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ABSTRACT

Populations of the earthworm Pontoscolex corethrurus *were measured in mounded sweet potato cultivation (*Ipomoea batatas *(L.), Lam.), and mean values for the trial blocks ranged from 93 to 302 individuals per m² (46.5 to 127.7 g fresh weight). Populations were higher on a drained peaty clay soil than on a drier, less organic alluvial soil. Mean sweet potato yields per block ranged from 324 to 776 g dry matter of tuber and 286 to 497 g dry matter of topgrowth per m². Soil moisture content was negatively correlated with crop production. There was no correlation between crop production and earthworm population for the whole trial, but mounds with less than 43 g of earthworm freshweight per m² showed a positive and significant correlation with topgrowth production. In one block of the trial with a peaty clay soil, tuber production was negatively correlated with worm yield. In another block with an alluvial soil, topgrowth yields were positively correlated with worm yields. Weekly rainfall was positively correlated to earthworm population.*

COMPARISON OF STYLO (*STYLOSANTHES GUIANENSIS* VAR GUIANENSIS) CULTIVARS IN THE MARKHAM VALLEY OF PAPUA NEW GUINEA

P.A. Chadhokar, Papua New Guinea Agricultural Journal, 31 (1-4): 15-21

ABSTRACT

Two new cultivars of the pasture legume, Stylosanthes guianensis *var. guianensis, Cook and Endeavour were compared with the cultivar Schofield in pure and mixed sward with grass under low (1,250 mm) and high (2,800 mm) rainfall conditions in the Markham Valley of Papua New Guinea. Performances of the three cultivars were similar and the differences between their dry matter yields were not significant. They combined well with the companion grasses and the mean percentage of legume in the dry matter was 48, 52 and 52 for Cook, Endeavour and Schofield respectively. All the three cultivars responded to the application of phosphorus and sulphur.*

(continued overleaf)

OPTIMUM REPLANTING STAGE FOR TWO VARIETIES OF PIT-PIT (*SETARIA PALMIFOLIA*) IN THE HIGHLANDS OF PAPUA NEW GUINEA

C.J. Rose, Papua New Guinea Agricultural Journal, 31 (1-4): 23-29

ABSTRACT

Two varieties of edible pit-pit were grown near Tari in the Southern Highlands Province. The crop was progressively harvested over 512 days with a total of five harvests. Yields over the whole trial were 5.0 and 3.9 tonnes of edible portion per hectare for the two varieties, Mbu and Banguma respectively.

A quadratic regression of cumulative edible portion per day on days after planting demonstrated that rate of growth declined approximately 350 days after planting for Mbu and 325 days for Banguma. The decline in both varieties was due to a lower individual stem weight and a higher percentage of waste (non-edible portion of total harvested) the longer the crop was in the ground.

It is estimated that an increase of 2.0 and 1.8 tonnes per hectare for Mbu and Banguma respectively could be attained by harvesting every 100 days and practicing 325 day replanting rather than leaving the crop in situ *for over 600 days.*

REPLANTING ON COPRA PLANTATIONS

A. Shepherd, Papua New Guinea Agricultural Journal, 31 (1-4): 31-35

ABSTRACT

A postal survey of the larger copra plantations in Papua New Guinea was undertaken in order to ascertain the level of replanting in recent years and the plantations' plans for the future. Results showed a very low level of replanting with no indication that this situation is likely to change in the near future. Reasons for this are considered and possible action to counter the trend is discussed.

ZOPHIUMA LOBULATA GHAURI (HOMOPTERA: LOPHOPIDAE) AND ITS RELATION TO THE FINSCHHAFEN COCONUT DISORDER IN PAPUA NEW GUINEA

E.S.C. Smith, Papua New Guinea Agricultural Journal, 31 (1-4):37-45

ABSTRACT

*Coconut palms (*Cocos nucifera*) in the Finschhafen area of the Morobe Province of Papua New Guinea are frequently affected by the feeding activities of* Zophiuma lobulata *Ghauri (Homoptera: Lophopidae), which causes bronzing of fronds, reduction in yield, marked stunting of growth and occasionally, the death of young palms. Typical symptoms were induced 7-15 months after caging adult and immature leaf hoppers over potted coconut palms.*

Studies on the life history and egg parasitism rates in the field showed that the total generation time was about four months, and included an 8-9 day egg incubation, 82-85 days in the immature nymphal stages and a 30 day preoviposition period. Egg masses were found to be heavily parasitised by an encyrtid wasp Ooencyrtus malayensis *Ferriere which, in conjunction with entomophagous fungi may possibly exert a controlling influence on* Z. lobulata *populations occurring in other areas. A second encyrtid, gen. nr.* Epiencyrtoides *was also found to parasitise an egg mass in the Northern Province.*

TOXICITY OF *LEUCAENA LEUCOCEPHALA* II. REDUCED FERTILITY OF HEIFERS GRAZING *LEUCAENA LEUCOCEPHALA*

J.H.G. Holmes, Papua New Guinea Agricultural Journal, 31 (1-4): 47-50

ABSTRACT

Twenty four heifers grazing Leucaena leucocephala *cv. Peru were mated when they reached 300 kg live weight. Eight heifers conceived in less than four months, ten conceived in 9-18 months and six did not conceive in 12-27 months. Eleven similar heifers on grass pastures all conceived in less than two months. Growth rates of heifers with different reproductive performances were similar. Fourteen heifers were slaughtered, including six which had not conceived, five which were not detectably pregnant by rectal palpation but had embryos one to six weeks old and three which had calved but not conceived again. All had some degree of goitre. All non-pregnant heifers had ovaries and uteri of normal appearance. All calves born had goitre. Five heifers tested pregnant failed to produce a calf. Three bulls used had normal semen and libido. A defect is suspected in establishment or maintenance of pregnancy after mating.*

(continued overleaf)

IMPERATA CYLINDRICA FOR CATTLE PRODUCTION IN PAPUA NEW GUINEA

J.H.G. Holmes, C. Lemerle and J.H. Schottler, Papua New Guinea Agricultural Journal, 31 (1-4): 51-62

ABSTRACT

Economic and practical farming considerations on smallholder farms in Papua New Guinea preclude replacement of lowly-productive Imperata cylindrica *with fully improved pastures, although a great increase in beef production could be obtained by full pasture improvement.*

A pasture cutting trial showed that Imperata cylindrica *cut every four weeks contained 1.5% N, but productivity rapidly declined. At six, eight or twelve week cutting intervals, yields of dry matter were greater than for nine improved species cut at six week intervals but N was less (0.93-1.14%).*

A grazing trial over three years showed higher production by fully improved pastures and a small increase due to Stylo + Imperata *over unimproved* Imperata. *A more suitable legume is needed for this soil type. Unimproved* Imperata *produced the same cattle weight gains at all stocking rates, indicating that at lower stocking rates cattle were unable to select a better diet.*

A nylon bag digestibility trial showed that Imperata *was about two thirds as digestible as Buffel grass, Setaria or Elephant grass, at three, five, seven and nine weeks. The rate of digestion was low. These data indicate that* Imperata *is never a high quality pasture and consequently no pasture management technique can produce rapid gains. Only substitution, partially with legumes or totally with fully improved pastures can produce rapid growth.*

On smallholder cattle farms with Imperata*-dominant pastures, breeding rate in cows ranged from 75 to 100%. Growth rates were variable and age at turnoff of steers at 450 kg ranged from 25 to 44 months; management was an important component in this variation.*

We conclude that Imperata *pastures can support a viable extensive beef production system which can be improved with broadcasting of those legumes appropriate to the environment. Low stocking rates are necessary in Papua New Guinea; but the large areas of unutilized grassland make this no obstacle.*

INSECT FAUNA OF OIL PALM IN THE NORTHERN PROVINCE OF PAPUA NEW GUINEA

P.M. Room, Papua New Guinea Agricultural Journal, 31 (1-4): 63-67

ABSTRACT

Pyrethrum knockdowns were used to sample the insect faunas of two 3 ha plots of oil palm. Approximately 150 samples were taken in each plot at regular intervals throughout 1973. The ant Anoplolepis longipes *was the most abundant insect present. Five or more specimens of a further 25 species of insect were taken, and the distribution of some of these was found to vary between plots and between the edges and interior of the plots. The insect fauna of the Saiho plot changed substantially between 1968 and 1973; it is suggested that the changes were associated with the development of the palms, and that change was continuing during the study. Very little insect damage was present, in marked contrast to plantation situations elsewhere; in particular no Psychidae were found.* Scapanes australis *was the only species causing significant damage.*

APPARENT DIGESTIBILITIES OF DRY MATTER, ORGANIC MATTER, CRUDE PROTEIN, ENERGY AND ACID DETERGENT FIBRE OF CHOPPED, RAW SWEET POTATO (*IPOMOEA BATATAS* (L.)) BY VILLAGE PIGS (*SUS SCROFA PAPUENSIS*) IN PAPUA NEW GUINEA

C.J. Rose and G.A. White, Papua New Guinea Agricultural Journal, 31 (1-4): 69-72

ABSTRACT

Mean apparent digestibilities of the components of sweet potato tubers measured with village pigs were 95.3%, 96.1%, 94.2% and 72.4% for dry matter, organic matter, energy and acid detergent fibre respectively. The digestibility of the crude protein was significantly different ($P < 0.05$) measured with two groups of pigs of different ages. These were 57.2% for 15 month old pigs and 42.3% for the 10 month old group.

SOME ENVIRONMENTAL FACTORS AFFECTING EARTHWORM POPULATIONS AND SWEET POTATO PRODUCTION IN THE TARI BASIN, PAPUA NEW GUINEA HIGHLANDS

C.J. Rose* and A.W. Wood†

ABSTRACT

Populations of the earthworm Pontoscolex corethrurus *were measured in mounded sweet potato cultivation (*Ipomoea batatas *(L.), Lam.), and mean values for the trial blocks ranged from 93 to 302 individuals per m² (46.5 to 127.7 g fresh weight). Populations were higher on a drained peaty clay soil than on a drier, less organic alluvial soil. Mean sweet potato yields per block ranged from 324 to 776 g dry matter of tuber and 286 to 497 g dry matter of topgrowth per m². Soil moisture content was negatively correlated with crop production. There was no correlation between crop production and earthworm population for the whole trial, but mounds with less than 43 g of earthworm freshweight per m² showed a positive and significant correlation with topgrowth production. In one block of the trial with a peaty clay soil, tuber production was negatively correlated with worm yield. In another block with an alluvial soil, topgrowth yields were positively correlated with worm yields. Weekly rainfall was positively correlated to earthworm population.*

INTRODUCTION

Interest in earthworms and sweet potato production developed from observations on village pigs (*S. scrofa papuensis*) at Piwa Agricultural Station near Tari. Tethered pigs ate considerable quantities of earthworms when foraging in old sweet potato gardens, and these were thought to account for a high proportion of total protein intake. The importance of earthworms is also asserted by the Huli people of Tari who transfer them to areas of low earthworm population to improve the quality of pig foraging. Swamp lands are considered most suitable for uncontrolled pig foraging, partly because of their high earthworm populations.

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Research on earthworm populations in cultivated areas has been largely connected with their beneficial effects on the break-down of organic matter and on aeration and soil structure (Edwards and Lofty 1977: ch. 8). In Papua New Guinea little research on earthworms has been reported apart from a study concerning the influence of earthworms on microrelief features in lowland areas (Haantjens 1965; Lee 1967).

A trial was carried out to observe earthworm populations under sweet potato cultivation, to identify the species of earthworm present, and to investigate any relationships between edaphic and climatic conditions and crop and earthworm yields. The trial was conducted at Piwa Agricultural Station in the Tari Basin, Southern Highlands Province (*Figure 1*).

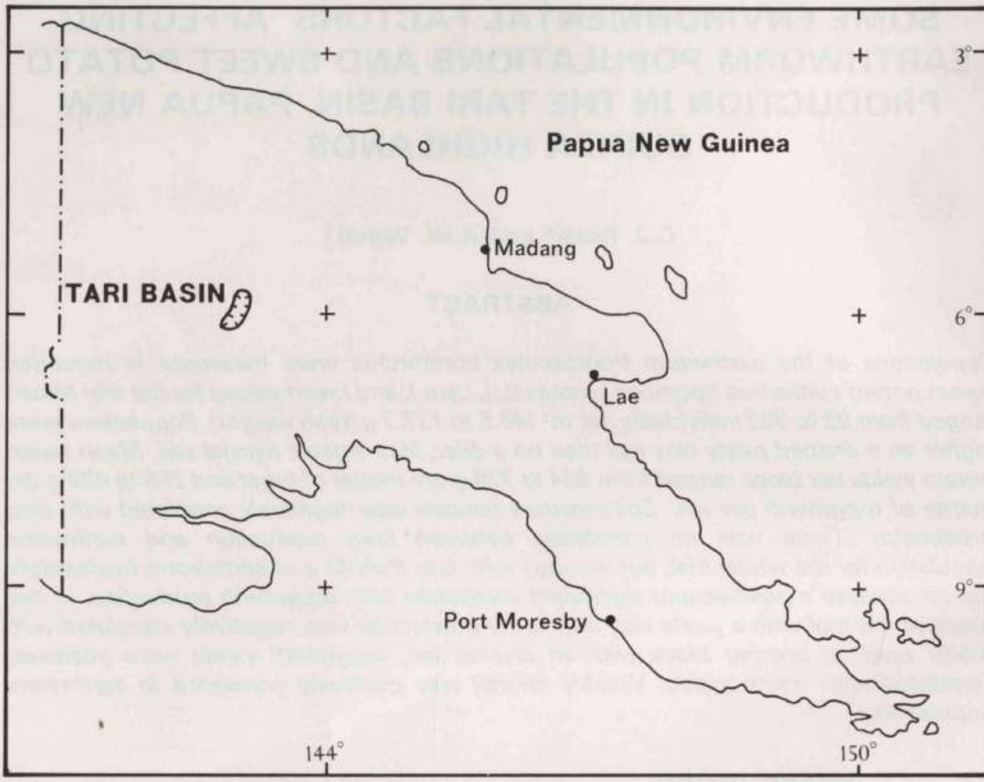


Figure 1.—**Location of the Tari Basin**

The Tari Basin is one of a series of intermontane valleys in the New Guinea Highlands between 1,500 and 2,000 m. These valleys are characterised by the intensive cultivation of sweet potato which forms the staple for the high human and pig populations (Brookfield 1964).

THE STUDY AREA

Piwa is situated 3.0 km south east of Tari at a height of 1,620 m, adjacent to an undrained swamp. The soils are typical of the intensively cultivated lowland parts of the Tari Basin. The climate is representative of the New Guinea Highlands with an annual rainfall of 2,693 mm, well distributed throughout the year, and no month registering less than 155 mm. Temperatures vary little during the year and mean monthly maxima range from 22.8 to 24.4°C and mean monthly minima from 12.5 to 14.0°C (McAlpine, Keig and Short 1975).

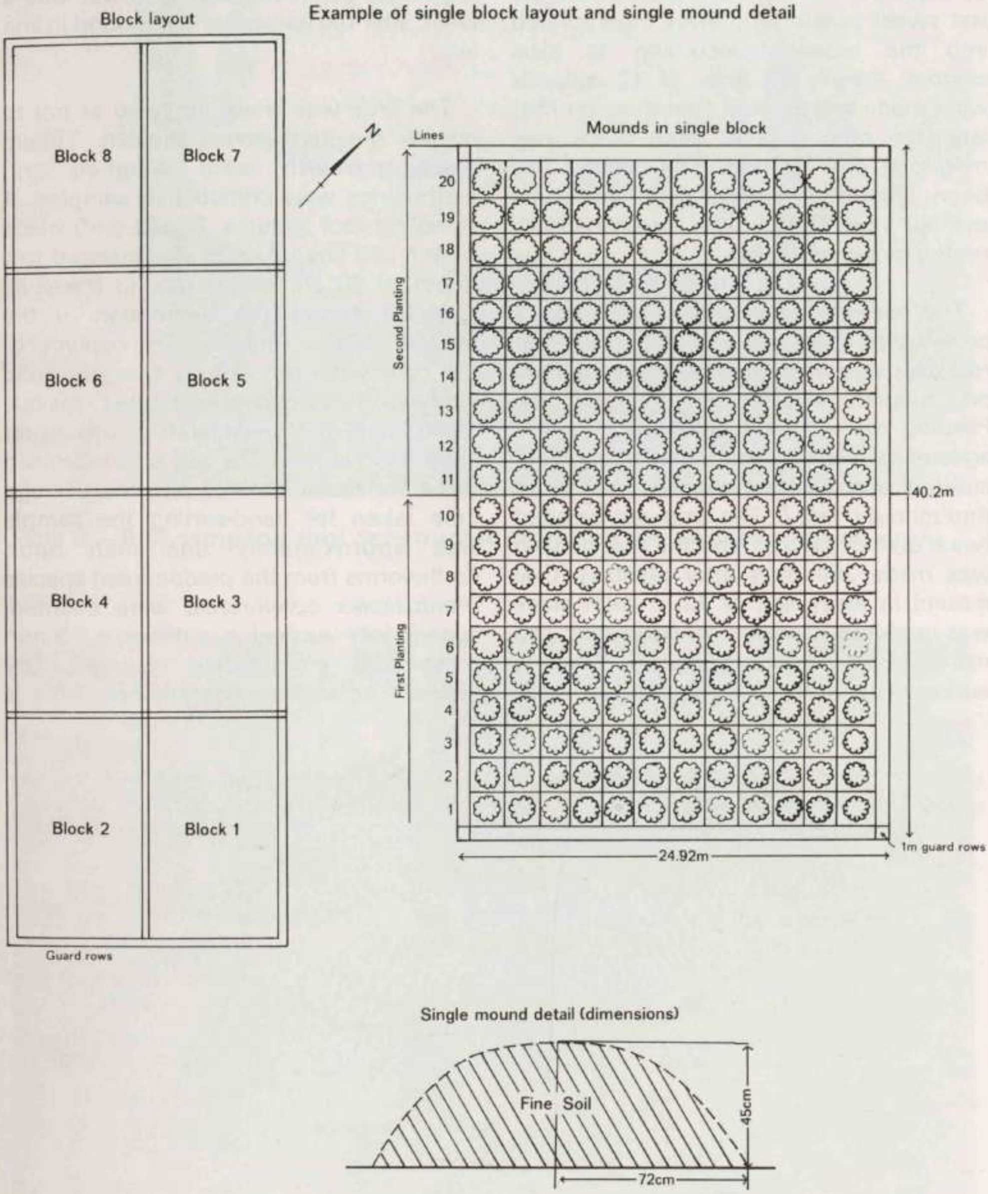
There are two main soil types in the Agricultural Station: peaty clay soils on the low lying, drained swampland; and less organic alluvial soils nearer the Piwa River. The peaty clay soils are very dark brown in colour, high in organic matter and usually wet due to a high water table. The alluvial soils are lighter in colour, drier, and commonly overlie sandy alluvial with rounded river gravels at a depth of about one metre.

METHODS

The trial was conducted on 0.70 ha, divided into eight blocks each measuring 22.92 by 38.20 m. Each block consisted of 240 mounds which were arranged in 20 straight lines of 12 mounds separated from adjacent blocks by a one m wide 'guard' row (*Figure 2*).

Individual mounds were composed of topsoil taken from an area of 3.65 m² and

Figure 2.— **Layout of blocks and mounds**



the completed mounds were 45 cm high and 144 cm in diameter. Compost consisting of the vines and weeds from the last sweet potato crop were incorporated into the mounds according to local custom. Initially 10 lines of 12 mounds were made and planted, and three months later the other half of each block was mounded and planted. The ground had been previously cultivated in the same manner and had been systematically rooted by tethered pigs.

The mounds were planted with sweet potato cuttings of one variety (local name: *Habare*) using six bunches of three cuttings per mound, (49,340 cuttings per ha). Planting material was collected from the agricultural station, and uniform length of cuttings and planting practice was used throughout (*Plate I*). The crop was weeded twice during the trial, and the first harvest was made 254 days after planting. One mound in every line of 12 in each block was randomly allocated for harvesting and marked with a stake. Marked mounds in successive lines were harvested each week for twenty weeks. The first harvest of the second planting was taken at 238 days after the first planting, which was a week after the harvest of the mound in line ten.

The crop was lifted gently so as not to disturb the earthworms present. Tubers and topgrowth were weighed and earthworms were immediately sampled. A sampling tool (volume 77,328 cm^3) made from a 200 litre oil drum was inserted to a depth of 30 cm in the mound (*Plate II*). *Plate III* shows the depression in the mound left after sampling. The contents of the core were put onto a steel tray and earthworms, cocoons, and other obvious macrofauna not considered in this paper were hand-sorted. The soil was examined twice for fauna content and the average time taken for hand-sorting the sample was approximately one man hour. Earthworms from the predominant species (*Pontoscolex corethrurus*) were counted, superficially washed in water on a 0.5 mm mesh and immediately weighed. Dry matter content was determined from a

Plate I.—**Planting sweet potato cuttings in a mound**

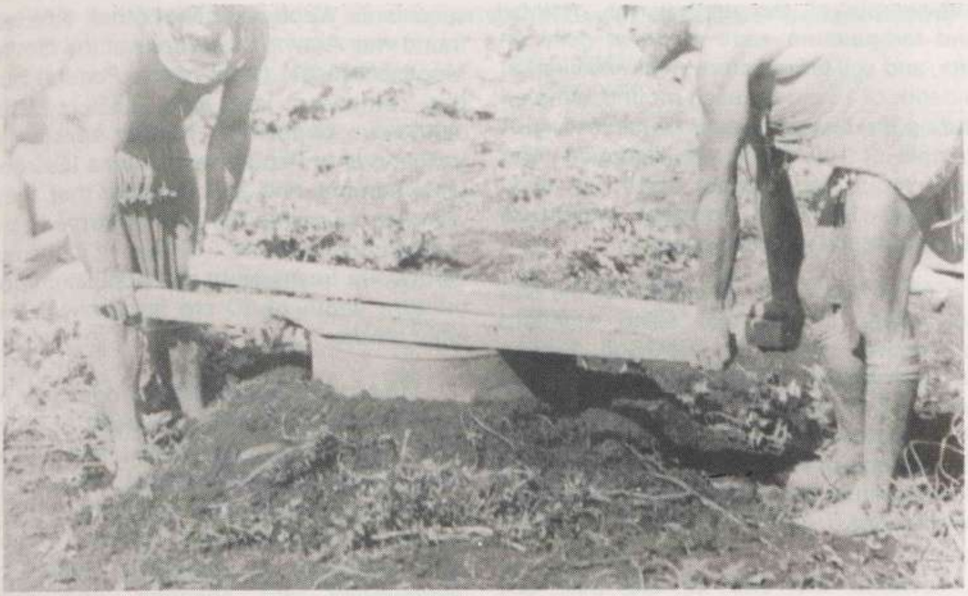


Plate II. — **Soil sampling tool constructed from the upper part of an oil drum**

Plate III. — **Depression left in the ground after sampling** sub-sample of the earthworms. Rainfall and temperature were recorded daily on site, and soil temperature was measured at a depth of 15 cm for each mound sampled during the last ten weeks of harvesting. A sample of 100 g soil was removed from each mound at a depth of 15 cm, oven dried at 105°C to constant weight to determine soil moisture content.

