Choko
Setaria palmifolia	Setaria
Solanum nigrum	Karakap
Spinacia olerarea	Spinach
Symphytum asperrimum	Russian comfrey
Vigna unguiculata	Cowpea

plot included a guard row 50 cm wide around the perimeter. A guard row of *Oenanthe javanica* was planted around the outside perimeter of each trial. The land was cultivated mechanically and the plots were prepared by hand. In Trial 1, coffee pulp was applied at a rate of 60 t/ha. No fertilizer was used in Trial 2 as the site was naturally fertile. Trial 1 was planted in November 1979 and Trial 2 in October 1980.

A locally grown variety was used for each species, except for cabbage, Chinese cabbage, silverbeet and spinach where Yates seed were used. The planting technique varied with different species, but it was generally done as would be normally done by village women in their subsistence gardens. Planting was done directly in the field for most species. Seedlings were raised in the nursery for cabbage, Chinese cabbage, silverbeet and spinach, and later transplanted into the field. The methods of propagation varied between species. These are detailed in Table 2. Replanting was done for several species when germination failed completely. Spacing between plants varied with species. Plant densities were determined after field establishment and are given in Table 2. Lima bean, winged bean and climbing bean (*Phaseolus*) were grown on stakes. Plots were weeded regularly.

Harvesting was done weekly until all species had finished producing. For most species the young leaves, petioles (and stems) were harvested, but fruit were also harvested for pumpkin and choko, and tubers were harvested from winged bean. The edible plant parts harvested are given in Table 2. Fresh weight of the edible portion was recorded at harvest and a sample taken from each plot to determine dry weight yield. The samples were oven dried for seven days before being weighed.

RESULTS

Fresh weight and dry weight yields and times to first and final harvest for each species are presented in Table 3. Yields in Trial 1 were generally greater than those in Trial 2, but there was reasonably good agreement in the rank of different species between trials (Table 3). There was considerable variation in yield between species. Mean fresh weights ranged from 300 kg/ha (spinach) to 68 t/ha (pumpkin fruit plus tips). Dry weight yield ranged from 40 kg/ha to 8.1 t/ha. The period taken to first harvest was also very variable. Some species were ready for harvest from 12 weeks after planting (*Nasturtium schlechteri*, peas) whilst lowland pitpit (*Saccharum edule*) was not ready to harvest till 49 weeks from planting. The harvesting period (first to last harvest) ranged from 2 weeks (peas) to 62 weeks (*Oenanthe*).

The species which recorded the highest yield were pumpkin (*Cucurbita moschata*), choko (*Sechium edule*), silverbeet (*Beta vulgaris*), *Oenanthe javanica*, cabbage (*Brassica oleracea*), Russian comfrey (*Symphytum asperrimum*), *Rungia klossii* and *Dicliptera papuana*. All these species recorded yields of over 5 t/ha fresh weight and over 1 t/ha dry weight.

DISCUSSION

A vegetable suitable for growing by an institution would have the following characteristics:

- (i) High yielding
- (ii) Nutritious
- (iii) Acceptable to the consumer
- (iv) Easy to cultivate
- (v) Have an extended harvest period
- (vi) Easy to prepare for cooking.

Table 2. **Method of plant propagation; parts of plant harvested; and plant density used (average of Trials 1 and 2).**

Vegetable species	Method of propagation	Plant parts harvested	Plant density (plants/ha)
Abelmoschus manihot	2-Stem cuttings	Young leaves, petiole, stem	23,000
Amaranthus tricolor	Seed	Young leaves, petiole, stem	383,000
Basella alba	Seed	Young leaves, petiole, stem	59,000
Beta vulgaris	Seed	Leaves, petiole	68,000
Brassica oleracea var. *capitata*	Seed	Leaves	54,000
Brassica chinensis	Seed	Leaves, petiole	25,000
Cucurbita moschata	Seed	Fruit, young leaves, petiole, stem	6,000
Cyanotis moluccana	Stem cuttings	Young leaves, petiole, stem	33,000
Dicliptera papuana	Stem cuttings/ splits	Young leaves, petiole, stem	21,000
Lagenaria siceraria	Seed	Young fruit	32,000
Nasturtium schlechteri	Seed	Young leaves, petiole, stem	2,560,000
Oenanthe javanica	Stem cuttings	Young leaves, petiole, stem	29,000
Phaseolus lunatus	Seed	Seed	11,000
Phaseolus vulgaris (climbing)	Seed	Pods, seed	34,000
Phaseolus vulgaris (dwarf)	Seed	Pods, seed	27,000
Pisum sativum	Seed	Pods, seed	29,000
Psophocarpus tetragonolobus	Seed	Tubers, pods, seed	94,000
Rungia klossii	Stem cuttings	Young leaves, petiole, stem	31,000
Saccharum edule	Stem cuttings	Inflorescence	17,000
Sechium edule	Seed	Fruit. Young leaves, petiole, stem	50,000
Setaria palmifolia	Stem cuttings	Young stem	20,000
Solanum nigrum	Seed	Young leaves, petiole, stem	1,092,000
Spinacia oleracea	Seed	Leaves, petiole	10,000
Symphytum asperrimum	Splits	Young leaves, petiole	25,000
Vigna unguiculata	Seed	Pods, seed	26,000

Each of the eight species which gave over 1 t/ha of dry weight yield will be discussed and these criteria considered. Nutritional information is obtained from WHO (1979). Pumpkin (*Cucurbita moschata*) gave a very high yield (mostly of fruit not tips). Both the fruit and leaf tips are nutritious, as they contain useful quantities of vitamin A precursor. Possible inadequate intake of vitamin A in the diets of residents of institutions is of concern in PNG (J. Badcock, pers.comm.). Both fruit and tips are acceptable to highlanders. The crop has an extended harvest period and is easy to cultivate. For these reasons it can be recommended to institutional farmers.

Choko (*Sechium edule*) was also high yielding. Again this occurred because of a high yield of fruit rather than tips. The fruit are of very low nutritional value and are rarely eaten by Papua New Guineans. Hence the fruit cannot be recommended.

Silverbeet (*Beta vulgaria*), also called Swiss chard, gave the third highest yield in the trial and the highest yield of leaf/petiole, although this was from Trial 1 only. A high proportion of the yield came from the petioles rather than the leaf blades. Silverbeet is rich in vitamin A. It is not usually eaten by Papua New Guineans. The harvest period of 47 weeks is extended, although

Table 3. **Fresh weight and dry weight yield and time taken to first and final harvest of various vegetable species (Trials 1 and 2).**

Vegetables species	Fresh weight yield (t/ha) Trial 1	Trial 2	Mean	Dry weight yield (t/ha) (1)	Time to first harvest (weeks) (1)	Time to final harvest (weeks) (1)
Abelmoschus manihot	2.0	3.6	2.8	0.5	24	76
Amaranthus tricolor	1.5	-	1.5(2)	0.3(2)	14	54
Basella alba	8.7	3.3	6.0	0.7	15	68
Beta vulgaris	16.4	-	16.4(2)	1.9(2)	16	63
Brassica oleracea var *capitata*	13.5	7.4	10.5	1.3	20	63
Brassica chinensis	2.1	4.7	3.4	0.3	20	25
Cucurbita moschata (tips)	13.4	3.4	8.4	0.9	16	74
Cucurbita moschata (fruit)	79.3	40.3	59.8	7.2	19	71
Cvanotis moluccana	11.3	8.8	10.1	0.8	14	76
Dicliptera papuana	7.2	2.8	5.0	1.0	15	76
Lagenaria siceraria	10.3	6.8	8.6	0.5	19	27
Nasturtium schlechteri	0.7	1.0	0.9	0.1	12	21
Oenanthe javanica	12.2	7.2	9.7	1.3	14	76
Phaseolus lunatus	4.9	1.2	3.1	0.5	23	72
Phaseolus vulgaris (climbing)	3.9	2.6	3.3	0.6	15	25
Phaseolus vulgaris (dwarf)	2.3	2.7	2.5	0.6	14	22
Pisum sativum	0.7	0.6	0.7	0.2	12	14
Psophocarpus tetragonolobus (pod)	3.3	2.9	3.1	0.6	20	29
Psophocarpus tetragonolobus (tubers)	2.3	-(3)	2.3	0.7	45	45
Rungia klossii	8.6	4.1	6.4	1.0	15	76
Saccharum edule	0.6	0.3	0.5	0.2	49	82
Sechium edule (tips)	9.0	2.7	5.9	0.6	15	74
Sechium edule (fruit)	28.7	40.3	34.5	4.8	18	74
Setaria palmifolia	3.2	3.0	3.1	0.3	17	69
Solanum nigrum	3.4	2.1	2.8	0.5	14	70
Spinacia oleracea	0.3	-	0.3(2)	0.04(2)	27	34
Symphytum asperrimum	15.6	7.6	11.6	1.5	15	77
Vigna unguiculata	4.0	3.0	3.5	0.8	19	56

Notes:- *(1) Mean of Trials 1 and 2*
(2) Crop failed to establish in Trial 2. Results are from Trial 1 only.
(3) Winged bean tubers were stolen from Trial 2.

it is shorter than some of the other high yielding species (Oenanthe, rungia, pumpkin fruit). Silverbeet is not easy to cultivate if seedlings are raised in a nursery. (Note the crop failure in Trial 2). However seeds planted directly in the field have established successfully under institutional conditions (B. Calcinai, pers.comm.). We recommend silverbeet as a vegetable for institutional farmers, provided problems with crop establishment can be overcome.

Oenanthe (*Oenanthe javanica*) satisfies all criteria for recommendation. It is high yielding, acceptable to Papua New Guineans, has an extended cropping period and is easy to cultivate. It also can be harvested from 14 weeks from planting. We have no information on its nutritional value, but presume it to be moderately nutritious as the leaves are medium dark green in colour.

Cabbage (*Brassica oleracea*) is high yielding and acceptable to highlanders. It is less nutritious than species with dark green leaves. Its harvesting period of 43 weeks is less than some other species, but still extended. Seedlings have to be raised in a nursery and it is very susceptible to insect attack. Hence it is a more difficult species to grow. It could only be recommended with reservation. The average fresh weight yields in these trials (13.5 and 7.4 t/ha) are lower than yields reported elsewhere in PNG (Blackburn 1976; Dever and Voigt 1976).

Russian comfrey (*Symphytum asperrimum*), rungia (*Rungia klossii*) and dicliptera (*Dicliptera papuana*) yielded 1.0-1.5 t/ha of edible portion on a dry weight basis. All these species have dark green leaves and are presumably nutritious. All have an extended harvest period, can be harvested from 15 weeks after planting and all are easy to cultivate. They can only be separated on their acceptability. Rungia is a very popular highland green and has a an acceptable flavour, cooked or uncooked. *Dicliptera* is coarser than rungia and is only a minor species in the highlands. Russian comfrey is not eaten by people in the highlands and there have been health concerns about the crop overseas. For these reasons we recommend rungia as a species suitable for institutions to grow, but not dicliptera or Russian comfrey.

Further work is needed to determine the length of time after planting that certain species can be economically maintained. Most of the high yielding species considered here (pumpkin, silverbeet, choko, oenanthe, rungia, Russian comfrey) can be maintained for extended periods. The period is dependent on the level of weed control and soil fertility. In the present trials, weeds were controlled regularly, but we suspect that the economic harvesting period would be less under actual farming conditions. Further information is needed on the nutritional value of the traditional Papua New Guinea greens, especially *Oenanthe javanica*, *Rungia klossii* and *Dicliptera papuana*.

Crop yields are affected by the planting density and variety used. Hence different results from those reported here would be expected if these two variables were different. Nevertheless we believe that these trials have given a good indication as to the most productive vegetable species in the highlands.

CONCLUSION

Based on yield and other criteria the following vegetables can be recommended for use by institutions in the highlands: Pumpkin, silverbeet, oenanthe and rungia. Cabbage is also a high yielding species, but it is recommended with reservation because it does not satisfy other criteria.

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EVALUATION OF INTRODUCED SWEET POTATO CULTIVARS AT AIYURA IN THE EASTERN HIGHLANDS OF PAPUA NEW GUINEA.

W.L. Akus[1, 2]

ABSTRACT

Seven selections of sweet potato were introduced into Papua New Guinea from IITA in Nigeria and Louisiana State University in the USA after intermediate quarantine in the United Kingdom. They were introduced as 12 separate accessions. Evaluation has been conducted at four locations in PNG including Aiyura. This paper reports on a preliminary unreplicated evaluation at Aiyura and two formal trials which include the selections from IITA and the USA and three high yielding PNG releases. Consistent results were obtained between the 5 trials. Two IITA selections (TIS 2525 and TIS 2534) outyielded the best of the PNG cultivar, Merikan. These two releases and other IITA selections were of acceptable flavour to local tasters. The USA selections were generally unacceptable in flavour to local tasters.

Keywords: *Aiyura, meristem culturing, electron miroscopy, local material, eating quality.*

INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam.) remains by far the most important food crop in Papua New Guinea (PNG). Much of the on-going programme of research into PNG food crops has been directed towards the collection and evaluations of thousands of cultivars grown in this country, in order to select high yielding, good quality varieties suitable for subsistence and commercial growers. Although selection and breeding of sweet potato is in progress in other countries, the Department of Agriculture and Livestock (DAL) has been very cautious about making introductions from overseas because of the difficulty of ensuring that the vegetative planting material is completely free from diseases or pests that might damage or even devastate our most important food crop. However, in the mid-1970s, there was a small introduction programme for the purpose of preliminary assessment of whether selected overseas varieties were superior to local varieties. If the introductions proved greatly superior, there would be a strong case for an expanded introduction programme. If the introductions proved similar or inferior to local material it would be better, for the present, to concentrate on local material, thus avoiding the quarantine risks involved with introductions

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Through the kindness of the Glasshouse Crops Research Institute in United Kingdom, the International Institute of Tropical Agriculture (IITA) in Nigeria and the Department of Horticulture of Louisiana State University (LSU) in the United States, seven promising selections were screened and freed from disease in the United Kingdom (UK) and thereafter introduced to PNG. The screening involved meristem culturing, electron microscopy and grafting on to indicator plants. These tests indicated that much of the original material carried some sub-microscopic particles and only material completely free from suspicion was sent to PNG, where it was subjected to post-entry quarantine prior to release for field planting.

Because several meristem cultures were established in the UK and there was variable survival of cuttings sent to PNG, each of the original varieties was represented by one to three introductions (distinguished by different NG numbers). These were planted to separate entries in the trials described in this paper. The United States material comprised the commercial varieties Centennial, selection L9-190, subsequently named Jasper, and L9-163. Information about the four IITA selections provided by IITA in 1976, is shown in Table 1.

After their release from post-entry quarantine in PNG, a preliminary unreplicated evaluation was conducted at Aiyura by B. Siki. This was followed by two formal experiments conducted by the author to assess yield, eating quality and pest and disease incidence. These two experiments are reported here. Aiyura is situated at a latitude of 6° 19' South and a longitude of 146° East with an altitude ranging from 1600 to 1850 metres above sea level. The mean annual rainfall is 2200 mm. Both the experiments were conducted at an altitude of 1630 m. Trial 1 was located on a dark brown clay loam soil and Trial 2 on black loam. Similar tests have been completed or are in progress at the Lowlands Agricultural Experiment Station near Rabaul and Laloki Horticulture Research Station outside Port Moresby, both in the lowlands. Very poor yields were obtained when the introduced cultivars were tried at Tambul at an altitude of 2320 m above sea level in the Western Highlands Province.

MATERIALS AND METHODS

A randomized block design was used with six replications of 15 lines in plots 12 m x 3 m. In each plot there were two rows of twelve mounds each measuring 1.5 m x 1.0 m. There was a guard row around the perimeter of the trials, but none between plots.

The ground was mechanically cultivated and mounds hand-made with spades. Four plants each spaced about 40 cm apart were planted on each mound. This planting arrangement gave a plant density of 27,000 plants per hectare. Weeding was done when it was found necessary. There was no fertilizer application or pest and disease control.

The trial included the different accessions of four cultivars from Nigeria (See Table 1), three from USA and three local cultivars. The local cultivars were Milne Bay (from coastal PNG), Serenta (PNG highlands) and Merikan (thought to be an earlier introduction from America but now widely grown in the PNG highlands) (A.J. Kimber, pers.comm.). Serenta and Merikan are high yielding releases from Aiyura (Akus 1982). At harvest the tubers (storage roots) were graded into marketable and stockfeed yields. Marketable tubers were those that weighed more than 100 grams and considered acceptable for human consumption while stockfeed were those less than 100 grams and considered suitable only for animal feeding. Sweetness and strength (soft or firm when cooked) are two important factors which determine acceptance or rejection of a cultivar and so tests were conducted to assess these characteristics. Usually most people prefer sweet and firm cultivars. Tuber samples of each cultivar were given to different people to cook, eat and comment on sweetness, strength and acceptability. Scores for each characteristic were given for each sample, as detailed in Table 2b.

Analysis of variance was carried out for the total tuber yield for each trial. The total rainfall during the growing periods and dates of planting and harvesting are given in Table 2a.

Table 1. **Information on the four IITA selections.**

Cultivar	TIS 1499	TIS 1487	TIS 2534	TIS 2525
Total tuberyield (t/ha)	30-35	25-30	35-40	30-40
Sweet potato weevil resistance	Medium to high	Mild	High	Mild
Virussusceptibility	Medium to high	Average	Very resistant	Resistant
Tuber shape	Fair to poor	Good: oblong and smooth	Good: very smooth	Good: smooth
Storability	Fair to medium	Fair	Medium	Average

Source: A.K. Howland, IITA, Nigeria (pers.comm., 1976)

RESULTS

Results of the preliminary evaluation are given in Table 3. Results of Trials 1 and 2 are summarized in Table 4. Table 5 gives the mean yields of the IITA, USA and PNG cultivars. Records of acceptability tests are given in Table 2.

DISCUSSION

Accessions from the IITA release TIS 2525 were the best tuber yielders in both trials with mean yields of 51.3 t/ha and 48.9 t/ha for the two accessions. The mean tuber yields calculated over trials one and two showed the two Nigerian cultivars, TIS 2525 and TIS

Table 2a. **Total rainfall during the growing periods and planting and harvesting dates.**

Trial	Rainfall during growing period (mm)	Planting date	Harvesting date	Growing period (days)
1	1523	10th Oct. 79	8th Dec. 80	270
2	1508	25th Nov. 80	12th Mar. 81	254

Table 2b. **Scores of sweetness, strength and acceptability of introduced and local cultivers.**

Cultivar and accession	Sweetness	Strength	Acceptability
Merikan	2.8	3.7	3.5
Serenta	3.0	2.8	3.3
Milne Bay	2.8	2.2	2.7
TIS 2534 (NG 7570)	2.5	2.0	2.5
TIS 2525 (NG 7575)	2.5	2.0	2.3
L9-190 (NG 7473)	2.2	2.3	2.2
TIS 1487 (NG 7571)	1.8	2.8	2.1
TIS 2525 (NG 7477)	2.0	3.0	2.0
TIS 1499 (NG 7479)	2.0	2.0	2.0
L9-190 (NG 7574)	2.3	1.8	2.0
TIS 1487 (NG 7475)	2.0	2.8	1.8
L9-163 (NG 7474)	1.9	1.7	1.7
L9-163 (NG 7472)	1.8	1.2	1.2
Centennial (NG 7572)	2.6	1.6	1.2
L9-163 (NG 7573)	1.7	1.7	1.0

Score scale

Score	*Sweetness*	*Strength*	*Acceptability*
1	*Not sweet*	*Very soft*	*Poor*
2	*Sweet*	*Soft*	*Fair*
3	*Quite sweet*	*Strong*	*Good*
4	*Very sweet*	*Very strong*	*Very good*

Table 3. **Results of preliminary evaluation of the introduced cultivars at Aiyura.**

Cultivar	Total tuber yield (t/ha)
TIS 1499 (NG 7479)	74.0
TIS 2534 (NG 7570)	58.7
TIS 2525 (NG 7575)	56.0
TIS 2525 (NG 7477)	55.1
TIS 1487 (NG 7571)	47.1
Centennial (NG 7572)	44.9
Meristem 22915 (NG 7474)	43.1
L9-163 (NG 7573)	33.3
L9-190 (NG 7473)	33.2
L9-190 (NG 7574)	30.7
L9-163 (NG 7472)	28.5
TIS 1487 (NG 7475)	18.7

Source: B. Siki (pers.comm., 1978)

2534 to be superior to Merikan which slightly outyielded another Nigerian cultivar TIS 1487. Milne Bay and TIS 1499 followed Merikan with equal performances. Two American cultivars, Centennial and L9-163 outyielded Serenta which was followed by L9-190 with a yield of 22.3 t/ha (Table 4).

In Trial 1, introduced cultivars on average were higher yielding than the PNG material. IITA cultivars with a mean tuber yield of 43.1 t/ha were higher yielding than American and PNG cultivars. In Trial 2, mean yields of introduced and PNG cultivars were very similar although again IITA cultivars were higher yielding than those from USA and PNG. Average yields of the three cultivars groups over two trials were quite consistent. Quality assessments showed the three PNG cultivars were superior to introduced material (Table 2).

The ranking and yield levels of the various accessions and cultivars were similar in Trials 1 and 2. There was also good agreement between results obtained in the

Table 4. **Total and mean tuber yields of Trials 1 and 2 (t/ha).**

Cultivar and accession	Total tuber yield Trial 1	Total tuber yield Trial 2	Mean yield Trials 1 and 2	Mean cultivar yield
TIS 2525 (NG 7477)	48.8	53.7	51.3	50.1
TIS 2525 (NG 7575)	51.1	46.6	48.9	
TIS 2534 (NG 7570)	45.3	52.2-	48.8	48.8
Merikan	40.9	42.6	41.8	41.8
TIS 1487 (NG 7571)	44.2	38.4	41.3	37.9
TIS 1487 (NG 7475)	37.2	31.8	34.6	
TIS 1499 (NG 7479)	31.6	39.1	35.4	35.4
Milne Bay	36.1	34.6	35.4	35.4
Centennial (NG 7572)	34.2	35.0	34.6	34.6
L9 - 163 (NG 7472)	34.9	32.8	33.9	
L9 - 163 (NG 7474)	33.0	26.1	29.6	30.3
L9 - 163 (NG 7573)	28.7	26.1	27.4	
Serenta	15.5	33.1	24.3	24.3
L9 - 190 (NG 7574)	22.5	25.8	24.2	22.2
L9 - 190 (NG 7473)	17.7	22.9	20.3	
Level of significance	*0.01*	*0.01*		
Least significant difference (p = 0.05)	*8.2*	*8.6*		

Table 5. **Mean tuber yield of IITA, USA and PNG cultivars (t/ha).**

Trial	IITA cult.	USA cult.	Introduced cult.	PNG cult.
1	41.6	27.6	35.8	30.0
2	42.6	28.5	35.9	36.0

cult. = cultivars

two formal trials and in the preliminary screening. Yield performance and quality assessments of different accessions of the same cultivars were generally similar.

Observations made for known pests and diseases (in the highlands) showed sweet potato weevil (*Cylas formicarius*) to be present in propagation material but this was not seen again in the experiment blocks. The loss due to taro beetle (*Papuana* spp.) was slight. Sweet potato leaf scab (*Elsinoe batatas*) was present. Rats caused some slight tuber damage.

CONCLUSION

Most IITA selections were very high yielding and some have good eating quality. Some of the United States selections were higher yielding than Serenta, but both Milne Bay and Merikan proved superior to them. A mean tuber yield of 28 t/ha by USA cultivars is considered a good experimental yield but quality assessments indicated that they were unacceptable to PNG tastes. IITA cultivars TIS 2525 and TIS 2534 from Nigeria proved to be higher yielding than Merikan, the best PNG material, but further tests are required before their release to the farming community. Further introduction of material from IITA in Nigeria is warranted.

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DEVELOPMENT OF MODERN UPLAND RICE (*Oryza sativa* L.) VARIETIES, WITH SUPERIOR MILLING AND PHYSICO-CHEMICAL TRAITS, FOR PAPUA NEW GUINEA.

M.S. Sajjad [1]

ABSTRACT

To select suitable upland variety(ies), the tailor made germplasm was imported from IRRI. After preliminary evaluation, six genotypes were selected. In both the confirmatory trials, under severe drought, selections ADT 31, IAC 165, IR 47686-6-2-2-1, IRAT 104 and Niupela outyielded the rest of the selections. The Regional yield trials on these promising varieties were conducted country wide during 1993, in comparison to either Niupela or a locally grown variety in the respective area (Finschafen) or other genotypes we have developed so far. IAC 165, ADT 31, IR 47686-6-2-2-1, IRAT 104 and Niupela proved their high yielding potentials in these regional yield trials. IAC 165 & ADT 31 are one month early maturing than the rest. The varieties IAC 165, IR 4768-6-2-2-1, IRAT 104 & Niupela possess good milling recovery and most of their physico-chemical traits are desirable. IAC 165 has very low amylose contents, but cooks as soft as IRAT 104 & IR 47686-6-2-2-1. Therefore it may be suitable as a glutinous variety. The varieties IRAT 104 & IR 47686-6-2-2-1 seem to be good for upland cultivation in the country.