Soil profiles were described for the two soil types in the trial using standard procedures given in the Soil Survey Manual (USDA 1951), and samples were removed for analysis. Samples for making thin sections were also taken according to the method of FitzPatrick (1970), and were subsequently examined under a polarizing microscope.

Towards the end of the trial, soil samples were taken from block 5 (peaty clay soil) and block 6 (alluvial soil). Samples were taken at a depth of 15 cm from twenty mounds selected at random in each block. These were bulked together, air dried and riffled, and analyses were performed on duplicate sub-samples.

Standard techniques of soil analysis were used as given in Black (1965). The exchangeable cations were determined by ammonium acetate extraction; available phosphorous by Olsen's method; organic carbon by the method of Walkley and Black; and total nitrogen by the Kjeldahl procedure.

Analysis of variance was carried out on dry matter production of leaf and tuber, wet weight of earthworms, and soil moisture and temperature. Least significant differences between two means were calculated for various probabilities. Appropriate linear regressions and correlations were calculated.

RESULTS

The predominant species of earthworm found was identified as being *Pontoscolex corethrurus*, of the family Glossoscolecidae. The local name for this species is *Kaungoe*. The other species found was *Amynthas corticus* of the family Megascolecidae, (local name, *Pedere*) but this comprised less than 0.5% of the earthworm population. Neither species is indigenous to Papua New Guinea (Easton, pers. comm.), and it is possible that they were introduced to the area by cattle or by road construction. *Table 1* shows earthworm freshweight and population per m^2 at a depth of 30 cm for each of the eight blocks.

Tuber and topgrowth production is also shown. The oven dry weight of tuber and topgrowth was 32% and 18% respectively of fresh weight. Mean soil moisture content and soil temperature results are also included. *Figure 3* shows the variation in rainfall, yields of earthworms and cocoons, and crop production for the whole area over time.

The soil thin sections showed evidence of faunal activity, some of which could be attributed to earthworms. The peaty clay soil in thin section indicated a predominance of opaque dark coloured organic material with numerous interconnecting, smooth sided channels coated with iron oxides. Some of these contained roots and others re-worked material, probably from earthworms. A few earthworm cocoons were observed. No faecal material was found. The alluvial soil contained a much higher proportion of mineral material, and channels and passages were again coated with iron oxides. There was less evidence of earthworm activity in this soil.

The results of the chemical analysis of soil samples are given in *Table 2*. The peaty clay soil is highly organic with a high cation exchange capacity and low pH. The alluvial soil is less organic and less acid. Levels of calcium, magnesium and potassium are low for both soils whereas available phosphorus is moderate to high.

The majority of earthworms were adults and there appeared to be little variation in

Table 1. — **Average yield of earthworms and sweet potato per square metre***

	EARTHWORMS		SWEET POTATO (Dry matter)		SOIL	
Block No.	Fresh weight (g)	Number	Tuber (g)	Leaf (g)	Soil moisture (%)	Temperature (°C)
1	78.7	181	415	331	171.6	21.1
2	77.4	152	551	329	138.1	21.5
3	78.8	180	324	286	164.3	21.6
4	100.5	226	480	394	129.1	21.4
5	127.7	302	585	434	103.3	21.5
6	59.8	130	670	418	84.7	21.4
7	84.0	187	621	497	91.4	21.2
8	46.5	93	776	417	94.8	21.2
LSD 0.05	15.5	—	308	55	8.6	NSD
0.01	20.3	—	405	73	11.4	—
0.001	25.9	—	518	93	14.8	—

NSD = No significant difference between means

LSD = Least significant difference

* The yield of earthworms was estimated from a sub-sample extrapolated to the total volume of a mound (which occupied a ground area of 3.65 m^2). The total volume of the mound was calculated by considering the mound as a ½ elipsoid with formula $\frac{\frac{4}{3} \times 3.14\, b^2 a)}{2}$ where b is the height of the mound from the base to the highest point on the surface, and a is the radius of the base.

size between individuals. A linear regression between weight of earthworms and number of earthworms was significant at the 1% level (*Figure 4a*). Oven dry matter of earthworms was constant at 21% of fresh weight. It was found that rainfall registration in the week preceding harvest was a significant factor affecting earthworm yield (*Figure 4b*). When earthworm populations were grouped into four classes on the basis of wet earthworm weight per m^2 (0-42, 43-87, 88-130, 131-173 g), the first group with less than 43 g was significantly correlated with production of topgrowth (*Figure 4c*). There was no significant correlation for the other groups. Examination of data from block 5 indicated a negative and significant correlation between earthworms and tuber yield (*Figure 4d*). A positive and significant correlation between earthworms and topgrowth production was found in block 6 (*Figure 4e*). Soil moisture was negatively correlated with crop production.

DISCUSSION

Mean earthworm populations ranged from 93 per m^2 (46.5 g fresh weight) in block 8 to 302 per m^2 (127.7 g fresh weight) in block 5 (*Table 1*). The highest population was in block 5 on the peaty clay soil, and was significantly lower on the alluvial soil. There appears to be a relationship between earthworm population and soil organic matter content, and this agrees with the findings of El-Duweini and Ghabbour (1965) for Egyptian soils. However, there is no relationship between earthworm populations and soil moisture content in the different blocks. The moisture content is far higher than recorded by El-Duweini and Ghabbour (1965), who also associated

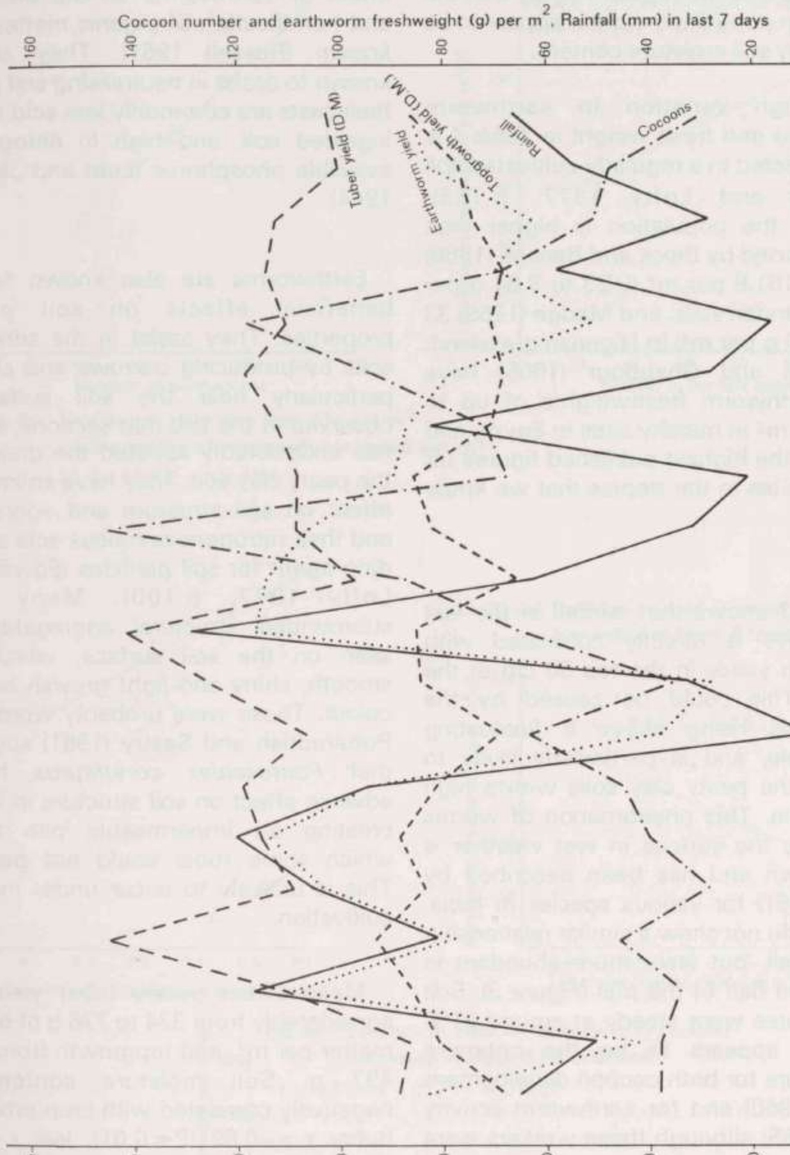
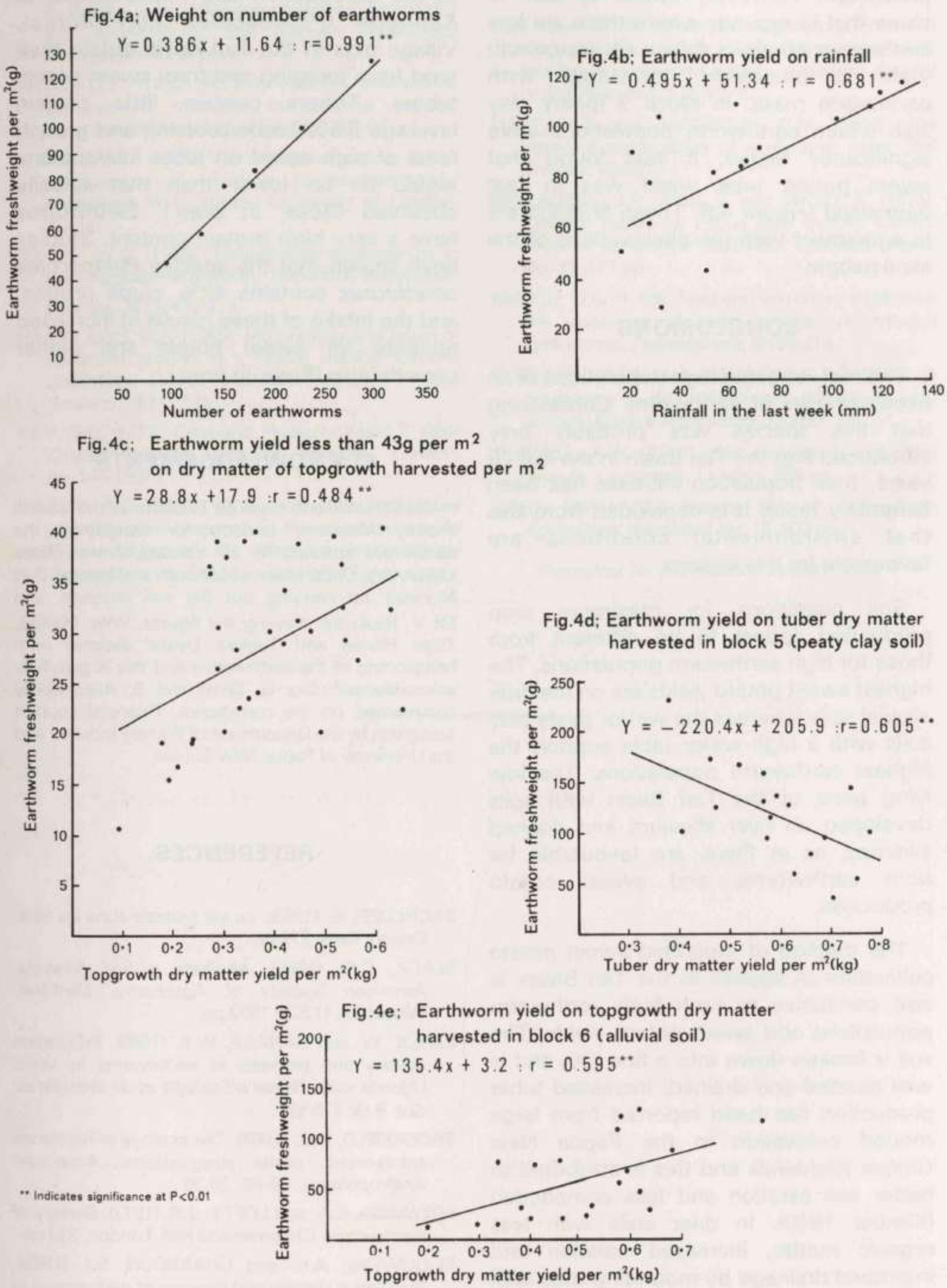


Figure 3. — Yields of earthworms, sweet potato dry matter and rainfall during the trial

Table 2.— **Chemical analysis of soil samples**

	AIR DRY MOISTURE (%)	LOSS ON IGNITION (%)	pH	EXCHANGEABLE CATIONS (mEq 100g⁻¹ Soil) Ca	Mg	Na	K	CATION EXCHANGE CAPACITY (mEq 100g⁻¹ Soil)	AVAILABLE P (ppm)	NITROGEN (%)	ORGANIC CARBON (%)
PEATY CLAY SOIL											
Profile topsoil	19.7	42.1	4.0	1.4	0.8	0.4	0.3	49	37	0.99	21 5
Block 5	13.7	24.8	5.2	3.6	0.8	0.1	0.2	34	22	0.70	10.6
ALLUVIAL SOIL											
Profile topsoil	14.5	19.8	5.1	2.4	0.6	0.2	0.1	29	17	0.58	7.5
Block 6	14.0	22.1	5.4	1.9	0.6	0.1	0.2	32	19	0.63	8.5

Figure 4. — **Linear regression relationships**



** Indicates significance at $P<0.01$

an increase in water content from 15-34% with an increase in numbers and average weight of adult *A. caliginosa*. It is probably because of the high moisture content of these soils and the regular rainfall that the earthworm population did not appear to be affected by soil moisture content.

The high variation in earthworm populations and fresh weight in *Table 1* is to be expected in a regularly cultivated soil (Edwards and Lofty 1977, p.123). However, the population is higher than those reported by Block and Banage (1968) of 7.4 to 101.8 per m² (0.23 to 3.64 g per m²) in Ugandan soils, and Madge (1969) 33 per m² (10 g per m²) in Nigerian grassland. El-Duweini and Ghabbour (1965) have found earthworm freshweights of up to 100 g per m² in marshy sites in Egypt, and these are the highest published figures for swampy sites in the tropics that we know of.

Figure 3 shows that rainfall in the last seven days is directly correlated with earthworm yields in the top 30 cm of the mound. This could be caused by the earthworms rising above a fluctuating water table, and is particularly likely to occur in the peaty clay soils with a high water table. This phenomenon of worms coming to the surface in wet weather is well known and has been described by Gates (1961) for various species in India. Cocoons do not show a similar relationship with rainfall, but were more abundant in the second half of the trial (*Figure 3*). Soil temperatures were steady at around 21°C and this appears to be the optimum temperature for both cocoon development (Gerard 1960) and for earthworm activity (Grant 1955) although these workers were studying other earthworm species. The acidity of the peaty clay soils (pH 5.2) does not appear to have affected earthworm populations, and it is likely that the species *Pontoscolex corethrurus* is adapted to an acid environment. Bachelier (1963) notes that certain tropical species of *Megascolex* are numerous in acid soils of pH 4.5 to 4.7.

The differences in chemical properties for the peaty clay soil between the profile topsoil and that in block 5 (*Table 2*) could be attributable to earthworm activity. The effect of earthworms on the breakdown and humification of organic matter is well known (Russell 1961). They are also known to assist in neutralising soil pH, and their casts are commonly less acid than the ingested soil, and high in nitrogen and available phosphorus (Lunt and Jacobson 1944).

Earthworms are also known for their beneficial effects on soil physical properties. They assist in the aeration of soils by producing burrows and channels particularly near the soil surface, as observed in the soil thin sections, and this has undoubtedly assisted the drainage of the peaty clay soil. They have an important effect on soil structure and aggregation, and their nitrogenous mucus acts as a binding agent for soil particles (Edwards and Lofty 1977, p.100). Many small, subrounded structural aggregates were seen on the soil surface, which were smooth, shiny and light greyish brown in colour. These were probably worm casts. Puttarudriah and Sastry (1961) suggested that *Pontoscolex corethrurus* had an adverse effect on soil structure in India by creating an impermeable pan through which some roots could not penetrate. This is unlikely to occur under mounded cultivation.

Mean sweet potato tuber yields vary considerably from 324 to 776 g of oven dry matter per m², and topgrowth from 286 to 497 g. Soil moisture content was negatively correlated with crop production (tuber $r = -0.89$ ($P < 0.01$), leaf $r = -0.87$ ($P < 0.01$)) (*Table 1*). According to Kay (1973), a sandy loam reasonably high in organic matter would seem to be the optimum soil for sweet potato production and soils very rich in humus normally result in lower yields. This could be the reason for the differences in yields between the peaty clay soil and the alluvial soil.

In general, there is no relationship between earthworm population and crop production. However, *Figures 4c* and *4e* show that in mounds where there are low earthworm numbers (block 6), topgrowth yield is positively correlated with earthworm mass. In block 5 (peaty clay soil) where earthworm populations were significantly higher, it was found that sweet potato tuber yield was in fact depressed (*Figure 4d*). These findings are in agreement with the observations of the local people.

CONCLUSIONS

The trial indicated high populations of an exotic species of earthworm. Considering that this species was probably only introduced into the Tari Basin in the last 20 years, their population increase has been extremely rapid. It is concluded from this that environmental conditions are favourable for this species.

Soil conditions for maximum crop production appear to be different from those for high earthworm populations. The highest sweet potato yields are on the drier alluvial soils whereas the wetter peaty clay soils with a high water table support the highest earthworm populations. The low lying parts of the Tari Basin with soils developed on river alluvium and drained swamps, as at Piwa, are favourable for both earthworms and sweet potato production.

The method of mounded sweet potato cultivation as applied in the Tari Basin, is also conducive to both high earthworm populations and sweet potato yields. The soil is broken down into a fine tilth and is well aerated and drained. Increased tuber production has been reported from large mound cultivation in the Papua New Guinea Highlands and this is attributed to better soil aeration and less compaction (Kimber 1970). In drier soils with less organic matter, increased aeration and improved drainage by mounding may well depress earthworm activity, although this cannot be proved in this study.

The Huli people attribute increased pig populations and growth rates specifically to the introduction and multiplication of *Kaungoe* (*Pontoscolex corethrurus*). Village pigs in the Tari Basin obtain their food from foraging and from sweet potato tubers. Tubers contain little protein (average 2.5% crude protein), and growth rates of pigs based on tuber intake alone would be far lower than that actually observed (Rose, in prep.). Earthworms have a very high protein content. Studies have shown that the species *Pontoscolex corethrurus* contains 42% crude protein, and the intake of these results in increased appetite for sweet potato and higher growth rates (Rose, in prep.).

ACKNOWLEDGEMENTS

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REFERENCES

BACHELIER, G. (1963). *La vie animale dans les sols.* Orston, Paris. 279 pp.

BLACK, C.A. (1965). *Methods of Soil Analysis.* American Society of Agronomy, Madison, Wisconsin, U.S.A. 1572 pp.

BLOCK, W. and BANAGE, W.B. (1968). Population density and biomass of earthworms in some Uganda soils. *Revue d'Ecologie et de Biologie du Sol,* 5 (3) 515-521.

BROOKFIELD, H.C. (1964). The ecology of highlands settlement: some suggestions. *American Anthropologist,* 66 (4): 20-38.

EDWARDS, C.A. and LOFTY, J.R. (1977). *Biology of Earthworms.* Chapman and Hall, London. 333 pp.

EL-DUWEINI, A.K. and GHABBOUR, S.I. (1965). Population density and biomass of earthworms in different types of Egyptian soils. *Journal of Applied Ecology,* 2 (2):271-287.

FITZPATRICK, E.A. (1970). A technique for the preparation of large thin sections of soils and unconsolidated materials. In D.A. Osmond and P. Bullock,(eds). *Micromorphological techniques and applications, Soil Survey Techniques Monograph No. 2.* pp. 3-13.

GATES, G.E., (1961). Ecology of some earthworms with special reference to seasonal activity. *American Midland Naturalist*, 66 (1):61-86.

GERARD, B.M. (1960). *The biology of certain British earthworms in relation to environmental conditions*. Ph.D. thesis. University of London. 214 pp.

GRANT, W.C. (1955). Temperature relationships in the Megasco-earthworm, *Pheretima hupeiensis*. *Ecology*, 36 (3):412-417.

HAANTJENS, H.A. (1965). Morphology and origin of patterned ground in a humid tropical lowland area, New Guinea. *Australian Journal of Soil Research*, 3:111-129.

KAY, D.E. (1973). *Crop and Product Digest 2, Root Crops*. Tropical Products Institute, London. pp. 144-159.

KIMBER, A.J. (1970). Some cultivation techniques affecting yield response in the sweet potato. In *Proceedings of the Second International Symposium on Tropical Root and Tuber Crops. Vol.* 1, *Tropical root and tuber crops tomorrow*. College of Tropical Agriculture, University of Hawaii, Honolulu. pp. 32-36.

LEE, K.E. (1976). Microrelief features in a humid tropical lowland area, New Guinea, and their relation to earthworm activity. *Australian Journal of Soil Research*, 5:263-274.

LUNT, H.A. and JACOBSON, G.M. (1944). The chemical composition of earthworm casts. *Soil Science*, 58:367.

MACALPINE, J.R., KIEG, G. and SHORT, K. (1975). Climatic Tables for Papua New Guinea. *CSIRO Division Land Use Research, Technical Paper* No. 37. 177 pp.

MADGE, D.S. (1969). Field and laboratory studies on the activities of two species of tropical earthworms. *Pedobiologia*, 9:188-214.

PUTTARUDRIAH, M. and SASTRY, K.S.S. (1961). A preliminary study of earthworm damage to crop growth. *Mysore Agricultural Journal*, 36:2-11.

RUSSELL, E.W. (1961). *Soil Conditions and Plant Growth.* Longmans, London. 688 pp.

USDA (1951). Soil Survey Manual. *U.S. Dept. Agricultural Handbook* No. 18. 503 pp.

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COMPARISON OF STYLO (*STYLOSANTHES GUIANENSIS* VAR GUIANENSIS) CULTIVARS IN THE MARKHAM VALLEY OF PAPUA NEW GUINEA

P.A. Chadhokar *

ABSTRACT

Two new cultivars of the pasture legume, Stylosanthes guianensis *var. guianensis, Cook and Endeavour were compared with the cultivar Schofield in pure and mixed sward with grass under low (1,250 mm) and high (2,800 mm) rainfall conditions in the Markham Valley of Papua New Guinea. Performances of the three cultivars were similar and the differences between their dry matter yields were not significant. They combined well with the companion grasses and the mean percentage of legume in the dry matter was 48, 54 and 52 for Cook, Endeavour and Schofield respectively. All the three cultivars responded to the application of phosphorus and sulphur.*

INTRODUCTION

Stylosanthes guianensis var. guianensis has shown promise as a forage legume in many tropical and subtropical countries (Vivian 1959, Adegbola 1965, Humphreys 1969, Harding and Cameron 1972). Stylo is also grown in Papua New Guinea in both lowlands and highlands and shows considerable promise for oversowing into natural grasslands to improve their productivity for cattle grazing (Chadhokar 1977).

Although there is no recorded evidence, the Stylo cultivar found in Papua New Guinea is undoubtedly Schofield which was probably introduced from Australia during the early 1950s. Recently in Australia two new cultivars, Cook and Endeavour, have been released which were found superior to Schofield in Queensland (Harding and Cameron 1972). The new cultivars were introduced to Papua New Guinea in 1973 for trial first in the highlands. For further information on their performance in the year round hot and humid lowland environment, trials were conducted in the Markham Valley, under both low and high rainfall conditions, to compare the three cultivars in pure and mixed swards with grass. The results on dry matter yield are presented in this paper.

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MATERIALS AND METHODS

Three experiments were conducted during 1974-76, two under low rainfall conditions (1,250 mm) at the Beef Cattle Research Centre Erap (45 km from Lae) and the third under high rainfall conditions (2,800 mm) at the Plant Industry Centre Bubia (15 km from Lae) in the Markham Valley. The soils at the first site were sandy loam with low fertility, while at the second site they were clay loam with moderate fertility. The rainfall during the growing season is available for Erap and is presented in *Figures 1* and *2*. There is little or no difference between day temperatures at both sites (average temperature at 3:00 pm about 29°C) but the humidity is higher at Bubia.

Experiment 1—Performance of Stylo cultivars in pure sward at Erap

Pure swards of Stylo cultivars were established in April 1974 with inoculated seed planted at 30 x 30 cm spacing in a randomised block design with four replicates. No fertilization was done during the experimental period. A uniform stand was obtained and dry matter yield was estimated by sampling every six weeks starting 70 days after planting. Four 50 x 50 cm quadrates were cut per plot from random positions at 15 cm height and the plots were cut back to the same height with bush knives. Samples were dried at 80°C for 48 hours before weighing.

Experiment 2—Performance of Stylo cultivars in a mixed sward at Erap

Stylo cultivars were planted in April 1974 in a mixed sward with a common grass *Paspalum plicatulum* var Rodds Bay in alternate rows at the same plant spacing as in Experiment 1. The experiment was conducted in a split plot design with four replicates with Stylos in main plots and fertilizer treatments in subplots. Stylos were planted with inoculated seed while the grass was planted from seedlings. The Stylos were slow to establish and the grass had to be topped off at 4 weeks after planting to avoid smothering of Stylos. Phosphorus as triple super and sulphur as sulphur powder were applied at 50 and 40 kg per ha respectively and were raked into the soil before planting. Dry matter yield was estimated 70 days after planting as in Experiment 1 and the samples were separated for botanical composition before drying.

Experiment 3—Performance of Stylo cultivars in a mixed sward at Bubia

Stylos with a common grass *Brachiaria dictyoneura* were established at the Plant Industry Centre Bubia in March 1975. Basal dressings of phosphorus, potash and sulphur at 50, 50 and 20 kg per ha respectively were applied before planting. Stylo seed and grass cuttings were planted at the same spacing as in Experiment 2 in a randomised block design with five replicates. Dry matter yield and botanical composition were estimated as in Experiment 2, starting 70 days after planting.

RESULTS

Experiment 1

The results on dry matter yields are presented in *Table 1* and *Figure 1*. No significant differences were obtained between the Stylo cultivars and their yields were comparable.

Experiment 2

In a mixed sward, although no significant differences were obtained between the Stylo cultivars, Cook gave the lowest yield of dry matter (*Table 2a*). Growth of Stylo cultivars appeared to have been influenced by rainfall variation (*Figure 2*). Endeavour gave higher yields following heavy rainfall (e.g. harvests 5, 7 and 8) and these differences were significant when the grouped data on various harvests were analysed according to rainfall variation. Percentages of legumes in the total dry matter averaged 43, 50 and 50 for Cook, Endeavour and Schofield respectively.

Table 1.—**Total dry matter yield of Stylo cultivars in pure sward at Erap over 22 months growing period**

Stylo cultivars	Dry matter yield (kg per ha)
Cook	21,623 a
Endeavour	19,389 a
Schofield	22,364 a

Values followed by the same letter do not differ at $P \leq 0.05$.

Figure 1.—**Dry matter yield of Stylo cultivars in a pure sward at Erap**

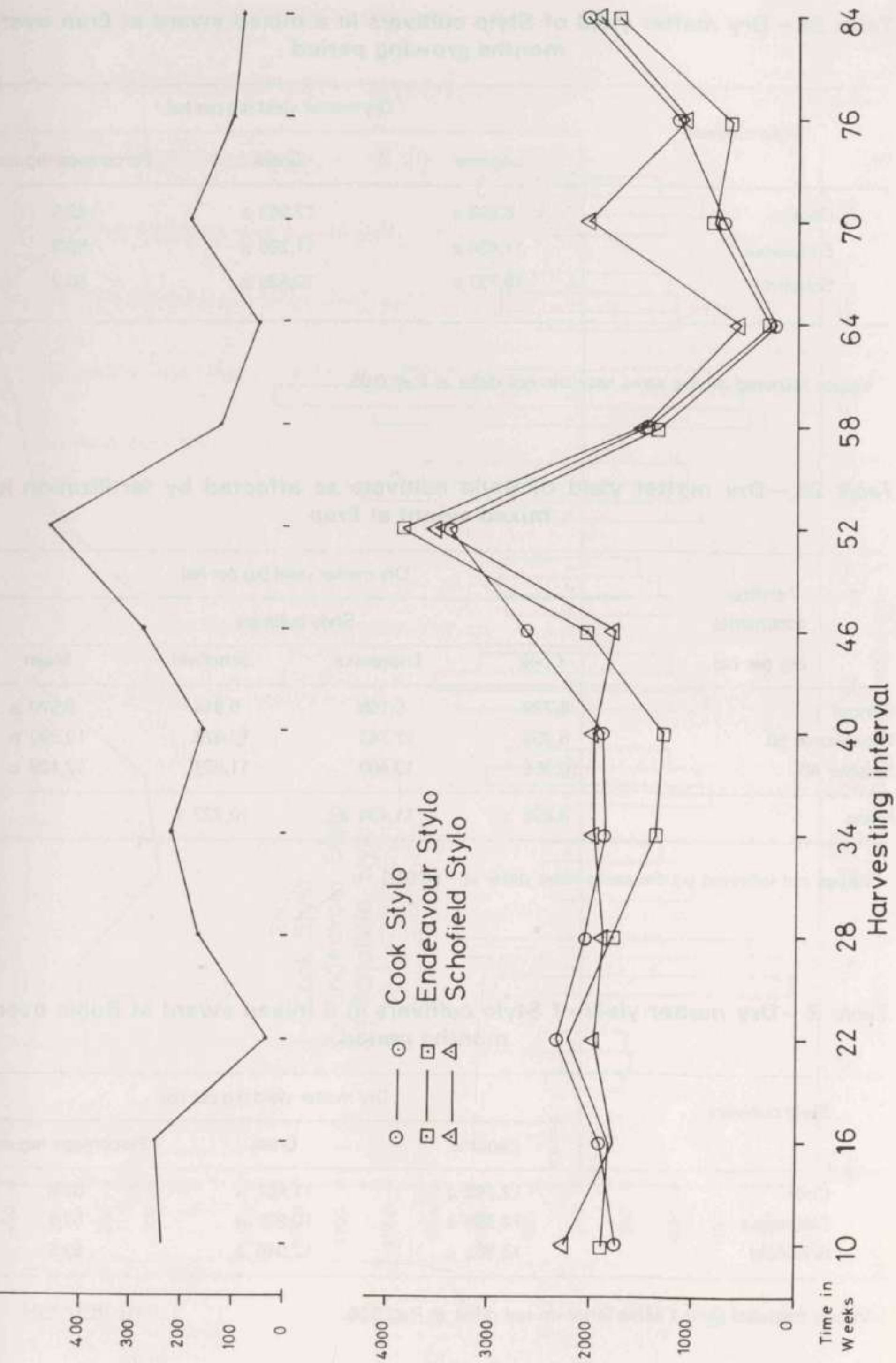


Table 2a.—**Dry matter yield of Stylo cultivars in a mixed sward at Erap over 17 months growing period**

Stylo cultivars	Dry matter yield (kg per ha)		
	Legume	Grass	Percentage legume
Cook	8,898 a	12,043 a	42.5
Endeavour	11,434 a	11,285 a	50.3
Schofield	10,737 a	10,639 a	50.2

Values followed by the same letter do not differ at $P \leqslant 0.05$.

Table 2b.—**Dry matter yield of Stylo cultivars as affected by fertilization in a mixed sward at Erap**

Fertilizer treatments (kg per ha)	Dry matter yield (kg per ha)			
	Stylo cultivars			
	Cook	Endeavour	Schofield	Mean
Control	6,738	9,158	9,814	8,570 a
Phosphorus 50	8,999	11,743	10,426	10,390 b
Sulphur 40	10,956	13,400	11,971	12,109 c
Mean	8,898 a	11,434 a	10,737 a	

Values not followed by the same letter differ at $P \leqslant 0.01$

Table 3.—**Dry matter yield of Stylo cultivars in a mixed sward at Bubia over 16 months period**

Stylo cultivars	Dry matter yield (kg per ha)		
	Legume	Grass	Percentage legume
Cook	12,748 a	11,461 a	52.6
Endeavour	14,386 a	10,803 a	57.1
Schofield	13,862 a	12,045 a	53.5

Values followed by the same letter do not differ at $P \leqslant 0.05$.

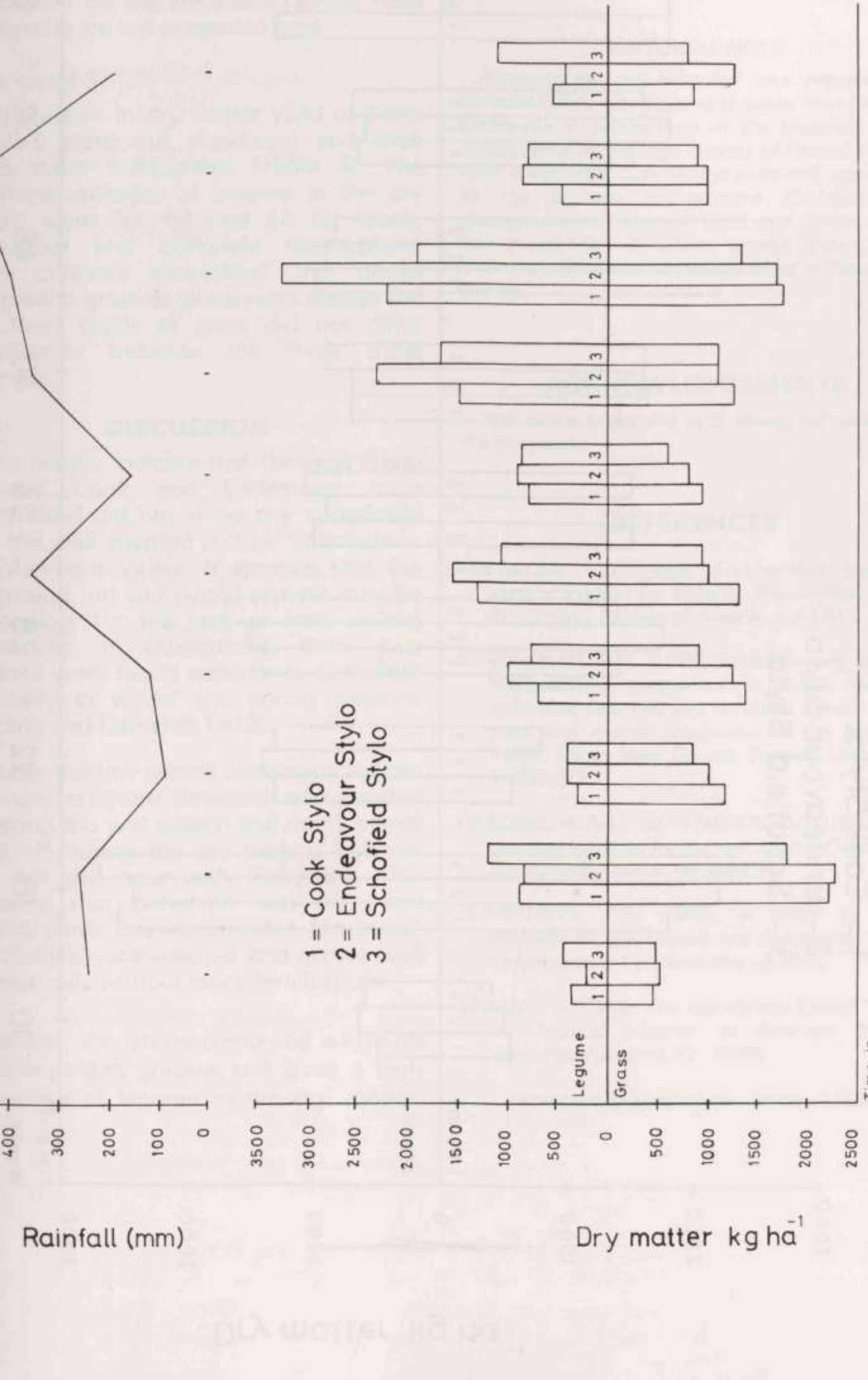
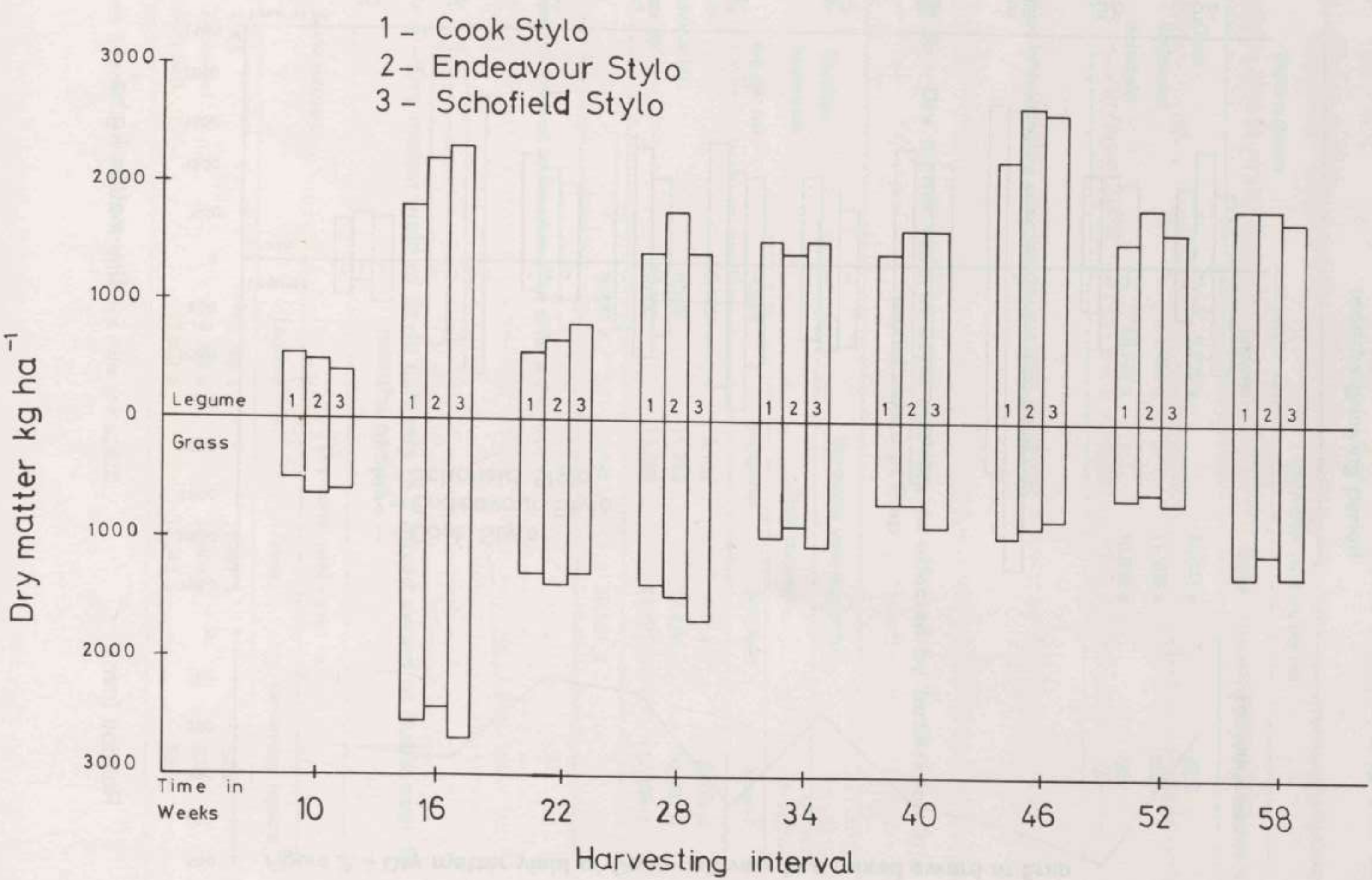


Figure 2.—Dry matter yield of Stylo cultivars in a mixed sward at Erap

Figure 3. — **Dry matter yield of Stylo cultivars in a mixed sward at Bubia**



Application of phosphorus and sulphur gave a significant increase in the dry matter yield (*Table 2b*) but interaction between Stylo cultivars and fertilizer was not significant. There was no effect of fertilization on the companion grass yield and results are not presented here.

Experiment 3

Differences in dry matter yield of Stylo cultivars were not significant and their yields were comparable (*Table 3*). The mean percentages of legume in the dry matter were 53, 57 and 54 for Cook, Endeavour and Schofield respectively. Stylo cultivars outyielded the dense companion grass at all harvests except the first four. Yields of grass did not differ significantly between the three Stylo cultivars.

DISCUSSION

The results indicate that the new Stylo cultivars Cook and Endeavour from Queensland did not show any superiority over the well adapted cultivar Schofield in the Markham Valley. It appears that the year round hot and humid climate may be responsible for the lack of inter-varietal differences. In Queensland, these two cultivars were found superior to Schofield especially in winter and spring seasons (Harding and Cameron 1972).

Under the low rainfall conditions at Erap the new cultivars flowered and seeded following the wet season and many plants dried off during the dry period, but this was not the case with Schofield. This indicates that Schofield may be more suitable under this environment. Moreover, Schofield is well adapted and grows well on poor soils without much fertilization.

In general, the Stylos combined well with the companion grasses and gave a high proportion of legume in the dry matter. This indicates that there is a good potential for Stylo in some areas of the Markham Valley, however, further studies are warranted to measure its performance under grazing.

EDITORIAL NOTE

*Although the trial recorded here indicated that Schofield Stylo was equal to or better than Cook and Endeavour in productivity in the lowlands, recent observations in the Rigo District of Central Province have shown that Schofield is extremely susceptible to the disease anthracnose (*Colletotrichum gloeosporioides*), whereas Cook and Endeavour are less susceptible. Schofield cannot, therefore, be recommended for use in wetter areas of Papua New Guinea.*

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REFERENCES

ADEGBOLA, A.A. (1965). *Stylosanthes gracilia* a tropical legume for Nigeria. *Proceedings of the Agricultural Society of Nigeria,* 4: 57-61.

CHADHOKAR, P.A. (1977). Establishment of Stylo (*Stylosanthes guianensis*) in Kunai (*Imperata cylindrica*) pastures and its effect on dry matter yield and animal production in the Markham Valley, Papua New Guinea. *Tropical Grasslands,* 11:263-272.

HARDING, W.A.T. and CAMERON, D.G. (1972). New pastures legumes for the wet tropics. *Queensland Agricultural Journal*, 98:394-406.

HUMPHREYS, L.R. (1969). *A Guide to Better Pastures for the Tropics and Subtropics*. Wright Stephenson & Co., Australia. pp.59-61.

VIVIAN, L.A. (1959). The leguminous fodder "Stylo" or "Tropical Lucerne" in Kelantan. *Malayan Agricultural Journal*, 42:183-98.

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OPTIMUM REPLANTING STAGE FOR TWO VARIETIES OF PIT-PIT (*SETARIA PALMIFOLIA*) IN THE HIGHLANDS OF PAPUA NEW GUINEA

C.J. Rose*

ABSTRACT

Two varieties of edible pit-pit were grown near Tari in the Southern Highlands Province. The crop was progressively harvested over 512 days with a total of five harvests. Yields over the whole trial were 5.0 and 3.9 tonnes of edible portion per hectare for the two varieties, Mbu and Banguma respectively.

A quadratic regression of cumulative edible portion per day on days after planting demonstrated that rate of growth declined approximately 350 days after planting for Mbu and 325 days for Banguma. The decline in both varieties was due to a lower individual stem weight and a higher percentage of waste (non-edible portion of total harvested) the longer the crop was in the ground.

It is estimated that an increase of 2.0 and 1.8 tonnes per hectare for Mbu and Banguma respectively could be attained by harvesting every 100 days and practicing 325 day replanting rather than leaving the crop in situ *for over 600 days.*

INTRODUCTION

Edible Pit-Pit (*Setaria palmifolia* (Koenig) Stapf.) or New Guinea asparagus is grown and eaten throughout the highlands of Papua New Guinea (Powell 1976). There are a number of different varieties in each area; sixteen in Mount Hagen (Powell *et al.* 1975), seven in Simbai (Rappaport 1968) and at least seven in Tari (Rose, unpublished data). Varieties are distinguished by the colour of the stem bases and leaf midribs. They also differ greatly in yields of edible portion, and Powell (1976) has reported a range of 8 to 49 tonnes of edible portion yield per hectare.

It is a perennial crop and the tillering of lateral shoots is accelerated by regular harvesting. Powell (1976) observed that the period of edible production was from four months to two years and Rappaport (1968) observed a period from six months to two years.

In the Tari area, mature single or double stems are planted at the edge of the ubiquitous sweet potato mounds on alluvial and volcanic ash soils between 1,500 and 1,800 m a.s.l.

The edible portion is the soft, white central stem just above and below the growing point (*Plate III*) that is exposed by the removing of the outer leaf sheaths from the stem. These stems can be eaten raw but are usually cooked in stone ovens with sweet potatoes. Their succulence undoubtably enhances the invariably dry-tasting sweet potatoes.

In a pilot trial during 1975, it was observed that a white stemmed variety called Mbu† and a red stemmed variety called Banguma out-yielded the other three varieties on trial. The aim of the present experiment was to record yields of these two varieties and to estimate the optimum stage to replant for maximum growth.

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† A local name. This variety is called Buka in the Hagen area. (Powell, pers. comm.).

METHODS

The trial was planted at Piwa Agricultural Station near Tari (1,620 m a.s.l.) on river alluvium which is re-worked volcanic ash (A. Wood, pers. comm.). The ground was well dug prior to marking out, having been fallow for a number of years. A randomised block design was used with two plots of 2.5 by 5.0 metres each per block and eight replicates. One metre wide drains were dug between blocks to a depth of 30 centimetres. Single stems, forty centimetres long, were planted at a slight angle to the vertical about eight centimetres deep at a spacing of fifty centimetres between plants and rows, i.e. 40,000 plants per hectare.