Key words: *Upland, germplasm, yield components, selection, adaptability trials, milling & physico-chemical traits.*

INTRODUCTION

Upland rice means a rice crop grown under scarce moisture, either on flat bunded or undulated unbunded fields. The fields are prepared and planted under dry condition. The crop depends on natural precipitation.

Upland rice is cultivated in the poorest countries of the world, in three continents viz. Asia, Latin America and Africa. Grain yields are low and vary from 0.5 t/ha in Africa, 0.5 to 1.5 t/ha in Asia and 1.0 to 4.0 t/ha in Latin America (De Datta 1975). But the area under upland rice is so large that a small increase in yield substantially affects the total upland rice production of the world. Like some other upland rice growing countries, PNG can also become self sufficient in rice, if she harnesses the niche for rice production.

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The last consultancy study to PNG (Sloan & King 1993) for, "Rice Sites development study" has emphasised the development of a rice based farming system (RBFS) approach to achieve this goal. In the proposed farming system, rice is one of the many crops, but not the only crop. They have also suggested that rice should be grown by partial irrigation, by harnessing the sub soil water.

But since rice is entirely a new & labour-intensive crop in PNG, we strongly suggest that rice should be promoted as a mono crop for at least next 10 years. This will certainly develop expertise of local scientists and rice farmers. RBFS will in fact at this stage of Agricultural development will open a Pandora box: and both the scientists and farmers will be like rolling stones; and will never gather masses.

However, the dream of developing many crops is realizable, only if the proposed RBFS is technically robust and economically viable; and farmers of the country are ready to be recipients of the new approach.

As a step towards making that ambitious dream realizable, we have envisaged some of the constraints for rice production for lowland, upland high altitude areas with cool climate and acid soil ecosystems of PNG. These constraints are non availability of modern High Yielding Varieties (HYV's) and lacuna in agronomic information to make the rice cultivation cost effective in the country. Therefore to tackle these two major problems for higher and sustainable yields of rice, we initiated a project, during the last quarter of 1990 on, "Breeding of modern High Yielding Varieties (HYV's) for lowland, upland, high altitude areas with cool climate & acid soils ecosystems and development of Agronomic practices, for lowland and upland ecosystems".

The development of varieties for upland was given a special emphasis and the progress on the area of research is reported in this paper. The progress of development of modern HYV's for lowland, high altitude areas with cool climate and acid soils will be presented elsewhere. After our preliminary evaluation of the potential of Markham valley, during 1991 for upland rice cultivation, semi mechanized-with medium inputs comercial trials (Sajjad and Beko 1994) & variety trials in the valley, we could successfully pin point an extremely promising variety for upland cultivation called Niupela (Wohuinangu & Sajjad 1992). Chang *et al.* (1974) have reported that many traditional upland rice varieties produce fully filled panicles with heavier grains, inspite of drought. We have also observed such a capability in Niupela, while testing it country wide for upland cultivation.

The variety posseses good agro-botanical traits, milling recovery & is being promoted by us, for the whole country. Niupela is short grain variety and is easier to harvest by hand, and has greater consumer acceptance (Fereday 1993). We had found the variety very promising during 1992 and since then its seed was multiplied on a top priority basis and has literally spread to every nook and corner of the country.

But since we envisaged avoiding the narrow genetic base for future upland varieties for the country from the very beginning, we are striving very hard to develop a gene source to act as donors of drought tolerance to develop future varieties by hybridization. Therefore, we tried to develop our gene bank by selecting more drought tolerant varieties, possessing either avoidance phenomenon i.e. early maturity or in possession of such Agro botanical traits, enabling them to cope effectively with drought.

It has been reported that the exotic germplasms of wide geographic origin possess the genetic plasticity to cope with adverse environments (Sajjad 1983, 1987). This prompted the present study to select suitable upland rice variety(ies) for PNG.

MATERIALS AND METHODS

The entries (53) of a set of high light entries of International Rice Testing Programme (IRTP-1991), were evaluated under ERDC conditions, in comparison to Niupela as the local standard. The experiment was planted on 19.10.1991 and was harvested on 6.2.1992. Each entry was planted on 2, 15 m - long rows per replication. the experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. The crop received N,P,K at the rate of 150:75:75 Kg/ha respectively. The data on yield and yield components were recorded on 20 guarded plants per entry per replication.

Two confirmatory trials were conducted, under very severe drought condition, under upland field at ERDC & Finschhafen, during 1992. The following six selections were tested, in comparison to Niupela.

1. ADT 31 (IR 8/Culture 340, from India).
2. IAC 165 (from Brazil).
3. IR 47686-6-2-2-1 (IRAT 104/Palawan, from IRRI).
4. IR 47686-9-2-B (IRAT 104/Palawan, from IRRI).
5. IRAT 104 (IRAT 13/Moroberekan, from Ivory Coast).
6. IRAT 13 (Mutant of 63-83, from Ivory Coast).

The crops were planted with a dibbling stick at plan to a row distances of 20 cm. The experiments were conducted in RCBD, with four replications. Each entry was planted on 9 m.sq. area per replication. Both the crops received N,P,K at the rate of 100:50:50 Kg/ha respectively.

The experiments were planted on 16.3.1992 (ERDC) & 24.4.1992 (at Ubegon Seven Lally Youngpela didiman Farm, Finschhafen). The crops were harvested on 17.7.1992 and 26.8.1992. The early maturing genotypes ADT 31 & IAC 165 were harvested one month before the rest of the lines, at both the sites. To record the data on fresh paddy weight, a net area of 4 m.sq (100 hills area) per entry per replication was harvested. The crop was threshed on the spot and data were recorded. The data on fresh paddy weight was later adjusted to 14% moisture contents. The data on yield components were recorded on 15 plants per entry per replication. The data were statistically analyzed by using DMRT. The regional yield trials were planted at Finschhafen, Bereina and ERDC, during 1993 to determine the yield potential and adaptability of the varieties.

Finschhafen. The comparative yield potential of most promising new varieties, and Niupela were tested in comparison to a variety (designated hereafter as Fins. (Finschhafen 91) already under cultivation in the area. The experiment was planted on 11.2.1993, at Walingai Yangpela Didiman Farm, near Sialum. The three varieties were planted at plant to row distances of 20 cm. Each variety was planted on an area of 9 m² per replication. The experiment was conducted in RCBD, with five replications. The crop received no fertilizer.

The most early maturing variety IAC 165 was harvested on 6.5.93, while the rest of the varieties were harvested at their maturity. To record the data on yield, the plants from a net area of 6 m. sq. (area of 150 hills) per entry per replication were harvested & threshed on the spot; and the data on fresh paddy weight was recorded. Fresh paddy weight was later adjusted to 14% moisture contents. The data on yield components were recorded on 15 plants per entry per replication. The data were statistically analyzed using DMRT.

Bereina, Central Province. Six genotypes namely IR 35366-62-1-2-2-3 (IRRI), S 8118-10-2 (Korea), IAC 165 (Brazil), Luke-3 & RP 1515-221-3-3-1 (India) and Niupela (standard)) were studied. The trial was conducted in RCBD, with five replications. Each genotype was planted on an area of 15 m² per replication. The planting (on 24.3.1993) was accomplished with a dibbling stick, at plant to row distances of 20 cm. The depth of sowing was kept uniform. The crop received N,P,K at the rate of 33:50:50 kg/ha respectively, only as a basal application. The most early maturing variety IAC 165 was harvested on 22.6.1993. The rest of the genotypes were harvested after about one month. Fresh paddy weight was recorded after harvesting a net area of 6 m² per entry per replication. The data on fresh paddy weight recorded were adjusted to 14% moisture contents. The data for yield components were recorded on 15 hills per entry per replication. The data were statistically analyzed using DMRT.

ERDC. The most promising selections; ADT 31, IAC 165, IR 47686-6-2-2-1, IR 47686-9-2-B, IRAT 104, IRAT 13 and a Nepalese variety KK-15-36-C (IR 5657-33-2/BKNBR 1031), for the lowland were yield tested in comparison to Niupela as standard. The rice plants were planted on 1.12.1993, at plant to row distances of 20 cm using a dibbling stick. The experiment was conducted in RCBD, with five replications. Each entry was planted on an area of 15 m² per replication. The crop received N,P,K at the rate of 100:50:50 Kg ha^{-1} respectively. Weeding was done only once, due to less recources available for the work. The crop was harvested on 7.4.1994. To record the data on yield, a net area of 6 m² per entry per replication was harvested and fresh paddy weight recorded. The data on fresh paddy weight were adjusted to 14% moisture contents. To record the data on yield components, 15 hills per entry per replication were harvested separately and stored in separate paper bags. The data on panicle traits were recorded in the laboratory. The data were statistically analyzed using DMRT.

EXPERIMENTAL RESULTS

The results of the preliminary evaluation of 53 entries (IRTP-1991), in comparison to Niupela as local stand-

Table 1. **Performance (yield and yield components) of most promising selections from the high light entries for International Rice Testing Programme (IRTP) 1991, under upland field condition at ERCD, during 1992.**

Name	Days to 50% flowering	Plant height (cm)	Productive tillers per hill	Panicle length (cm)	Grains per panicle	Spikelet fertility (%)	Thousand grain weight(g)	Yield per hill (g)
ADT 31	65b	72.2c	21.2a	19.4c	68.2d	79.2b	21.8c	22.8c
IAC 165	65b	103.7b	12.7b	23.1a	120.8a	90.2a	34.1a	41.6a
IR 47686-6-2-2-1	91a	113.0a	12.4b	22.0ab	71.1d	82.0b	29.8b	24.4b
IR 47686-9-2-B	93a	111.8a	10.6b	23.7a	96.0b	71.8b	29.9b	22.5c
IRAT 104	94a	112.5a	8.6c	24.1a	119.5a	83.1b	31.2a	23.2c
IRAT 13	93a	103.4b	10.6b	22.3a	79.9c	72.1b	33.9a	20.2d
Niupela	91a	104.5b	11.5b	20.1c	48.7e	45.6c	22.5c	12.9e

Figures followed by different letters are significant at 5% level, according to DMRT.

Table 2. **Performance (yield and yield components) of selections from IRTP-1991 & a Standard in a microplot yield trial at ERDC, during 1992.**

Genotypes	Days to flowe-ing	Yield t/ha	Plant height (cm)	Productive tillers/hill	Panicle length (cm)	Grains per panicle	Spikelet fertility (%)	Thousand grain weight (g)
ADT 31	63b	2.6a	56.0d	12.0a	21.1c	65.8b	70.0c	19.5c
IAC 165	60b	2.7a	73.4c	6.3c	16.9d	87.9a	71.5c	20.9d
IR 47686-6-2-2-1	90a	2.5a	93.3a	4.6d	23.6a	50.3d	62.9d	28.9b
IR 47686-9-2-B	88a	1.9b	86.2b	6.3c	21.7b	60.1c	70.7c	27.0c
IRAT 104	90a	2.5a	86.3b	4.1d	24.1a	58.9c	75.5b	33.5a
IRAT 13	88a	1.5b	70.5c	4.1d	20.9c	51.7d	58.1c	29.4b
Niupela	90a	2.6a	98.8a	7.5b	23.7a	91.5a	80.0a	19.4c

Figures followed by different letters are significant at 5% level, according to DMRT

ard indicated that lot of variability existed not only among varieties, but also among the various plant attributes studied.

Based on the performance for yield and yield components, phenotypic acceptability at maturity, ripening colour, tolerances to insect pests and diseases and various paddy characteristics, 6 most promising genotypes viz. IAC 165, IR 47686-6-2-2-1, IRAT 104, ADT 31, IR 47686-9-2-B and IRAT 13 were selected for further studies. The characteristics of these promising selections are presented in Table 1. It is evident that IAC 165 & ADT 31 are the most early maturing; and IAC 165 the highest yielding. The tallest plant height were of IR 47686-6-2-2-1, IR 47686-9-2-B & IRAT 104. ADT 31 produced the maximum number of productive tillers per hill, IAC 165, IR 47686-9-2-B, IRAT 104 & IRAT 13 the longest panicles, IAC 165 & IRAT 104 maximum grains per panicle. The spikelet fertility was maximum for IAC 165 and the heaviest grains were produced by IAC 165, IRAT 104 & IRAT 13.

The results (Table 2) of a confirmatory trial at ERDC show that both ADT 31 and IAC 165 were the earliest flowering. ADT 31, IAC 165, IR 47686-6-2-2-1, IRAT 104 (at par with each other) were the highest yielding.

Table 3. **Performance (yield and yield components) of selections from IRTP-1991 & standard in a micro plot yield trial at Finschhafen (Ubegon Seven Laly Youngpela Didiman Farm) under upland field, during 1992.**

Designation	Days to flower	Yield t/ha	plant height (cm)	Productive tillers perhill	Panicle length (cm)	Grains per panicle	Spikelet fertility (%)	Thousand grain weight (g)
ADT 31	67c	3.5a	61.2f	16.2a	22.5bc	110.2c	79.2ab	20.5
IAC 165	59d	3.6a	120.0c	14.9a	23.9b	125.9b	80.0a	30.7a
IR 47686-6-2-2-1	90b	3.1a	94.5d	7.9b	22.9bc	113.8c	78.0c	30.7a
IR 47686-9-2-B	88b	2.6b	90.4d	5.9c	22.9bc	102.9d	71.9c	28.1c
IRAT 104	90b	3.2a	86.9d	8.0b	24.5b	101.8d	76.8d	28.5c
IRAT 13	86b	1.8b	76.1e	7.5b	23.0bc	104.7d	75.7e	29.1b
Niupela	90b	3.0a	145.0b	8.7b	24.50b	150.4a	80.9a	27.9c
Finschhafen 91	118a	3.0a	160.0a	14.5a	25.8a	135.4b	79.7ab	28.5c

Figures followed by different letters are significant at 5% level, according to DMRT.

Table 4. **Performance (yield & its components) of different varieties, under upland field condition at Walingai Yangpela Didiman Farm, Finschhafen, during 1993.**

Variety	Days to flowering	Yield (t/ha)	Plant height (cm)	Productive tillers/hill	Panicle length (cm)	Grains per spike	Spikelet fertility (%)	Thousand grain weight (g)
FINS. 91	145a	3.0b	163.7a	16.0b	26.7a	140.9a	91.7a	30.0a
Niupela	125b	3.4a	151.1b	8.5c	25.4b	155.7a	91.0a	27.8b
IAC 165	85c	3.5a	123.8c	26.9a	24.0b	150.8a	92.5a	30.5a

Figures followed by different letters are significant at 5% level, according to DMRT.

Niupela and IR 47686-6-2-2-1 were the tallest of all the varieties under test and the tillering capacity was maximum for ADT 31. The panicle length of IR 47686-6-2-2-1, IRAT 104 & Niupela was maximum and the highest no. of grains per panicle were produced by Niupela and IAC 165. Spikelet fertility % was the highest for Niupela and IRAT 104 produced the heaviest grains. However, due to dry months, the performance of all the entries for yield and yield components was not good. This was largely due to the drought at the time of grain-filling stage in the area. But this proved a panacea for our confirmatory investigation for correct assessment of relative drought tolerances of the strains under test.

The results (Table 3) of another confirmatory trial at Finschhafen indicated that varieties IAC 165 & ADT 31 were the earliest flowering & the varieties ADT 31, IAC 165, IR 47686-6-2-2-1, IRAT 104, Niupela, and Fins. 91 (at par with each other) were the highest yielding. Fins. 91 was the tallest of all the varieties; and tillering capacity was maximum for ADT 31, IAC 165, & Fins. 91 (at par with each other). Fins. 91 produced the longest panicle, and Niupela produced the highest number of grains per panicle. The spikelet fertility was maximum for IAC 165 & Niupela. The heaviest grains were produced by IAC 165 & IR 47686-6-2-2-1.

The results (Table 4) of a regional yield trial at Finschhafen indicated that IAC 165 was the earliest flowering; and, Niupela and IAC 165 (at par with each other) were the highest yielding, Fins. 91 was the tallest of all the varieties under test, followed by Niupela and IAC 165. The tillering capacity of IAC 165 was the highest followed by Fins. 91 and Niupela. The panicle length of Fins. 91 was the maximum, while the trait was

Table 5. **Performance of different selections in a Regional Yield Trial at Kivori Village, Central Province, under upland field condition during 1993.**

Designation/origin	Yield (t/ha)
IR-35366-62-1-2-2-3	1.5b
Luke 3	2.5a
S 8188-10-2	1.2b
RP 1515-221-3-3-1	1.6b
IAC 165	2.5a
Niupela	2.9a

Figures followed by different letterers are significant at 5% level, according to DMRT.

Table 6. **Comparative yield potentials of very promising selections for upland, in a Regional yield trial, at ERDC, during 1993.**

Name	Yield (t/ha)
ADT31	2.5a
IAC 165	2.6a
IR 47686-6-2-2-1	2.3a
IR 47686-9-2-B	1.9b
IRAT 104	2.4a
IRAT 13	1.5c
Niupela	2.1b
Tai Chung Sen 10	1.9b
KK-15-36-C	1.3c

Figures followed by different letters are significant at 5% level of significance according to DMRT.

Table 7. **Total milling recovery potentials of the most promising selections (in advanced stage of testing) standard varities for upland ecosystem of PNG.**

Variety	Total milling recovery %
FINS.91	53
Niupela	58
ADT 31	53
IAC 165	59
IR 4768-6-2-2-1	57
IR 47686-9-2-3	55
IRATP 104	58
IRAT 13	56
IR 29725-117-2-3-3	57
IR 5040-57-2-2-3	57
IR 52287-15-2-3-2	53
BG 932	58
Sanduangzhan No. 2	58
Tai Chung Sen 10	58
KK-15-36-C	59

at par with each other for Niupela and IAC 165. The rest of the attributes for the three varieties were at par with each other, except thousand grain weight.

The results (Table 5) of the Regional yield trial at Bereina indicated that yield of IAC 165, Niupela and Luke-3 was the highest among all the genotypes studied. It is very interesting to note that Luke 3 was developed for lowland cultivation, but has performed equally well for upland growing conditions. The yield of rest of the entries viz. IR 35366-62-1-2-2-3, S8188-10-2 and RP 1515-221-3-3-1 was statistically at par with one another.

The results (Table 6) of a Regional Yield trial conducted at ERDC, indicate that the yield potential of ADT 31, IAC 165, IR 47686-6-2-2-1, IRAT 104 (at par with one another) was the highest of all the entries.

Milling studies. The milling studies for all the genotypes tested in this investigation were accomplished with Satake laboratory huller and polisher. The paddy was sun dried consecutively for 4-5 days in the clear sun, to bring down the moisture contents in the vacinity of 11-12%. An equal amount of paddy was weighed and milled. Both the broken and head rice were weighed together to calculate the totalling milling recovery. The milling recoveries (Table 7) for IAC 165, Niupela, IR 47686-2-2-1, IRAT 104 were the highest, followed by rest of the genotypes under study. Variety ADT 31 performed very poorly for milling recovery.

Physico-chemcial traits. Some of the physico_chemical traits (Table 8) provided by IRRI, for some of the genotypes under study indicate that the varieties IRAT 104 & IR 47686-6-2-2-1 have very desirable physico-chemical traits. Both the varieties have 18% amylase contents, intermediate to high alkali digestion and possess almost similar gel consistencies. Their grains are long and are free from white belly character. The variety ADT 31 posesses very chalky grain & medium amylose contents (25%).

DISCUSSION

The results of the three regional yield trials clearly indicate the more or less superiority of IRAT 104, IR 47686-6-2-2-1, IAC 165, Niupela and ADT 31. The discrepancy for yield potentials of the varieties at some locations may be due to genotypes x environment interaction caused by different times of planting, rainfall, soil types etc. Among the four highest yielding

Table 8. **Some physico-chemical characteristics of modern High Yielding Varieties for upland rice cultivation in PNG.**

Designation	Nature of brown rice length	Brown rice shape	Chalkiness of endosperm	Alkali digestion	Amylose contents %	Gel consistency
ADT 31	short	round	9	*	25.2	95 (soft)
IAC 165	long	slender	-	L	5.4	88 (soft)
IR 47686-6-2-2-1	long	slender	1	HII/I	18.0	90 (soft)
IR 47686-9-2-B	long	slender	9	I	20.0	95 (soft)
IRAT 104	long	slender	5	HI/I	17.6	100 (soft)

varieties, ADT 31 does not possess the desirable physico-chemical traits for the country, therefore the variety has been rejected altogether.

Among the rest of the highest yielding varieties, Niupela was recommended by us for general cultivation as far back as 1992. At the moment Niupela is popular with the farmers, thoroughout the country.

The two new varieties viz. IR 47686-6-2-2-1 & IRAT 104 possess good agro-botanical traits, good milling recovery and desirable physico-chemical traits. Therefore both the varieties are suitable for upland rice cultivation in the country. The most recent consultancy team on the site development studies for rice production has also emphasized the selection of IRAT varieties. Fortunately two out of three new selections are either a derivative (IR 47686-6-2-2-1) or a direct IRAT variety (IRAT 104).

The third new variety IAC 165 is ninety days-maturing and is suitable for progressive farmers, because it has very early vegetative vigour and completes its life cycle (seed to seed) one month earlier than the other varieties. Consequently it requires a greater care by the farmer for early topdressing, weeding and pest scouting etc. In fact this variety is able to escape drought by maturing before severe drought develops.

At Maprik, we have also conducted an observational micro plot trial (planted at Nala area) on IAC 165 and other selections including Niupela. The planting time was mid-year 1993. The very severe drought adversely affected the growth of rest of the genotypes including Niupela, at the panicle initiation stage. While IAC 165 proved its potential by avoiding the severe drought, we could not have any grain from rest of the genotypes. On the contrary we had harvested a good crop of IAC 165 and have used the seed for the experiments conducted during the first quarter of 1994 at ERDC. From this observational trial, we deduced that the variety possesses the mechanism to avoid drought by maturing one month earlier. In fact such a variety has been envisaged most useful for PNG by a consultancy study (Anonymous 1993). The variety may be recommended for late planting.

IAC 165 is really a marvelous plant, because it possesses most of the good attributes of an upland variety. We are envisaging it as the future donor of early maturity, drought tolerance, thick culm, deep and well developed & profuse root system, high test weight etc. It will be a good fit for growing 4 crops a year, under lowland; and two crops a year, under upland field conditions. The variety will also fit in very nicely in the sequential planting's (or relay cropping) of following rotations, for Markham Valley in particular and PNG in general:

Rice (90-days variety) - Nov Dec Jan	Rice (90-days variety), Jan Feb March
Rice (90 days variety) - Nov Dec Jan	Legume (60 days variety) Feb Mar

Unfortunately IAC 165 like other traditional upland rice varieties seems to possess less tillering capacity. But this problem can be overcome by increasing the seed rate. Regarding physico-chemical traits, it possesses very low amylose contents (5%), but cooks as soft as IR 47686-6-2-2-1 & IRAT 104. Therefore, the variety may be recommended as a glutinous variety for the country.

All the three new varieties have the traditional tall plant posture, medium tillering capacity, droopy but very long flag leaves, droopy but well exserted (suitable for hand harvesting) & fully filled panicles with heavier grains. Their foliage remain green up to maturity, the trait very vital for photosynthates translocation (from source to sink) up to late maturity, resulting in the higher yield.

The results of the yield trial at Bereina were very interesting, because we tested Luke-3, a lowland variety, under upland field in comparison to the rest of the entries. The results of the yield trial have proved that Luke-3 is equally good for upland field conditions. Another variety KK 15-36-C (from Nepal) was extremely good for lowland, but from the yield trial conducted at ERDC, it is evident that the variety is not good for upland niche.

CONCLUSION

The varieties IRAT 104, IR 47686-6-2-2-1 & IAC 165 have exhibited their high yield potentials under upland ecosystem, in the yield trials conducted, country wide. They have also surpassed for milling recoveries; and possess very desirable physico-chemical traits. Therefore, it is concluded that the three varieties may be released for general cultivation in the country for upland rice cultivation. IAC 165 has low amylose contents, but cooks soft like those of IRAT 104 & IR 47686-6-2-2-1. Therefore variety IAC 165 may specifically be recommended as glutinous rice for the country.

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Appendix 1: **Most promising selections, suitable for upland ecosystems of Papua New Guinea.**

S.No.	Code name	Experimental name	Designation/origin
1.1 Ready for release.			
25	ER 25	RTP-19-91	IAC 165/Brazil
26	ER 26	IRTP-29-91	IR 47686-6-2-2-1/IRRI(IRAT 104/Palawan)IRRI
27	ER 27	IRTP-38-91	IRAT 104 (IRAT 13/Moroberekan)/Ivory Coast
1.2 Advane stage material.			
28	ER 28	IRDTN-1-91	Agulha/Brazil
29	ER 29	IRDTN-23-91	IRAT 170/Ivory Coast
30	ER 30	IRDTN-79-91	235D-IRAT/IRAT
31	ER 31	IURON-2-91	BR 4285-5-2/Bengla Desh
32	ER 32	IURON-83-91	IR 55411-53/IRRI
33	ER 33	IURON-84-91	IR 55433-63/IRRI
34	ER 34	IURON-92-91	IR 43/IRRI
1.3 Elite selections.			
35	ER 35	IURON-26-93	IR 47686-16-7-1/IRRI
36	ER 36	IURON-27-93	IR 47686-31-1-1/IRRI
37	ER 37	IURON-38-93	Kalaris/Hungary
38	ER 38	IURON-45-93	RP 2235-200-91-62/India
39	ER 39	IURON-53-93	Toxi 1889-4-102-3-2-1/IITA/Nigeria
40	ER 40	IURON-54-93	Toxi 1889-6-102-1-1-2/IITA/Nigeria
41	ER 41	IURON-58-93	Salumpikit/Philippines
42	ER 42	IURON-67-93	CT 8422-8-M-2-3-2-1/CIAT
43	ER 43	IURON-69-93	IRAT 136/Ivory Coast
44	ER 44	IURON-77-93	ITA 301/IITA, Nigeria
45	ER 45	IURON-83-93	PR 36-1-4-1/Zaire
46	ER 46	IURON-85-93	PR 39-1-2/Zaire
47	ER 47	IURON-90-93	Toxi 1791-15-B-4/IITA/Nigeria
48	ER 48	IURON-94-93	Wabis 844/WARDA

WILD TARO (*Colocasia esculenta* (L.) Schott.) POPULATIONS IN PAPUA NEW GUINEA.

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ABSTRACT

Wild taro (Colocasia esculenta *(L.) Schott.) populations were evaluated for breeding purposes in several locations of Papua New Guinea. All evaluated populations were found to be susceptible to taro leaf blight* (Phytophthora colocasiae) *and the Alomae-Bobone virus complex. Absence of taro leaf symptoms was mainly due to isolation of the population (the pathogen did not reach the population). Flowering ability was relatively high. At least a few plants were found to be flowering in each population. The analysis of quantitative variation indicates that there was relatively high uniformity in leaf dimensions and number of lamina veins within populations. Relatively low variation of measured quantitative characteristics and uniformity in qualitative traits indicate that seed propagation may be extremely rare and that at least some PNG wild taro populations may consist of a single clone. In breeding wild taro genotypes can be used as sources of genes for the improvement of flowering ability, environmental adaptability (for swampy or dry land conditions), growth vigour and earliness.*

Key words: *Wild taro,* Colocasia esculenta*, variability, population characteristics.*

INTRODUCTION

Taro, *Colocasia esculenta* (L.) Schott., belongs to the monocotyledonous family *Araceae*, the aroids or the *Arum* family. It is believed to have originated from the Indo-Malayan region (Plucknett 1984) and spread to almost every tropical region.

People usually distinguish two groups of *C. esculenta* taro: wild (naturally growing) and cultivated. Cultivated taro is usually grown as a root and/or vegetable crop. In the Pacific region, taro used to be a very important crop. It played an important role in the people's customs and traditions. Nowadays, taro is being replaced by other more adaptive crops (such as sweet potato, cassava etc.) because of pests and disease problems and taro's requirements for high soil fertility.

In Papua New Guinea (PNG), the main pest of taro is taro beetle (*Papuana* spp) which is considered as one of the main limiting factors in taro production. Similarly, the most important taro diseases in PNG are taro leaf blight (caused by *Phytophthora colocasiae* Racib.), Alomae-Bobone virus complex (ABVC) and the nematode disease - Mitimiti (caused by *Hirschmanniella miticausa*). Taro leaf blight is considered as a relatively new disease in PNG. According to Packard (1975) and Connell (1978), it appeared around the beginning of the second world war. Similar situation is with Mitimiti, which has recently been introduced to several new places with soil and planting materials.

The diseases and pests of taro in PNG are the main reasons that a breeding programme is needed. The local taro germplasm seems to be a good base for breeding for yield and quality, but not sufficient for breeding for resistance or tolerance against pests and diseases.

The dynamics of the creation of new genetic variability among cultivated taro is very limited because of continuous vegetative propagation. Taro cannot respond fast to the dynamic changes in the environment.

Wild taro is considered to be more dynamic. The existing wild genotypes together with the structure of their populations are predominantly the result of the natural selection under natural conditions while cultivated taros are mainly the result of artificial selection.

In the past, wild taro was considered as a weed or as an exotic plant type. In many cases, these plants were undesired, especially when they penetrated into gar-

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den plots. Because of their environmental fitness and long stolons, they could spread very fast inside relatively clean and fertile areas. In some Pacific countries, wild taro is used as vegetable crop. Corms of some special wild genotypes can also be used as food.

There are not much data on wild taro germplasm in PNG or elsewhere. A survey of wild together with cultivated taro germplasm in PNG was reported by Matthews (1990). Another survey was done by Lebot and Aradhya (1991). The scientists involved in taro research were much more interested in cultivated genotypes.

PNG is considered to have high diversity of wild *Colocasia* germplasm but little is known about this diversity.

The aim of this study was: (i) to evaluate the variation of wild taro populations, (ii) to determine the main characteristics which are typical for wild genotypes, (iii) to determine the main factors of environmental pressure on wild taro populations and (iv) to determine the value of the wild taro germplasm for breeding (which genetically controlled characteristics could be used in breeding programmes)

Characterization of wild taro populations in PNG

Systematic studies of wild taro populations in PNG were initiated together with taro breeding programme in November 1993 at Bubia Agricultural Research Centre (BARC). The main objective was to investigate variation and to estimate the value of wild germplasm for breeding work.

Previous breeding experience and results indicated that wild genotypes can be efficiently used as donors of genes for several specific characteristics in breeding programmes: resistance to taro leaf blight, resistance to nematodes, tolerance to Alomae - Bobone virus complex, specific environmental adaptability (swampy or dryland conditions), earliness, flowering ability and growth vigour.

General characteristics of wild taro populations and communities

Taro (*Colocasia esculenta* (L.) Schott) is traditionally divided into two groups: cultivated and wild or naturally growing taro. The cultivated taros are expressing special characteristics as a result of long term artificial and natural selection. In this group, the 'guided' or artificial selection is more important than the natural one.

Cultivated genotypes express several characteristics which are biologically negative such as reduced flowering and larger corms. Wild taro populations are under permanent pressure of natural selection. Genotypes tend to reach the equilibrium structure of the population which will insure the stability in space and time. The dynamics of the environment has to be followed by the dynamics of the population. In comparison with the cultivated group, wild taro populations are much more dynamic. The main indicator of their dynamics is flowering ability. Wild genotypes of PNG are characterized by high level of fertility and seed set.

One may conclude that the existing flowering ability, fertility, and protogyny together with cross-pollination mechanisms are sufficient to insure high dynamics of wild taro populations. The main limitation, however, is the small chance of a seed to germinate and to develop to a mature plant. The seeds are very small and if they germinate, they do not have much chance to develop further because of 'aggressive' growth of stronger taro plants developed from stolons and other competing plant species in the community. In natural conditions, seed multiplication of wild taro is probably of minor importance in comparison with vegetative propagation.

Regarding single taro plants, it is relatively simple to separate wild from cultivated individuals. The basic characteristics of wild genotypes are small, elongated corms with high concentration of calcium oxalate. Another very typical characteristic is the production of very long stolons. Stolon producing cultivars usually have shorter runners.

Taro is considered to be a partly cross-fertilizing species, propagated vegetatively. Permanent or predominant vegetative propagation of taro under heavy selection pressure logically results in low variability, especially when all individuals in a population belong to the same clone. In areas isolated from migration, where flowering does not occur, the population can consist of only one or few closely related genotypes (mutations derived from the same ancestor). Such a genotype (or a group of closely related genotypes) is characterized by a certain level of adaptability which can sometimes be very low if there is no competition among different taro genotypes and other species present in the community.

When there is no genetic variability the selection pressure is directed to the same genetic base. The chance of each individual to survive depends only on the specific position in the micro environment.

In areas where taro flowers, the genetic structure depends on several factors such as level of cross-fertilization, seed set, chances of a seed to germinate and develop to a mature plant, history of the population (do all plants involved in intercrossings originate from one seed or from several), environmental pressure, frequency of mutations and migrations. Natural taro populations are very rarely in a stage of population equilibrium of Hardy - Weinberg type. The populations possess limited genetic variability. Genotypes in the population are in special equilibrium with the natural pressure.

Propagation and dispersal

Generally, taro can be propagated by seeds or in a vegetative way. According to Purseglove (1972), flowering of cultivated taro is not frequent.

Vegetative propagation is obviously the most important. The climate in most parts of PNG is favourable for taro. Frequent flowering and frequent seed set are good indicators. The seeds, however have very little chance for developing to mature individuals.

New taro genotypes in nature can be created by genetic recombination (hybridization, self-pollination) and mutations. Because of low frequencies, mutations are usually considered less important, but in some cases, they may play the key role in evolution. In continuous vegetative propagation (continuous mitosis), mutations are the only source of variation within certain clone.

Taro propagation is closely related to taro dispersal. Wild taro can be dispersed through seeds or through vegetative parts (for example stolons, suckers and parts of corms) by water, animals, people or landslides.

From an ecological point of view, the most interesting way of dispersal is by water. Taro plants or seeds 'travel' down stream until they reach a certain barrier. If the place is suitable, they start growing and multiplying. Once the first 'colony' is established and stabilized, spread inside the micro-environment can be very fast because of the efficient growth and spread of stolons. If the colony is developed vegetatively from one plant, then there will be no genetic variation. When mutations are neglected, there will be only one genotype.

One interesting point of the dispersal by rivers or creeks is 'travelling' to places which are already inhabited by other wild taros or sometimes where both cultivated and wild taros exist. These places are usually called 'meeting sites' and can be rich with variation. If several genetically different individuals, which appear to be on the same area, flower and produce seeds, then the offspring generations will show a variety of genotypes. The genetic segregation takes place immediately in the first resulting offspring generation because of predominant heterozygosity of the parents. The individuals, which will be able to develop and pass the selection pressure will be incorporated into the existing population structure. Such a population will be characterized by overlapping generations.

People are also playing an important role in the dispersal of wild taro. These plants are usually not desired in garden plots because it is difficult to get rid of them. They can resist even very strong herbicides. If they are thrown out of the garden plot, they will continue to grow and very soon they 'return' by long stolons (sometimes more than two metres long) back to the clean garden area. For this reason, farmers often throw them further away or into small streams or rivers.

Classification of wild taro genotypes

Wild taro genotypes cannot always be clearly distinguished from cultivated types. In some Pacific countries, such as the Solomon Islands, it is possible to find wild taro as a crop (used as a vegetable or even as a root crop).

Wild genotypes have several advantages when grown to provide green leaves. The growth is continuous, almost indeterminate, leaf regeneration is fast and the plants spread by themselves. The basic division of wild taro germplasm based on the authors' research and experience includes four groups.

1. *"True" wild taros:* The plants are maximally adapted to typical natural environmental conditions with strong pressure of natural selection. The main characteristics are: fast leaf regeneration, extremely long stolons, small elongated corms, continuous growth and predominantly high concentration of calcium oxalate.

2. *Wild taro genotypes with some characteristics of cultivated types:* The genotypes belonging to this group can be characterized by larger and well shaped corms and determinate growth. Sometimes the concentration of oxalates in corm is low. This results in the possibility of using them as normal food. These genotypes are also spreading by stolons, similarly to "true" wild types.

3. *Wild genotypes with some of the genetic material originating from cultivated germplasm*: Because of high level of cross-fertilization, hybrids between cultivated and wild genotypes occur frequently in all areas where the majority of taros flower naturally. This is the main reason why taro breeders in PNG keep wild taro germplasm strictly separated from the cultivated genotypes.

Wild genotypes usually produce more pollen, attract more insects - vectors and pollen is easily spread. The offspring generation results in immediate segregation because of high level of heterozygosity of the parents. The individuals usually express several "wild" characteristics.

The main problem for breeders is in fitness of the individuals with some "wild" genes. They usually germinate better, grow better and faster inside greenhouse, are less affected by diseases and generally have healthier appearance. The breeder can easily reject the genotypes, which have high yield potential but slow early growth, and select "semi-wild" types.

In natural conditions the hybrids (wild x cultivated taro) are exposed to the selection pressure and the general tendency is the return to the most suitable genotype which is wild. The majority of characteristics originating from cultivated genotypes will be eliminated but some will remain. The plants will predominantly express wild characters.

Allard (1992) came to a similar conclusion when studying changes in barley germplasm. When populations had been formed by bulking seeds produced by F_2 families which were advanced into F_3, F_4 and later generations under conditions of competition, the wild alleles rapidly became predominant.

4. *"Escapes" from cultivation*: Taro plants can remain for a long time in an abandoned field or garden. Frequently they become stable members of a particular plant community. In the long term, genetically based stability will possibly be achieved through genetic recombination followed by natural selection. In this way biologically negative traits (large corm etc.) will be eliminated and "wild" genes will become predominant. The resulting individuals can be considered as wild types with some genes originating from cultivated germplasm and not as "escapes".

"Escapes" from cultivation remain genetically more or less unchanged. The phenotypic changes are mainly the result of the effects of the environment.

According to the environmental adaptability, wild taro germplasm can be divided into:

- wetland or swampy types
- dryland or upland types (they usually rot in swampy environment)
- intermediate or neutral types (adapted for wide range of environments)
- genotypes tolerant to shade
- genotypes tolerant to salinity.

For taro breeders, the most useful systematization includes data about resistance and/or tolerance to pests and diseases. The majority of resistance genes against *Phytophthora colocasiae* (taro leaf blight) Alomae - Bobone virus complex (ABVC) and nematode infections caused by *Hirschmanniella miticausa* in PNG and the Solomon Islands originate from wild germplasm.

Another very useful approach in classification of wild taro genotypes is according to the ploidy level which includes three main groups: diploids ($2n = 28$), triploids ($3n = 42$) and tetraploids ($4n = 56$).

MATERIALS AND METHODS

The studies include wild taros growing: (a) out of their original environment (44 collected samples) and (b) in their original or natural environment.

Wild taro studied out of its original environment in this paper originated from Mt. Hagen area, Kuk, Dolsor, swampy areas near Hati Agricultural College (Western Highlands Province); Barawaghi (Simbu Province); Boana, Gaing, Wampit region, Omsis, Lake Wanum, Gabensis, Labu Butu, Lae area, Wapi, Bukaua, Situm, Upper Markham Valley and Bubia (Morobe Province); Bangkok (Thailand); Phillppines and Solomon Islands. The collected (wild taro) material was planted at the agricultural research farm at Bubia Research Centre inside alleys of *Gliricidia sepium* planted at a spacing distance of 7 metres.

The first screening was conducted immediately after the growth had been fully established. This screening included mainly the resistance to TLB (taro leaf blight) and tolerance to ABVC (Alomae - Bobone virus complex). Unfortunately all genotypes were found to be susceptible or their level of resistance (tolerance) was too low.

Detailed study of the collected germplasm took place from March to July, 1994. Wild genotypes were analyzed for growth vigour, earliness, density tolerance, leaf position, leaf shape, flowering ability, self-compatibility, fertility and corm characteristics. As a result of this analysis, wild taros were classified into four groups;

1. *true wild taro,*
2. *wild taro with some characteristics of cultivated genotypes,*
3. *Wild taro with some of the genes originating from cultivated genotypes via natural crossings,*
4. *escapes from cultivation.*

Plants with at least one desired characteristics (excluding flowering ability) were immediately used in hybridization.

Wild populations in their original (natural) environment were studied in 16 locations in Morobe and Madang Provinces. In addition, the study included three artificially created, segregating populations and two "populations" of cultivars (Numkowi, Ph-15). The total number of studied populations was 21 (Table 1). The data (plant height, leaf length, leaf width, number of leaves in function, number of veins, population density, frequency of flowering plants, corm flesh pigmentation, stolone number and length, incidence of TLB, incidence of ABVC) were collected during the rainy season in July - August, 1994. Leaf measurements were taken on maximally developed leaf.

RESULTS

Studies of wild taro populations out of their original environments

The analysis of wild taro 'populations' out of their original environments indicated that variation within and between studied samples of these wild taro populations was not high. There was high uniformity in leaf shape, lamina position, plant height, flowering ability, corm shape and corm flesh pigmentation. The most significant differences appeared in leaf petiole pigmentation.

Table 1. **List of taro populations studied in their original environments.**

Location number	Location/population name
1	Bubia Mountain (Morobe Province)
2	Brahman (Madang Province)
3	Labu 1, close to Markham River, near Lae (Morobe Province)
4	Labu 2, next to Labu 1
5	Omsis, road to Bulolo (Morobe Province)
6	Open pollinated population "N", Bubia A.R.C. field (Morobe Province)
7	Ph-17 (semi-wild genotypes) Bubia A.R.C.
8	Numkowi (local cultivar), Bubia A.R.C.
9	Open pollinated population "P", Bubia A.R.C.
10	Population developed from cross: wild genotype from Bangkok x genotype S-NK from the Solomon Islands, Bubia A.R.C.
11	Population from area between Gebensis and Wabit village (Morobe Province)
12	Population 1km away from location 11
13	Wampit area, road Lae-Bulolo (Morobe Province)
14	Samsam village, road Lae-Bulolo
15	Mumeng River (island), Morobe Province
16	Labu plantation (Morobe Province)
17	Yong, road to Boana (Morobe Province)
18	Moimbung, road to Boana
19	Bema, road to Boana
20	Bema, 1km away from location 19
21	Boana (Morobe Province)

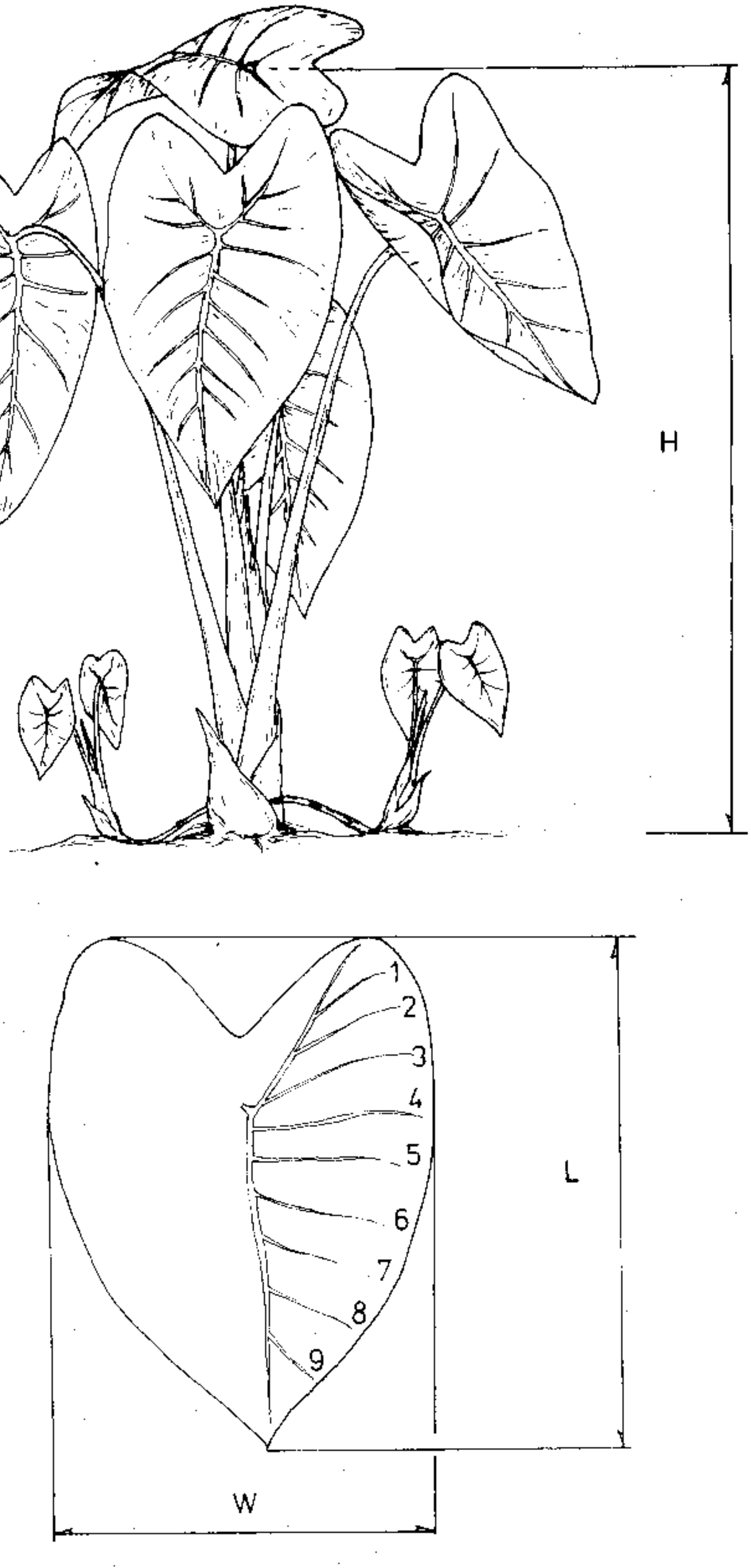
Table 2. **Variation of plant height measured (cm).**

Location	N	Mean	S. Dev	C.V.	Min.	Max.
1	30	102.01	14.52	14.23	77.8	131.8
2	40	122.57	11.05	9.01	102.2	149.5
3	20	85.57	8.63	10.08	71.2	108.5
4	40	64.74	6.68	10.32	50.0	80.0
5	40	105.61	13.64	12.91	79.8	149.2
6	50	60.83	9.67	15.90	41.3	85.3
7	30	87.03	7.14	8.20	74.5	106.8
8	30	70.58	5.98	8.47	61.0	82.5
9	61	67.41	10.61	15.74	45.5	93.5
10	50	54.64	10.55	19.31	34.9	78.9
11	30	97.00	7.73	7.97	80.7	112.2
12	29	133.25	16.39	12.30	95.7	165.8
13	20	106.66	26.87	25.19	33.3	150.0
14	20	139.47	15.66	11.23	104.4	165.7
15	21	57.41	12.71	22.14	40.0	85.6
16	30	87.20	15.04	17.25	61.5	121.5
17	25	94.68	22.73	24.01	57.5	129.0
18	26	101.96	26.31	25.80	60.6	145.0
19	30	150.71	24.00	15.92	89.0	230.0
20	27	134.28	14.58	10.86	103.5	180.3
21	51	106.70	16.34	15.31	75.6	133.0

Table 3. **Variation of leaf length measured (cm).**

Location	N	Mean	S. Dev.	C.V.	Min.	Max.
1	30	48.68	4.58	9.41	41.2	58.5
2	40	51.38	3.39	6.60	45.0	58.5
3	20	41.80	4.82	11.53	33.3	51.0
4	40	27.08	3.56	13.15	14.4	34.2
5	40	43.22	6.42	14.85	22.9	55.2
6	50	36.58	6.46	17.66	25.4	50.4
7	30	37.34	3.16	8.46	32.6	46.9
8	30	53.95	4.07	7.54	44.8	63.5
9	61	41.38	6.02	14.55	26.2	52.7
10	50	36.31	6.42	17.68	22.7	58.1
11	30	29.66	2.73	9.20	25.5	36.0
12	29	58.38	7.43	12.73	43.4	73.3
13	20	37.07	2.87	7.74	31.6	42.2
14	20	53.70	7.58	14.11	44.2	69.0
15	21	33.79	5.91	17.49	22.2	43.5
16	30	41.75	5.45	13.05	30.6	53.0
17	25	47.28	9.48	20.05	33.3	66.1
18	26	48.45	9.06	18.70	33.0	67.0
19	30	64.22	7.36	11.46	49.5	82.5
20	27	69.31	7.37	10.63	58.0	88.1
21	51	50.40	11.07	21.96	29.5	83.5

Figure 1. **Taro plant and leaf lamina showing parts measured; H - plant height, L - leaf length, w - leaf width, 1...9 - number of veins.**



The majority of the collected wild genotypes had green leaves with some red pigmentation on upper portion of the leaf petiole. Only few accessions were characterized by other types of petiole pigmentation (purple or purple-brown, dark red, light red, light green or white-green, green with purple or red stripes, red with green stripes and green with light white-green stripes). Genotypes with these (for wild taro) usual pigmentations were considered to have some genes originating from cultivated genotypes. Most of them produced both runners and suckers.

Quantitative characteristics (plant height, leaf dimensions etc.) could not be studied properly. The field conditions at Bubia ARC were not natural for wild taro. Plants were more or less all seriously affected by drought. For this reason it was decided to study quantitative characteristics in naturally grown wild taro populations, in their original environments.

Studies of naturally grown wild taro populations

1. Population size and density

The majority of investigated naturally growing wild taro populations were growing in optimal environments. The micro-environments were usually not uniform. Taro plants were forming associations or communities with other plant species.

The size of populations depended on several factors such as vigour of wild taro individuals, number and vigour of stolons, presence of *P. colocasiae* - leaf blight, density pressure of other plant species, insects, shade, soil moisture etc. It was difficult to find large population with uniform density. Populations were often split into smaller sub-populations which included from thirty to two hundred taro individuals. The most frequent average densities within populations varied from 0.8 to 4 taro plants per square metre. The typical (compact) taro populations however, were usually very dense (overcrowded) with eight or more individuals per square metre.