Initially, the leaves on the planted stems wilted and faded in colour but within a month, new, light green leaves were observed emerging from the central stem of the parent material. The blocks were weeded 65 days after planting and thereafter were left unattended except for harvesting. No fertiliser treatments were applied. No pest or disease damage was observed during the trial.

Table 1.—**Yield of edible portion (EP), mean stem weight and percentage waste for two varieties of pit-pit**

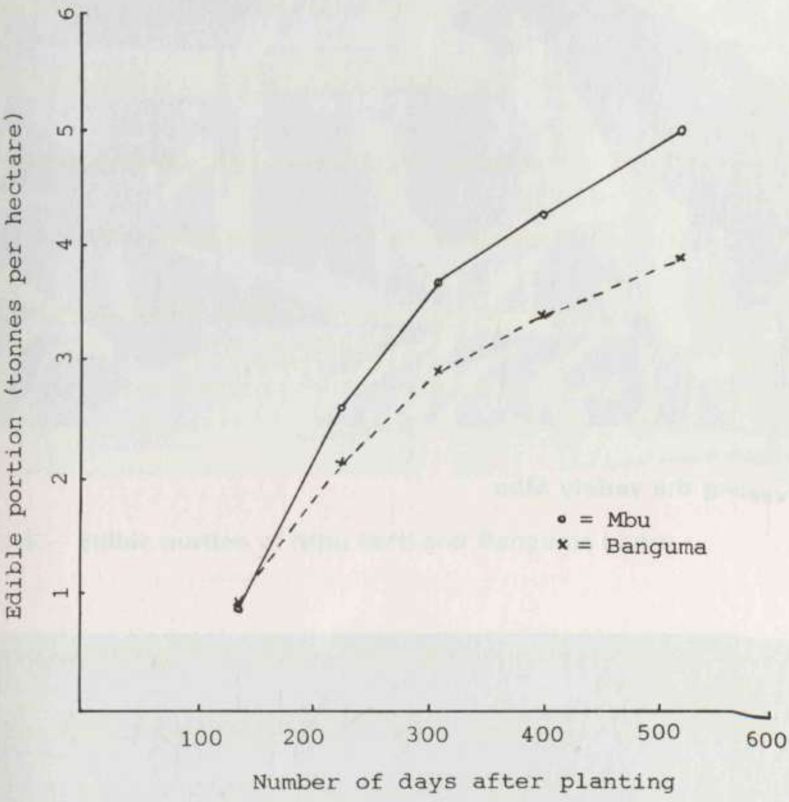
	VARIETY			
	Banguma	Mbu	(s.e.)	
Edible portion (t ha^{-1})	3.88	5.05	(± 0.436)	*
Weight of indiv. stems (g)	9.9	10.6	(± 0.29)	NS
Percentage waste	77.2	75.1	(0.47)	**

Levels of significance
NS = not significant
* = $0.01 \leq P < 0.05$
** = $0.001 \leq P < 0.01$

Table 2.—**Estimated yield of edible portion (EP) and expected difference with a 325-day planting cycle (tonnes per hectare)**

Days after planting	Harvest No.	Mbu	Banguma
125	1	1.11	1.05
225	2	1.21	0.95
325	3	1.14	0.80
Sub total harvests 1–3		3.46	2.8
425	4	0.90	0.60
525	5	0.51	0.35
625	6	0	0.05
Sub total harvests 4–6		1.41	1.0
Difference between harvests 1–3 and 4–6		2.05	1.8

Figure 1.—**Yield of cumulative edible portion for two varieties of pit-pit over five harvests (tonnes per hectare)**



Harvests were made 136, 222, 308, 339 and 512 days after planting. Two people harvested one block at a time and alternated harvesting each variety, thereby overcoming the bias of one operator harvesting the same variety in every block. The stems were broken off about two nodes below the growing point (*Plate I*); not all stems were harvested, only those suitable for eating. The top leaves were twisted off as is the local custom (*Plate II*) and the stems were counted and weighed. These were immediately stripped to edible portion and weighed (*Plate III*).

The total edible portion harvested, percentage waste and mean individual stem weight were calculated. The quadratic equation, $y = a_2x^2 + a_1x + a_0$ where x was the number of days after planting was used:

1. To estimate the cumulative edible portion per day (rate of crop growth) as the crop was harvested.

2. To estimate the yield effect of replanting after 325 days rather than leaving the crop for 625 days.

Estimates of yields of edible portion (kg ha^{-1}) at each harvest were interpolated using the following equations:

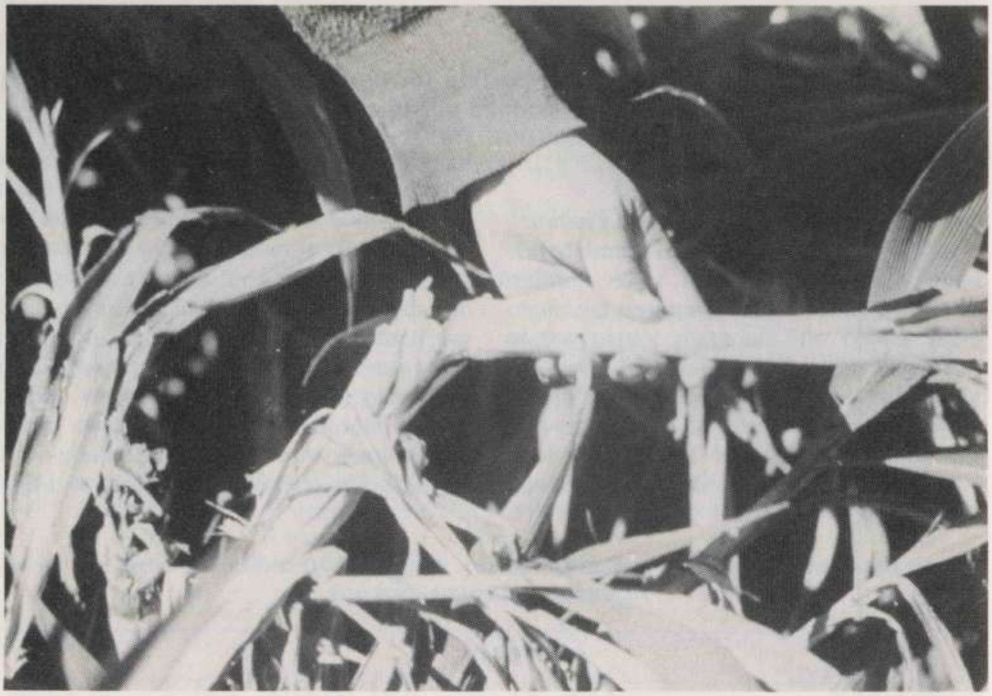


Plate I. — **Harvesting the variety Mbu**

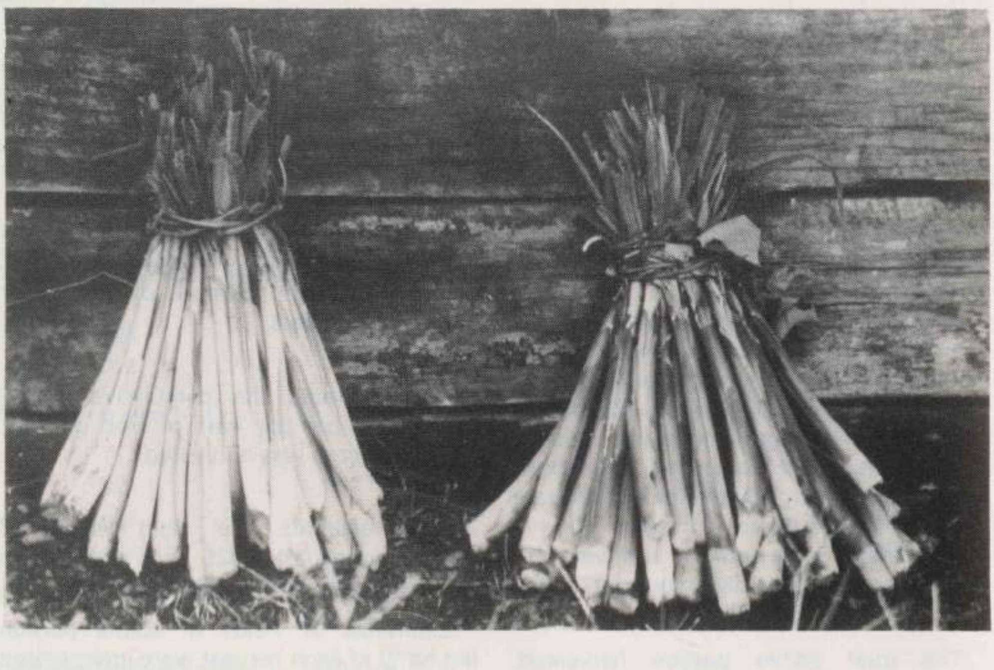


Plate II. — **Harvested portion of Mbu (left) and Banguma (right)**

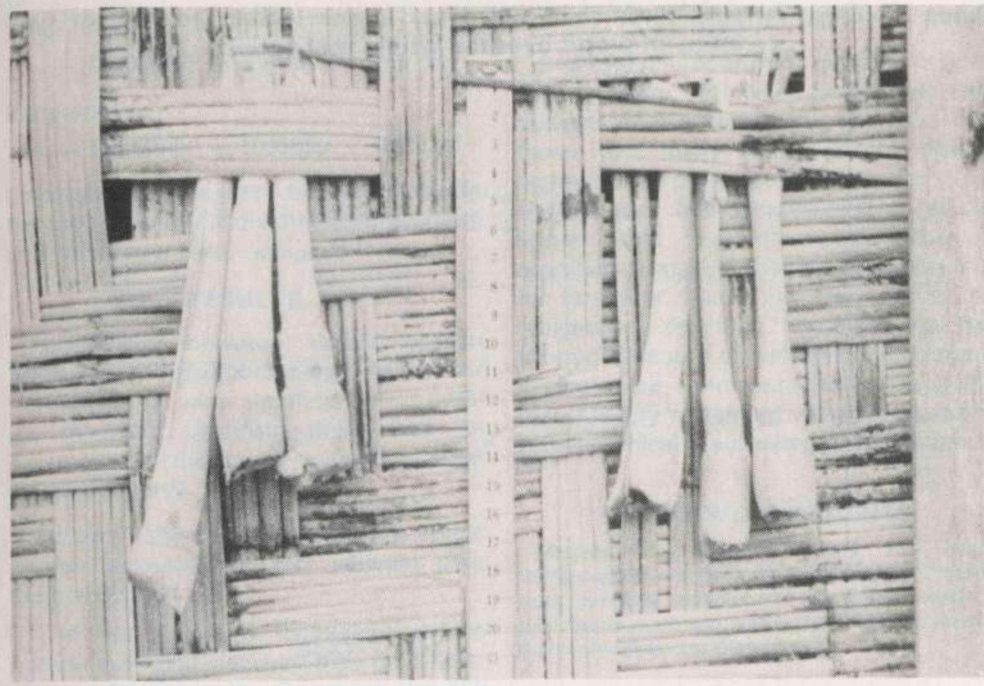


Plate III. — **Edible portion of Mbu (left) and Banguma (right)**

Figure 2. — **Cumulative yield per day (rate of crop growth) for two varieties of pit-pit (kg per ha)**

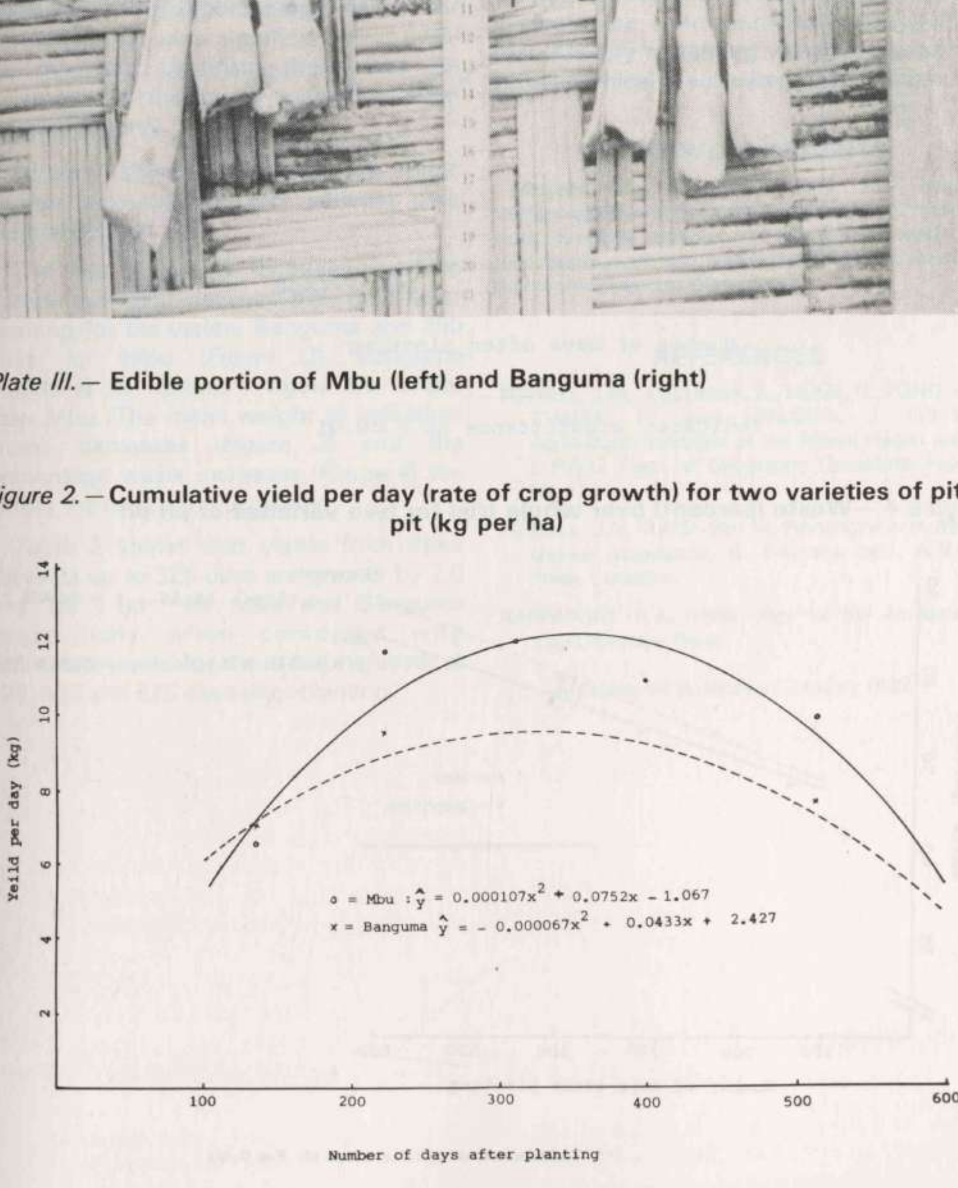
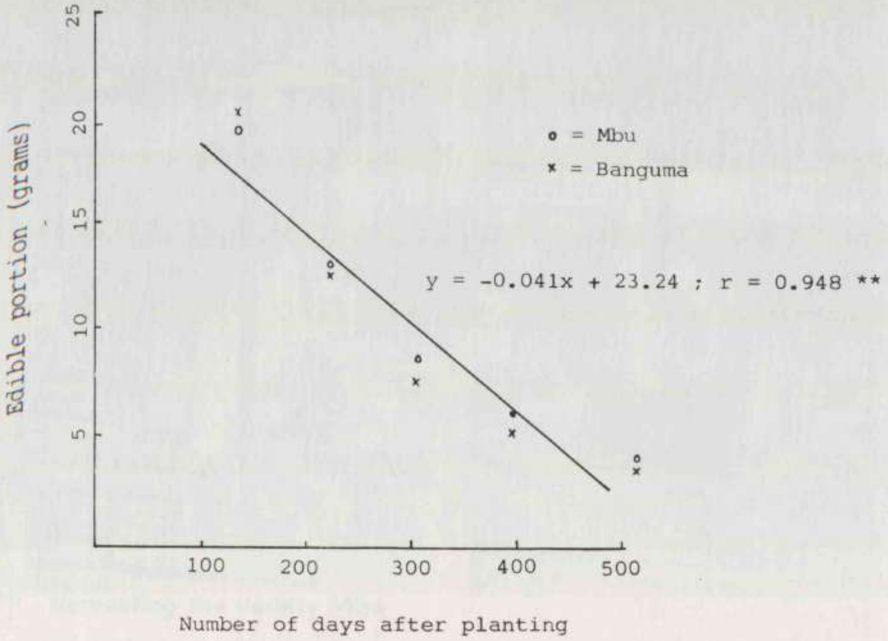
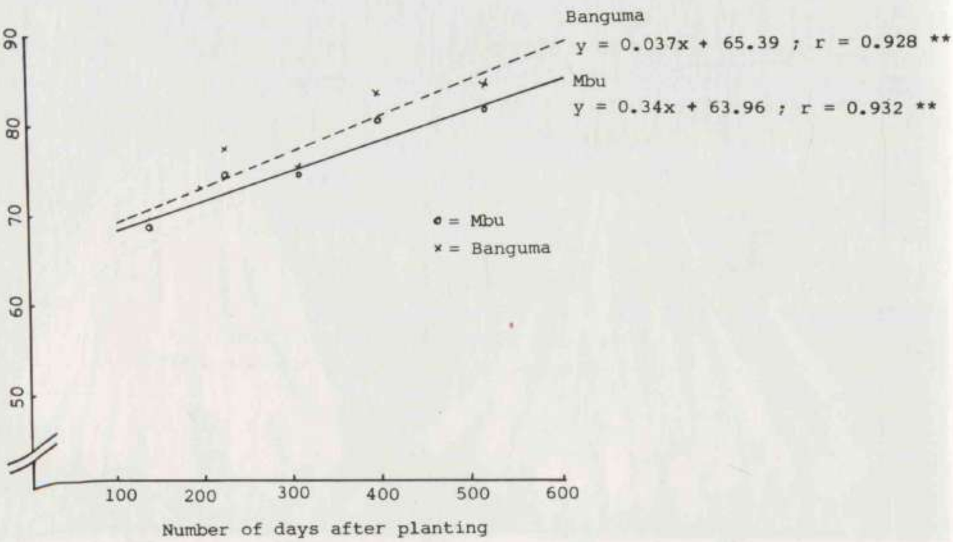


Figure 3.—**Mean weight (grams) of individual stems (edible portion) of two varieties of pit-pit over the whole trial period**



** Indicates significance at P <0.01

Figure 4.—**Waste (percent) over whole trial for two varieties of pit-pit**



** Indicates significance at P< 0.01

Mbu:

$\hat{y} = -0.00818x^2 + 3.8158x + 762.06$

Banguma:

$\hat{y} = -0.00258x^2 - 0.0585x + 1095.68$

Linear regressions were used to illustrate the progression of individual stem weights and waste over time.

RESULTS

Differences between edible portion harvested (EP) and percentage waste over the whole trial were significant ($P < 0.05$) for the two varieties; there was no difference in the mean individual stem weight (*Table 1*).

Figure 1 shows the cumulative edible portion harvested for both varieties over the trial period.

The rate of growth (cumulative edible portion per day) declines 325 days after planting for the variety Banguma and 350 days for Mbu (*Figure 2*). Banguma maintains its optimum vigour for longer than Mbu. The mean weight of individual stems decreases (*Figure 3*) and the percentage waste increases (*Figure 4*) the longer the crop is in the ground.

Table 2 shows that yields from three harvests up to 325 days are greater by 2.0 and 1.8 t ha^{-1} for Mbu and Banguma respectively when compared with estimated yields for the three harvests at 425, 525 and 625 days after planting.

DISCUSSION

The rate of crop growth declined in both varieties after 350 days. In the last two harvests of this trial it was observed that there were many lateral shoots tillering higher up the parent stems since the lower shoots had been harvested. It would appear that nutrient translocation is physically impaired after 350 days and that for optimum yields the crop should be replanted at this time. Since this trial has taken no account of yield per labour input, it cannot be concluded from area yields that 325-day replanting would necessarily be economical in subsistence agriculture.

ACKNOWLEDGEMENTS

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REFERENCES

POWELL, J.M., KULUNGA, A., NOGE, R., PONO, C., ZIMIKE, F., and GOLSON, J. (1975). Agricultural traditions of the Mount Hagen area, *U.P.N.G. Dept. of Geography Occasional Paper* No. 12.

POWELL, J.M. (1976). Part III, Ethnobotany. In *New Guinea Vegetation*, K. Paijmans (ed.). A.N.U. Press, Canberra.

RAPPAPORT, R.A. (1968). *Pigs for the Ancestors*. Yale University Press.

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REPLANTING ON COPRA PLANTATIONS

A. Shepherd*

ABSTRACT

A postal survey of the larger copra plantations in Papua New Guinea was undertaken in order to ascertain the level of replanting in recent years and the plantations' plans for the future. Results showed a very low level of replanting with no indication that this situation is likely to change in the near future. Reasons for this are considered and possible action to counter the trend is discussed.

INTRODUCTION

The report below presents the results of a survey of replanting of coconuts by plantations. The survey was carried out in late 1978 and took the form of a postal questionnaire sent to all plantations with a 1977 copra production level in excess of 100 tonnes (according to Copra Marketing Board records). Two hundred and five questionnaires were sent out and a total of 83 replies were received (40.5%). In addition, a summary of the situation on 29 Burns Philp plantations (14.1%) was received from Burns Philp New Guinea Ltd. The information provided by this company was not detailed enough to incorporate in the analysis of the other plantations but is referred to in passing in the text.

Of the plantations replying to the questionnaire, 26 were situated in East New Britain, 21 in Madang Province, 15 in New Ireland, 6 each in Central and North Solomons Provinces and 8 in other provinces. Twenty eight per cent of these plantations reported production in 1977 at below 200 tonnes, 29% recorded production between 200 and 300 tonnes, 26% between 300 and 500 tonnes and 17% reported production as being over 500 tonnes. Reported yields varied from less than 0.60 tonne/hectare (17%) to over 1.20 tonnes/hectare (20%). Maximum yields were in the region of 2 tonnes/hectare, mainly in the Madang Province.

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Plantations were also asked to provide information on the year coconuts were first planted on the property. All but three of the plantations were first planted prior to 1940 and 40 were first planted before 1920. Thus, it is evident that almost all plantations are now past the point when, if no replanting had taken place, the age of the trees would tend to cause the average yield to fall. It is generally accepted that output of tall varieties begins to fall off at around 30 years with the rate of decline increasing at around 50 years.

Only five of the plantations concerned were sole copra producers. Over half produce copra and cocoa (58.5%) and nothing else while a further 24.4% have both cocoa and cattle on the plantation together with copra. In 1972, Sackett and Williamson (1973) found that 20.8% of all plantations producing more than 100 tonnes of copra a year were sole copra plantations compared with the 6.1% of this survey. This almost certainly reflects the fact that several plantations have planted cocoa for the first time in the last few years which, in turn, is perhaps a reflection of the low profitability of copra and recent high returns from cocoa.