The largest series of populations were found in Brahman (Madang Province) with more than 15,000 taro plants. The density was very high, varying from 6 - 10 plants per square metre. This extreme density was probably the result of optimal, humid climate, rich soil, low population pressure of other plant species and high

Table 4. **Variation of leaf width measured (cm).**

Location	N	Mean	S. Dev.	C.V.	Min.	Max.
1	30	36.79	4.34	11.80	29.7	46.2
2	40	37.84	2.50	6.61	31.5	42.6
3	20	31.02	4.06	13.09	23.6	39.3
4	40	19.97	2.42	12.12	14.6	24.9
5	40	31.47	4.06	12.90	22.8	40.5
6	50	25.09	4.86	19.37	16.2	37.6
7	30	25.72	2.15	8.36	22.4	31.0
8	30	37.41	3.18	8.50	31.2	43.4
9	61	28.98	4.83	16.67	19.5	39.7
10	50	24.76	5.49	22.17	14.8	43.3
11	30	21.80	2.20	10.09	18.4	26.2
12	29	42.93	5.47	12.74	33.2	55.7
13	20	26.19	2.81	10.73	20.9	32.5
14	20	39.88	5.78	14.49	31.9	51.6
15	21	25.47	4.65	18.26	16.0	32.6
16	30	31.40	4.60	14.65	22.9	42.2
17	25	31.03	6.64	21.40	21.2	44.3
18	26	31.36	6.72	21.43	20.7	47.1
19	30	41.58	4.65	11.18	31.4	52.7
20	27	45.59	5.80	12.72	33.2	60.9
21	51	34.37	7.41	21.56	23.0	53.7

Figure 2. **Frequency distribution for number of veins (counted on half of the leaf blade) and leaf blade length estimated in a wild taro population in Boana (Morobe Province). The distributions indicate the presence of two distinct sub-groups within the population.**

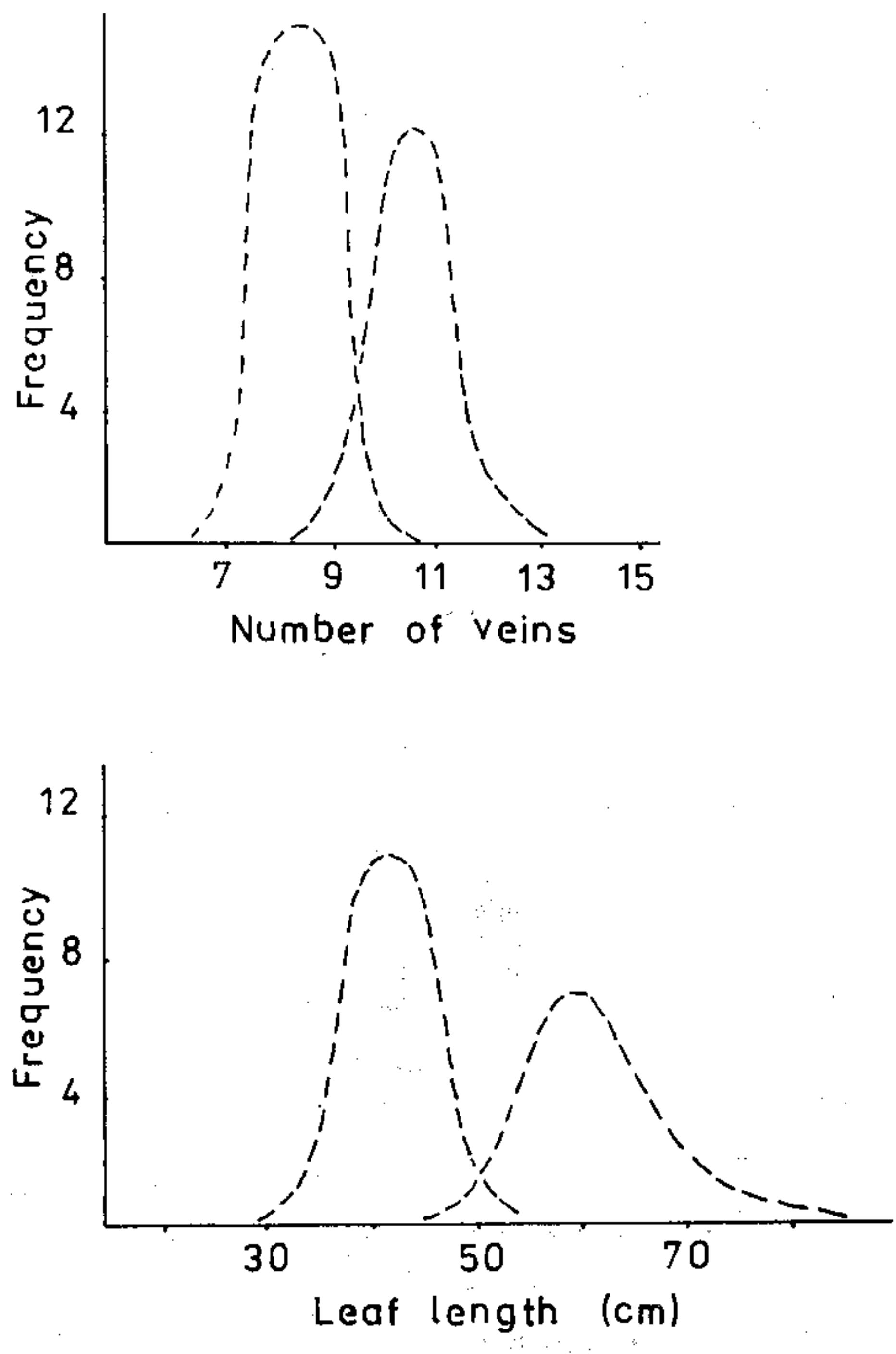


Table 5. **Variation of leaf width: leaft length ratio.**

Location	N	Mean	S. Dev.	C.V.	Min.	Max.
1	30	0.75	0.027	3.60	0.70	0.81
2	40	0.74	0.024	3.24	0.68	0.79
3	20	0.74	0.021	2.84	0.70	0.79
4	40	0.74	0.084	11.35	0.58	1.24
5	40	0.73	0.067	9.18	0.60	1.00
6	50	0.68	0.050	7.35	0.57	0.90
7	30	0.69	0.043	6.23	0.62	0.89
8	30	0.69	0.033	4.78	0.61	0.76
9	61	0.70	0.062	8.86	0.55	0.93
10	50	0.68	0.097	14.26	0.47	1.24
11	30	0.73	0.027	3.70	0.68	0.82
12	29	0.74	0.071	9.59	0.66	1.07
13	20	0.71	0.073	10.28	0.62	0.91
14	20	0.75	0.069	9.20	0.52	0.84
15	21	0.75	0.024	3.20	0.71	0.81
16	30	0.75	0.032	4.27	0.70	0.86
17	25	0.66	0.042	6.36	0.52	0.71
18	26	0.65	0.058	8.92	0.49	0.74
19	30	0.65	0.021	3.23	0.62	0.71
20	27	0.66	0.042	6.36	0.50	0.71
21	51	0.69	0.118	17.10	0.59	1.49

pressure of *Phytophthora* leaf blight.

Continuous presence of *P. colocasiae* caused fast dying of taro leaves. Plants were uniformly susceptible and had only few younger leaves in function (Table 7). The reduced number of leaves enabled more plants to grow in the same area. The relationship, *P. colocasiae*: density of wild taro populations is far from being simple. This pathogen is continuously present. The heaviest pressure of the pathogen takes place during rainy season.

Wild taro population in Brahman will be studied in future more systematically. For this reason, in September 1994, several wild and semi-cultivated taro genotypes with different levels of resistance to the leaf blight were inserted inside naturally growing subpopulations.

2. Incidence of taro leaf blight and viruses

All investigated wild taro populations were found to be susceptible to the leaf blight and Alomae-Bobône virus complex. Two populations on the road to Boana (the altitude between 950 and 1050m) were found to be free of *Phytophthora* symptoms. Later, the test of the sampled plants at Bubia ARC showed that there was no resistance. The populations were free of the pathogen due to isolation or "escape".

3. Leaf and corm pigmentation

Leaf laminas of wild taro plants in all locations were more or less uniformly green. Leaf petioles were in majority green with some red pigmentation on the upper portion, next to the junction with the leaf lamina. Corm flesh pigmentation was white-yellow and uniform in all populations.

4. Plant height

Plant height was highly influenced by the environment. Population in location 19 (road to Boana) showed variation range (min. - max.) of 141.0 cm, C.V. 15.92% (Table 2). The plants were growing on slope and the tallest individuals were found on partly shaded spots or in small depressions which provided the taro plants with more water.

Populations growing on open, not shaded area were

Table 6. **Variation of number of veins (on one half of the leaf lamina).**

Location	N	Mean	S.Dev.	C.V.	Min.	Max.
1	30	10.03	0.41	4.08	9	11
2	40	11.17	0.59	5.28	10	12
3	20	7.95	0.59	7.42	7	9
4	40	9.55	0.70	7.33	8	11
5	40	10.05	0.77	7.66	8	12
6	50	8.24	0.91	11.04	7	11
7	30	9.43	0.99	10.50	8	12
8	30	9.87	0.56	5.67	9	11
9	61	9.62	1.04	10.81	6	11
10	50	9.60	0.98	10.21	7	11
11	30	8.30	0.52	6.27	7	9
12	29	10.59	0.85	8.03	9	12
13	20	10.20	0.68	6.67	9	12
14	20	10.20	0.74	7.26	9	11
15	21	9.57	0.66	6.90	8	10
16	30	10.83	0.78	7.20	9	12
17	25	8.92	0.93	10.43	7	11
18	26	9.23	1.12	12.13	7	11
19	30	9.93	0.44	4.43	9	11
20	27	10.18	0.54	5.30	9	11
21	51	9.31	1.35	14.50	7	13

characterized with smaller and shorter plants. As an example is the population from Mumeng River island - location 15 (Table 2).

5. Leaf dimensions

Taro leaf length and width are highly correlated characteristics (Table 9). The largest leaves were observed generally on higher altitudes (> 1000 m) - location 19, 20, 21, (Fig. 1), (Tables 3 and 4). Leaf width: leaf length ratios (Table 5) indicate that the basic leaf shapes of wild taros in all studied populations were more or less the same. The density tolerance depends strongly on leaf shape. Long and narrow leaves are usually associated with vertical position, which enables more light to penetrate. Narrow leaves required for breeding for density tolerance (with w:l ratio lower than 0.5) were not found.

6. Number of leaf lamina veins

The number of veins counted on one half of the leaf blade (Fig. 1, Table 6) varied from 6 to 13 across populations. Variation of this characteristic within naturally grown wild taro populations was generally low in comparison with other measured traits. An exception was the population from Boana (location 21). Additional observation and analysis of variability indicated that the population consisted of two sub-groups (Fig. 2, Table 8).

Separation of the population from Boana into two subgroups resulted with the decrease of coefficient of variation (C.V.) for plant height, leaf length, leaf width and the number of veins (Table 8). This sounds logical because they are correlated characteristics (Table 9).

7. Number of leaves per plant

The number of leaves in function, counted on the main stem, was generally low (Table 7). The main reason was *Phytophthora* leaf blight or other factors associated with high density or presence of twisting plants. Generally, higher number of leaves was observed in artificially created populations (number 6,8,9,10-Table 7).

Table 7. **Variation of number of taro leaves (counted on the main stem).**

Location	N	Mean	S.Dev.	C.V.	Min.	Max.
1	30	1.90	0.39	20.53	1	3
2	40	3.15	0.42	13.33	2	4
3	20	3.15	0.36	11.43	3	4
4	40	2.17	0.67	30.87	1	3
5	40	2.55	0.74	29.02	1	4
6	50	4.96	1.23	24.80	2	7
7	30	2.87	0.76	26.48	2	5
8	30	4.33	0.74	17.09	3	6
9	61	4.54	0.88	19.38	3	7
10	50	4.06	1.01	24.88	2	6
11	30	2.37	0.48	20.25	2	3
12	29	4.38	1.27	28.99	3	8
13	20	3.10	0.43	13.87	2	4
14	20	3.45	0.50	14.49	3	4
15	21	2.76	0.68	24.64	2	4
16	30	2.07	0.51	24.64	1	3
17	25	2.92	0.89	30.48	2	5
18	26	3.08	0.47	15.26	2	5
19	30	3.40	0.61	17.94	2	5
20	27	2.92	0.46	15.75	2	4
21	51	3.02	0.67	22.18	2	5

Table 8. **Variability of the population 21 (Boana) after separation into two sub-groups.**

	Group	N	Mean	S.Dev.	C.V.	Min.	Max.
Plant height (cm)	A	28	100.47	14.99	14.92	75.6	129.5
	B	23	114.29	15.30	13.39	85.4	133.0
Leaf length (cm)	A	28	42.69	5.48	12.84	29.5	51.2
	B	23	59.79	8.93	14.93	47.4	83.5
Leaf width (cm)	A	28	28.56	4.79	16.77	23.0	44.0
	B	23	40.21	5.82	14.47	30.2	53.7
Number of veins	A	28	8.39	0.68	8.10	7	10
	B	23	10.43	1.21	11.60	9	13
Number of leaves	A	28	2.86	0.52	18.18	2	4
	B	23	3.22	0.79	24.53	2	5
Leaf width : leaf length	A	28	0.701	0.160	22.82	0.59	1.49
ratio	B	23	0.673	0.026	3.86	0.64	0.72

Table 9. **Correlations between studied wild taro characteristics.**

B	0.9715**				
C	0.7565**	0.7694**			
D	0.4328*	0.5188*	0.4369*		
E	0.1930	0.1459	- 0.1406	- 0.1211	
F	-0.4149	- 0.1936	- 0.1694	0.1965	- 0.3443
	A	B	C	D	E

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

A ..... Leaf length
B ..... Leaf width
C ..... Plant height
D ..... Number of veins
E ..... Number of leaves
F ..... Leaf width : leaf length ratio

8. Flowering ability

All studied taro populations were found to have at least a few flowering plants. The frequency of flowering plants varied from 3 to 100%. The highest frequency of flowering plants were observed among artificially created wild populations (populations grown out of their natural environment).

Seed set was found to be very common, similarly to flowering ability.

Good flowering ability of wild taro has already been efficiently used in PNG Taro Breeding Programme. Wild taros were used in basic crosses (in cycle zero of the recurrent selection). The offspring generations were vigorously flowering but had several undesired wild characteristics (low yield, low eating quality). The flowering ability was improving from cycle to cycle automatically because, in absence of artificial treatment with flowering hormones, the non-flowering genotypes were not able to contribute to the gene pool of the next cycle (generation).

DISCUSSION

Processes and structure of wild taro populations are much different from those described in classical population studies. Wild taro is predominantly vegetatively propagated. This does not mean that the genetic recombination is not present. The flowering process and seed set is very common but the chances of seed to germinate and develop to a mature individual are extremely low.

It is difficult to say what is the important source of genetic variations of wild taro: hybridization, self-pollination or mutagenesis. Genetic changes in vegetatively propagated individuals are subjected to bud mutations. The frequencies of occurrence of these mutations, according to Wright (1977) seem to be no greater than the rates usually ascribed to gene mutations. The mutation rate of an individual gene is very low, but when taking into account thousands of genes and thousands of plants (with numerous buds) in large taro populations, one can easily conclude that mutants are always present.

Phenotypic uniformity of wild taro populations is not necessarily associated with genotypic uniformity. Phenotypic uniformity is mainly the result of a long term evolution while genotypic uniformity originates from continuous vegetative propagation.

The evolution of taro is probably slow due to predominant vegetative propagation. There are several factors which are responsible for the evolution of wild taro populations such as interspecific competition, interaspecific competition, environmental pressure (climate, diseases, pests), frequency and efficiency of genetic recombinations and frequency of mutations.

Intraspecific and interspecific competition can be often characterized as a density pressure. Broad leaves of taro are not suitable for high densities, but they can be very efficient in control of the number other plant individuals (belonging to other species) in a community. Heavy density pressure and individual differentiation in wild taro communities usually results in certain balanced density where no more individuals can be accepted.

Balanced density is not equal to optimal density. It provides certain level of stability in a plant (taro) community. Optimal density of taro plants in a community is usually much lower. Lower densities enable other plant species present inside or around particular community to spread, increase their number and become dominant. The domination can affect taro population seriously, especially if twisting plants and climbers are involved. They usually do not eliminate taros completely, but they can reduce their number significantly. One of the typical species that taros in PNG hardly resist is the giant *Mimosa*. It is one of few species which can destroy taro populations totally.

Stable wild taro communities in Papua New Guinea and Solomon Islands are overcrowded. In such communities taro plants are thin and the leaf number is reduced. The process of self-thinning in wild taro communities results in very uniform, compact, dense and stable populations. Taro individuals in a community usually have very similar genetic structure. Frequently they originate from the same plant and for this reason they are affected more or less equally.

Overcrowded communities can be found among several vegetatively propagated perennial species, especially grasses. The structure, processes and regulation mechanisms in such communities were described by Yoda *et al.* (1963), Kays and Harper (1974) and Hutchings (1979).

Very intensive processes can be observed on the edges of a balanced, stable and overcrowded community. The edge of a community is the place where two communities meet. It can be characterized as a place of permanent "struggle" for dominance. As an example are wild taro populations within plant communities in Brahman.

The competition on edges of wild taro communities in Brahman was very strong. Interspecific competition (competition between plants belonging to different species) was much more important. The incidence of the leaf blight was lower and the plants were stronger. They produced more and longer stolons. They tried to expand to the area inhabited by other plants, mainly grasses. Grasses too, were healthier and stronger on the edge and tried to expand inside taro population. The actual edge probably represented the equilibrium between the expansion of taros and the penetration of grasses.

Based on limited number of short term observations, it is impossible to describe and characterize processes in wild taro populations and communities. Vegetative propagation requires even longer period of time for their investigation.

All investigated PNG wild taro populations were found to be susceptible to taro leaf blight (TLB) and to Alomae-Bobone virus complex (ABVC). As a result of continuous presence of TLB, the average number of matured functional leaves per plant appears to be very low in number. Lower number of leaves enables more plants to grow per unit area.

For pioneer taro breeding, wild genotypes are extremely important source of genes for disease resistance, flowering ability, seed productivity, specific environmental adaptability, earliness and growth vigour.

Papua New Guinea wild taro populations analyzed in this paper are showing relatively high uniformity in majority of the qualitative characteristics; plant pigmentation, corm shape, corm pigmentation, leaf shape, and quantitative characteristics; plant height, leaf dimensions, number of leaves, number of veins on leaf surface.

The relatively low variation within populations is mainly the result of continuous vegetative propagation and limited chances of a seed to germinate and develop to a mature plant.

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CONSUMER PREFERENCE OF SOME RICE VARIETIES GROWN LOCALLY IN PAPUA NEW GUINEA.

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ABSTRACT

Consumer preference tests were conducted on three varieties of rice grown in Papua New Guinea and their blends with Trukai rice, an imported variety. Significant differences were observed in consumer preference for the different rice varieties. Trukai was most preferred followed by Taichung Sen 10. The pure varieties of Niupela and Wantok were found unacceptable by the consumers. However, blending them with Trukai at 25% level of substitution greatly increased their acceptability.

Keywords: *Papua New Guinea rice, Trukai, Wantok, Niupela, Taichung Sen 10, consumer preference.*

INTRODUCTION

Rice (*Oryza sativa* L.) is a very important staple in Papua New Guinea (PNG). It contributes 16-20% of total energy and 14% of total protein in the diet of Papua New Guineans (Juliano 1993). It is the cheapest source of energy in the urban centers. Although small amounts of rice have been growing in P.N.G. for over 100 years, the country depends almost entirely on imported rice, on an average 120-130,000 tons/year to meet consumers' demands (Sloan Cook & King 1993; PPBD 1994). Research for varieties which can grow in P.N.G. in commercial quantities has been going on for many years (Wohuinangu and Kap 1982) and varieties: Wantok, Niupela, E1, Senis, Tambu, and Taichung Sen 10 (TCS 10) were released for cultivation (unpublished P.N.G. rice reports of Wohuinangu 1992/93 and Lin 1993). While these breeding efforts have been successful in producing a number of high yielding varieties, systematic tests of the promising varieties for consumer preference and acceptance have been neglected, and some of these varieties are still being vigorously promoted without consideration for preference (Sajjad 1994).

Varieties need evaluation for their suitability for the end uses and consumer preferences. Rice varieties have specific milling, cooking, eating and processing characteristicts and an agronomically superior cultivar may be unacceptable for traditional cooking and processing (Del Mundo 1979; Siaka and Bains 1993). The importance of combining sensory quality with physico-chemical quality in any rice breeding programme has been stressed (Juliano and Pascual 1980).

This paper examines consumer preference of the three varieties currently cultivated on commercial basis in P.N.G.: Varieties Wantok in Bereina area (Central Province), Niupela in Maprick and Nuku (West and East Sepik Provinces) and TCS10 (Morobe Province). It also evaluates their blends with Trukai, the rice preferred by the majority of Papua New Guineans.

METHODOLOGY

Milled samples of Niupela and Wantok (Bereina rice) varieties were obtained from the Department of Agriculture and Livestock Research Station, ERAP. Milled TCS 10 was supplied by the Taiwanese Research Station at Bubia in Lae. These three rice varieties were subsequently referred to as "local rice". Trukai rice was bought from a supermarket in Lae. Cooking in excess water was done following essentially the method by Myklestad *et al.* (1968). 0.1% brine solution was used.

Cooking times were established in preliminary experiments according to the excess water method of Perez

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Table 1. **Mean consumer preference scores of rice varieties and blends.**

% Trukai in Blend	Niupela	Wantok	TCS 10
100%	2.14 a	2.37 a	2.19 a
95%	2.35 a	2.67 a	2.32 ab
90%	2.17 a	2.57 a	2.29 ab
85%	2.35 a	2.23 a	2.29 ab
75%	2.41 a	2.67 a	2.69 ab
50%	2.93 b	2.80 ab	2.71 ab
25%	3.17 b	3.33 bc	2.81 b
0%	3.17 b	3.47 c	2.77 ab

Note: 1. Based on a scale of 1 - 5, where 1=like extremely (best score) and 5=dislike extremely (worst score).
2. In a column, treatments with the same letter are not significantly different from each other at $p < 0.05$ based on DMRT.

et al. (1993). After cooking for the set time, the rice was drained in sieves and allowed to stand for 2 mins. The rice was kept warm in covered containers until it was ready to be served. Consumer preference was determined by indication of degree of likeness (1-5 scale; 1-best score, 5-worst score) as per Lamond (1977). Two separate evaluations were conducted. In the first experiment, coded samples comprising 100% Trukai, 100% local samples as well as blends of Trukai and the local samples at various levels of substitution (100%, 95%, 85%, 75%, 50%, 25%, 0% Trukai) were served warm to 30 random untrained panelists. One variety and all its various blends were served at the same sitting.

Based on the results obtained from the first evaluation,

Figure 1. Some sensory quality parameters of rice in Papua New Guinea

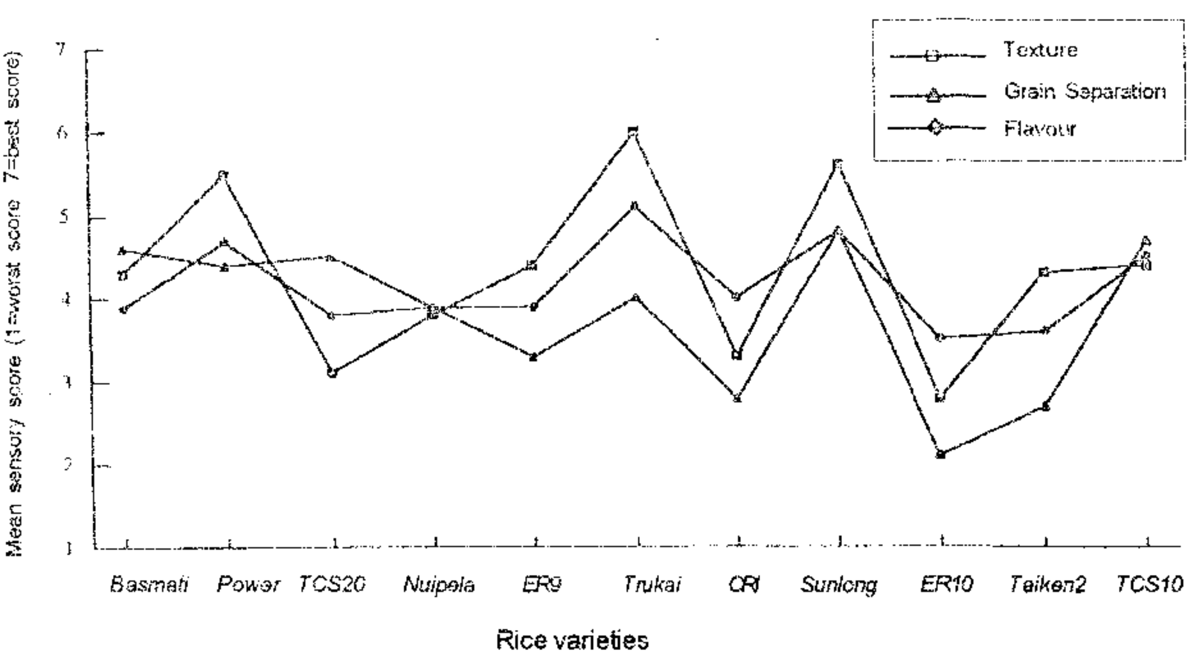

Table 2. **Rice consumer preference evaluation, mean scores of adult and youth groups 1.**

Treatment	Youth Group	Adult Group	Weighted mean	[Rank]
Trukai 100% (control)	2.65 a	2.27 ab	2.51 a	2nd
Trukai 75%/TCS 10, 25%	3.14 bc	2.21 a	2.80 b	4th
Wantok 100%	3.34 cd	3.13 d	3.26 c	7th
Trukai 75%/Niupela 25%	2.47 a	2.37 abc	2.43 a	1st
TCS 10, 100%	3.01 a	2.57 bc	2.84 b	5th
Trukai 75%/Wantok 25%	2.50 a	2.54 abc	2.51 a	2nd
Niupela 100%	3.45 d	2.64 a	3.17c	6th

Note: 1. Based on a sclae of 1-5, where 1=like extremely and 5=dislike extremely
2. In a column, means followed by a common letter are not significantly different from each other at $p < 0.01$ by DMRT.

Table 3. **Summary of rice consumer preference evaluation indicators, based on all samples.**

Variety/Blend	Mean Score [Rank]	% Based on Best Score(1)[Rank]	% Based on Like Score(2)[Rank]	Mean Ranks (3)
Trukai 100%	2.51 [2nd]	21.8 [2nd]	56.5 [2nd]	2.00 ab
Trukai 75%/TCS 10, 25%	2.80 [4th]	17.0 [4th]	45.4 [4th]	3.66 bcd
Wantok 100%	3.26 [7th]	12.9 [6th]	28.8 [7th]	6.00 c
Trukai 75%/Niupela 25%	2.43 [1st]	25.5 [1st]	55.7 [3rd]	1.66 a
TCS 10, 100%	2.94 [5th]	18.1 [3rd]	43.9 [5th]	4.00 cd
Trukai 75%/Wantok 25%	2.51 [2nd]	17.0 [4th]	59.8 [1st]	2.33 abc
Niupela 100%	3.17 [6th]	12.9 [6th]	34.6 [6th]	5.33 dc

(1) - Based on the % of people giving the best score of 1=like extremely.
(2) - Based on the total % of people giving scores 1=like extremely and 2=like very much.
(3) - Mean ranks followed by the same letter are not significantly different from each other at $p < 0.05$ by DMRT.

the 75% Trukai/25% local variety blends were selected for further consumer testing. Two tests were conducted using a total of 271 consumers representing a cross-section of Papua New Guineans in the various age and ethnic groups residing in Lae city. The first test involved 172 consumers from a predominantly youth group between 15-20 years of age, while the second test involved 99 predominantly adult group between 25-50 years. The results were analysed by analysis of variance and Duncan's Multiple Range Test (DMRT) using IRRISTAT 93 software.

RESULTS

The results of the first evaluation indicated, that there were significant differences in consumers' preference of some of the pure varieties and their blends (Table 1). Based on the mean scores, Trukai 100% and TCS10, 100% were equally liked. Niupela 100% and Wantok 100% were not so well liked. Their scores bordered on dislike, with Wantok 100% receiving the worst scores. There were no significant differences in the preference of the consumers for blends of Trukai 50-90%/corresponding proportions of TCS and Wantok. In the case of Niupela, blend levels of only 75-95% Trukai could be made without affecting consumer preference.

The second evaluation of rice consumer preference on a relatively large scale using blends of Trukai 75% and Local rice 25% confirmed the poor performance of Niupela 100% and Wantok 100% (Table 2). The larger consumer groups were however more discriminating in their preference for all the pure varieties except Trukai. There were no significant differences in the preference of both the youth and older consumer groups for Trukai 100%, Trukai 75%/Niupela 25% and Trukai 75%/ Wantok 25% blends. The marked difference in the preference for Trukai 75%/TCS10 25% blend by the two consumer age groups could be due to the different taste preference of youth as compared to adults.

An analysis of the the results based on the percentage of people that gave each sample a particular score, the mean ranks (Table 3) resulted in the following decreasing order of preference: The most preferred were, Trukai 75%/Niupela 25%>Trukai 100%>Trukai 75%/ Wantok 25%. Of intermediate preference were Trukai 75%/TCS10 25%>TCS10 100%. Wantok 100% and Niupela 100% again were the least preferred.

DISCUSSION

People from different regions have different tastes and preferences. What consumers consider good rice depends partly on historical and sociocultural factors (Kaosa-ard and Juliano 1990). Rice quality characteristics, to a large extent, determine market price and consumer acceptance. Next to yield, grain quality is the most important factor considered by plant breeders. If consumers do not care for the taste, texture, aroma, or appearance (sensory characteristics) of a newly developed rice variety, any other outstanding characteristic may be worthless.

There are two dominant varieties of rice on the market, all of which are imported. There is the long grain with 90% head rice (rice has 10% broken), which sells at a higher price and is marketed as Sunlong and the medium grain with 80% head rice (rice has 20% broken), japonica type, which sells at a lower price and is marketed as Trukai. Partly because of the price difference, the majority of Papua New Guineans especially those in the rural areas have opted for and identify with Trukai rice. The results of the consumer preference tests (Table 1-3) and those of a laboratory taste panel tests reported elsewhere (Fig. 1) confirm this pattern. Trukai was consistently preferred over the other varieties in the consumer tests. In the laboratory taste panel tests, the texture and flavour of cooked Trukai were scored higher than those for all the other varieties tested including Sunlong. Consumers will choose a new variety over the preferred and accepted variety only if it has superior quality characteristics and sells at an affordable price (Bhattacharya 1979). Trade stores in Bereina Region in the Central Province sell a ton of Wantok rice in three weeks as against one week for a ton of Trukai, even though Wantok sells at a lower price (Rice Industries-personal communication). A similar trend is seen in Maprik.

The results indicated, that the quality characteristics of Wantok and Niupela varieties will have to be improved if they are to succeed on their own on the domestic market. The preference for TCS 10 is intermediate (between that of Trukai and Wantok/ Niupela). It is therefore imperative that rice breeders in the country identify with the help of sensory and chemical tests, those quality characteristics which consumers find most pleasing and breed them into new varieties. It may mean crossing these three higher yielding local varieties with others having known desirable quality characteristics. This is a generally acceptable practice by breeders emphasising the significance given to grain quality in modern rice improvement programmes. Scientists have been successful in producing high-yielding rices with good grain quality and high acceptability (Bhattacharya 1979). It is by no means an easy matter and it has to be looked at as a long term strategy in Papua New Guinea's rice breeding programme with breeders, biochemists, chemists, food scientists, agronomists, engineers and entomologists working together to produce acceptable varieties. Quality cannot be ignored since the ultimate test of the success of the programme is high consumer preference and acceptance.

In the interim it may be possible to market blends of above local varieties with Trukai as the results indicate. The Trukai 75%/Niupela 25% was preferred as equally as Trukai 100%. The practice of blending rice varieties is not new. Traders in Hong Kong and Philippines blend rice from different origins to achieve the desired cooking and sensory quality (Kaosa-ard and Juliano 1990; Samiano, ERAP, personal communication). The fact that the blends performed as well as Trukai 100%, seems to indicate that blending will increase the consumer preference and market acceptability of the local varieties. Even though the high yielding varieties tested here may not be accepted as the principal cereal on their own, they may probably have other characteristics that would make them ideal for processing into some types of rice products (Del Mundo 1979), and these should be investigated.

CONCLUSION

Among the pure varieties tested, Trukai was the most preferred followed by TCS10. Wantok and Niupela were the least preferred. However blends of these local rices with Trukai (75% Trukai) greatly improved their consumer preference. These results underscore the importance of incorporating sensory quality tests into rice breeding programmes to help identify the varieties which will not only satisfy farmers in terms of yield but also possess sensory qualities acceptable to consumers.

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NEW SPECIES OF *Allacta* Saussure and Zehntner FROM PAPUA NEW GUINEA, IRIAN JAYA AND SARAWAK (Blattaria, Blattellidae: Pseudophyllodromiinae).

Louis M. Roth[1]

ABSTRACT

Ten new species of Allacta *Saussure & Zehntner are described of which nine are from the island of New Guinea, and one is from Sarawak. A key is presented to distinguish the New Guinea males.*

Key words: *New Guinea, Sarawak, cockroaches, taxonomy, new* Allacta *spp., Blattellidae.*

INTRODUCTION

The cockroach genus *Allacta* Saussure & Zehntner (= *Arublatta* Bruijning) consists of about 30 described species and has been reviewed (Roth 1991, 1993). More recently I received a collection of New Guinea Allacta from the Bernice P. Bishop Museum (BPBM) which included nine new species, belonging to the *funebris* and *polygrapha* species groups. These are described below, as is one new taxon from Sarawak belonging to the *hamifera* species group, in the Zoological Institute, Lund, Sweden (ZILS). Previously only *basivittata* Bruijning, was known from New Guinea (Irian Jaya) and Aroe Island. A few specimens are from the Hope Entomological Collections, Oxford, England (HECO). Some BPBM specimens have been retained in the Museum of Comparative Zoology, Harvard University (MCZ).

Symbols used		
@	=	male
$	=	female

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SYSTEMATIC SECTION

Genus *Allacta* Saussure & Zehntner

Allacta Saussure & Zehntner, 1895: 45; Roth 1991: 996 (synonymy and literature); 1993: 361. (Type species: *Abrodiaeta modesta* Brunner, by selection, Hebard 1922: 326).

Diagnosis: Tegmina and wings fully developed (Figs. 2A, C, E), or reduced in females (Figs. 7F, 8H); tegmina with oblique discoidal sectors. Cubitus vein of hind wing with three to six complete and no incomplete branches, apical triangle small or absent (Figs. 4D, 7D, 9E). Front femur Type B; pulvilli present on fourth proximal tarsomere only, tarsal claws simple, symmetrical, arolia present (Fig. 10F). Male: abdominal terga unspecialized. Genitalia with four principal phallomeres: hook on right side; median phallomere with or without lateral flange or extension; associated median phallomere usually curves under median sclerite and usually terminates in setose membrane (Fig. 3D), or a few spines (Fig. 3E).

Distribution: The distribution of the New Guinea *Allacta* is shown in Figure 1.

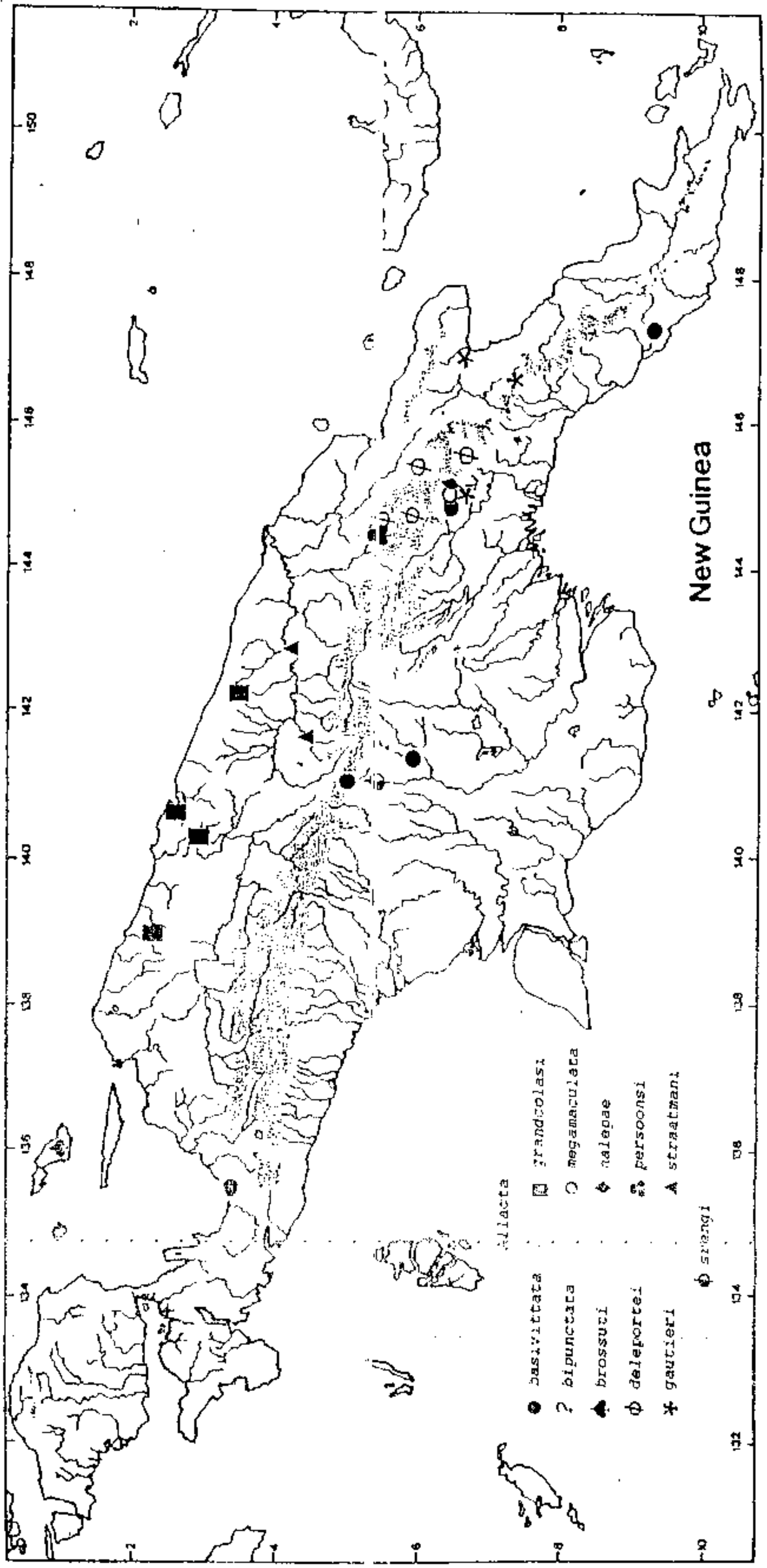
Key to adult *Allacta* males from New Guinea

1 Face entirely dark (Figs. 2G, J) or with the lower part dark, upper region light (Figs. 2B, D, F) (*funebris* - species group) 2

- Face with median dark longitudinal stripe (Figs. 4A, 5A, 6A, 8A, 9A) (*polygrapha* - species group) 6

2. Face with region above antennal sockets orange (Figs. 2B,

Figure 1. **Distribution of *Allacta* spp. in New Guinea. Three of the species also occur elsewhere as follows: *basivittata* on Aroe Island; *bipunctata* on Sulawesi; *grandcolasi* on New Ireland.**



D, F). Tegmina with maculae at the bases of anal fields (Figs. 2A, C, E) 3
- Face entirely dark (Figs. 2G, J) 5

3. Tegmina without medial pale maculae (Fig. 2C) .... *basivittata*
- Tegmina with pair of medial pale maculae (Figs. 2A, E) 4

4. Medial maculae of tegmina very small (Fig. 2A) .... *bipunctata*
- Medial maculae of tegmina very large (Fig. 2E) .... *megamaculata*

5. Pronotum with broad lateral orange zones (Fig. 2I) .... *straatmani*
- Pronotum without orange zones (Fig. 2H). Tegmina only with oblique yellowish maculae at bases of anal field (Fig. 2H). .... *grandcolasi*

6. Interocular space 0.5 mm or less (Figs. 5A, 9A) 7
- Interocular space more than 0.5 mm 8

7. Median genital phallomere with large lateral membrane on distal half (Fig. 5C). Pronotum as in Fig. 5B .... *brossuti*
- Median genital phallomere without lateral flange (Fig. 9C). Pronotumas in Fig. 9B .... *srengi*

8. Median genital phallomere without lateral flange (Fig. 7E). 9
- Median genital phallomere with lateral flange (Figs. 4C, 6D). 10

9. Dark pronotal macula almost completely solid (Fig. 7B). Apex of median phallomere swollen (Fig. 7E) .... *persoonsi*
- Pronotal macula with more pale areas (Fig. 8B). Apex of median phallomere not swollen (Fig. 8D) .... *nalepae*

10. Genitalia as in Fig. 6D, Pronotum as in Fig. 6B. Interocular width 0.9-1.0 mm (Fig. 6A) .... *deleportei*
- Genitalia as in Fig. 4C. Pronotum as in Fig. 4B. Interocular width 0.7 mm (Fig. 4A) .... *gautieri*

funebris - species group

Diagnosis: Very dark. Head entirely dark (Figs. 2G, J) or with region above antennal sockets orangish, lower portion dark (Figs. 2B, D, F). Pronotum entirely dark or with lateral margins or posterolateral corners narrowly yellowish or yellowish white (Figs. 2A, C, E, H), or broad lateral borders orange (Fig. 2I). Tegmina dark with yellow, yellowish white, or white maculae at base of anal field and with (Figs. 2A, E) or without (Figs. 2C, H, I) pale maculae medially, sometimes without any pale marks.

Species: basivittata (Bruijning); *bipunctata* (Walker); *grandcolasi* spec. nov.; *megamaculata* spec. nov.; *straatmani* spec. nov.

Allacta basivittata (Bruijning)
(Figs. 1; 2C, D; 3B, C)

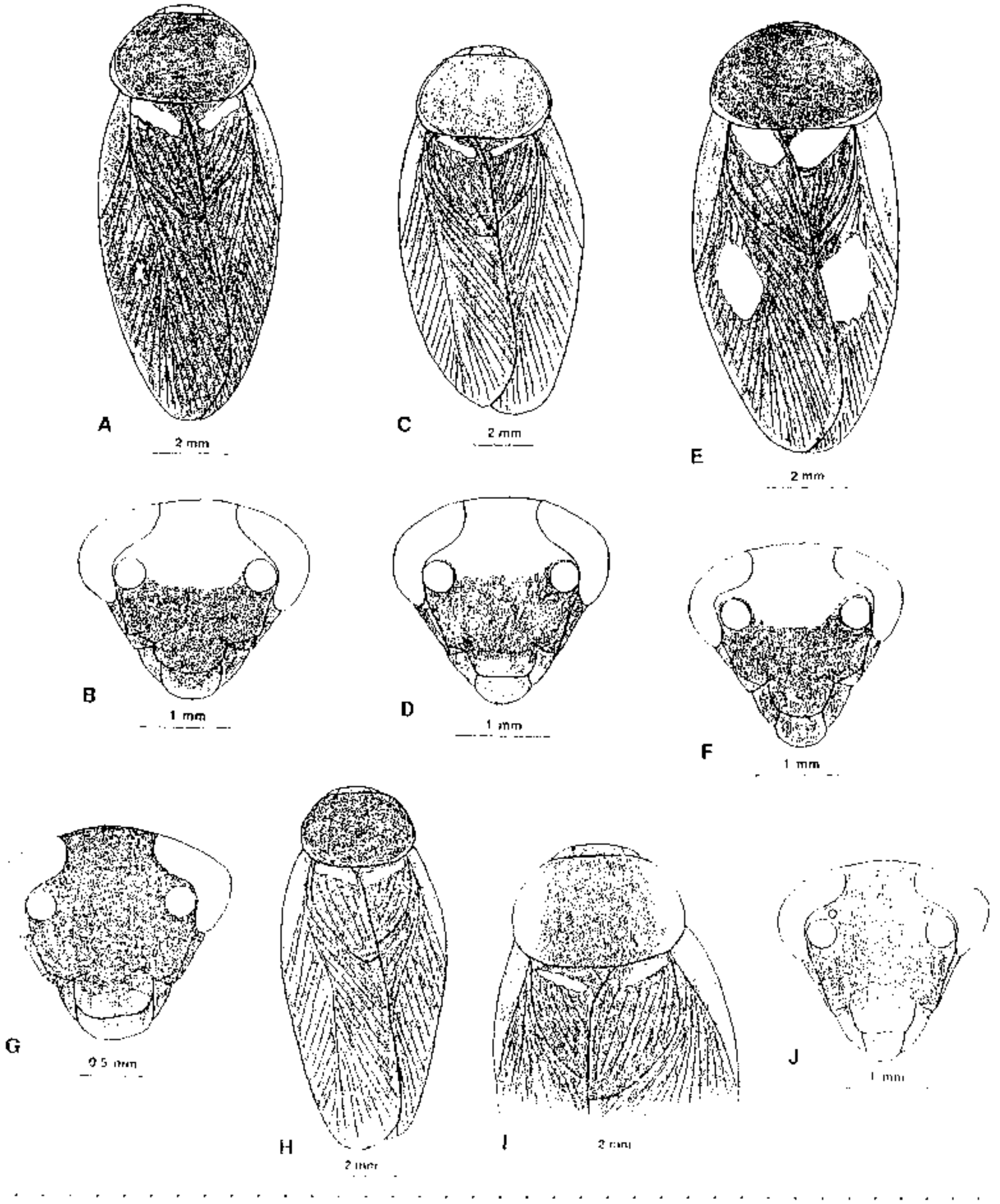
Arublatta basivittata Bruijning 1947:224, figs. 4a-d (@ & $); Princis 1953:55; 1965:151 (synonymized with *bipunctata*).
Allacta basivittata (Bruijning): Roth 1991:1010, fig. 31 (redescribed @ & $ as *bipunctata*).

Material examined: Papua New Guinea. BPBM: Oriomo river, 6 m, 1@ (terminalia slide 510), 21.ii.1964, light trap, 2$$ (one carrying an ootheca in the vertical position), 14.ii.1964, H.C.; Koitaki [9+$+23'S 147+$+16'E], 1500 ft., 1@, xi.-xii.1928, 1$, x.xi.1928, Pemberton; "Ruka", 9 m, 1$, 9.viii.1965, H. Clissold; Kiunga, 35 m, 1$ (carrying an ootheca in the vertical position), viii.1969, J. & M. Sedlacek; Kiunga, Fly River [6+$+07'S 141+$+17'E], 2@@, 1$, 23-25.vii.1957, 1$, 5-7.viii.1957, 1$, 26-30.vii.1957, 1@, 4-5.ix.1957, W.W. Brandt. The following were collected by J.L. or J.L. & M. Gressitt: W. District, Oriomo Gov't. Sta., 2@@ (one on shelf fungus), 26-28.x.1960; Karimui [6+$+32'S 144+$+47'E], south of Goroka [6+$+04'S 145+$+23'E], 1000 m, 1@, 4.vi.1961, 1$, 3.vi.1961; Karimui, 1$, 4.vi.1961. Irian Jaya. BPBM: Star Mts., Sibil Val. [5+$+00'S 141+$+00' E] 1245 m, 1$, 18.x.-8.xi.1961, L.W. Quate. The following were collected by J. Sedlacek: Nabire [3+$+22'S 135+$+29'E], 5-50 m, 1@, 25.viii.-2.ix.1962; Nabire, S. Geelvink Bay, 10-40 m, 1$, 1-4.ix.1962. Four specimens retained in the MCZ.

Comments: Roth (1991: 1010) redescribed this species as *Allacta bipunctata* (Walker) (from Sulawesi) with which it had been synonymized by Princis (1965: 151; 1969: 941). However, after examining Walker's type in my recent revision of *Allacta*, I (Roth 1993: 361) decided to keep the two species distinct, until its male (from the type locality) is described, because the males and females of *basivittata* lack two small yellow spots in the middle of the tegmina which are found in *bipunctata* (Roth 1993: 364). The tegmina of all the above specimens have the maculae at the bases of the anal field and lack the yellowish maculae near the middle (Fig. 2C). The pale markings on the pronota and tegmina may vary in size and color (yellow, yellowish white or white); on the pronotum the yellowish margin may extend along the lateral edge (Fig. 2C) or may be reduced and restricted to the rounded hind corner. The head always is bicolorous, the region above the antennal sockets orange, the remainder blackish (Fig. 2D). The subgenital plate, styli, and genitalia are shown in Figs. 3B, C.

Measurements (mm) ($ in parentheses): Length, 7.6-9.5 (8.0-9.7); pronotum length x width, 2.0-2.6 x 3.1-4.1 (2.3-2.7 x 3.7-4.4); tegmen length, 8.0-10.0 (7.5-9.1); interocular width, 0.7-0.8 (0.7-0.9).

Figure 2. **Allacta spp., habitus and heads: A, B) = *bipuntata* (male from Olsobip, Papua New Guinea). C, D) = *basivittata* (male from Kiunga, Papua New Guinea). E, F) = *megamaculata* (E, male holotype, F, female paratype). G, H) = *grandcolasi* (male paratype). I, J) = *stratmani* (male holotype).**



Allacta bipunctata (Walker)
(Figs. 1, 2A, B; 3A)

Blatta bipunctata Walker 1869:141 ($).
Pseudectobia bipunctata (Walker): Shelford 1907:495, pl. 30, fig. 3
Pseudophyllodromia bipunctata (Walker): Shelford 1908:17; Hanitsch 1933:134; Bruijning 1947:223.
Arublatta bipunctata (Walker): Princis 1965:151.
Allacta bipunctata (Walker): Roth 1991:1010, fig. 31 (redescribed *basivittata* as the junior synonym of bipunctata); 1993 (1992): 364, fig. 1) (redescribed

the $ as distinct from *basivittata*).