RESULTS OF SURVEY

Each plantation was asked about replantings and new plantings in the 1971-77 period and about plans for the 1978-82 period. The results show that there has in recent years been relatively little planting and that plantations do not presently intend that this situation should change in the near future.

Answers to the questions were combined in *Table 1* which gives the actual and planned replantings and new plantings between 1971 and 1982.

When considerably more than half of the plantations record nil plantings between 1971 and 1982, a statistical comparison of planting in this period with other variables is rendered rather difficult. There is, for example, no evidence to support a relationship between yield and new planting. This could, of course, be what is expected. On the one hand, the more progressive plantations are likely to have a higher yield and are more likely to replant. On the other, there is less reason for a high yielding plantation to replant. It is noticeable, however, that of those plantations with a yield of less than 0.75 tonne/hectare, 74% report no plantings between 1971 and 1982 while only 57% of plantations with a yield of 1.05 tonnes/hectare or greater, report the same.

Because they are more likely to have trees in need of replanting, it might be thought that the older plantations would show greater evidence of planting activity between 1971 and 1982. However, the survey found no evidence for this.

Tables 2 and *3* show how few plantations have more than a small number of young palms. *Table 2* shows how many plantations have trees up to seven years old, and what proportion of the estates are accounted for by such trees, while *Table 3* shows the same for trees in the 8-14 years category.

Sackett and Williamson (1973) in a survey carried out in 1972, found that 9.8% of the land on plantations with production greater than 100 tonnes per annum was devoted to palms of 0-7 years old. Although the present survey was not designed to provide information comparable with that study, it is fairly clear from an inspection of *Table 2* that the present total can be nothing like as high as

Table 1.—**Actual and planned coconut plantings by plantations, 1971-82**

Hectares	Number of plantations	Percent
0	53	63.8
1-9	5	6.0
10-19	8	9.6
20-39	7	8.4
40-99	2	2.4
100-199	4	4.8
200 plus	4	4.8
Total	83	

Table 2.—**Proportion of planted areas devoted to palms 0-7 years old**

Percent of planted area	Number of plantations	Percent
0-4	56	70.0
5-9	14	17.5
10-14	5	6.2
15 and over	5	6.2
Total	80	

Table 3.—**Proportion of planted areas devoted to palms 8-14 years old**

Percent of planted area	Number of plantations	Percent
0-4	38	47.5
5-9	16	20.0
10-14	12	15.0
15 and over	14	17.5
Total	80	

9.8%. Seventy out of eighty plantations (87.5%) have less than 10% of their land given over to palms under eight years old and it is likely that, over all plantations, the area of palms less than eight years old is no more than 5% of the total hectares.

Further evidence of the decline in planting in the last few years can be gained by comparing *Tables 1* and *2*. This suggests that there was considerably more planting between 1964 and 1971 (i.e., palms now in 8-14 years age group) than between 1971 and 1978.

An analysis of the number of hectares which estates planted between 1971 and 1977 and intend to plant between 1978 and 1982 shows an average planting of 31.3 hectares over the period. However, if the two plantations which reported plantings between 1971 and 1982 in excess of 500 hectares are excluded from consideration, the average planting is just 19.2 hectares.

Burns Philp plantations have been slightly more active in replanting. Over six percent of the company's palms were under eight years old at the time the survey was carried out.

It was felt that one reason for a lack of replanting in recent years was probably the fact that estates might be waiting for hybrid seed nuts to become available. However, a significant number of plantations do not appear desperately keen to utilise these nuts as the response to the question, "Do you intend to plant hybrids when they become available?" shows (*Table 4*).

If an estate does not intend to plant hybrids, it can be reasonably assumed that it does not intend to plant at all. Thus, 17 out of 83 (20.4%) probably intend to carry out no replanting whatsoever, while a further 27 (32.5%) are undecided on this. Burns Philp plans to plant approximately 300 hectares of hybrids per annum in the next decade, "subject to the Government revising its arrangements for compensation to insure the company against loss".

Table 4.—**Plantations planning to plant hybrids**

	Number
Yes	32
No	17
Undecided	27
No Answer	7
Total	83

REASONS FOR LACK OF REPLANTING

Respondents were asked to reply to the following questions: "If you have not been actively replanting coconuts in recent years, what are the reasons for this?"

The main reason offered was the uncertainty that surrounded the future ownership of the plantation. Also on the theme of uncertainty, one or two answers implied that the planters doubted the future political stability of Papua New Guinea. Clearly, no plantation is going to invest large sums of money in new plantings if it is likely to be taken over by the traditional land holders before a reasonable return on investment can be secured.

A further reason given for a lack of replanting is the high cost of such an operation and the relatively low return from copra. Most long-term price projections for copra imply a slight decline in the 'real' price and thus caution on the part of plantations is probably justified, although a few estates are replanting extensively. It must be borne in mind, however, that extremely high prices for copra prevailed in late 1973 and 1974. There is little evidence to suggest that the extra income accruing to plantations as a result of these prices was invested, at least not in new coconut trees.

One reason for the lack of replanting could be the fact that cocoa is frequently intercropped with coconuts. It is not really practical to replant coconuts without first cutting out the cocoa and, as cocoa is normally more rewarding than copra, such an idea is unlikely to be considered. When cocoa is interplanted, the replanting options would appear to be twofold, i.e.:

a. Keep existing coconuts and replant the cocoa.

b. When the cocoa ceases to be economic, replace the coconuts and replant with cocoa.

Replanting would possibly have been somewhat higher in the last few years, were it not for the fact that reasonable quantities of hybrid seed nuts were to be available in the next few years. Several plantations stated that they were waiting for hybrids to become available before replanting. It is clearly pointless to plant established varieties if higher yielding varieties will shortly be ready for planting.

Some plantations expressed the opinion that the land was not suitable for replanting. This suggests that the enthusiasm for copra plantations in days gone by sometimes led the planters to utilise unsuitable land.

Other reasons offered for a lack of new plantings were that cocoa took priority, that the plantation was changing over to cattle and that the palms were too young to replant. Problems associated with the availability of quality management and of sufficient labour were also cited as being a disincentive to new investment.

CONCLUSIONS AND RECOMMENDATIONS

If Burns Philp plantations are excluded, a response rate of 47% was achieved by this survey. It might be argued that those plantations that took the trouble to fill out the questionnaires were not representative of the plantation sector as a whole. This would not be disputed but it needs to be pointed out that it is probable that plantations in the sample would be more "progressive" than plantations that either could not be bothered to fill in the form or did not maintain the necessary records to enable them to answer the questions. Thus, it can be reasonably assumed that the level of replanting among all plantations is no greater and is probably a good deal less than that revealed by the sample.

The picture that emerges from this survey is one of a declining industry. Replanting by plantations is not sufficient to maintain the level of production in the future and it must be expected that the proportion of copra production contributed by the plantation sector (presently about 50%) will decline, albeit slowly.

Presumably, many of these plantations (along with others) will eventually be acquired by the traditional land owners. However, this is a slow process and while it is taking place, the value of the resource is declining. It is appropriate to ask whether it is in the best interests of Papua New Guinea to allow this to happen. It is certainly not in the interests of the traditional land owners, but they are powerless to do anything about it. Consideration must be given to ways in which plantations, which are presently being run down, can be maintained at an adequate level until such time as they are taken over. It is clearly better for Papua New Guineans to acquire profitable plantations that have witnessed some re-investment rather than plantations which have been run down.

The study has shown the need for firm policy with regard to the ownership of plantation land, a policy which has not been particularly evident up to the present. If the plantation sector is to be allowed to decline, then it must decline as the result of a conscious decision not as the result of neglect. The following courses of action are recommended:

a. A clearly defined acquisition policy must be developed *and* be effectively communicated to the plantation sector.

b. The terms under which plantations will be compensated on acquisition must be clarified. Particularly, attention should be paid to ensuring that any new investment by plantations is compensated and that plantations are aware of the way in which this compensation is to be calculated.

c. Ideally, the transfer of plantations to traditional land owners should be carried out on a free market basis. The Government should only be called in to value a plantation when no agreement can be reached.

d. Consideration should be given to loans for hybrid planting. The I.B.R.D. would be a possible source of finance for such an operation.

ACKNOWLEDGEMENTS

The author would like to take this opportunity to thank those persons who returned completed questionnaires. Thanks are also due to the Rural Statistics Section of the Department of Primary Industry and to Messrs B. Carrad, A. Charles and J. MacEwan for their comments.

REFERENCES

SACKETT, M.A. and WILLIAMSON, P.G. (1973). *The Copra Industry in Papua New Guinea.* Papua New Guinea Department of Primary Industry. pp. 20-21.

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ZOPHIUMA LOBULATA GHAURI (HOMOPTERA: LOPHOPIDAE) AND ITS RELATION TO THE FINSCHHAFEN COCONUT DISORDER IN PAPUA NEW GUINEA

E.S.C. Smith*

ABSTRACT

*Coconut palms (*Cocos nucifera*) in the Finschhafen area of the Morobe Province of Papua New Guinea are frequently affected by the feeding activities of* Zophiuma lobulata *Ghauri (Homoptera: Lophopidae), which causes bronzing of fronds, reduction in yield, marked stunting of growth and occasionally, the death of young palms. Typical symptoms were induced 7-15 months after caging adult and immature leaf hoppers over potted coconut palms.*

Studies on the life history and egg parasitism rates in the field showed that the total generation time was about four months, and included an 8-9 day egg incubation, 82-85 days in the immature nymphal stages and a 30 day preoviposition period. Egg masses were found to be heavily parasitised by an encyrtid wasp Ooencyrtus malayensis *Ferriere which, in conjunction with entomophagous fungi may possibly exert a controlling influence on* Z. lobulata *populations occurring in other areas. A second encyrtid, gen. nr.* Epiencyrtoides *was also found to parasitise an egg mass in the Northern Province.*

INTRODUCTION

During the early 1960's, many coconut palms in the Finschhafen area of the Morobe Province became affected with an unknown disorder. Fronds of affected palms turned a bronze colour and, in severe cases, young palms died. After intensive checking by soil chemists (DASF 1966), plant nutritionists (DASF 1963), pathologists (DASF 1965) and entomologists (DASF 1968, 1969, 1972) the disorder was linked to a sucking bug *Zophiuma lobulata* Ghauri (Homoptera: Lophopidae) (Ghauri 1966). Although the species occurs on coconuts along the North Coast from Alotau to Finschhafen (Bourke *et al.* 1973), only in the Finschhafen area does the insect cause significant damage. There is some evidence that it may be sporadically serious in other areas, one minor outbreak being reported from Popondetta (Bourke *et al.* 1973), but it is not known what factors keep numbers down under normal circumstances. Relatively poor growing conditions in the Finschhafen area may help to explain the frequently observed severity of symptoms there.

Over the years, many Department of Primary Industry officers investigated the problem and this paper summarises the information now available on *Z. lobulata*, some of which was extracted from unpublished reports in Departmental files.

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DAMAGE SYMPTOMS

The condition was first noticed near Finschhafen in 1960 (DASF 1963), but was not considered particularly serious until 1965 when many older coconut palms began dying and the affected area increased. In the area where it was first noticed, up to 10% of older palms died as a result of the disorder, and at least 80% of all palms showed damage symptoms.

At the onset, the disorder is difficult to recognise, and may be confused with normal yellowing of fronds due to adverse climatic conditions, nutritional deficiencies, insect damage or other factors. Within several months however, the symptoms appear as an advanced senescence, with yellowing and necrosis occurring exactly where they would normally occur in an ageing frond, and in the same sequence, but greatly accelerated and more pronounced. Leaflets first show a yellow bronzing from the tip, and as the condition advances, the bronzing extends toward the petiole. The yellowing spreads much more rapidly in the distal leaflets than in the proximal ones, and the distal leaflets often become bronzed along their entire length (DASF 1966; Anon. 1969). Successively less yellowing in the proximal leaflets gives an arrow-head shape to the affected area which is evenly coloured over the affected portion of the leaflets.

As the condition advances, the leaflet tips become necrotic and this necrosis gradually spreads until all the former bronzed area may be replaced by necrotic material. Rarely does the necrosis invade the former green areas. The symptoms are most evident in lower fronds, but as the condition develops, appear to spread upwards to the younger fronds (Anon. 1969).

In severe cases, the petiole appears to become soft and the frond may bend above the basal expansion of the petiole, causing an affected frond to droop much more than a healthy one. The lower fronds die prematurely, and frequently, normal abscission does not occur. A marked reduction in nut production is evident in the later stages (Anon. 1969).

Palms which have recovered from an attack are characterised by a large amount of necrotic tissue on otherwise healthy fronds.

RELATIONSHIP BETWEEN THE DISORDER AND *Z. LOBULATA* INFESTATION

In the Finschhafen area, *Z. lobulata* was associated with palms affected by the unthrifty condition described, but on healthy palms adults and nymphs were observed in only small numbers (Anon. 1969). It was also noted that in areas which had previously been free of the disorder, a large build up of the insect preceded damage symptoms. Both the lophopid and the unthrifty condition appeared to be absent from a small island off the coast near Finschhafen. In addition, where previously affected palms recovered from the condition, the improvement appeared to be related to a general decrease in *Z. lobulata* populations throughout the affected areas (Anon. 1971).

Both nymphs and adult *Z. lobulata* fed on the fronds, and showed a marked preference for the oldest frond on the palm. There was also a general insect movement upward from old debilitated fronds towards younger healthy ones and confinement to the healthy portion of debilitated fronds. These trends are similar to those shown by the yellowing symptoms during the progress of the condition.

Further evidence was gathered when a very debilitated young coconut palm was removed from Finschhafen to Port Moresby. The palm was potted with its own soil and grown in an insect proofed cage for four months, during which time the old affected fronds died but newly emerging ones were perfectly healthy and showed no signs of yellowing. Sap extracts from this palm were also examined for virus infection by electron microscopy, with negative results.

Although the bronzing of fronds associated with reduced nut production and the occasional death of palms in the Finschhafen area were assumed to be caused by the feeding of *Z. lobulata*, the evidence was only circumstantial.

SYMPTOM INDUCEMENT EXPERIMENT

In an attempt to induce the symptoms of the 'Finschhafen coconut condition', *Z. lobulata* were caged on potted coconut seedlings at Popondetta in the Northern Province.

MATERIALS AND METHODS

In early 1974, 20 seed nuts were planted in 30 cm plastic pots and divided at random into two groups, each placed within a 4 m x 4 m x 3 m high field cage constructed of insect screening. Two months later, when the seedlings were at the two to three leaf stage, *Z. lobulata* adults and nymphs were collected locally and placed on the 10 palms in one of the cages. Over the next three months leafhoppers were added until a viable colony of some 120 nymphs and 15 adults was maintained on the palms. This situation existed from July 1974 to August 1975 when the tent cages were dismantled. The 10 seedlings in the second cage were maintained as a control group without leafhopper feeding. Weeding of the pots and cages was carried out regularly and urea fertiliser (about 20 g per seedling) was applied in October, 1974.

RESULTS AND DISCUSSION

The first signs of yellowing on the fronds were noticed in January 1975 after six to seven months of intensive feeding by the lophopids, and by February 1975, bronzing of the fronds was readily noticeable. Two months later, the bronzing was general over all the fronds in the cage containing the leafhoppers, while the control palms displayed no yellowing symptoms. By August 1975, some 14-15 months after intensive feeding was initiated, the potted seedlings were very stunted, many fronds had died and the palms looked very unthrifty. All fronds had turned a bronze colour and no green fronds were present. In contrast, the control palms appeared healthy, were growing vigorously and the fronds were a deep green colour.

In late August, 1975, after the coconuts were sprayed to run off with 0.1% lindane insecticide to kill the leafhoppers, the number of fully expanded, unexpanded and dead fronds were counted and the height from the emergence of the stem to the tip of the unfurled fronds (spear) was

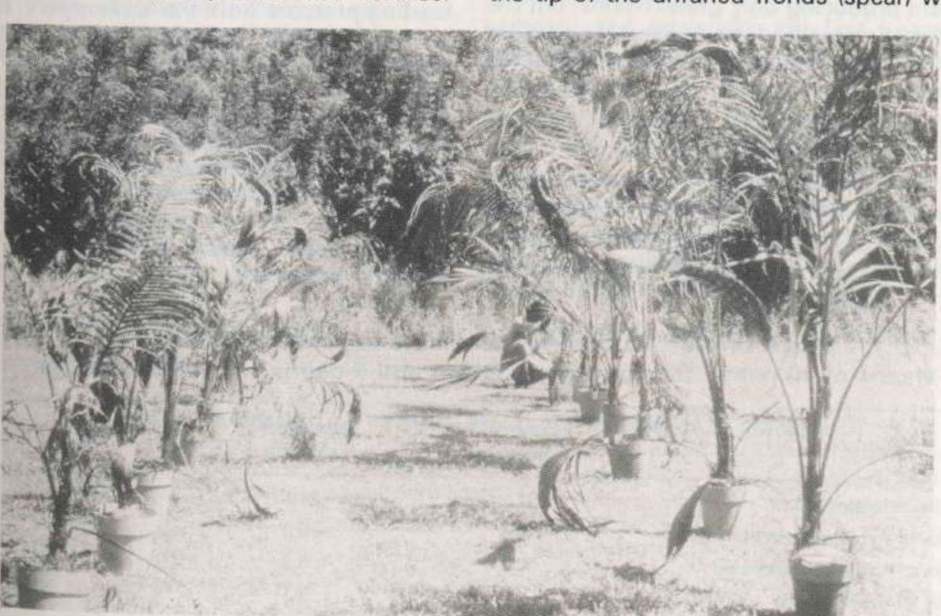

Plate I.—**Inducement of symptoms in potted coconut seedlings by *Z. lobulata*. Infested plants on left, uninfested plants on right** recorded for each seedling. These measurements are presented in *Table 1*.

Feeding by *Z. lobulata* was shown to induce bronzing symptoms very similar to those noticed on young palms at Finschhafen, but the symptoms did not start to appear until some six to seven months after intensive feeding had begun. Insect feeding was also shown to reduce the vigour of the palms and to cause stunting (*Plate I*). The average height of the control palms was significantly higher (P < 0.001, Students 't' test) than that of the seedlings which had been exposed to leafhopper feeding for 14-15 months (*Table 1*). Slightly more fronds were produced and more dead fronds counted on the seedlings exposed to leafhopper feeding, but these differences were not significant (*Table 1*).

Following the termination of the experiment all palms were field planted, and the damaged seedlings subsequently appeared to recover fully and produce green fronds. After three years in the field, all palms were completely healthy and were producing only green fronds, but the control palms had maintained their height advantage over the previously affected palms.

CONCLUSIONS

The results from this experiment suggest that *Z. lobulata* is intimately involved in the Finschhafen coconut disorder, and that feeding by large numbers of this insect cause symptoms to be expressed that are very similar to those observed on young palms at Finschhafen. The remission of symptoms indicated that a viroid or a mycoplasma-like organism (MLO) was unlikely to have been involved in the disorder, although some MLO-like diseases on coconut palms have been known to exhibit symptom remission (e.g. Harries 1978). The findings by Dr D.E. Shaw that an obviously debilitated palm produced only healthy fronds after being removed from the range of *Z. lobulata* and that sap extracts showed negative results also suggest the absence of an MLO in the Finschhafen coconut disorder.

The production of healthy fronds after insect removal would indicate that any toxicogenic substance which may be introduced by the leafhoppers was not translocated within the palm.

It is probable that the symptoms are caused by a localised toxic reaction to *Z. lobulata* feeding on the frond and that the effects may not be manifest for many months, or unless large numbers of insects are involved. This situation has been reported in other insect/host relations (Carter 1962).

It is also possible that under light feeding pressure from the leafhoppers, the symptoms may only be expressed in palms which are initially unthrifty due to nutrient imbalances, poor soil drainage, climatic or other factors. For instance, palms may suffer mild mineral deficiences without exhibiting any visual symptoms except for reduced yield (Southern and Dick 1969). In the Finschhafen area, coconut palms which have shown the disorder symptoms grow in a rendzina

Table 1.—**Effect on potted coconut seedlings exposed to feeding by *Z. lobulata* (Means of 10 palms for control treatment and 9 palms for exposed treatment)**

Parameter	Control (no exposure)	Exposed to leafhoppers	(s.e.)[1]	
Height (cm)	157.0	84.1	±10.74	***
No. of fully expanded fronds	4.6	5.9	± 0.76	NS
No. of fronds unexpanded	0.7	0.8	± 0.21	NS
No. of dead fronds	4.9	3.1	± 0.69	NS
Total No. of fronds	10.2	9.8	± 0.43	NS

[1] Levels of significance NS = not significant *** = P < 0.001

type coral derived soil which is likely to be deficient in potassium (DASF 1966) and sulphur (Gallasch, pers. comm.). Since these soils are slightly alkaline (Fahmy pers. comm.), some minor elements such as iron or manganese may be unavailable to the palm and the poor growth may be partially due to a lime induced iron deficiency (DASF 1966; Southern and Dick 1969).

BIOLOGY AND ECOLOGY OF *Z. LOBULATA*

LIFE HISTORY STUDIES

Techniques

In an attempt to rear *Z. lobulata* in the laboratory, egg masses were collected from lightly infested palms in the Northern Province and placed in petri dishes in the laboratory. After the nymphs had emerged, small sections of coconut leaflet in vials of water were offered as a food source, and although the nymphs moved onto the fresh leaflets, most died within a few days and only one insect reached the third instar stage.

A more successful technique was then used to rear nymphs to the adult stage on potted coconut seedlings enclosed in insect screening cages 40 cm x 40 cm x 1 m high. Egg masses, which adults had deposited onto potted palms in a large field cage, were removed daily and, still attached to a small portion of coconut leaflet, were stapled to coconut fronds in the small outside cages. Daily records were kept as nymphs developed through to adult leafhoppers. Data on the instar durations are presented in *Table 2*.

Results

The total generation time was about four months, and included an 8-9 day egg incubation, 82-85 days in the immature stages and a 30 day preoviposition period.

Egg. In the field, egg masses were usually deposited on the fibrous material at the base of the petiole or on the lower surfaces of terminal leaflets. However, egg masses were also commonly encountered on the corrugated iron walls and wooden super structure of copra dryers, where the often very hot conditions did not appear to affect viability. The eggs, covered by a white woolly secretion, are a translucent pale green in colour, ovoid in shape and measure about 2 mm by 1 mm. The number of eggs in an egg mass varies greatly, and in one 500 egg mass sample, ranged from 1-217, averaging 38.8 eggs per mass.

Nymphal stages. Five immature stages are passed before the insect becomes adult. First instar nymphs (*Figure 1A*) tended to remain in the vicinity of the egg masses, but older nymphs moved onto the older fronds of an infested palm. All nymphs, and especially the first instars, have two very long, waxy filaments extending from the posterior end of the abdomen but these frequently break off even under natural conditions. Each of the nymphal stages has two horizontal red bands on the frons, and two longitudinal red bands on the prothorax. There is much variation in the duration of the nymphal instars (*Table 2*), but on average, the nymphal period lasts about 12 weeks.