Material examined: Papua New Guinea. BPBM: Fly river, Olsobip [5+$+23'S 141+$+32'E], 400-600 m, 1@ (terminalia slide 507), viii.1969, 1@, 400 m, 23.viii.1969, J. & M. Sedlacek.

Description: *Male:* Interocular space slightly less than distance between antennal sockets (Fig. 2B). Pronotum subelliptical, widest near middle (Fig. 2A). Tegmina and wings fully developed extending well beyond end of abdomen, former with oblique discoidal sectors. (Wings were not spread). Front femur Type B_2, with one to four stout proximal spines (some very small); pulvilli on fourth proximal tarsomere of all legs, tarsal claws simple, symmetrical, arolia small. Abdominal terga unspecialized. Supraanal plate strongly transverse, very short, hind margin weakly convexly rounded, paraprocts similar plates. Subgenital plate with shallow medial excavation which is visible in slide preparation because pressure of coverslip exaggerates excision (Fig. 3A); in pinned specimen inner excavated margins are contiguous forming keel-like ridge between small styli (e.g., Fig. 3C). Genitalia as in Fig. 3A: hook on right side with preapical incision; median phallomere with broad, irregularly rounded membrane distad; associated with median phallomere is rodlike sclerite which has densely setose structure distad; left phallomere consisting of several simple sclerites.

Colouration: Black. Head with orange region from occiput to level of antennal sockets, remainder black (Fig. 2B). Pronotum black with narrow yellowish white margin limited to rounded posterior corners (Fig. 2A). Tegmen with large, rectangular, oblique, yellowish white macula at base of anal field and very small yellow or whitish spot (may be single or very narrowly unequally divided) near middle (Fig. 2A). Abdomen, legs, and cerci black.
Measurements (mm): Length, 8.7-9.2; pronotum length x width, 2.6-2.7 x 3.9-4.1; tegmen length, 8.8-9.2; interocular width, 0.8.

Comments: The male's median and left genital phallomeres are similar to those of *basivittata*, and these two specimens may simply be a variant of that species. However, the male of *bipunctata* from Sulawesi (type locality) is still unknown and its genitalia should be compared with the present Papua New Guinea material to be certain the taxa are not conspecific. The principal difference between the male markings of the two taxa are the presence of small whitish medial maculae on the tegmina of *bipunctata* (absent in *basivittata*) and these are distinctly larger in the female type from Sulawesi..

***Allacta megamaculata* spec. nov.**
(Figs. 1, 2E, F; 3D)

Material examined: *Holotype:* @ (terminalia on slide 506), New Guinea NE, Karimui [6+$+32'S 144+$+47'E] [Papua New Guinea], 1080, 13.vii.1963, J. Sedlacek; in BPBM. *Paratype:* Papua New Guinea. BPBM: same data as holotype, 1$.

Etymology: The specific name refers to the very large maculae near the middle of the tegmina.

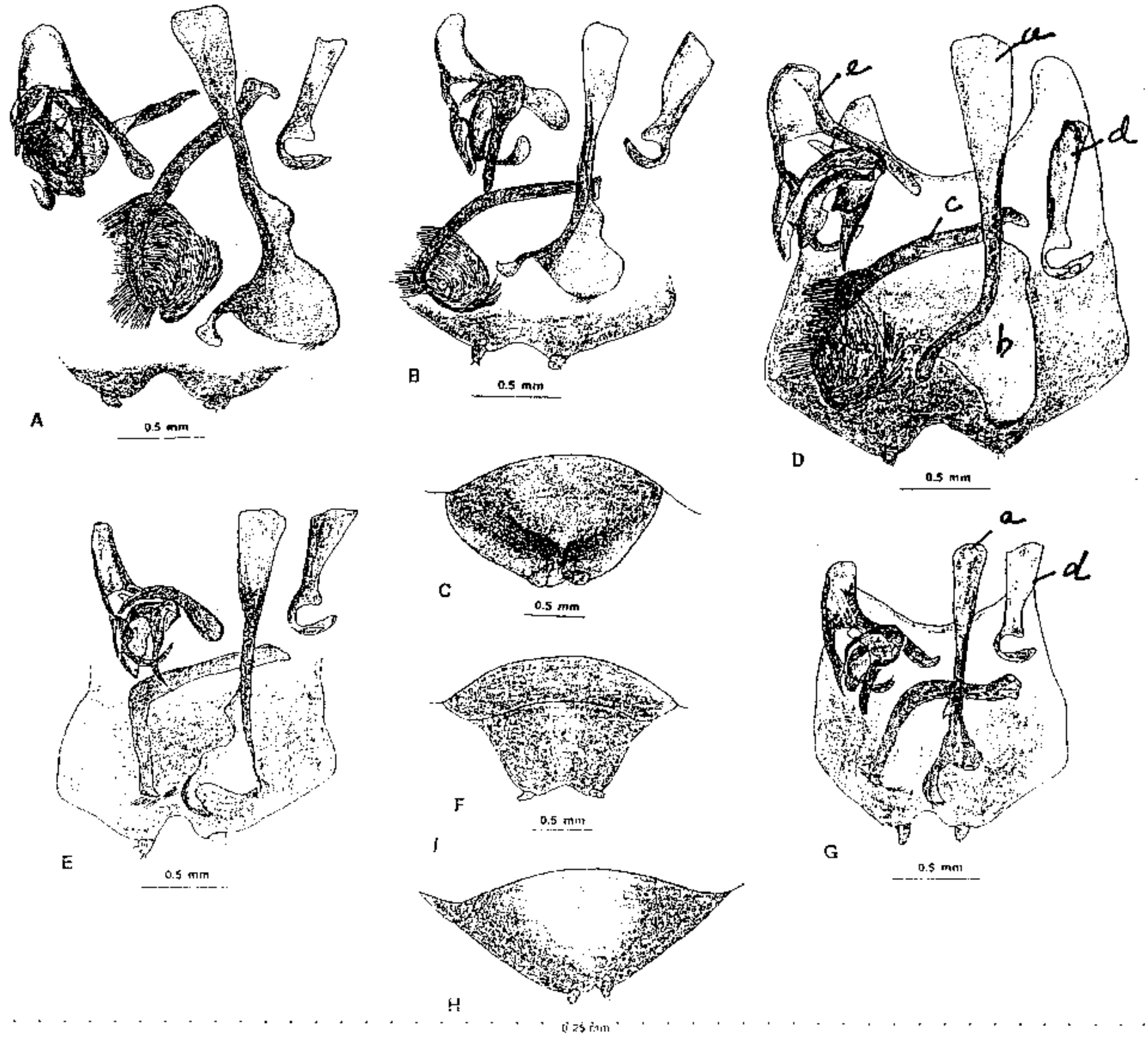
Description: *Male:* Head slightly exposed, interocular width slightly less than distance between antennal sockets (Fig. 2F). Pronotum transverse, subelliptical, widest behind middle (Fig. 2E). Tegmina and wings fully developed extending beyond end of abdomen, former with oblique discoidal sectors (wings were glued to abdomen and therefore not spread). Front femur Type B_2 with one or two small stout spines about length of piliform spinules; pulvilli only on fourth proximal tarsomere of all legs, tarsal claws symmetrical, simple, arolia small (only one front leg intact). Abdominal terga unspecialized. Supraanal plate transverse, hind margin convexly rounded, paraprocts similar plates. Subgenital plate with medial excision forming ridge or keel between small similar styli (e.g., Fig. 3C); in slide preparation, excised region spreads apart and distance between styli is exaggerated (Fig. 3D). Genitalia as in Fig. 3D; hook on right side with preapical incision; median phallomere apically rounded, distal half with large irregular lightly sclerotized plate bearing small group of setae along margin; below median phallomere is additional sclerite distally modified with densely setose plate; left phallomere consisting of several closely associated sclerites.

Female: Supraanal plate strongly transverse, hind margin convex with shallow V-shaped excavation medially.

Colouration: Black. Head orange from occiput to level of antennal sockets (Fig. 2F). Pronotum black with posterior rounded corners narrowly yellowish white (Fig. 2E). Tegmen black with two large yellowish white maculae one at base of anal field, other near middle (Fig. 2E). Abdomen and legs black, cerci black with preapical segment white.

Measurements (mm) ($ in parentheses): 9.5 (9.7); pronotum length x width, 2.7 x 4.1 (2.7 x 4.3); tegmen length, 9.5 (9.0); interocular width, 0.8 (1.0).

Figure 3. ***Allacta*** **spp., males, subgenital plates and genitalia [A, B, D, E, G, are from slide preparations (dorsal); only the hind margin of the subgenital plate is shown in A and B, and only the distal half in E; C, F, H, are from pinned specimens (ventral)]: A) =** ***bipuntata*** **(from Fly River, Olsobip, Papua New Guinea). B, C) =** ***basivittata*** **(B from Oriomo River and C from Kiunga, Fly River, Papua New Guinea); D) =** ***megamaculata*** **(holotype; a = median phallomere; b = lateral membrane; c = associate median phallomere; d = right hooklike phallomere; e = left phallomere). E, F) =** ***straatmani*** **(E from paratype, F from holotype). G,H) =** ***grandcolasi*** **(G from holotype, H from paratype).**



Comments: The male genitalia of this species shows a close relationship to *bipunctata* and *basivittata*. The white maculae in the middle of the tegmina of *megamaculata* are much larger than those found in *bipunctata* and the species is distinctly larger than the other two related taxa.

Allacta grandcolasi spec. nov.
(Figs. 1, 2G, H; 3G, H)

Material examined: Holotype: male, Hollandia (= Jayapura) [Irian Jaya] [2+$+32'S 140+$+42'E], 0-300 m., 1$, 22.xii.1961-2.i.1962, S. & L.Quate; BPBM.

Irian Jaya. BPBM: *Paratypes:* same data as holotype, 2@@ (1 with terminalia on slide 509), 1$; Ifaar [2+$+34'S 140+$+31'E], Cyclops Mts. [2+$+32'S 140+$+36'E], 300-500 m, 1 (abdomen missing), 23-25.vi.1962, J.L. Gressitt; Ifaar, Cyclops Mts. 300-500 m, 1$, 23-25.vi.1962, J. Sedlacek. The following were collected by T.C. Maa: Bodem [2+$+20'S 138+$+55'E], 100 m, 11 km SE. of "Oeberfaren", 1@, 7-17.vii.1959; Genyem [2+$+46'S 140+$+12'E], 40 km W. of Hollandia, 100-200 m, 1@, 1-10.iii.1960; Hollandia, 1@, 13.iii.1960; Ifar, 400-550 m, 1$, 23.vi.1959. Papua New Guinea. BPBM: Torricelli Mts. [3+$+25'S 142+$+15'E], "Mobitei", 750 m, 1@, 16-31.iii.1959, W.W. Brandt. New Ireland. BPBM: New Ireland (SW), "Camp Bishop", 12 km up Kait R., 240 m, 1$, 15.vii.1956, B.J. Ford Jr. Three specimens retained in MCZ.

Etymology: The species is dedicated to Dr. Philippe Grandcolas, URA 373 CNRS, Laboratoire de Primatologie, Station Biologique de Paimpont, France, for his important contributions to cockroach taxonomy.

Description: *Male:* Head slightly exposed, interocular space less than distance between antennal sockets (Fig. 2G). Pronotum suboval, widest near middle (Fig. 2H). Tegmina and wings fully developed extending beyond end of abdomen, former with oblique discoidal sectors. Hind wing with simple radial and media veins, cubitus vein with five complete and no incomplete branches, apical triangle small. Front femur Type B_2, with two stout proximal spines; pulvilli on fourth proximal tarsomere only, tarsal claws symmetrical, simple, arolia small. Abdominal terga unspecialized. Supraanal plate transverse, hind margin rounded, right and left paraprocts similar simple plates. Subgenital plate with small similar styli, one on each side of shallow medial excision (Figs. 3G, H). Genitalia as in Fig. 3G: Hook on right side, with preapical incision; median phallomere distally enlarged with small group of terminal setae; curved rod under median phallomere bends in middle, apical margin setose; left phallomere several closely arranged sclerites.

Female: Tegmina and wings slightly reduced. Supraanal plate strongly transverse, hind margin convex with small medial excavation.

Colouration: Head very dark reddish brown to black; vertex, clypeus, and labrum lighter, minute ocellar spots yellowish (Fig. 2G); maxillary palpi dark reddish brown to black; antennae brown or brownish yellow, or proximal antennomeres brownish yellow, remainder brown. Pronotum very dark reddish brown, lateral edges yellow or yellowish white, or pale edging limited to posterior rounded corners only (Fig. 2H). Tegmina dark reddish brown with narrow, oblique, yellowish or yellowish white band at bases of anal fields (Fig. 2H). Wings very dark, costal region reddish. Abdomen dark reddish brown. Cerci black with four terminal segments yellowish white or white. Legs reddish brown to black, tarsi lighter.

Measurements (mm) ($ in parentheses): Length, 7.4-8.5 (7.9-9.6); pronotum length x width, 2.1-2.3 x 3.1-3.6 (2.3 x 3.6-3.7); tegmen length, 8.6-10.0 (7.2-7.8); interocular width, 0.6 (0.7).

Comments: This species is closely related to *straatmani* because of their strongly similar median genital phallomeres.

Allacta sp. A

Material examined: Papua New Guinea. BPBM: Bulolo [7+$+12'S 146+$+39'E], 650 m, 1$, 3.viii.1968; Ambunti [4+$+14'S 142+$+49'E], Sepik R., 50 m, 1$ (carrying ootheca in vertical position), 10.v.1963, R. Straatman. Irian Jaya. BPBM: The following were collected by T.C. Maa: Hollandia-Kotanica [2+$+36'S 140+$+39'E], 1$, 25-28.ii.1960; Waris [3+$+30'S 140+$+55'E], S. of Hollandia, 450-500 m, 1$ (carrying ootheca in vertical position), 27-30.vii.1959.

Comments: These females are dark reddish brown. The head and tegmina are completely dark; the pronotum may or may not have very narrow yellow lateral margins. The cerci are completely dark or the penultimate segment may be pale. Except for the absence of basal yellow markings on the tegmina, the species strongly resembles and may be a color morph of *grandcolasi* but males are needed to determine if this is true or if it is new. Both forms are sympatric.

Measurements (mm): Length, 8.2-10.0; pronotum length x width, 2.3-2.5 x 3.4-3.8; tegmen length, 8.1-9.3; interocular width, 0.6-0.7.

Allacta straatmani spec. nov.
(Figs. 1, 2I, J; 3E, F)

Material examined: *Holotype:* male, New Guinea NE [Papua New Guinea], May R. Patrol Sta., [4+$+28'S 141+$+37'E], dry forest, 250 m, 3.vi.1963, R. Straatman; BPBM. *Paratypes:* Papua New Guinea. BPBM: New Guinea NE, Ambunti [4+$+14'S 142+$+49'E], Sepik R., 50 m, 1@ (terminalia slide 508), 10.v.1963, R. Straatman. Iryan Jaya. HECO: The following were collected by Dr. S.G. Burgers on The Kaiser Augustafl. Exp. to D.N. Guinea: Hauplg. b.

Malu, 1@, 3.ii.1913, 1@, 6.ii.1913; Lager am Rosensee, 1@, 15.ii.1913, 2$$, 14.ii.1913; Standlager b. Malu, 1$, iii-iv.1912; Maanderberg, 1$, 21-30.viii.1913. Two specimens retained in the MCZ.

Etymology: The species is dedicated to Dr. R. Straatman who collected the holotype.

Description: *Male:* Head slightly exposed, interocular space slightly less than distance between minute ocellar spots (Fig. 2J). Pronotum suboval, widest near middle (Fig. 2I). Tegmina and wings fully developed extending beyond end of abdomen, former with oblique discoidal sectors. Hind wing with radial and media veins straight, simple, cubitus vein with five complete and one long incomplete branches, apical triangle small. Front femur Type B_2, with two to four large proximal spines and long row of piliform spinules; pulvilli on fourth tarsomere only on all legs, tarsal claws symmetrical, simple, arolia small. Abdominal terga unspecialized. Supraanal plate transverse, hind margin convexly rounded, right and left paraprocts similar simple plates. Subgenital plate with pair of small similar styli one on each side of a shallow excision (Figs. 3E, F). Genitalia as in Fig. 3E: hook on right side, with preapical incision; median phallomere with distal enlargement terminating in group of small setae; sclerotized rod bends strongly in middle below median sclerite, terminating in group of setae. Left phallomere consisting of several small sclerites.

Colouration: Head black or dark reddish brown, ocellar spots yellowish (Fig. 2J). Pronotum black with wide lateral orange zones (Fig. 2I). Tegmen black except for distinct narrow (variable in size) oblique yellow macula at base of anal field (Fig. 2I). Hind wing very dark. Abdomen and cerci black. Legs dark reddish black.

Female: Similar to male. Supraanal plate transverse, hind margin with shallow medial excision.

Measurements (mm) ($ in parentheses): Length, 8.0-9.3 (9.0-10.7); pronotum length x width, 2.5-2.7 x 3.7-4.0 (2.6-2.8 x 3.9-4.1); tegmen length, 9.5-9.8 (8.8-9.4); interocular width, 0.7 (0.7).

Comments: The broad lateral orange zones on the pronotum of *straatmani* are distinctive. *Allacta luteomarginata* (Hanitsch) from Singapore has a completely dark head and its pronotum is blackish brown with broad yellowish-hyaline lateral zones (Roth 1991: figs. 30A, B). The median and accessory median phallomeres (Roth 1991, fig. 30G) differ distinctly between the two taxa. The male genitalia of *straatmani* relates it more closely to *grandcolasi* than to others in the species group.

polygrapha - species group

Diagnosis: Head with a medial longitudinal stripe extending from occiput or vertex to clypeus (Figs. 4A, 8A, 9A), or with transverse facial markings (Roth 1991: fig. 29A). Pronotal disk usually with large symmetrical pattern of dark dots, lines, or blotches (Fig. 9B). Tegmina usually checkered with dark cells between veinlets, and with one or more larger blotches (Fig. 9D). The tegmina and wings of females in this species group (in New Guinea) are usually variably reduced. The similarity between females of these species, and variability in color pattern intraspecifically makes it difficult to identify that sex in most species. This is particularly true because of the paucity of topotypic males and females so that the extent of variation is unknown. Also a number of species are sympatric which makes matching some females with a particular male equivocal. For this reason I have usually not designated females as paratypes, unless their color markings were very similar to males (e.g., *A. persoonsi*).

Species: brossuti spec. nov.; *deleportei* spec. nov.; *gautieri* spec. nov.; *nalepae* spec. nov.; *persoonsi* spec. nov.; *srengi* spec. nov.

Two females (Normanby, Wakaiuna I., Wakaiuna, Sewa Bay, 21-30.xi.1956 and 11-20.xii.1956, leg. W.W. Brandt) have almost completely dark heads (no longitudinal facial band) but their pronota and tegminal markings are typical of the *polygrapha* group. Their legs and abdomens are dark brown to black. They may be a new species but males are needed to determine this. It is possible that they are melanistic forms of one of the described taxa.

Allacta gautieri spec. nov.
(Figs. 1, 4A-H)

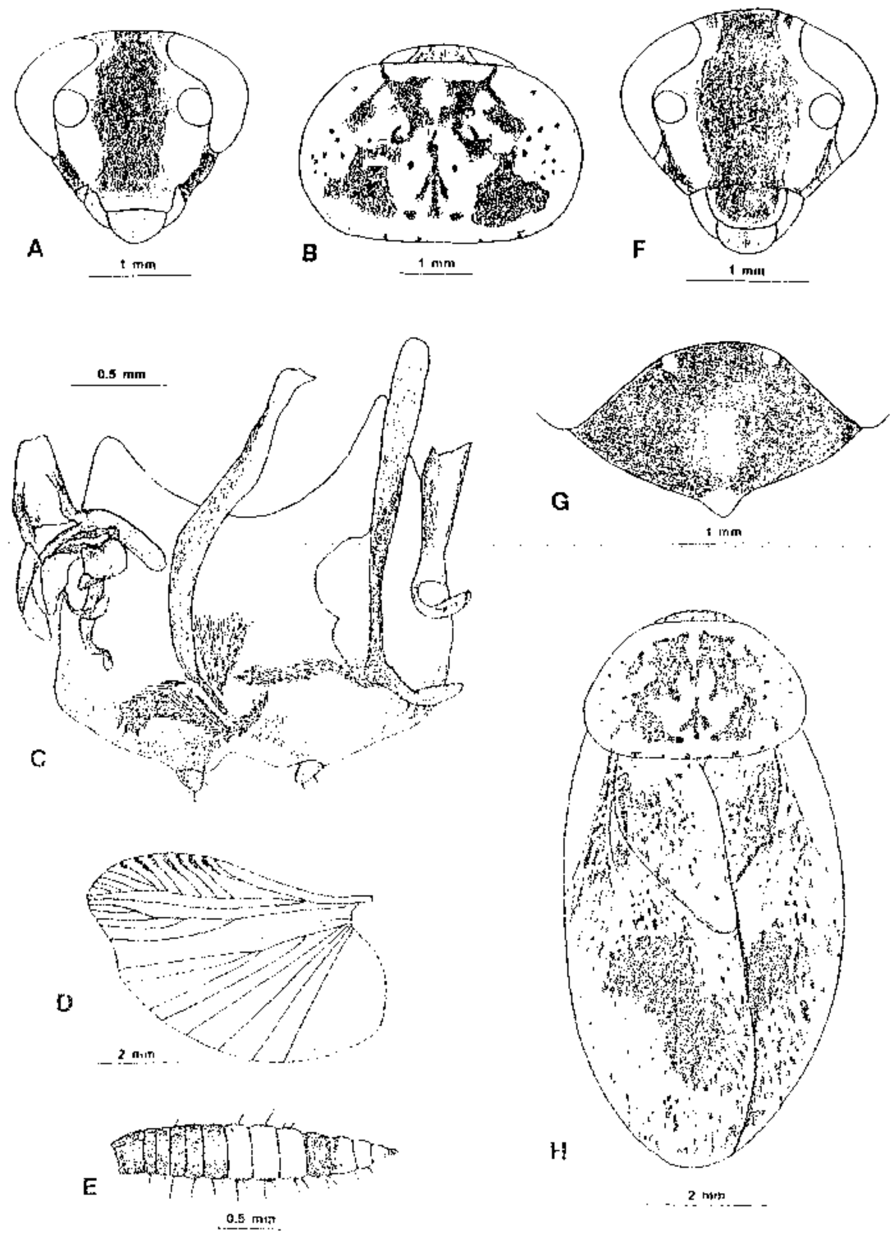
Material examined: *Holotype:* male (terminalia slide 513), Mt. Missim [7+$+20'S 146+$+43'], New Guinea (NE) [Papua New Guinea], Malaise trap, 7.xii.1966, G.A. Samuelson. *Paratypes:* Papua New Guinea. BPBM: same locality as holotype, 1@ (terminalia slide 512), 1500-2000 m, 15-21.iv.1968, J. & M. Sedlacek. Additional material.- Papua New Guinea. BPBM: Wau [7+$+20'S 146+$+43'E], 1150-1600m, 1$, 9.ii.1968, J. Sedlacek; Busu R. [6+$+36'S 147+$+00'E], E. of Lae [6+$+43'S 147+$+00'E], 100 m, 1$, 15.ix.1955, J.L. Gressitt. Karimui [6+$+32'S 144+$+47'E], 1080 m, 1$, 13.vii.1963, J. D. Sedlacek.

Etymology: The species is dedicated to Dr. J.Y.

Gautier, Université de Rennes, France, for his contributions to our knowledge of cockroach biology and taxonomy.

Description: *Male:* Head slightly exposed, interocular width less than space between antennal sockets (Fig. 4A). Pronotum subelliptical, widest at middle (Fig. 4B). Tegmina and wings fully developed extending well beyond end of abdomen, discoidal sectors of former oblique. Front femur Type B_2 with three large proximal spines; pulvilli only on fourth tarsomere of all legs, tarsal claws simple, symmetrical, arolia well developed. Abdominal terga unspecialized; supraanal plate strongly transverse, hind margin convex, entire, right

Figure 4. ***Allacta gautieri*** **sp. n. A - C) = head; B = pronotum; c) = subgenital plate and genitalia (dorsal); D - H) = females: D, E) = from Busu R., left hind wing, and cercus; F - H) = from Karimui: F) = head; G) = subgenital plate (ventral); H) = habitus.**



and left paraprocts similar simple plates. Subgenital plate with a pair of small similar styles separated by shallowly excised margin (Fig. 4C). Genitalia as in Fig. 4C: hook on right side with preapical incision; median phallomere with large flange on distal half, apical region curved laterally and with some minute spicules along edge; accessory median phallomere broad, becoming narrow at apex where it is surrounded by large setose membrane; left phallomere consisting of several simple sclerites.

Colouration: Yellow and dark reddish brown. Head yellow with broad dark reddish brown longitudinal stripe from occiput to distal region of clypeus, labrum dark (Fig. 4A); maxillary palpomeres three and four pale, terminal segment darker with pale apex; proximal antennomeres yellowish on upper surface, darker below, remaining segments light brown. Pronotum with symmetrical dark brown pattern of blotches, lines, and dots, few dark dots in pale lateral zones (Fig. 4B). Tegmina mottled with yellowish white veins, cells between veinlets dark with large reddish brown blotches. Legs yellowish brown with black markings as follows: front coxae black at base, mid and hind coxae black basally and along outer margins; front femur dorsal margin and anterior surface base and apex black, ventral margin posterior surface black; tibiae with dark rings at base, apex, and middle; first tarsal segment with dark rings at base and apex, second and third tarsomeres dark. Abdominal terga dark brown laterally, middle zones mixture of light and dark. Abdominal sterna with broad medial area light brown, remaining lateral zones dark brown, distal half of subgenital plate pale. Cerci with five dark proximal segments succeeded by three cercomeres partly pale and dark (along lateral margins) then dark segment and three terminal pale segments.

Female: Head with interocular space slightly less than distance between antennal sockets (Fig. 4F); maxillary palpomeres three and four pale, the fifth dark. Pronotum subelliptical, widest behind middle (Fig. 4H). Tegmina and wings fully developed reaching tip of abdomen, former with oblique discoidal sectors (Fig. 4H). Hind wing with simple costal veins except for branched third one from apex, distally clubbed or thickened; radial vein straight, simple, media straight, simple or forked apically, cubitus vein weakly curved with four or five complete (one may be forked) and no incomplete branches, apical triangle obsolete (Fig. 4D). Front femur Type B_2 with four large proximal spines; pulvilli on fourth proximal tarsomere only, tarsal claws simple, symmetrical, arolia present. Supraanal plate strongly transverse, hind margin convex, apex arched.

Colouration: Head occiput with narrow, black or reddish brown curved lateral stripe near each eye, medially with pair of stripes that fuse on vertex, widen longitudinally and extend to clypeus, labrum lighter, background color yellow (Fig. 4F). Pronotum with black or reddish brown symmetrical pattern on pale background, lateral zones semihyaline sprinkled with white and dark dots (Fig. 4H). Tegmina with pair of dark reddish brown blotches in anal vein area, and larger pair on distal half (Fig. 4H). Abdominal terga with yellow and brown areas. Abdominal sterna dark brown to blackish, sprinkled with yellow spots; subgenital plate very dark with pair of small yellow dots near anterior margin and at apex of hind margin, medial region may be tinged with reddish brown (Fig. 4G). Cerci with six black basal segments succeeded by three pale, one dark then two pale cercomeres, apex dark (Fig. 4E). Legs with dark rings on femora, tibiae, and tarsi.

Measurements: (mm) ($in parentheses): Length, 9.0-10.0 (8.0-10.0); pronotum length x width, 2.5-2.6 x 3.9-4.0 (2.1-2.5 x 3.8-4.3); tegmen length, 13.5-14.0 (7.4-8.1); interocular width, 0.7 (0.8-1.0).

Comments: A male specimen from U. Watut, SW [7+$+11'S 143+$+39'E], 1300-1600 m, 1@ (terminalia slide 519), 1.v.1963, J.L. Gressitt, differs from the type males of *gautieri* in having distinctly smaller tegmina and wings that reach to a little beyond end of abdomen and its habitus resembles that of a female. I provisionally labelled it *Allacta* sp., close to *gautieri* because its genitalia come closest to this species.

Measurements (mm): Length, 9.0; pronotum length x width, 2.5 x 4.1; tegmen length, 8.9; interocular width, 0.7.

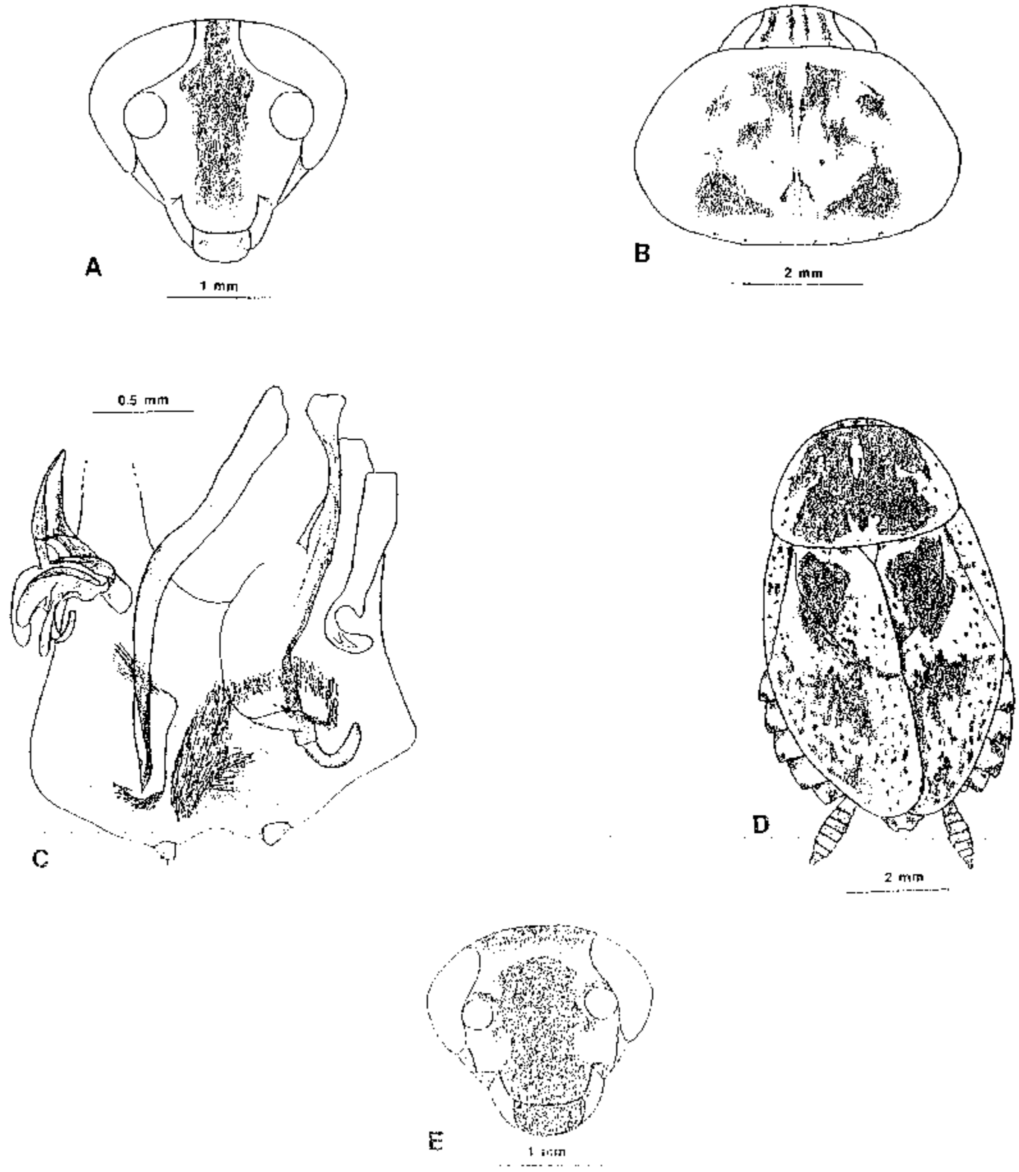
Allacta brossuti spec. nov.
(Figs. 1, 5A-C)

Material examined: *Holotype:* male (terminalia slide 517), New Guinea (NW) [Irian Jaya], SE. Biak I. [1+$+00'S 136+$+06'E], light trap, 1.vii.1962, J.L. Gressitt & J. Sedlacek; in BPBM.

Etymology: The species is dedicated to Dr. R. Brossut of the Université de Bourgogne, Dijon, France, for his contributions to our knowledge of cockroach biology.

Description: Male: Head slightly exposed, eyes close together, interocular width distinctly less than space between antennal sockets (Fig. 5A). Pronotum subelliptical, widest behind middle (Fig. 5B). Tegmina and wings fully developed extending well beyond end

Figure 5. **A - C) = *Allacta brossuti* sp. n., male holotype: A) = head; B) = pronotum. C) = subgenital plate and genitalia (dorsal); E, D) = *Allacta* sp., female from Tsenga, habitus and head.**



of abdomen, former with oblique discoidal sectors. (Wings were stuck to the abdomen and therefore were not spread). Front femur Type B_2 with three large proximal spines; pulvilli only on fourth proximal tarsomere of all legs, tarsal claws symmetrical, simple, arolia well developed. Abdominal terga unspecialized; supraanal plate strongly transverse, hind margin convexly rounded; right and left paraprocts similar, simple sclerotized plates. Subgenital plate almost symmetrical with pair of small similar styli separated by shallowly excavated margin (Fig. 5C). Genitalia as in Fig. 5C: hook on right side with preapical incision; median phallomere with membrane on distal half, apically curved, hook-like and minutely spined; associated median phallomere dark broad rod terminating in membrane, setose at both ends; left phallomere consisting of several simple sclerites.

Colouration: Head yellow with four small dark stripes on occiput, one curved on each side next to eyes, two median ones less distinct; black longitudinal stripe extends from vertex to proximal half of clypeus, distal half yellowish brown, labrum brownish (Fig. 5A); maxillary palpi yellow, base of fifth palpomere dark. Pronotum yellow, disk with dark reddish brown symmetrical pattern, few dark dots (Fig. 5B). Tegmina with yellow veins and large reddish brown maculae, small cells between veinlets dark giving checkered appearance, anterior edge without dark spots. Abdominal terga brownish mottled with light and dark areas. Abdominal sterna with distal segments pale medially, dark laterally. Cerci with segments one to five dark brown, six to ten whitish, 11 and 12 dark, cercomeres 13-15 white, apex dark.

Female: Unknown.

Measurements (mm): Length, 9.8; pronotum length x width, 2.4 x 3.6; tegmen length, 10.1; interocular width, 0.4.

Allacta sp. B
(Figs. 5D, E)

Material examined: Papua New Guinea. BPBM: Daulo Pass [5+$+55'E 145+$+18'E], 2400 m, Asaro-Chimbu div., 15.vi.1955, 1$, 12.vi.1955, J.L. Gressitt; 13 km SE. of Okapa [6+$+32'S 145+$+41'E], 1$, 26.viii.1964, J. & M. Sedlacek.

Description: *Female:* Head slightly exposed, eyes wide apart, interocular space slightly more than distance between antennal sockets (Fig. 5E). Tegmina and wings reduced, reaching to end of abdomen (Fig. 5D) or only to about sixth tergum. Front femur Type B_2 with one to three large proximal spines; pulvilli only on fourth proximal tarsomere, tarsal claws simple, symmetrical, arolia small. Supraanal plate transverse, apex of hind margin shallowly concave.

Colouration: (based mainly on specimen from near Okapa; female from Daulo Pass is badly discolored). Head occiput dark with pair of round yellow maculae, vertex with transverse yellow stripe succeeded by broad blackish longitudinal band extending to clypeus (Fig. 5E). Pronotal disk with large blackish brown macula with few pale markings, lateral border zones hyaline with few dark dots (Fig. 5D). Tegmina with large reddish brown maculae separated by yellowish vein areas (Fig. 5D). Abdominal terga black and yellow, supraanal plate black with longitudinal medial yellow stripe. Subgenital plate dark reddish brown with yellowish anterior border and pale diffuse medial zone, remaining sterna mottled with small dark dots. Cerci blackish, with couple of terminal segments pale on dorsal surface. Legs with infuscated coxae, femora with dark basal and apical bands, tibiae and tarsi with dark incomplete rings.

Measurements (mm): Length, 8.1-9.2; pronotum length x width, 2.2-2.3 x 3.7-3.8; tegmen length, 5.1-6.0; interocular width, 1.2.

Comments: One of the females from Daulo Pass has the same collection data as the holotype male of *deleportei*, but it and the second female have a yellowish transverse band anterior to the antennal sockets, which is absent in the male of that species. The females of sp. B differ from the female which I have determined as *deleportei* in length of tegmina, interocular width, and color pattern of head and pronotum.

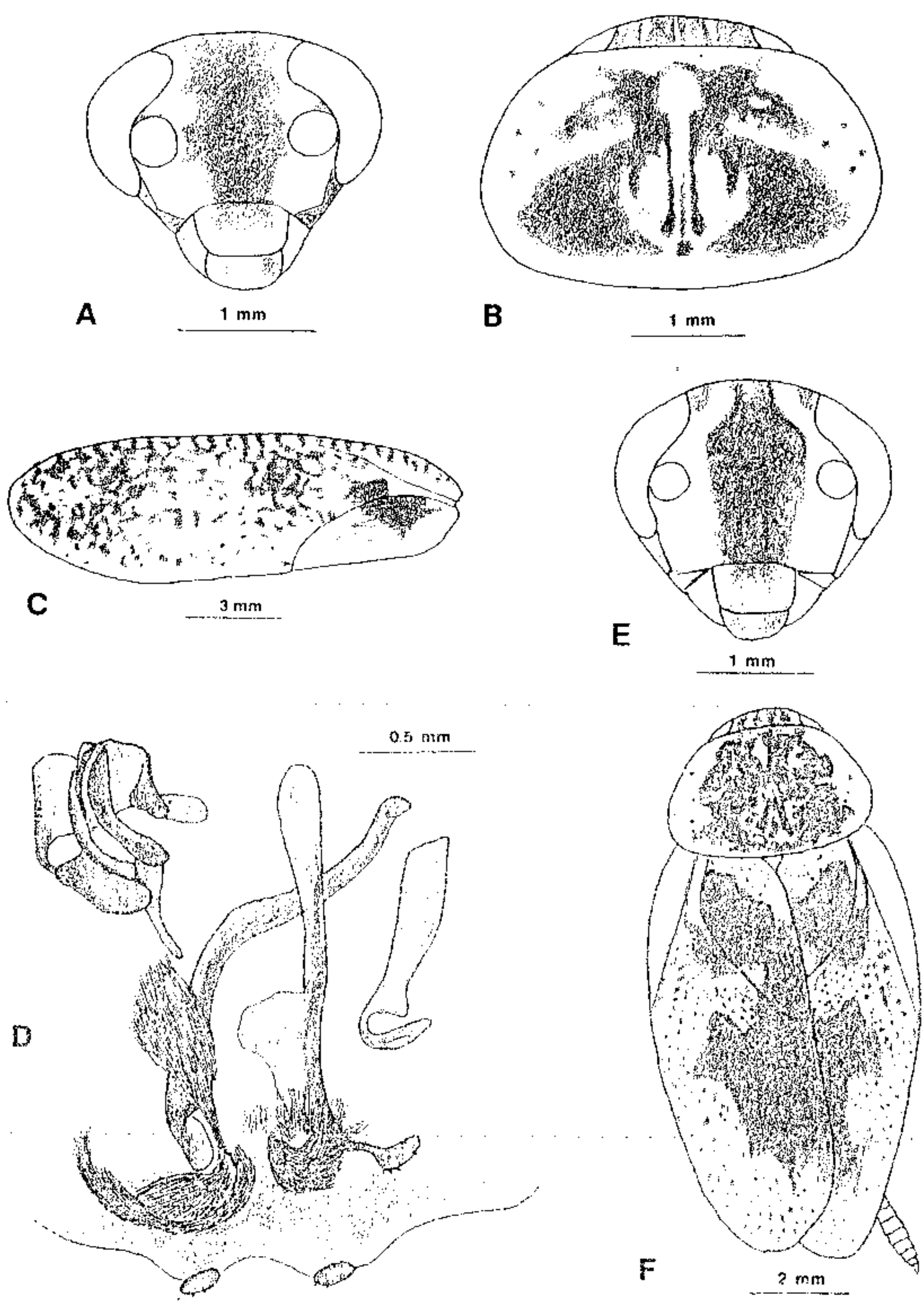
Allacta deleportei spec. nov.
(Figs. 1, 6A-F)

Material examined: *Holotype:* male (terminalia slide 515), New Guinea (NE) [Papua New Guinea], Daulo Pass [5+$+55'E 145+$+18'E], 2400 m, Asaro-Chimbu div., 15.vi.1955, J.L. Gressitt; in BPBM. *Paratype:* Papua New Guinea. BPBM: New Guinea (NE), Purosa [6+$+45'S 145+$+35'E], 20-26 km SE. of Okapa [6+$+32' 145+$+41'E], 1800-2020 m, 1@ (terminalia slide 518), 28.viii.1964, J. & M. Sedlacek. Additional material.- Papua New Guinea. BPBM: New Guinea (NE), 13-20 km SE of Okapa [6+$+32'S 145+$+41'E], 1650-1770 m, 1$, 26.viii.1964, J. & M. Sedlacek; New Guinea (NE), Tsenga [5+$+26'S 144+$+36'E], Upper Jimmi V., 2$$, 15.vii.1955, J.L. Gressitt.

Etymology: The species is dedicated to Dr. Pierre Deleporte, University of Rennes, for his contributions to our knowledge of cockroaches.

Description: *Male:* Head exposed, interocular space about same or slightly less than distance between antennal sockets (Fig. 6A). Pronotum subelliptical, widest near middle (Fig. 6B). Tegmina and wings fully developed extending well beyond end of abdomen, former with oblique discoidal sectors. Front femur Type B_2, with one large proximal spine; pulvilli on fourth proximal tarsomere, tarsal claws symmetrical, simple, arolia present. Abdominal terga unspecialized. Supraanal plate transverse, hind margin shallowly convex, right and left paraprocts similar plates. Subgenital plate with pair of small, deflexed similar styli, interstylar margin concave (Fig. 6D). Genitalia as in Fig. 6D: hook on right side, with preapical incision; median phallomere with apex

Figure 6. ***Allacta teleportei*** **sp. n., male holotype: A) = head; B) pronotum; C) = left tegmen; D) = genitalia and hind margin of subgenital plate; E - F) = female from Daulo Pass Papua New Guinea, head and habitus.**



curved and slightly enlarged, distal region with large lateral membrane; accessory median phallomere broad throughout, apex rounded and with large setose membrane; left phallomere consisting of several simple sclerites.

Colouration: Head yellowish, occiput with four broad light reddish brown stripes that join darker reddish brown band extending from vertex to clypeus, labrum yellowish white (Fig. 6A); maxillary palpomeres three and four pale, fifth segment dark. Pronotum with large symmetrical reddish brown pattern on white and yellowish background, lateral zones with small hyaline areas and opaque white with several small reddish brown dots (Fig. 6B). Tegmina with large reddish brown maculae and smaller dots, veins whitish (Fig. 6C). Abdominal terga and sterna with small dark dots, subgenital plate whitish. Front coxae with small basal and apical brown marks, mid and hind coxae dark (appear to be discolored); femora with dark basal and apical maculae, tibiae and tarsi with dark rings. In male paratype mid and hind coxae have small white basal maculae and cerci are pale on both surfaces.

Female: Head slightly exposed, interocular width less than distance between antennal sockets. Pronotum subelliptical, widest near hind margin (Fig. 6F). Tegmina and wings well developed extending beyond end of abdomen (Fig. 6F). Most legs missing. Supraanal plate transverse, trigonal, apex weakly concave, not quite reaching hind margin of subgenital plate.

Coloration: Head with blackish stripe from vertex to basal half of clypeus, background color on face and occiput whitish, labrum pale (Fig. 6E); maxillary palpomeres three and four pale, terminal segment weakly infuscated basad. Pronotum with reddish brown pattern on yellowish and whitish background, broad lateral borders hyaline with small dots. Tegmina with large reddish brown maculae as in Fig. 6F.

Measurements (mm) ($ in parentheses): Length, 9.5 (9.0-10.4); pronotum length x width, 2.1-2.2 x 3.3-3.5 (2.6-3.0 x 4.0-4.7); tegmen length, 12.0-13.6 (8.5-9.4); interocular width, 0.9-1.0 (0.9-1.0).

Comments: The color patterns on the pronotum and tegmina are slightly different and darker in the male paratype, but the genital phallomeres are almost identical in both type specimens.

Allacta persoonsi spec. nov.

(Figs. 1, 7A-H)

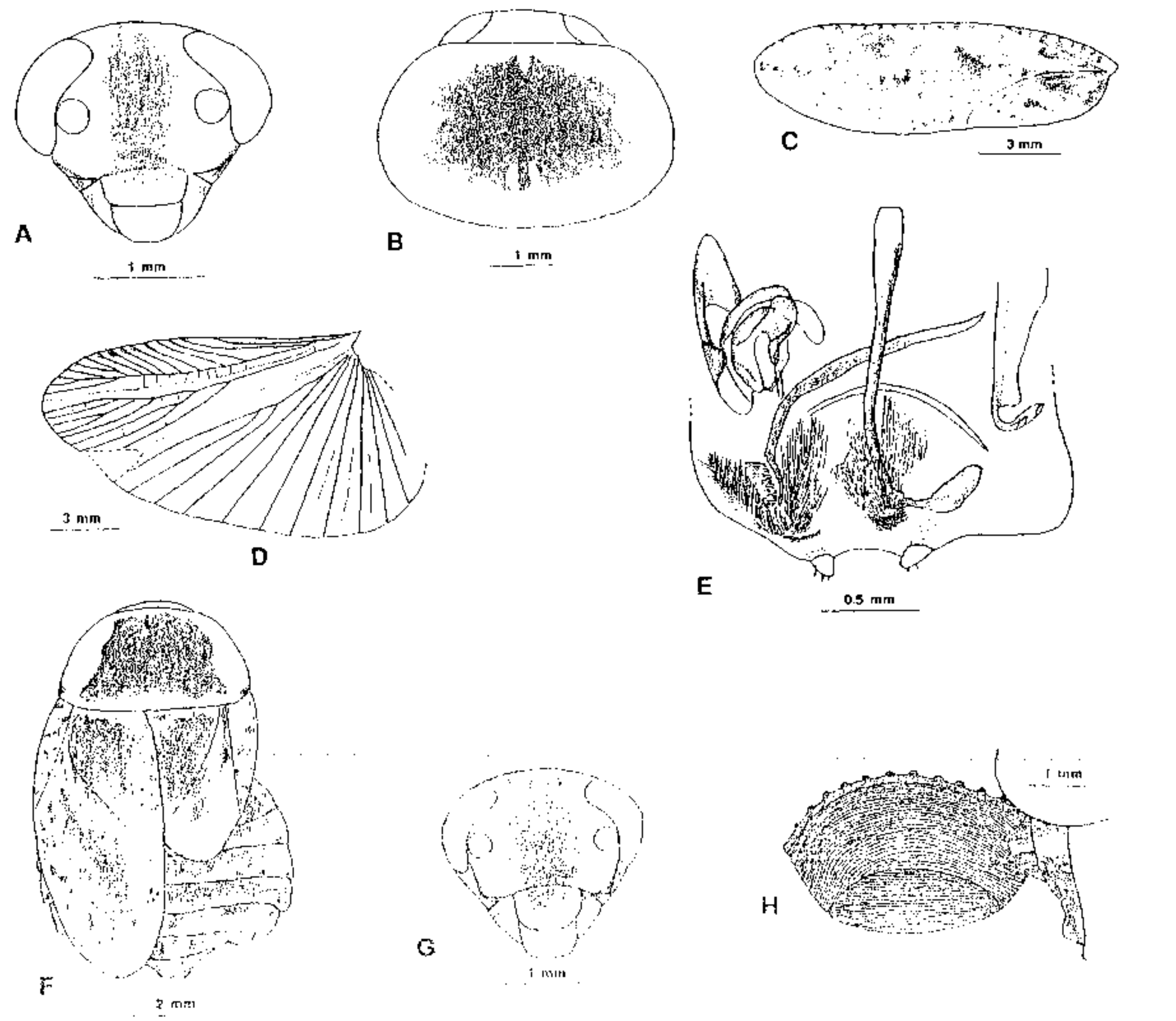
Material examined: *Holotype*: male, New Guinea (NE) [Papua New Guinea], Tsenga [5+$+26'S 144+$+36'E], Upper Jimmi V., 14.vii.1955, J.L. Gressitt; in BPBM. Paratypes.- Papua New Guinea. BPBM: same data as holotype, 1@ (terminalia slide 511), 1$ (carrying ootheca), 1@, 13.vii, 1955. One retained in MCZ.

Etymology: The species is dedicated to Dr. C.J. Persoons of the Netherlands Organization for Applied Scientific Research, who was the first to identify the female sex pheromones of *Periplaneta americana*.