Table 2. — **Duration of various life cycle stages of *Z. lobulata***

Life history stage	Mean duration (days)	Range (days)	No. of measurements
Egg mass	8.3	7 - 10	27
1st instar	12.9	3 - 17	191
2nd instar	8.2	4 - 14	131
3rd instar	17.9	11 - 27	112
4th instar	17.7	7 - 35	50
5th instar	25.4	13 - 37	32
Egg to adult	85.9	69 - 112	30

Adult. Both sexes of *Z. lobulata* were described by Ghauri (1966). The adults (*Figure 1B*) are 16-18 mm in length, brownish in colour and also have the two horizontal red frontal bands. A characteristic black spot with a sub-central white dot is easily noticeable on the apical portion of the tegmen.

FEEDING HABITS AND ALTERNATE HOSTS

The insects are mainly found on the oldest frond on the palm, and are most abundant on the lower surface of the petiole and to a lesser extent, on the terminal portion of the frond. The central area is usually less densely populated. Most feeding occurs on the petiole, midrib or central veins of the leaflets. In some cases, extremely heavy infestations of leafhoppers occur, and populations exceeding 1,000 per frond have been recorded on several occasions.

Besides coconuts, the leafhopper has been observed in moderate numbers on betel nut (*Areca catechu*) and on granadilla (*Passiflora quadrangularis*) (Bourke *et al.* 1973). Adults and nymphs have also been reported from pandanus (probably *Pandanus lerum*).

NATURAL ENEMIES

It is probable that a range of general predators feed on *Z. lobulata*, but only one unidentified salticid spider has actually been observed preying on a nymph. Two species of wasp parasitoid have been reared from egg masses of the coconut leafhopper. In the Popondetta area about 10% of all eggs in one egg mass collected from a leaf of cultivated sugar cane (*Saccharum officinarum*) were parasitised by an unidentified micro-hymenopteran (gen. nr. *Epiencyrtoides*, Fam. Encyrtidae). During 1973, egg masses of *Z. lobulata* in areas near Finschhafen were found to be heavily parasitised by another encyrtid wasp, *Ooencytrus malayensis* Ferriere, an

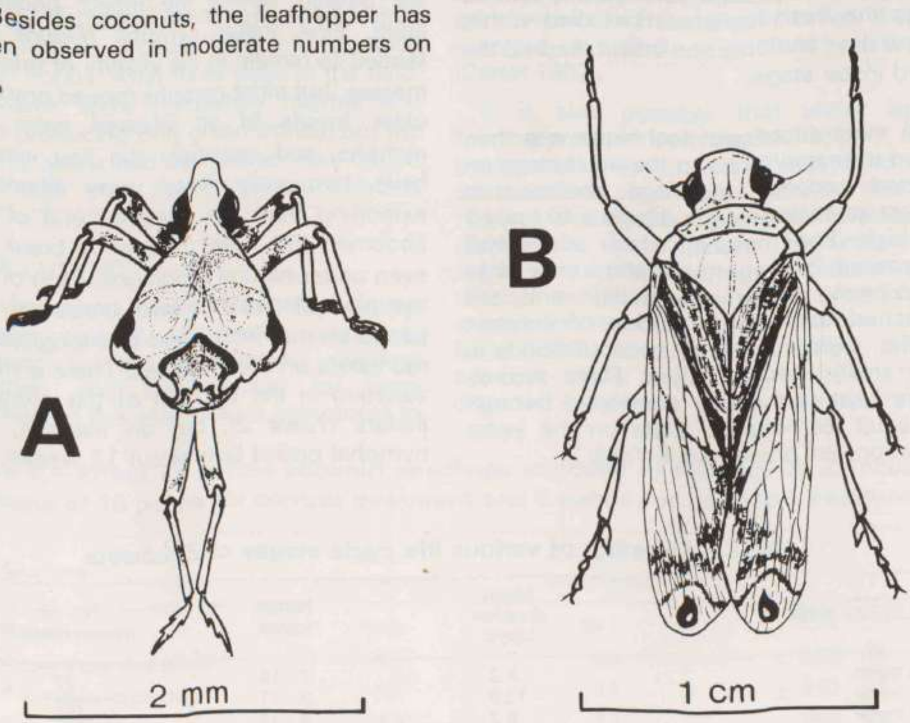

Figure 1.—Zophiuma lobulata **Ghauri**
A — first instar, B — adult

egg parasitoid of several hemipteran and lepidopteran pests in Papua New Guinea (Sands 1977).

The level of egg parasitism by *O. malayensis* was measured over a 10 month period from September 1973 to July 1974 in two localities of the Finschhafen area (*Table 3*). It ranged from 45 to 82% and averaged 65.5% and 69.9% of all eggs sampled in the two localities. It seems that, at any given time, there may be wide variation in levels of parasitism between different sites in the Finschhafen area. Two species of entomophagous fungi have also been collected from *Z. lobulata* at Finschhafen (infected nymph) and Popondetta (infected adult) and are awaiting identification at the Commonwealth Mycological Institute.

POSSIBILITIES OF CONTROL

A major difficulty with coconut pests is that the crop has a relatively low value per hectare, so that effective control treatments are often uneconomic to apply. Several small- scale spraying trials at Finschhafen showed that Ultra Low Volume malathion applied through a misting machine achieved good control of adult and nymphal *Z. lobulata* on young palms five to seven metres in height for up to two weeks, and it is probable that aerial spraying using this insecticide would be effective. However, ULV malathion had no ovicidal effect and a follow up spray two weeks after the first would be required for effective control (DASF 1972). In recent years, several coconut pests have been controlled by trunk injections of the organophosphate insecticide monocrotophos, which is effective against frond feeding (Stelzer 1970; Rai 1973; Ooi *et al.* 1975) and sap sucking insects (Perry, pers. comm.). It is likely that this or other systemic chemicals would be effective against *Z. lobulata*, but the considerable costs involved would probably preclude treatment except in very damaging infestations or in a small outbreak area.

A very similar coconut disorder in Solomon Islands appears to be associated with the lophopid *Painella simmondsi* Muir. When palms infested with *P.*

Table 3.—**Rates of parasitism in *Z. lobulata* eggs collected from two localities in the Finschhafen area**

Locality and collection date	No. egg masses collected	No. and type of insect emerging from eggs			
		Nil	Leafhoppers	Wasps	%Parasitism
ELIMO					
September 1973	120	10	1,388	1,292	48.2
October 1973	100	10	926	3,811	80.5
November 1973	100	16	1,387	1,138	45.1
January 1974	107	11	1,158	2,235	65.9
February 1974	116	12	777	2,340	75.1
April 1974	110	18	1,053	2,653	71.6
June 1974	101	4	763	2,668	77.8
July 1974	120	12	2,116	3,242	60.5
SALANKAUA					
September 1973	—		—	—	—
October 1973	70	38	164	670	80.3
November 1973	87	32	283	1,311	82.2
January 1974	124	11	879	2,608	74.8
February 1974	119	17	660	2,247	77.3
April 1974	120	29	568	1,127	66.5
June 1974	80	13	929	777	44.9
July 1974	120	5	1,661	2,888	63.5

simmondsi were injected with monocrotophos, all leafhoppers died or disappeared within 24 hours, and the treated palms recovered several months before a general recovery in the affected block began (Stapley, pers. comm.).

Attempts at biological control may prove successful, and would of course be preferable in the long term. It may be possible to collect parasitised leafhopper egg masses from 'non-out-break' areas in order to release the emerging parasites in badly affected coconut blocks elsewhere in the Finschhafen area. If the parasitised egg masses are held for emergence in a container covered with a medium size mesh (e.g. 1 mm x 1 mm), the parasites could escape through the holes, leaving the newly hatched leafhoppers trapped in the container in which they could easily be destroyed. Introductions of the other encyrtid parasite (gen. nr. *Epiencyrtoides*) could also be made to the Finschhafen area, and if parasites of *P. simmondsi* are found, they could perhaps be introduced to Papua New Guinea for laboratory screening against *Z. lobulata*.

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REFERENCES

ANON. (1969). Insect pest survey for the year ending 30th June 1967. *Papua New Guinea Agricultural Journal*, 21(2): 49-75.

ANON. (1971). Insect pest survey for the year ending 30th June 1968. *Papua New Guinea Agricultural Journal*, 22(3): 179-201.

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

CARTER, W. (1962). *Insects in Relation to Plant Disease*. Interscience, New York. 705 pp.

DASF (1963). *Annual Report 1960-61*. Department of Agriculture, Stock and Fisheries, Port Moresby. 125 pp.

DASF (1965). *Annual Report 1963-64*. Department of Agriculture, Stock and Fisheries, Port Moresby. 150 pp.

DASF (1966). *Annual Report 1964-65*. Department of Agriculture, Stock and Fisheries, Port Moresby. 164 pp.

DASF (1968). *Annual Report 1965-66*. Department of Agriculture, Stock and Fisheries, Port Moresby. 168 pp.

DASF (1969). *Annual Report 1966-67*. Department of Agriculture, Stock and Fisheries, Port Moresby. 196 pp.

DASF (1972). *Annual Report 1967-69*. Department of Agriculture, Stock and Fisheries, Port Moresby. 240 pp.

GHAURI, M.S.K. (1966). *Zophiuma lobulata* sp. n. (Lophopidae: Homoptera), a new pest of coconut in New Guinea. *Annals and Magazine of Natural History*, Ser. 13, 9: 557-561.

HARRIES, H.C. (1978). Lethal yellowing disease of coconuts in global perspective. *Philippine Journal of Coconut Studies*, 3(3): 1-4.

OOI, Peter A.C., YUNAS, A., GOR, K.G. and BALASUBRAMANIAM, A. (1975). Control of the coconut leaf moth, *Artona catoxantha* Hamps.: Trunk injection technique. *Malayasian Agricultural Journal*, 50(2): 159-168.

RAI, B.K. (1973). *Brassolis sophorae* and *Castnia deadalus*: Chemical control of these major pests of coconut in Guyana. *Journal of Economic Entomology*, 66(1): 177-180.

SANDS, D.P.A. (1977). The Biology and Ecology of *Leptocorisa* (Hemiptera: Alydidae) in Papua New Guinea. *Research Bulletin* No. 18, Department of Primary Industry, Port Moresby, Papua New Guinea. 104 pp.

SOUTHERN, P.J. and DICK, Kay (1969). Trace element deficiencies in tropical tree crops in Papua New Guinea. *Research Bulletin* No. 3, Department of Agriculture, Stock and Fisheries, Port Moresby. 41 pp.

STELZER, M.J. (1970). Preliminary studies on the control of the coconut stick insect, *Graeffea crouanii* (Le Guillou), with systemic insecticides. *Bulletin of Entomological Research,* 60(1): 49-51.

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TOXICITY OF *LEUCAENA LEUCOCEPHALA* II. REDUCED FERTILITY OF HEIFERS GRAZING *LEUCAENA LEUCOCEPHALA*

J.H.G. Holmes*

ABSTRACT

Twenty four heifers grazing Leucaena leucocephala *cv. Peru were mated when they reached 300 kg live weight. Eight heifers conceived in less than four months, ten conceived in 9-18 months and six did not conceive in 12-27 months. Eleven similar heifers on grass pastures all conceived in less than two months. Growth rates of heifers with different reproductive performances were similar. Fourteen heifers were slaughtered, including six which had not conceived, five which were not detectably pregnant by rectal palpation but had embryos one to six weeks old and three which had calved but not conceived again. All had some degree of goitre. All non-pregnant heifers had ovaries and uteri of normal appearance. All calves born had goitre. Five heifers tested pregnant failed to produce a calf. Three bulls used had normal semen and libido. A defect is suspected in establishment or maintenance of pregnancy after mating.*

INTRODUCTION

Leucaena leucocephala is a leguminous browse tree or shrub with great potential for production of high protein forage. It occurs in many areas of the tropics and sub-tropics, where it is used as forage or as a shade for plantation crops such as cocoa or coffee. Its agronomic, genetic, nutritional and toxic characteristics were reviewed by Gray (1968). Toxicity was manifest in depilation, growth reduction, infertility in rats and embryonic death in mice. In ruminants the most obvious toxic features are hair or fleece loss (Hegarty *et al.* 1964), oesophageal ulcers and enlarged thyroids in sheep (Bindon and Lamond 1966) and cattle (Hamilton *et al.*1971), when it is fed as the sole diet in pens. Goitre has been found in cattle grazing *Leucaena* as mixed pasture or pure stands (Jones *et al.* 1976). Although Hylin and Lichton (1965) and Joshi (1968) have shown effects of mimosine and *Leucaena* on reproduction of rats, the effects upon reproduction in ruminants is not clear. Beaumont (1948) fed *Leucaena* as the sole roughage to dairy cows for two years and recorded no abnormalities. However Hutton and Gray (1959) and Gohl (1975) state that *Leucaena* is suspected of causing sterility in cows. Bindon and Lamond (1966) fed *Leucaena* to ten pregnant ewes in pens and recorded one abortion and the birth of small weak lambs with 50% mortality in one month. Hamilton *et al.* (1971) fed *Leucaena* to five heifers in pens, and recorded no alterations in oestrus cycle length, conception rate or gestation length, but recorded one still birth and four undersized (19 kg) calves with enlarged thyroids. The present paper reports on a two and half year trial with 24 heifers grazing pure stands of *Leucaena*, in which reproduction was severely affected. A preliminary report has been published (Holmes 1976).

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MATERIALS AND METHODS

Leucaena leucocephala (cv. Peru) was established at Erap, Morobe Province in 1967 on light sandy soil, in rows two to three metres apart. Guinea grass and

Buffel grass failed to persist between the rows despite repeated sowings. The pasture during the experiment contained *Leucaena* and inedible weeds (*Sida* spp., *Solanum torvum*, *Digitaria insularis*). For the first five months, four paddocks totalling 5.35 ha were available for grazing and subsequently 7.15 ha were used.

The experiment was designed to measure heifer and calf growth rate on a diet of *Leucaena*. The trial was set up in August, 1974, using 24 crossbred (½ to ¾ Brahman) heifers 12-18 months old grazed rotationally on *Leucaena*. Twelve heifers received two grams of potassium iodide orally per month for the first year and subsequently the same amount of iodine in iodized oil by injection. When they reached 300 kg, they were placed with a bull in a separate paddock of *Leucaena*.

Eleven similar heifers, grazing grass, *Imperata cylindrica, Themeda australis* and *Cenchrus ciliaris,* were also mated at 300 kg. All animals were weighed every 28 days and calving dates were recorded.

When a pregnancy examination revealed that many mated heifers grazing *Leucaena* were not pregnant, a second bull was used after eight months and a third bull 12 months later. The bulls were proven sires and throughout the trial semen evaluation was normal. The experiment was terminated after 27 months. Eleven nonparous, apparently non-pregnant heifers and three which had calved but not become pregnant again were slaughtered, and thyroids and genitalia examined. Ten heifers which were detectably pregnant or had small calves at this time were not slaughtered.

Apparent conception interval (ACI), the period from placing the heifers with the bull until conception occurred, was calculated using calving date or foetal size at slaughter.

RESULTS

Weight gains for both *Leucaena*-fed and grass-fed heifers have been reported previously (Holmes 1976). All eleven grass-fed heifers conceived within two months (*Table 1*). *Leucaena*-fed heifers fell into three groups, eight with short ACI, ten with long ACI and six which did not conceive. There was no difference associated with iodine supplementation.

ACI was not related to season, since heifers mated at the same time had different reproductive performances; for

Table 1.—**Breeding and growth performances of Brahman Cross heifers grazed on mixed grasses or on *Leucaena leucocephala* (means ± S.E.M.)**

	Native pasture	*Leucaena*		
Conception interval group	Short	Short	Long	No Conception
No. of heifers	11/11	8/24	10/24	6/24
Mating interval, to conception or slaughter (days)	30 ± 7	65 ± 11	388 ± 43	564 ± 90
Live weight at conception or slaughter (kg)	308 ± 5	320 ± 9	423 ± 17	468 ± 90
Live weight gain in 56 days after placing with bull (kg)	18.6 ± 2	13.0 ± 3	19.0 ± 3.0	15.1 ± 7
Live weight gain in 56 days before conception (kg)	19.6 ± 2	17.8 ± 3.8	16.2 ± 6.9	
Period of grazing *Leucaena* prior to mating (days)	0	228 ± 52	277 ± 47	224 ± 73
Weight of thyroid of slaughtered heifers (g)	—	69 ± 9 (3 heifers)	116 ± 11 (5 heifers)	224 ± 73 (6 heifers)

example, of those mated at eight weeks from the start of the experiment, two were classed short ACI, two were classed long ACI and one did not conceive. Five heifers showing positive pregnancy tests at three to five months failed to produce a calf at the expected time. Live weight at the conception which produced a calf or a foetus at slaughter and rates of growth at the time of first mating and at the time of conception are presented in *Table 1*. Animals which conceived after greater than normal ACI were significantly heavier, but their rates of growth at the time of first mating and at the time of conception did not differ from those of grass-fed or *Leucaena*-fed heifers which bred normally. The average period of grazing *Leucaena* prior to mating, with a minimum of 56 days, did not differ between ACI groups.

Of the fourteen heifers slaughtered, six had not calved and were not pregnant at slaughter. All had apparently normal, active ovaries and visually normal uteri. All six had goitre (*Table 1*). Five heifers from the long ACI group were slaughtered: one had an apparently dead embryo while the others carried embryos which appeared normal. Goitre was less pronounced. The three short ACI heifers, which had not conceived rapidly a second time, exhibited normal genitalia and mild goitre. Thyroid size was not related to iodine treatment.

Birth weight of calves was 22 $\pm$ 2 kg, only slightly underweight for Brahman calves. However, the lightest calf weighed only 11 kg and died on the day of birth. No autopsy was performed. One apparently normal 20 kg calf suffered an accidental death at birth. This animal was goitrous, with the thyroid weighing 83 g, compared to the normal weight of about six grams. Other calves had goitre detected by palpation, but growth rates for the first three months of life, 0.73 $\pm$ 0.06 kg per day, were normal for Erap conditions.

DISCUSSION

Although reproductive problems in ruminants grazing *Leucaena* have been suspected previously, and undersized offspring have been produced in pen feeding trials, Everist (1974) states that no definite experimental evidence is available for lowered fertility of ruminants grazing this plant.

The results of this trial clearly show a marked deficiency in breeding performance of heifers fed on *Leucaena* for even a short period before and during mating.

The cause of reproductive failure has not been identified but a number of factors can be eliminated. Failure was not related to iodine treatment or duration of feeding *Leucaena*, over a minimum of 56 days. Failure was not related to season or to growth rates of heifers. Since the bulls used were proven sires and semen evaluations were all normal the problem was presumably not one of male sterility. No systematic mating records were kept, since the infertility was not suspected until the trials had run six months, but animals which failed to conceive were observed mating, so oestrus and libido appeared to be normal. Ovaries of infertile heifers had normal-appearing follicles and *corpora lutea*.

The remaining possible areas for failure are the processes of sperm and egg transport, implantation or placental defects and maintenance of pregnancy. In rats, Joshi (1968) found *Leucaena* caused foetal death and resorbtion. Bindon and Lamond (1966) working with sheep, and Hamilton *et al.* (1971) working with cattle reported undersized offspring, abortions and still births. One of the heifers slaughtered in this trial had a three months foetus which appeared dead; five other heifers, shown to be pregnant by rectal palpation by two operators, failed to produce a calf and one undersized calf died at birth. This suggests that in several cases conception, implantation and early development did occur, but that some type of failure occurred in mid pregnancy resulting in abortions or production of undersized weak offspring.

The results confirm the suspicions aroused in some previous work with *Leucaena* as a forage for ruminants. Under the conditions in this trial 16 of 24 animals experienced reproductive failure, which may have been due to failure of maintenance of pregnancy after successful conception.

REFERENCES

BEAUMONT, J.H. (1948). Koa haole roughage as a substitute for oil cake meals. *Report of the University of Hawaii Experiment Station for the Biennium ending June 30, 1948*. pp. 38-39.

BINDON, B.M. and LAMOND, D.R. (1966). Examination of tropical legumes for deleterious effect on animal reproduction. *Proceedings of the Australian Society of Animal Production*, 6: 109-116.

EVERIST, SELWYN L. (1974). *Poisonous Plants of Australia*. Angus and Robertson. 1325 pp.

GOHL, B. (1975). Tropical Feeds. Feeds information summaries and nutritive values. *FAO Agricultural Studies* No. 96. pp. 196-197.

GRAY, S.G. (1968). A review of research on *Leucaena leucocephala*. *Tropical Grasslands*, 2 (1): 19-30.

HAMILTON, R.I., DONALDSON, L.E. and LAMBOURNE, L.J. (1971). *Leucaena leucocephala* as a feed for dairy cows: Direct effect on reproduction and residual effect on the calf and lactation. *Australian Journal of Agricultural Research*, 22: 681-692.

HEGARTY, M.P., SCHINKEL, P.G. and COURT, R.D. (1964). Reaction of sheep to the consumption of *Leucaena glauca* Benth, and to its toxic principle mimosine. *Australian Journal of Agricultural Research*, 15: 153-167.

HOLMES, J.H.G. (1976). Growth of Brahman cross heifers grazing *Leucaena*. *Proceedings of the Australian Society of Animal Production*, 11: 453-456.

HUTTON, N.M. and GRAY, S.G. (1959). Problems in adapting *Leucaena leucocephala* as a forage for the Australian Tropics. *Empire Journal of Experimental Agriculture*, 27 (107): 187-196.

HYLIN, J.W. and LICHTON, I.J. (1965). Production of reversible infertility in rats by feeding mimosine. *Biochemical Pharmacology*, 14: 1167-1169.

JONES, R.J., BLUNT, C.G. and HOLMES, J.H.G. (1976). Enlarged thyroid glands in cattle grazing *Leucaena* pastures. *Tropical Grasslands*, 10 (2): 113-116.

JOSHI, H.S. (1968). The effect of feeding of *Leucaena leucocephala* (Lam) de Wit., on reproduction in rats. *Australian Journal of Agricultural Research*, 19: 341-352.

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IMPERATA CYLINDRICA FOR CATTLE PRODUCTION IN PAPUA NEW GUINEA

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ABSTRACT

Economic and practical farming considerations on smallholder farms in Papua New Guinea preclude replacement of lowly-productive Imperata cylindrica *with fully improved pastures, although a great increase in beef production could be obtained by full pasture improvement.*

A pasture cutting trial showed that Imperata cylindrica *cut every four weeks contained 1.5% N, but productivity rapidly declined. At six, eight or twelve week cutting intervals, yields of dry matter were greater than for nine improved species cut at six week intervals but N was less (0.93-1.14%).*

A grazing trial over three years showed higher production by fully improved pastures and a small increase due to Stylo + Imperata *over unimproved* Imperata. *A more suitable legume is needed for this soil type. Unimproved* Imperata *produced the same cattle weight gains at all stocking rates, indicating that at lower stocking rates cattle were unable to select a better diet.*

A nylon bag digestibility trial showed that Imperata *was about two thirds as digestible as Buffel grass, Setaria or Elephant grass, at three, five, seven and nine weeks. The rate of digestion was low. These data indicate that* Imperata *is never a high quality pasture and consequently no pasture management technique can produce rapid gains. Only substitution, partially with legumes or totally with fully improved pastures can produce rapid growth.*

On smallholder cattle farms with Imperata*-dominant pastures, breeding rate in cows ranged from 75 to 100%. Growth rates were variable and age at turnoff of steers at 450 kg ranged from 25 to 44 months; management was an important component in this variation.*

We conclude that Imperata *pastures can support a viable extensive beef production system which can be improved with broadcasting of those legumes appropriate to the environment. Low stocking rates are necessary in Papua New Guinea; but the large areas of unutilized grassland make this no obstacle.*

INTRODUCTION

Although the area of Kunai (*Imperata cylindrica*) dominant grassland in Papua New Guinea covers millions of hectares, very little research has been carried out on its productivity for beef cattle raising. Most effort here, and elsewhere in the tropics, has been devoted to the assessment of introduced species of grass and legumes (e.g. Hoshino 1975). This concentration on new species ignores a number of factors:

(a) the *Imperata* grasslands are there, already established,

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(b) the cost of establishing new grasses is high, the results uncertain and the economics very dubious,

(c) for the smallholder cattle raiser, with 10-50 breeding cows, full pasture improvement is just not feasible, due to lack of capital and skill, as well as representing a gross over-capitalisation.

Imperata dominant grasslands are found from sea level to nearly 2,000 m, with rainfalls varying from 1,250 mm at Erap to 4,000 mm at Situm, and on soils with pH ranging from 5 at Urimo in the Sepik to 9 at Erap. The definition of productivity of *Imperata* over this range of conditions will take an enormous amount of work. This paper reports some trials carried out at Erap and near Lae in Morobe Province, Papua New Guinea.

MATERIALS AND METHODS

Erap Beef Cattle Research Centre is situated in the Markham Valley, 50 km from the sea at an altitude of 100 m. The terrain is flat; the soils are recent alluvial sandy loams and gravelly loams, very free draining, with a pH of up to 9. There are no major mineral deficiencies although legumes respond to sulphur sometimes, and occasionally to phosphorus application (Chadhokar 1974). The high pH appears to be the main soil chemistry problem, limiting normal legume growth. Rainfall of 1,250 mm per annum falls in a major wet season from December to April and a minor wet season in July and August. Temperatures range from 23 to 35ºC in December and from 18 to 30ºC in July. Frequent strong winds in dry periods dry out the light soils very quickly.

TRIAL 1: PRODUCTIVITY OF DRY MATTER AND NITROGEN

A cutting trial was carried out at Erap over a 12 week period, from April to July. A block of 0.2 ha was divided into 20 plots, each 10 m × 10 m, and the whole area slashed to a height of 7.5 cm on 18 April. Five plots were cut three times at four week intervals, five more cut twice at six week intervals, five once at eight weeks and five once at twelve weeks (*Table 1*). Each cut was to a height of 7.5 cm; total yield, dry matter (DM) and nitrogen (N) were determined.

TRIAL 2: BEEF PRODUCTION: STOCKING RATE TRIAL

A grazing trial using a factorial design was set up. Four pastures: *Imperata*, *Imperata* + legumes, *Panicum maximum* (var. Hamil) + initial N (50 kg in 1st year as ammonium sulphate) and Hamil + legumes, were grazed each at four stocking rates (*Table 2*). The legumes initially sown were *Glycine javanica, Stylosanthes guyanensis* and *Phaseolus atropurpureus* (Siratro), but only *Glycine* in Hamil, and Stylo and Siratro in *Imperata* have persisted, and the proportion of legume in the *Imperata* is low. The stocking rates were not the same for all pastures since it was already known that Hamil grass could be grazed more heavily than *Imperata*. Within each pasture, one stocking rate was replicated. Initial grazing group size was three Brahman-cross heifers, 12 months old in each plot. Live weights were recorded each four weeks. All animals were removed when 20-30% reached 300 kg and were replaced with a new group. Each group remained about six or seven months. After 14 months, the stocking rate in the *Imperata* paddocks was increased by addition of a fourth heifer per paddock because the quantity of feed available indicated that the stocking rates were too low. The trial has continued for another 22 months at the time of writing.

TRIAL 3: NYLON BAG DIGESTIBILITY OF IMPERATA

A factorial trial, four grasses (*Imperata, Setaria sphacelata* (var. Nandi), *Cenchrus ciliaris* (var. Biloela), *Pennisetum purpureum* (Elephant grass)) × four ages of grass (3, 5, 7 and 9 weeks) × three digestion times (20, 48 and 72 hours) was run using two rumen fistulated steers, with two replicates of each treatment in each steer.

Table 1.—**Dry matter production (kg ha^{-1}) and N concentration, (%), of *Imperata*, cut at 4, 6, 8 or 12 weeks**

Frequency (weeks)		Cutting dates 16 May	30 May	13 June	11 July	Mean DM production (kg $weeks^{-1}$)	Mean N (%)
4	DM	586 ab		829 b	411 a	152	1.48
	N	1.54%		1.30%	1.59%		
6	DM		1,524 c		1,531 c	255	1.14
	N		1.01%		1.26%		
8	DM			2,490 d		311	0.97
	N			0.97%			
12	DM				3,836 e	320	0.93
	N				0.93%		

a, b, c, d, e Numbers with different superscripts are significantly different at $P < 0.05$, S.E.M. = 90 kg DM.

Table 2.—**Growth rate (kg day^{-1}) of heifers on 4 pastures grazed at 4 stocking rates at Beef Cattle Research Centre, Erap**

Species	Stocking rate (ha beast^{-1})	Gain (kg day^{-1}) in grazing period 5.12.74 to 18.12.74	18.12.74 to 31.7.75	31.7.75 to 7.4.76	Weighted mean growth rate (kg day^{-1})	Growth rate (kg ha^{-1} day^{-1})
Imperata	1.29	0.26	0.20	0.22	0.22	0.17
	1.06	0.25	0.23	0.27	0.25	0.24
	0.83	0.24	0.16	0.24	0.21	0.26
	0.61	0.20	0.18	0.23	0.20	0.34
Imperata	1.06	0.34	0.32	0.33	0.33	0.31
+	0.89	0.26	0.27	0.24	0.26	0.29
legumes	0.72	0.25	0.16	0.24	0.22	0.31
	0.56	0.19	0.22	0.23	0.21	0.38
Hamil	0.68	0.44	0.38	0.42	0.41	0.60
+	0.55	0.45	0.28	0.40	0.38	0.69
Nitrogen	0.42	0.44	0.32	0.31	0.35	0.83
	0.29	0.37	0.29	0.38	0.35	1.21
Hamil	0.76	0.43	0.30	0.42	0.38	0.50
+	0.59	0.53	0.38	0.45	0.45	0.76
legumes	0.46	0.55	0.39	0.43	0.45	0.98
	0.33	0.38	0.37	0.34	0.36	1.09

LSD for significant ($P < 0.05$) differences between individual periods and grasses = 0.058

Grass plots of *Imperata*, Nandi *Setaria*, Biloela Buffel and Elephant grass (4 m² of each) were cut back to 15 cm high. Square metre samples were then recut back to 15 cm after three, five, seven and nine week intervals. The grass samples were dried at 70°C for 24 hours and ground through the 4 mm screen of a Retsch K.G. Hammer Mill (a lower screen size gives greater particle loss through the bags other than by digestion (Playne *et al.* 1978)). On average 4-7 g of dried sample were used per nylon bag. After filling, the nylon bags containing the grass samples were redried at 70°C for 24 hours and weighed to give the actual DM content per bag. The method of bag manufacture and the digestion technique were as used by Playne *et al.* (1978) but with some modifications due to resources available.

Two two-year-old Droughtmaster steers with rumen fistulas were used in the trial. Three iron rings with 32 nylon bags attached to each of them were placed in the ventral sac of the rumen. One ring was removed after 20, 48, and 72 hours. There were four bag replications per treatment as this is thought to be sufficient to detect biologically important differences between treatments (Playne *et al.* 1972). Each steer held half of these replicates. The steers were fed a basal diet of Buffel:Siratro hay.

On removal from the rumen the bags plus undigested residues were rinsed in two changes of water for a few minutes, dried for 36 hours at 80°C, weighed, and the % DM loss calculated. There were no corrections made for loss of particulate matter from the bags or additions of rumen DM to the bags.

TRIAL 4: PRODUCTIVITY OF SMALLHOLDER CATTLE ON IMPERATA *PASTURES*

The growth rates and reproduction rates on smallholder cattle farms were determined over 1974-1975. The five farms studied, all at 0-300 m, are described in *Table 4*. None had significant pasture legume present. At intervals of 3-4 months, all new cattle (births or purchases) were identified, all were weighed and females were examined for pregnancy and lactation. No weaning is practised on any of these farms; animals up to 225 kg or 10 months old are assumed to be still sucking their dams and are classified as calves. Most cows lactate for at least 10 months after calving, and some for 15 months. Castrated males were retained until they reached 450 kg, which occurred at 2-3½ years of age. Data for growth of steers were collected over periods of at least 9 months and up to 2 years for individual animals. Growth data for heifers are presented for the period from 9-10 months of age until conception occurred. Weight of cows is the last weight prior to calving, this being the only weight collected when all cows were in the same physiological status, i.e. late pregnancy and non-lactating. An analysis by seasons is beyond the scope of this paper, although marked variations did occur between years on farms 4 and 5.

All farms were in the initial stages of development and were still purchasing cattle to build up herd size. Farms 1 and 2 bought heifers in 1973, while farms 3, 4 and 5 bought groups of steers in 1973 and farm 3 bought steers in 1974.

RESULTS

TRIAL 1

The data in *Table 1* show the lower yield of DM and higher N% of cuts made at 4 and 6 weeks, while at 8 and 12 weeks, production per week and N concentration are very similar. Although rainfall in consecutive 4 week periods increased (40 mm, 55 mm and 58 mm), production in the third 4 week period was markedly depressed, probably due to the sensitivity of *Imperata* to too-frequent defoliation.

TRIAL 2

Growth rate of heifers is presented for a period of 22 months subsequent to the stocking rate adjustment at 14 months (*Table 2*). During these 22 months, 3 groups of heifers were used, for 196, 225 and 251 days respectively. There was a significant difference between growth rate of groups due to season. Overall, the *Imperata* was least productive and the Hamil + legumes pasture was most productive. Growth rate increased (but production per ha decreased) with increased area available per heifer.

TRIAL 3

The percentage disappearance of DM for each grass at each age and time of digestion (*Table 3*) shows the lower relative digestibility of *Imperata* at all ages ($P < 0.001$) while the other 3 grasses were not significantly different. The increase in digestion % with increase in digestion time ($P < 0.001$) and the decrease in digestion % with age of grass ($P < 0.001$) are as expected. A significant interaction ($P < 0.01$) between grasses and digestion times revealed that the rate of digestion of *Imperata*, although slower than the other grasses, did not decline with time as much. The significant age by time interaction was due to the similar situation with older grasses: a slower initial rate of digestion but less reduction in rate with time. This suggests that lignification, which increases with age, renders digestible material less accessible to fermentation, so that digestion will continue steadily but slowly for a long time rather than rapidly at first then slowly as the most digestible material is used up. Even at 3 weeks of age, *Imperata* suffers from the same restraints upon digestion rate as affect other grasses at 7-9 weeks.

TRIAL 4

The growth rates of male and female calves, steers and heifers (*Table 5*) showed wide differences between farms, even when these were adjacent to one another, on similar soil and with no apparent difference in pastures, as were farms 1 and 2 and farms 4 and 5. A marked deficiency of dietary sodium has been demonstrated on farms 1 and 2 and the difference in performance reflects the differing diligence of the owners in making salt blocks available to their animals. The best growth rates were recorded at Tararan, farm 3, where the soils are heavier than on the other farms or at Erap, and green *Imperata* is available almost all the year round. Even on farm 2, where sodium deficiency retarded growth, steers and heifers grew faster than the heifers in Trial 2, due to the constant availability of green feed. The performance of growing animals on farms 4 and 5 was depressed in the second year due to seasonal variations in time and amount of rain, so that feed was

Table 3.—**Nylon bag digestibility (%) of four tropical grasses at four ages**

Age of grass	Grass	Duration of digestion (hours)		
		20	48	72
3 weeks	*Imperata*	11.0	30.8	42.6
	Setaria	24.1	47.9	58.7
	Buffel	24.2	43.5	57.5
	Elephant	18.6	43.7	57.5
5 weeks	*Imperata*	11.4	31.6	41.1
	Setaria	22.8	46.3	63.0
	Buffel	20.5	43.0	56.2
	Elephant	20.5	49.9	59.4
7 weeks	*Imperata*	8.5	25.5	36.4
	Setaria	19.2	31.5	49.5
	Buffel	18.4	37.4	53.8
	Elephant	21.1	42.2	57.5
9 weeks	*Imperata*	13.2	21.4	32.6
	Setaria	20.7	43.9	53.0
	Buffel	14.3	37.9	51.7
	Elephant	20.5	38.2	50.6

Table 4. — **Details of smallholder cattle farms examined**

No.	Site	Rainfall	Terrain	Soil	Pasture	Area	Number of cattle	Area per beast
1	Situm near Lae	4,000 mm	Gentle slope	Recent alluvium Free draining Sodium deficient	*Imperata* dominant Stylo less than 1%	360 ha	100	3.6 ha
2	Situm near Lae	4,000 mm	Gentle slope	Recent alluvium Free draining Sodium deficient	*Imperata* dominant Stylo less than 1%	240 ha	80	3.0 ha
3	Tararan Markham Valley	1,250 mm	Flat	Recent alluviums Free draining alkaline Sandy loams	*Imperata* dominant Stylo less than 5%	200 ha	154	1.3 ha
4	Adjacent to Erap	1,500 mm	Gentle & steep slopes	Recent alluviums, calcareous, free draining. Shallow soils on steep slopes	*Imperata* dominant on gentle slopes. *Themeda* dominant on steep slopes. Stylo and *Leucaena* less than 5%	119 ha	70	1.7 ha
5	Adjacent to Erap	1,500 mm	Gentle & steep slopes	Recent alluviums, calcareous, free draining. Shallow soils on hills	*Imperata* dominant on gentle slopes. *Themeda* dominant on steep slopes. Stylo and *Leucaena* less than 5%	100 ha	50	2.0 ha

Table 5.—**Growth rate of cattle on 5 smallholder cattle farms grazing *Imperata*-dominant pastures in Morobe Province (kg day^{-1} ± S.E.M.). Number of animals in brackets**

Class of animal	Farm No. 1	2	3	4	5
Female calves to 9-10 months	0.50 ± 0.02 (19)	0.39 ± 0.04 (14)	0.60 ± 0.02 (26)	0.49 ± 0.02 (21)	0.51 ± 0.03 (12)
Heifers to first. conception or 2 yrs	0.36 ± 0.03 (15)	0.27 ± 0.04 (11)	0.39 ± 0.01 (19)	0.35 ± 0.03 (12)	0.35 ± 0.05 (9)
Male calves to 9-10 months	0.52 ± 0.02 (23)	0.40 ± 0.04 (17)	0.69 ± 0.01 (38)	0.51 ± 0.02 (28)	0.57 ± 0.03 (12)
Steers to 450 kg	0.32 ± 0.02 (22)	0.30 ± 0.02 (26)	0.46 ± 0.01 (82)	0.26 ± 0.02 (30)	0.33 ± 0.03 (16)
Steers: age at 450 kg	37 months	44 months	25 months	44 months	35 months

Table 6.—**Calving % per annum and weight of cows before calving (kg ± S.E.M.) on 5 smallholder cattle farms with *Imperata* dominant pastures. Number of animals in brackets**

Class of female		Farm No. 1	2	3	4	5
1973 heifers calving in 1975	Calving %	88%	67%	73%	89%	100%
	Liveweight	312 ± 17	305 ± 26	353 ± 21	343 ± 10	332 ± 12
	Number	(9)	(6)	(11)	(9)	(7)
1972 heifers, bought in 1973, calving 1974-1975	Calving %	62%	77%	—	—	—
	Liveweight	364 ± 10	318 ± 12			
	Number	(16)	(11)			
Mature cows calving in 1974-1975	Calving %	82%	78%	75%	86%	100%
	Liveweight	403 ± 11	341 ± 9	417 ± 7	394 ± 9	394 ± 8
	Number	(20)	(12)	(44)	(23)	(15)

in very short supply, but in the first year growth approached that of farm 3.

Reproductive rates in all herds were satisfactory, and on farms 4 and 5 were extremely good. The liveweight of cows before calving reflects the same nutritional factors as the growth rates of young stock (*Table 6*).

The non-agreement between number of calves born and number of calves contributing to the growth data is due to some calves being born too late in the two year period to contribute data over a minimum of 150 days, but also is due to incomplete mustering of cattle on occasion. Owing to the incomplete musters, no estimate can be made of calf or adult mortality. Many heifers conceived at about 12 months so there was little if any time between the animal being classified as a calf and as a pregnant heifer, hence the small numbers of non pregnant heifers available.

DISCUSSION

TRIAL 1

Maximum productivity of *Imperata*, at 8-12 week cutting intervals is in excess of that recorded by Chadhokar (1974) for introduced grasses in a sustained (1 year) 6 week intervals cutting trial at Erap (*Table 7*) but N concentration in *Imperata* was lower. At 6 week cutting intervals, *Imperata* out-yielded all these grasses but still had a low N concentration. It is doubtful whether these yields could be sustained over a longer period, but nevertheless this trial shows that the DM productivity of the much despised *Imperata* can be higher than that of introduced pasture grasses. When defoliated with sufficient frequency to keep N concentration as high as the improved grasses, however, *Imperata* rapidly declined in production.

TRIAL 2

Production per animal and production per ha were considerably greater for Hamil grass pastures than for *Imperata* pastures. The productivity per heifer on pure *Imperata* (no legumes), changed very little with halving of the stocking rate and consequently more than doubling the amount of feed available. Availability is therefore not limiting intake and performance. When a legume is included in the *Imperata* pasture, both growth per animal and growth per ha increase, and there is a marked increase of growth rate with increased area per heifer and increased availability. This suggests that the pure *Imperata* pasture is uniformly inadequate in N or digestible energy (DE) so that, regardless of the degree of selection available, cattle cannot select a diet sufficiently high in N or DE to support rapid growth. If a legume is present, growth of cattle is improved to a degree dependent on the amount of selection available, but at the highest stocking rates used here, legume availability was inadequate and growth was no better than

Table 7.—**DM production and mean N concentration of "improved" grasses at Erap, Morobe Province (Chadhokar 1974)**

Variety	DM ha^{-1} $week^{-1}$	N concentration
Boorara Buffel	152	1.23
Molopo Buffel	180	1.22
Biloela Buffel	181	1.21
Green Panic	179	1.26
Hamil	191	1.23
Rodds Bay Plicatulum	195	1.32
Hartley Plicatulum	191	1.37
Nandi Setaria	180	1.51
Rhodes Pioneer	54	1.54

on the no-legume pastures. The greatest increase in production per ha was at the lowest stocking rates where the amount of legume available per beast was greatest. Although the main legume component in the *Imperata* pasture was Schofield Stylo, this cultivar is not considered satisfactory on the highly alkaline soils at Erap. Establishment is slow; in pot trials establishment is much improved by acidification of the soil to pH 6.5-7.0 but this is not a practical management procedure. The search for a more suitable legume is continuing, with emphasis on newer cultivars of *Stylosanthes*.

The results of this trial are in close agreement with animal production data from *Imperata* produced by Magadan *et al.* (1974) (*Table 8*) who were working in a higher rainfall area and possibly with more fertile volcanic soils. Production on "improved" grass and grass + legume was also almost identical at similar stocking rates. Magadan *et al.* (1974) point out that at current Philippines prices there is no financial advantage of fertilizing over establishing a grass-legume mixed pasture.

TRIAL 3

The nylon bag digestion technique used can only rank grasses in order of digestibility; true digestion data cannot be obtained consistently. A number of sources of error, i.e. loss or gain of DM through the bag not as a result of digestion and the use of a basal diet different from some of the experimental diets, render the use of these data in other than a relative fashion, quite unreliable (Playne *et al.* 1978).

With these restraints, the data presented show the problem with *Imperata*; digestibility is low and digestion slow. Even at 3 weeks, digestibility at 48 hours (usually considered to approximate true digestibility) is only ⅔ that of other tropical grasses. To ingest equivalent digestible DM of *Imperata*, cattle must consume 50% more DM and excrete 100% more DM yet the rate of passage of ingesta will be very slow, due to the slow rate of breakdown of ingesta particles, so intake will be reduced. Digestibility, rate of

Table 8.—**Comparison of grazing trials at Erap and in the Philippines (Magadan *et al.* 1974)**

Pastures	Site	Stocking rate ha beast^{-1}	Gain beast^{-1} kg day^{-1}	Gain ha^{-1} kg day^{-1}
Imperata	Erap	1.06	0.22	0.24
		0.83	0.21	0.26
	Bukidnon	1.00	0.27	0.27
"Improved grass" + *legumes*	Erap (Hamil + *Glycine*)	0.59	0.45	0.76
		0.46	0.45	0.98
	Bukidnon (Para + Centro)	0.50	0.36	0.72
"Improved grass" + fertilizer	Erap (Hamil + N)	0.55	0.38	0.69
		0.42	0.35	0.83
		0.29	0.35	1.21
	Bukidnon (Para + N + P)	0.50	0.42	0.84
		0.33	0.28	0.84

digestion and rate of passage are difficult, if not impossible, to alter under grazing conditions. The only way to achieve high rates of gain is to increase the proportion of more digestible material in the pasture, e.g. by introducing legumes. The addition of nitrogen to the rumen in this way may accelerate digestion of the *Imperata*, but the main effect will be that of replacing poor quality feed with better quality feed. Since *Imperata* is practically *never* of truly high quality as pasture *no* technique of intensive management to cause consumption of very young feed will result in rapid weight gains. *Imperata* will support slow gains: these will be maximised by a low stocking rate allowing maximum selection, which is also conducive to pasture survival. Increased weight gains above this can only be achieved by replacing *Imperata* in the diet, partially, by legume introduction or totally, by introducing new grasses.

TRIAL 4

The data from these farms shows that *Imperata* pastures under field conditions are capable of supporting high reproduction and acceptable growth rates. On soils which dry out rapidly, such as farms 4 and 5, and at Erap in Trial 2, growth rate can be quite poor due to cessation of growth, and a consequent lack of young growing green feed. When the *Imperata* has dried right out it appears so harsh and unpalatable that cattle will not eat it and there is an actual shortage of feed.

The growth rates achieved indicate that a large proportion of the diet must have consisted of other species, even though *Imperata* made up the bulk of the available feed.