Description: *Male:* Head exposed, interocular space slightly less than distance between antennal sockets (Fig. 7A). Pronotum subelliptical, widest near middle (Fig. 7B). Tegmina and wings fully developed extending well beyond end of abdomen, former with oblique discoidal sectors. Hind wing with proximal seven costal veins clubbed, radial vein simple, straight, cubitus vein almost straight with five complete (two bifurcate) and no incomplete branches, apical triangle small (Fig. 7D). Front femur Type B_2 with three large proximal spines; pulvilli only on fourth proximal tarsomeres, tarsal claws symmetrical, simple, arolia small. Abdominal terga unspecialized. Supraanal plate strongly transverse, hind margin shallowly convex, entire, right and left paraprocts similar simple sclerites. Subgenital plate with pair of small similar styli separated by weakly concave interstylar margin (Fig. 7E). Genitalia as in Fig. 7E: hook on right side with preapical incision; median phallomere distally swollen and with large setose membrane lying above it; two rodlike sclerites curve under median phallomere, one very dark terminating in large dense group of setae, other much more slender and unmodified distally; left phallomere consists of several small sclerites.

Colouration: Yellow and dark reddish brown. Head yellow with a wide longitudinal stripe between antennal sockets extending from vertex almost to distal margin of clypeus, labrum yellow (Fig. 7A); maxillary palpomeres three and four pale, segment five slightly darker; antennae yellow. Pronotal disk with large reddish brown macula that may be almost solidly dark (Fig. 7B), or with variable amounts of dull yellowish areas or small symmetrical dots and lines, broad lateral and narrow anterior and posterior zones subhyaline yellow. Tegmina hyaline, veins yellowish or white, reddish brown between veins and veinlets, and two or three small solidly dark areas (Fig. 7C). Wings clear, veins yellowish, some infuscation for short

Figure 7. ***Allacta persoonsi*** **sp. n. A - E) = males: A = head; B) = pronotum; C) = left tegmen; D) = left hind wing (apical triangle region damaged); E) = subgenital plate and genitalia (dorsal); F - H) female: F) = habitus; G) = head; H) = Ootheca attached to the end of the subgenital plate (dorsal view of supraanal plate which is partly hidden by the apex of the left tegmen; the ootheca is rotated to the left so that its flat bottom surface is visible). (A - D, from holotype, E - H, from paratype, same locality as holotype).**



distance on margin posterior to apical triangle. Abdomen dark reddish brown, supraanal and subgenital plates yellowish brown. Legs yellowish brown with dark brown bands: coxae and femora dark brown in basal and distal regions; metatarsi darkly ringed at base, apex, and middle. Cerci light brown.

Female: Shorter and stockier than male. Interocular space slightly less than distance between antennal sockets (Fig. 7G). Pronotum subparabolic (Fig. 7F). Tegmina reduced reaching to end of abdomen (left tegmen), right tegmen abnormal reaching only to fourth abdominal tergum (Fig. 7F). Hind wing vestigial, lateral, reaching only to first abdominal tergum. Brown areas much darker than male. Pronotal macula solidly dark (Fig. 7F). Abdominal terga dark with lateral yellow spots on segments two to five, sixth mostly yellow, segment seven dark with two medial yellow longitudinal stripes, supraanal plate with narrow yellow stripe medially (Fig. 7F). Abdominal sterna with large dark medial macula on proximal segments, lighter areas with dark dots, subgenital plate blackish, anterior margin yellow.

Measurements (mm) ($in parentheses): Length, 9.0-9.2 (7.0);pronotum length x width, 2.2 x 3.4-3.5 (2.2 x 3.6); tegmen length, 12.0-12.8 (5.5); interocular width, 0.7-0.8 (1.2).

Ootheca: The ootheca carried by the female is attached to the tip of the subgenital plate by a small piece of dried membrane and is rotated to the left at a 45° angle (Fig. 7H). This suggests that the egg case was being rotated prior to its deposition, but that is questionable since the Pseudophyllodromiinae normally do not rotate their oothecae. It is possible that the egg case was being deposited in the vertical position but accidentally assumed a 45° angle when the female was collected. The ootheca is reddish brown, bulbous, with a flat bottom that suggests it is probably cemented vertically to a surface (perhaps on leaves) with its keel directed dorsad; the keel has 15 distinct rounded serrations indicating the presence of 15 eggs; the outer walls have many fine curved parallel ridges and no longitudinal egg cell demarcations are visible.

Measurements (mm): Length, 3.5; width, 2.0; height, 1.5.

The ootheca resembles the egg case of *Chorisoneura apolinari* Hebard (Pseudophyllodrom-iinae) but that species has considerably fewer parallel ridges in the outer membranous covering (Roth 1968: fig. 68).

Allacta nalepae spec. nov.
(Figs. 1, 8A-H)

Material examined: *Holotype:* male (terminalia slide 514), New Guinea (NE) [Papua New Guinea], Karimui [6+$+32'S 144+$+47'E], 3.vi.1961, J.L. & M. Gressitt; BPBM. Additional material.- Papua New Guinea. BPBM: Mt. Karimui [6+$+32'S 144+$+47'E], 2100-2300 m, 1$, 16-20.iv.1977, J.L. Gressitt *et al.*

Etymology: The species is dedicated to Dr. Christine A. Nalepa, North Carolina State University, for her contributions to our knowledge of *Cryptocercus* biology.

Description: *Male:* Head with interocular space about same as distance between antennal sockets (Fig. 8A). Pronotum subelliptical widest near middle (Fig. 8B). Tegmina and wings fully developed extending beyond end of abdomen, discoidal sectors of former oblique. Front femur Type B_2, with one large proximal spine; pulvilli on fourth proximal tarsomere only, tarsal claws simple, symmetrical, arolia present. Abdominal terga unspecialized. Supraanal plate transverse, hind margin convexly rounded, medially slightly indented, right and left paraprocts similar simple plates (Fig. 8C). Subgenital plate with pair of small similar styli, interstylar margin concave (Fig. 8D). Genitalia as in Fig. 8D: hook on right side with preapical incision; median phallomere without lateral membrane, distal end scythe-like, apex not swollen; accessory median phallomere slender throughout with large apical setose membrane.

Colouration: Head with four dark occipital bands, the medial stripes fusing on vertex and extending as dark brown stripe to anteclypeus, labrum lighter, cheeks yellowish white (Fig. 8A). Pronotal disk with reddish brown pattern, broad lateral zones hyaline (Fig. 8B). Tegmina with large reddish brown maculae and small dots and patches, anterior costal region hyaline. Legs brownish yellow, coxae dark brown proximally and distally; femora with dark spots basad and near apices. Cerci pale, apex dark.

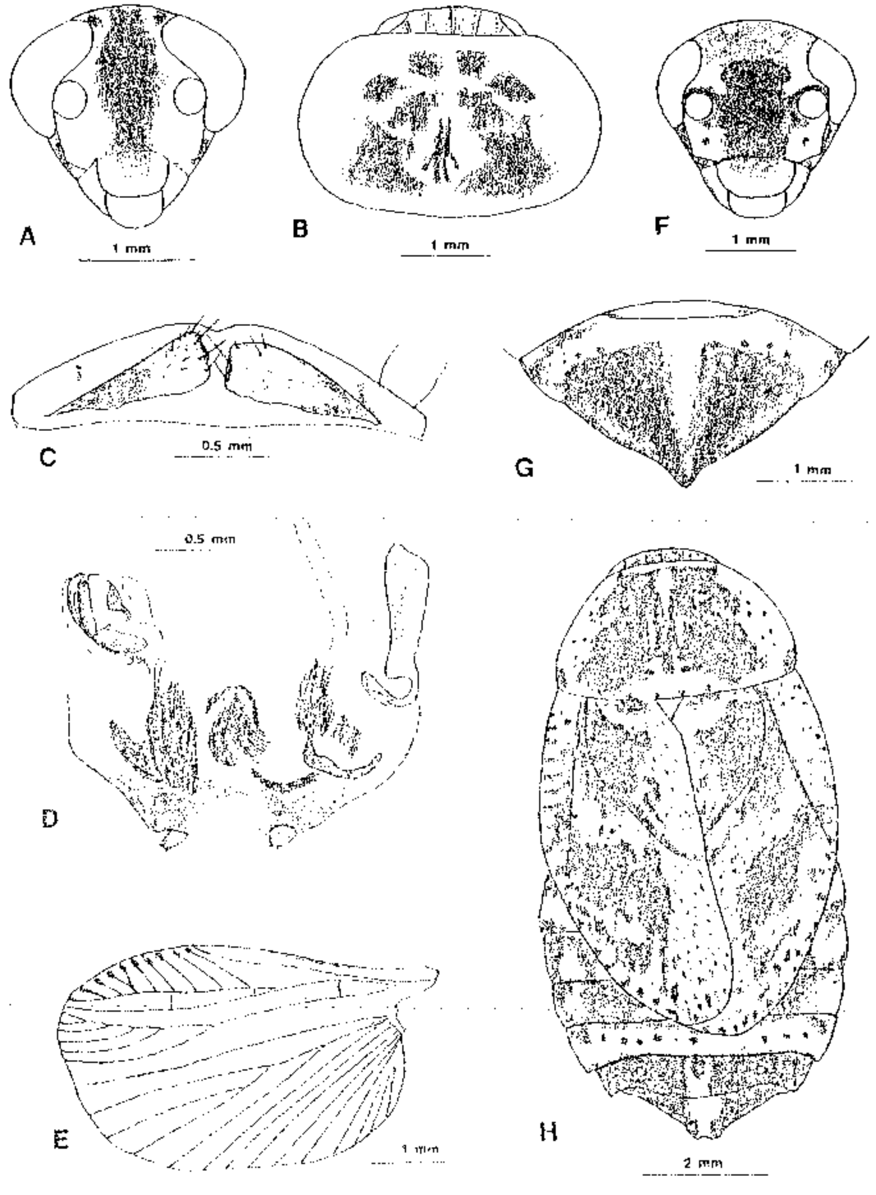
Female: Head exposed, eyes wide apart, interocular width greater than distance between antennal sockets (Fig. 8F). Pronotum subparabolic (Fig. 8H). Tegmina and wings reduced, former with oblique discoidal sectors, reaching only to sixth segment (Fig. 8H). Hind wings slightly smaller reaching to segment five, cubitus vein with five complete and no incomplete branches, apical triangle absent (Fig. 8E). Front femur Type B_2 with two large proximal spines; pulvilli on fourth proximal tarsomere only, tarsal claws symmetrical, simple, arolia small. Supraanal plate transverse, trigonal, apex, shallowly concave (Fig. 8H).

Colouration: Head with occiput light reddish brown and three small yellow spots; broad dark reddish brown stripe extends from vertex to clypeus, labrum and cheeks yellow (Fig. 8F). Pronotum with very dark reddish brown symmetrical pattern on yellow background, broad lateral zones opaque yellow with numerous small reddish brown dots (Fig. 8H). Tegmen with large reddish brown macula in anal vein area and one large and two smaller marks, rest of tegmen checkered with small dots (Fig. 8H). Abdominal terga mostly reddish brown with yellowish areas. Subgenital plate mostly reddish brown with narrow yellow band along anterior border and partway down middle (Fig. 8G). Coxae and femora with dark areas basad and apically; tibiae with dark rings basad, medially, and apically; tarsi with dark apical rings.

Measurements (mm) ($ only): Length, 9.2; pronotum length x width, 2.3 x 3.7; tegmen length, 5.8; interocular width, 1.2.

Comments: The female was taken in the same area as the male type of *nalepae* but their head color patterns differ. However, I am provisionally considering them to be conspecific. The problem is exacerbated by the fact that females from Karimui have colour patterns similar to those of what I have determined as *gautieri*. More males and females are needed to determine if the sexes have been properly matched.

Figure 8. ***Allacta nalapae*** **sp. n. A - D) = male holotype: A) = head; B) = pronotum; C) = supraanal plate and paraprocts (ventral); D) = distal part of subgenital plate, and genitalia (dorsal); E - H) = female from locality as holotype: E) = hind wing; F) = head; G) = subgenital plate (ventral); H) = habitus.**



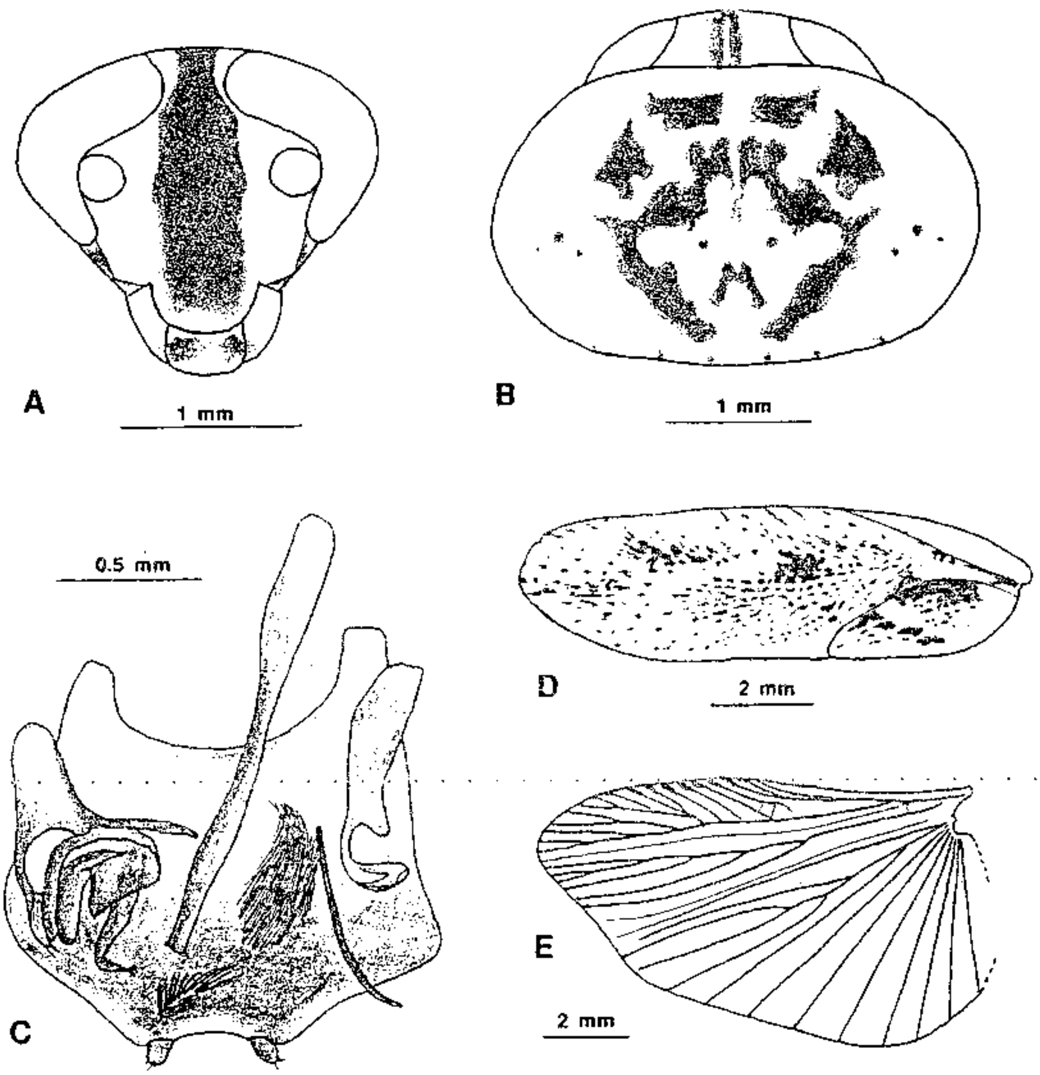
Allacta srengi spec. nov.
(Figs. 1, 9A-E)

Material examined: *Holotype:* male (terminalia slide 516), New Guinea (NE) [Papua New Guinea], 10 km N. of Angoram [4+$+04'S 144+$+03'E], 10-30 m, 15.viii.1969, J.L. Gressitt; in BPBM. Additional material.- Papua New Guinea. BPBM: Star Mts., Sibil Val., [5+$+00'S 141+$+00'E], 1245 m, 1@ (terminal abdominal segments missing), 18.x.-8.xi.1961, L.W. Quate.

Etymology: The species is dedicated to Dr. Leam Sreng of the Centre National de la Recherche Scientifique, Marseille, France, for his contributions to our knowledge of cockroach pheromones.

Description: *Male:* Head with eyes close together, interocular space distinctly less than distance between antennal sockets (Fig. 9A). Pronotum subelliptical widest near middle (Fig. 9B). Tegmina and wings fully developed extending well beyond end of abdomen, former with oblique discoidal sectors. Hind

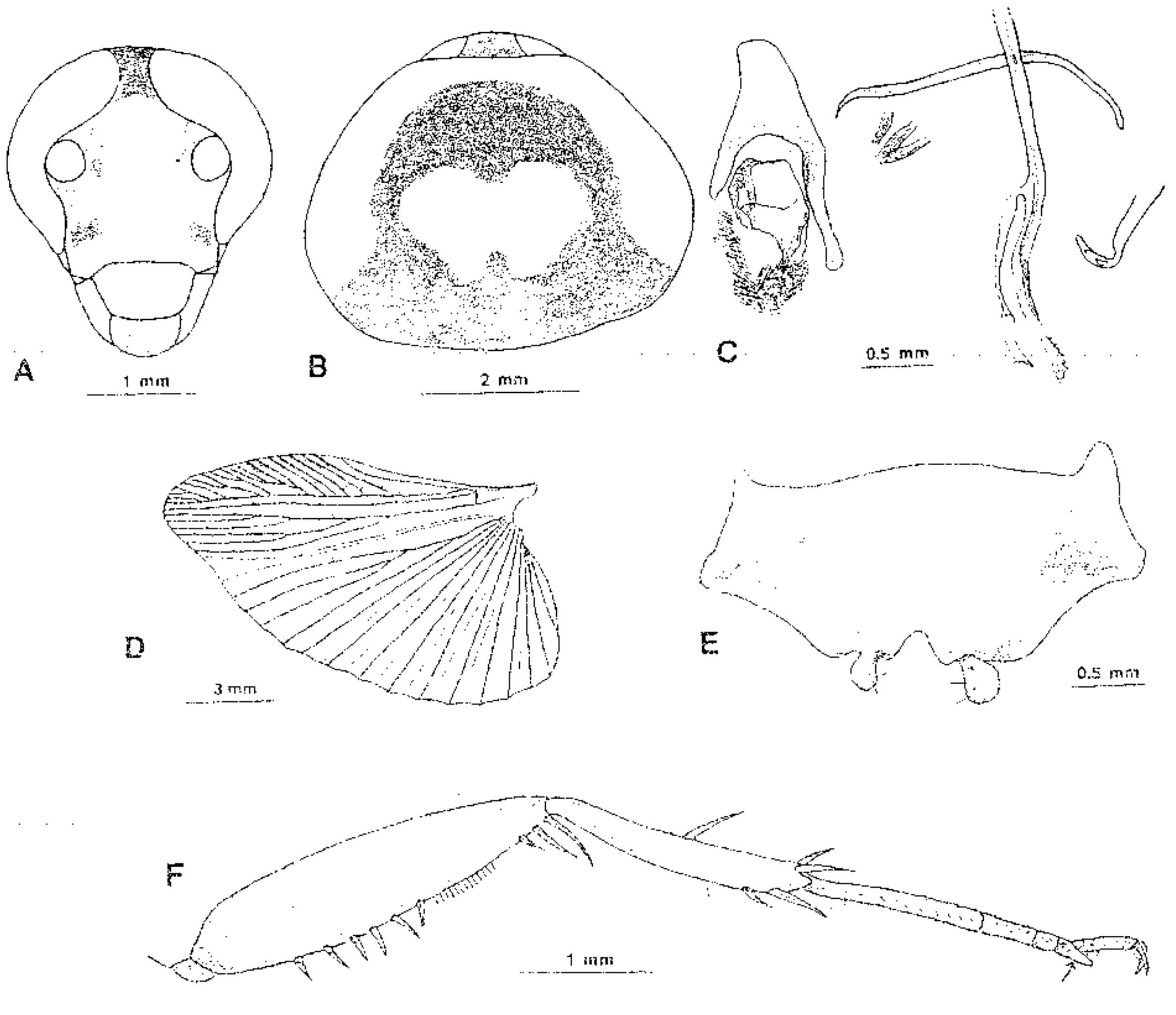
Figure 9. ***Allacta srengi*** **sp. n., males: A) = head; B) = pronotum; C) = subgenital plate and genitalia (dorsal); D) = left tegmen; E) = left hind wing. (A - D, from holotype, E, Ffrom Star Mts., Sibil Valley).**



wing with simple and one multiple branched clubbed costal veins, radial and media veins simple straight, cubitus vein straight with four complete (one branch may be forked) and no incomplete branches, apical triangle subobsolete (Fig. 9E). Front femur Type B_2 with three large proximal spines; pulvilli on fourth proximal tarsomere only, tarsal claws simple, symmetrical, arolia small. Abdominal terga unspecialized. Supraanal plate transverse, hind margin shallowly convexly rounded, right and left paraprocts similar simple plates. Subgenital plate with two small similar styli, interstylar margin weakly concave (Fig. 9C). Genitalia as in Fig. 9C: hook on right side, with preapical incision; median phallomere rodlike, unmodified apically; accessory median phallomere a simple slender rod; two patches of setae, one on right side, and smaller one near apex of median phallomere.

Colouration: Head whitish with pair of very close dark brown longitudinal stripes that fuse on vertex, broaden and extend to about middle of pale clypeus, labrum darker, mandibles whitish (Fig. 9A); maxillary palpomeres pale, fifth segment weakly infuscated. Pronotum with reddish brown pattern on sparsley

Figure 10. ***Allacta svensonoru*** **sp. n., male holotype: A) = head; B) = pronotum; C) = genitalia (dorsal); F) = front leg (anterior surface, coxa not shown; arrow indicates pulvillus on fourth tarsomere).**



speckled white background (Fig. 9B). Tegmina with white veins, and three reddish brown blotches, some veins and cells between veinlets reddish brown giving checkered appearance (one large blotch occurs in anal vein area and two smaller ones in remaining part of the tegmen; Fig. 9D) (maculae larger on right tegmen). Front coxae pale, others dark brown; femora pale with dark brown basal and apical spots, tibiae and tarsi with dark spots. The leg markings of the Star Mts. male are more pronounced than those of the holotype.

Female: Unknown.

Measurements (mm) (the Star Mt. @ is larger than the holotype and is listed in brackets): Pronotum length x width, 2.0 x 3.1 [2.2 x 3.6]; tegmen length, 9.1 [11.4]; interocular width 0.4 [0.5].

hamifera **- species group**

***Allacta svensonorum* spec. nov.**
(Figs. 10A-F)

Material examined: *Holotype:* male (terminalia slide 427), Borneo, **Sarawak,** Bako National Park, 26-31.xii.1978, Gärdenfors, Hall, Hansson, Samuelsson; in ZILS.

Etyomology: The species is named after Dr. Göran K. Svensson, biophysicist, and his wife Ingela, good friends and neighbors.

Description: *Male:* Head slightly exposed, eyes very close together, interocular space much less than distance between antennal sockets (Fig. 10A). Pronotum suboval, widest behind middle (Fig. 10B). Tegmina and wings fully developed extending beyond end of abdomen, former with oblique discoidal sectors. Hind wing with radial and media veins straight, simple, cubitus vein straight, with four complete (one forked) and no incomplete branches, apical triangle small (Fig. 10D). Front femur Type B_3 with five or six large proximal spines; pulvilli only on fourth proximal tarsomere, tarsal claws symmetrical, simple, arolia small (Fig. 10F). Abdominal terga unspecialized. Supraanal plate strongly transverse, hind margin convex; paraprocts simple similar plates. Subgenital plate hind margin medially excised (seen more clearly in slide preparation) with pair of small bulbous styli, right one slightly larger (Fig. 10E). Genitalia as in Fig. 10C: hook on right side, small, with preapical incision, median phallomere with minutely spicular apex, and slender process arising about near middle; slender, longitudinal, narrow, rodlike sclerite lies under median phallomere; left phallomere with large setose membrane.

Colouration: Head with occiput and vertex dark brown, remainder yellowish with some weakly dark areas near eyes and on cheeks (Fig. 10A). Pronotum with yellowish macula surrounded by dark brown, anterior and lateral regions yellowish, subhyaline (Fig. 10B). Tegmina reddish brown, hyaline, humeral field yellowish, distinct markings absent. Hind wing with costal vein zone yellowish, anal field weakly infuscated. Abdominal terga and sterna brownish yellow, lateral edges dark. Dorsal surface of cerci with three or four dark basal segments, remaining cercomeres pale. Legs brownish yellow.

Female: Unknown.

Measurements (mm): Length, 12.0; pronotum length x width, 3.6 x 4.9; tegmen length, 13.0; interocular width, 0.2.

Comments: The pronotal markings of *svensonorum* resemble those of *Allacta interrupta* (Hanitsch) (Sarawak, Java) (Roth 1993: fig 4A), *A. figurata* (Walker) (India) (Roth 1993: fig. 5B), and *A. maculicollis* (Hanitsch) (South Vietnam) (Roth 1991: fig. 33C). *Allacta svensonorum* keys to couplet 11 in Roth (1993: 363) where it can be separated from *interrupta* and *figurata* by differences in head and tegminal markings.

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