At Situm, even on farm 1, salt was not available continuously, and had it been so, more rapid growth rates and a reduction in age at turn-off would be achieved. Differences between managers on adjacent farms produce differences in production of the same order as differences between areas. The small sample size means that these data do not accurately reflect the productive capacity of the 3 areas. The amount of work involved in collection of these data shows that a different data collection procedure and greater sample is needed to measure the productivity of each area.

GENERAL DISCUSSION

The utilization of *Imperata* pasture must be considered in the light of the alternatives available, which are as in Trial 2, addition of a legume, or the complete establishment of improved pastures, either grass-legume or grass plus fertilizer. Bunning (1975) commented in an economic analysis of pasture improvement in PNG; "Pasture improvement is a high risk exercise. It requires a high resource input and, as in all agriculture programmes, the benefits are uncertain. It should, then, only be attempted where necessary and where other alternatives have been considered first. A weed free Kunai pasture should not be replaced by a high carrying capacity Elephant grass pasture as a matter of course. An improved pasture takes almost a year before it can carry any cattle so there is an opportunity cost involved; it is not certain it will establish successfully; it requires careful management. While a natural pasture is present and productive, the project will continue successfully without the expense and risk of attempting pasture improvement. Once the natural pastures have been cropped out or grazed out and weed invasion is high, then the cattle owner should consider ploughing up a block."

Bunning estimated the cost of improving pastures by ploughing and sowing as K170 per ha (US$210 per ha). Considering the middle stocking rates in Trial 2, *Imperata* produced 0.25 kg per ha per day, *Imperata* + legumes 0.30 kg per ha per day and Hamil + legumes 0.87 kg per ha per day. Full improvement returned 0.62 kg per ha per day, about 125 kg of carcass currently valued at K100 (K0.8 per kg) (US$140). When allowance is made for 1 year for establishment, it takes three years to recoup the initial cost. With the legumes employed for improving the *Imperata*, we achieved a return of 0.05 kg per ha per day, 10 kg of carcass and K8 per annum against a cost of K5-12 per ha for seed. Allowing a year for establishment, the initial cost is recouped in 1½-2½ years. Since the PNG smallholder usually does not have access to a tractor and implements and the necessary expertise to do his own pasture improvement, nor K170 per ha to pay someone else to do so, full pasture improvement is not a realistic consideration. The return on legume broadcasting into *Imperata* is very small in the lower Markham Valley; further research is needed to find a more suitable legume for these alkaline soils. In the upper Markham Valley on less alkaline soils, ph 7, Stylo broadcast onto burnt *Imperata* pastures has established well and on occasions the pasture is almost Stylo-dominant.

The establishment of legumes in *Imperata* is done most efficiently and economically after burning the *Imperata*. Chadhokar (1974) found a population of 0 plants per m² for three varieties of Stylo broadcast into *Imperata*, and 7.7, 2.5 and 6.8 plants per m² for Schofield, Cook and Endeavour broadcast after *Imperata* was burnt.* Javier (1973) found Schofield Stylo plants were twice as big at 4 months if broadcast onto burnt rather than grazed *Imperata*. Practical experience on PNG cattle ranches confirms that it is essential to burn *Imperata* to establish a strong stand of Stylo in the pasture. Once the Stylo is established and has seeded, a second burn may be used to produce a thick stand of Stylo which will support rapid cattle growth rates. If the soil is of a crumbly nature many seeds lodged in cracks will survive the fire and germinate rapidly after rain. To maximise growth per beast to obtain the earliest possible turnoff, and to minimise weed invasion, *Imperata*-Stylo pastures should be lightly stocked, but not to the extent that the *Imperata* crowds out the Stylo. If it does, another burn is indicated.

* These low germinations were related to failure of rains.

REFERENCES

BUNNING, A. (1975). *Pasture Improvement in Papua New Guinea.* Intra Departmental Report, D.P.I. Beef Cattle Research Centre, Erap, PNG.

CHADHOKAR, P. (1974). *Annual Report, Bubia Agriculture Research Centre.* Department of Primary Industries, Lae, Papua New Guinea.

HOSHINO, M. (1975). Report to the National Research Council of Thailand: *Studies on the Tropical Forage Crop in Thailand.* Tropical Agricultural Research Centre, Ministry of Agriculture and Forestry, Japan.

JAVIER, E.Q. (1973). The improvement and utilization of *Imperata* and *Themeda* grasslands. (Mimeographed) presented at the N.S.D.B. Evaluation Seminar, P. Gracia Hall, N.S.D.B., Herron, Manilla, May 31, 1973.

MAGADAN, Prudencio B., JAVIER, Emil Q., and MADAMBA, Joseph C. (1974). Beef production on native (*Imperata cylindrica*) (L.) (Beauv.) and Para grass (*Brachiaria mutica* (Forsk.) Stapf) pastures in the Philippines. *Proceedings of the XII International Grasslands Congress. Grassland Utilization Part I,* Moscow, June 1974, 370-378.

PLAYNE, M.J., KHUMNUALTHONG, W. and ECHEVARIA, M.G. (1978). Factors affecting the digestion of oesophageal fistual samples and hay samples in nylon bags in the rumen of cattle. *Journal of Agricultural Science,* Cambridge, 90: 193-204.

PLAYNE, M.J., McLEOD, M.N. and DEKKER, R.F.H. (1972). Digestion of dry matter, nitrogen, phosphorus, sulfur, calcium and detergent fibre fraction in the seed and pod of *Stylosanthes humilis* contained in terylene bags in the bovine rumen. *Journal of Science in Food and Agriculture,* 23: 925-932.

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INSECT FAUNA OF OIL PALM IN THE NORTHERN PROVINCE OF PAPUA NEW GUINEA

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ABSTRACT

Pyrethrum knockdowns were used to sample the insect faunas of two 3 ha plots of oil palm. Approximately 150 samples were taken in each plot at regular intervals throughout 1973. The ant Anoplolepis longipes *was the most abundant insect present. Five or more specimens of a further 25 species of insect were taken, and the distribution of some of these was found to vary between plots and between the edges and interior of the plots. The insect fauna of the Saiho plot changed substantially between 1968 and 1973; it is suggested that the changes were associated with the development of the palms, and that change was continuing during the study. Very little insect damage was present, in marked contrast to plantation situations elsewhere; in particular no Psychidae were found.* Scapanes australis *was the only species causing significant damage.*

INTRODUCTION

In 1967 the Department of Agriculture, Stock and Fisheries, planted two small plots of oil palm in the Northern Province of Papua New Guinea with a view to establishing the suitability of the soil and climate for palm oil production. During the late 1960s and early 1970s the major cash crop industry in the area, cocoa, went into a decline associated with insect pest problems. In 1972 it was suggested that areas of unproductive cocoa be cleared and replanted with oil palm to establish a production system similar to that on West New Britain (Anon. 1972).

This paper presents the results of a one-year survey of the more abundant insects found in the two small experimental plots of oil palm. The aims of the survey were to provide general information on the insect fauna present and to establish which species known as oil palm pests elsewhere were already present in the area.

SAMPLING SITES

One plot of oil palm was located at the Saiho Agricultural Field Station about 30 km SW of Popondetta. It was surrounded by food garden clearings and coffee plantings interspersed among patches of rainforest.

The second plot was in the grounds of the Popondetta Agricultural Training Institute (PATI) 3 km E of Popondetta. PATI contained extensive cocoa plantings, and the oil palm plot was adjacent to an area of rubber on one side and pasture dominated by *Imperata cylindrica* (L.) on another. PATI has an appreciably drier climate than Saiho. Haantjens (1964) gives details of the soils, climate and vegetation of the Northern District.

Both oil palm plots contained 19 × 17 palms on a triangular spacing of approximately 12 m. The palms at Saiho were 3-4 m tall at the crown and bearing fruit; the palms at PATI were only 1.5-2 m tall and bore no fruit.

METHODS

All sampling was by 'pyrethrum knock-down': a white sheet was placed on the ground and the foliage above it was sprayed to runoff with 0.2% bioresmethrin from a 'Solo' mistblower. All insects falling onto the sheet within 30 min of spraying were collected.

Each plot was mapped and divided into four quadrants. On each sampling occasion one sample was taken from each

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quadrant. Alternate samples were taken using intact 3 × 3 m sheets placed equidistant from surrounding palm trunks (canopy samples); the remaining samples were taken using 3.3 × 3.3 m sheets which had a slit from one side to a 1.5 m diameter central hole and were placed around the bases of palm trunks (trunk samples). On each sampling occasion, sampling sites were two palms away from the sites used on the previous occasion. Sampling was carried out between 08.00 and 11.00 hrs on the first three Wednesdays of all months between 1 January 1973 and 18 December 1973, except in July and August when sampling occurred on four occasions in each month.

In such small plots, edge effects were expected to be important. To enable preliminary analysis of these effects, all samples within two palms of the edge of a plot were recorded as 'edge samples', while the remainder were recorded as 'interior samples'

Table 1. — **Total numbers of individuals taken in each location/position (figures in parenthesis are individuals per sample)**

	Saiho	PATI	Trunk	Canopy	Edge	Interior
Number of samples:	152	148	150	150	63	237
Blattodea						
indeterminate sp.6	676	674	432	918	156(2.5)	1194(5.0)
indeterminate sp.21	6	93	57	42	22(0.4)	77(0.3)
Dermaptera						
Chelisoches morio (F.)	2365	522	2 760	127	891(14.1)	1196(8.4)
indeterminate sp.16	106	0	48	58	21(0.3)	85(0.4)
indeterminate sp.26	10	12	21	1	9(0.1)	13(0.1)
indeterminate sp.30	3	2	5	0	0	5
Orthoptera						
Segestidea princeps Bolivar	211	0	83	128	39(0.6)	172(0.7)
Tettigoniidae sp.2	37	140	33	144	13(0.2)	164(0.7)
Mecopoda elongata (L.)	296	2	133	165	24(0.4)	274(1.2)
Cardiodactylus novaeguineae Haan	333	7	284	56	44(0.7)	296(1.3)
Phasmatodea						
indeterminate sp.18	117	0	79	38	8(0.1)	109(0.5)
Coleoptera						
Scarabaeidae						
Dermolepida noxium Britton	26	35	15	46	7(0.1)	54(0.2)
Curculionidae						
Rhabdoscelus obscurus (Boisd.)	83	78	153	8	25(0.4)	136(0.6)
Oribius sp.15	16	14	19	11	9(0.1)	21(0.1)
Elateridae						
Simodactylus sp.23	36	1	35	2	5(0.1)	32(0.1)
Chrysomelidae						
Rhyparida coriacea Joic	29	8	23	14	20(0.3)	17(0.1)
Rhyparida sp.27	23	4	20	7	18(0.3)	9(0.0)
indeterminate sp.22	21	53	6	68	45(0.7)	29(0.1)
Cerambycidae						
Mulciber linnaei Thoms	13	23	33	3	20(0.3)	16(0.1)
Alleculidae						
indeterminate sp.12	24	8	10	22	5(0.1)	27(0.1)
Anthribidae						
indeterminate sp.13	5	7	10	2	9(0.1)	3(0.0)
Galerucidae						
Cassena papuana Jac.	24	8	14	18	18(0.3)	14(0.1)
Diptera						
Chrysosoma sp.17	29	205	122	112	77(1.2)	157(0.7)
Lepidoptera						
larva sp.19	4	23	13	14	5(0.1)	22(0.1)
larva sp.28	3	4	2	5	1	6

RESULTS

Table 1 shows the abundance of all species (except ants) of which more than four individuals were taken classified with respect to plot, trunk/canopy and edge/interior. Species reference numbers refer to specimens deposited in the Department of Agriculture, Stock and Fisheries central insect collection, Port Moresby.

Table 2 shows the numbers of individuals of each species taken in each of the 12 sampling months. With the exception of the Coleoptera and Diptera for which no larvae were taken, and the Lepidoptera for which no adults were taken, both tables show total numbers of adults plus immatures for each species.

In terms of numbers of individuals, ants were the most abundant insects present. *Anoplolepis longipes* (Jerdon) dominated the canopy both at Saiho and PATI. *Paratrechina ? stigmatica* Mann and *Polyrhachis* (*Chariomyrma*) spp. were also present in the canopy, while *Odontomachus simillimus* F.Sm. was occasionally taken on trunks.

One specimen was also taken of each of the following two beetles known as pests of palms elsewhere (Lamb 1974):

Table 2.—**Total numbers of individuals taken in each month**

	J	F	M	A	M	J	J	A	S	O	N	D
Number of samples:	20	24	24	24	24	24	32	32	24	24	24	24
Blattodea sp.6	66	93	77	79	95	90	83	140	147	237	115	128
Blattodea sp.21	4	14	14	18	9	10	11	5	2	5	7	0
Chelisoches morio	345	289	116	362	158	269	228	164	103	227	316	312
Dermaptera sp.16	3	4	27	9	11	5	5	11	2	17	10	2
Dermaptera sp.26	0	0	3	2	4	8	1	3	1	0	0	0
Dermaptera sp.30	0	0	0	0	0	0	0	1	1	2	1	0
Segestidea princeps	11	22	14	16	9	11	14	13	11	25	36	28
Tettigoniidae sp.2	4	9	5	13	13	19	34	15	9	29	4	15
Mecopoda elongata	0	3	15	20	15	40	44	35	54	22	32	18
Cardiodactylus novaeguineae	17	20	14	23	9	18	19	29	47	46	49	47
Phasmatodea sp. 18	1	7	7	6	11	5	19	11	6	8	11	25
Dermolepida noxium	2	2	3	2	1	4	4	7	13	14	3	6
Rhabdoscelus obscurus	10	14	4	19	9	8	17	5	13	27	14	21
Oribius sp. 15	1	1	1	1	0	1	2	0	3	14	4	2
Simodactylus sp.23	0	2	1	3	3	2	1	7	5	5	5	4
Rhyparida coriacea	8	1	5	4	0	6	0	5	6	1	1	0
Rhyparida sp.27	0	0	2	2	0	2	6	0	0	12	1	2
Chrysomelidae sp.22	1	3	4	2	5	3	0	6	37	0	11	2
Mulciber linnaei	0	8	8	4	5	1	1	1	3	1	4	0
Alleculidae sp.12	3	2	4	0	1	6	11	0	1	0	2	2
Anthribidae sp.13	5	0	0	0	0	1	2	1	0	2	0	1
Cassena papuana	13	2	5	0	3	3	1	2	0	0	1	1
Chrysosoma sp.17	21	25	23	26	19	25	22	12	11	13	18	4
Lepidoptera sp.19	1	3	1	4	3	6	2	3	0	2	1	1
Lepidoptera sp.28	0	0	0	0	0	0	2	4	0	0	1	0

Scapanes australis (Boisd.) (Dynastidae) at Saiho in August, *Rhynchophorus bilineatus* Mont. (Curculionidae) at PATI in July.

DISCUSSION

Anon. (1971) lists seven species found in the Saiho plot in 1968 which were not found in 1973. Only *Cardiodactylus novaeguineae, Scapanes australis, Rhinoscapha thomsoni* Waterh, and *Acanthotyla* sp. were present in both years. This suggests that a change in the composition of the insect fauna has occurred with development of the palms from seedlings to maturity.

Table 1 shows that in 1973 11 species were more abundant at Saiho than PATI, eight species were equally abundant in both plots, and six species were more abundant at PATI than Saiho. To some extent the different stage of palm growth in each plot might be responsible for the differences. It also seems likely that the factors promoting faster palm growth at Saiho, possibly higher rainfall, and the surroundings of each plot might be important.

The following species were found to be more abundant on the edges rather than in the interior of plots: *Chelisoches morio,* Chrysomelidae sp. 22, *Rhyparida* sp. 27 and *Chrysosoma* sp. 17. Under large scale plantation conditions these species would be expected to be much less prominent than in the study plots. Other species were more abundant in the interior of plots and would be expected to be common inhabitants of large scale plantations: Blattodea sp. 6, Tettigoniidae sp. 2, *Mecopoda elongata*, *Cardiodactylus novaeguineae,* Phasmatodea sp. 18 and *Dermolepida noxium.*

Insect damage to palms was minimal in both plots, with the exception of three palms killed and two severely damaged at Saiho by rhinoceros beetles, *Scapanes australis.* Palms could not be felled and dissected, but external examination suggested that the weevils *Rhabdoscelus obscurus* and *Oribius* sp. 15 caused little damage. Leaf damage was negligible in both plots, though a little greater at Saiho than PATI. The very abundant Blattodea sp. 6 and *Chelisoches morio* appeared to cause no damage.

The lack of damage contrasts strongly with the situations on the Malaysian mainland reported by Wood (1968) and in Sabah reported by Conway and Tay (undated). Larvae of Psychidae and Limacodidae in particular underwent devastating outbreaks in both areas. However, Conway (1969) suggested that insecticide applications released the species involved from effective control by natural enemies. No insecticides were used in the study plots in 1973 (with the exception of bioresmethrin for sampling). In 1968 Psychidae of the genera *Clania* and *Plutorectis* severely defoliated young and seedling oil palms on West New Britain, whereas an unidentified Psychid was present in the Saiho plot but caused no damage (Anon. 1971).

Wood (1968) describes *Rhynchophorus schach* Oliv. as a secondary pest whose adults gather to feed on exudations from fresh trunk wounds and subsequently lay eggs. During the present work, numbers of adult *Rhabdoscelus obscurus* were seen gathered on fresh cuts after old leaves had been pruned. If this species becomes troublesome a change in pruning policy might be sufficient to reduce its numbers.

Plotting the data in *Table 2* in the form of number of individuals per sample against month showed little in the way of universal phenological trends. However, the more common species can be grouped into six categories according to abundance:

1. Decreasing from January to December: Blattodea sp. 21 and *Chrysosoma* sp. 17.
2. Increasing from January to December: *Cardiodactylus novaeguineae* and Phasmatodea sp. 18.
3. Minima between June and September: *Segestidea princeps, Chelisoches morio* and *Rhabdoscelus obscurus.*

4. Maxima between June and September: *Mecopoda elongata.*
5. Maxima in September/October: Blattodea sp. 6, *Dermolepida noxium* and Chrysomelidae sp. 22.
6. Fluctuations irregular.

Data from several years are required before conclusions could be drawn from the above groupings, but tentative suggestions as to the meaning of the groups are as follows.

Groups 1 and 2 might represent a continuation of the successional changes which appear to have occurred between 1968 and 1973 at Saiho. As the palms get older, the canopy becomes thicker and intercepts more light, making conditions below the canopy more humid and temperature stable. Species in group 1 might find such changes deleterious, while species in group 2 might find them beneficial. Additional evidence for this suggestion is present in *Table 1* where *Chrysosoma* sp. 17 is shown as an 'edge species', while members of group 2 are 'interior species'.

Mean monthly rainfall and sunshine figures for Popondetta in Room and Smith (1975) show that there is a dull/wet season between December and March, and a sunny/dry season between June and August. Groups 3 and 4 might have population extremes associated with the sunny/dry season, while group 5 species might have population maxima associated with the return of wet conditions after the sunny/dry season.

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REFERENCES

ANON. (1971). Insect pest survey for the year ending 30th June 1968. *Papua New Guinea Agricultural Journal,* 22: 181-201.

ANON. (1972). The Oilpalm industry in West New Britain. *Harvest*, 2: 57-60.

CONWAY, G.R. (1969). Ecological aspects of pest control in Malaysia. In Farvar, T.M. and Milton J.P. (eds) *The Careless Technology*. Garden City, N.Y., Natural History Press. pp. 467-488.

CONWAY, G.R. and TAY, E.B. (undated). *Crop Pests on Sabah, Malaysia, and Their Control.* State Ministry of Agriculture and Fisheries, Sabah, Malaysia. 74 pp.

HAANTJENS, H.A. (ed.) (1964). General report on lands of the Buna-Kokoda area, Territory of Papua and New Guinea. *Australian CSIRO Land Research Series* No. 10.

LAMB, K.P. (1974). *Economic Entomology in the Tropics.* Academic Press London. 195 pp.

ROOM, P.M. and SMITH, E.S.C. (1975). Relative abundance and distribution of insect pests, ants and other components of the cocoa ecosystem in Papua New Guinea. *Journal of Applied Ecology,* 12: 31-46.

WOOD, B.J. (1968). *Pests of Oilpalm in Malaysia and Their Control.* Inc. Soc. Planters, P.O. Box 262, Kuala Lumpur. 210 pp.

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APPARENT DIGESTIBILITIES OF DRY MATTER, ORGANIC MATTER, CRUDE PROTEIN, ENERGY AND ACID DETERGENT FIBRE OF CHOPPED, RAW SWEET POTATO (*IPOMOEA BATATAS* (L.)) BY VILLAGE PIGS (*SUS SCROFA PAPUENSIS*) IN PAPUA NEW GUINEA

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ABSTRACT

Mean apparent digestibilities of the components of sweet potato tubers measured with village pigs were 95.3%, 96.1%, 94.2% and 72.4% for dry matter, organic matter, energy and acid detergent fibre respectively. The digestibility of the crude protein was significantly different ($P < 0.05$) measured with two groups of pigs of different ages. These were 57.2% for 15 month old pigs and 42.3% for the 10 month old group.

INTRODUCTION

There is usually discussion and often confusion in development programmes in Papua New Guinea concerning the nutritional value of sweet potato (*Ipomoea batatas* (L.) Lam.) for both man and pig. In the Highlands where pig numbers are greatest, this is of particular importance. As the pig slowly assumes a greater nutritional role than the previous social and cultural role, the need to evaluate its feed, and efficiency of usage increases.

In the literature there are a limited number of references concerning the evaluation of sweet potato and even fewer for its evaluation as a pig feed (Zarate 1956; Calder 1960; Pond and Maner 1974). However, there does seem to be some indication (Zarate 1956) of a difference between breeds in the ability to digest sweet potato. It seemed necessary to evaluate this root crop using the indigenous Papua New Guinea village pigs. It is recognized that there are many varieties of sweet potato in Papua New Guinea. They vary in colour of both skin and flesh. This indicates, perhaps, a variety of levels of the carotenes. They also vary in the level of nitrogen. It ranges from 0.3% to 1.1% (White, unpub.). This trial was conducted with a uniform line of sweet potato tubers of 0.4% level of nitrogen on a dry matter basis.

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MATERIALS AND METHODS

The trial was conducted at the Tropical Pig Breeding and Research Station at Goroka, in the Eastern Highlands of Papua New Guinea (altitude 1,600 m; Latitude 6° 05′ S; longitude 145° 25′ E).

Eight village pigs (*Sus scrofa papuensis,* Lesson and Garnot in Laurie and Hill 1954), four male castrates of approximately 15 months and four boars of 10 months of age, were individually penned and restrained in an open-sided, corrugated iron roofed shed (temperature maximum 28°C; minimum 17°C). The pigs were on wood slats over concrete. Faeces collection trays were fitted beneath the slats below the animals' hind quarters. Urine did not contaminate these collections. Removable galvanised buckets were used for feeding and fresh water was freely available.

A preliminary feeding period of seven days was allowed for the pigs to get accustomed to the diet and the restraint of the pens. The diet was of raw chopped sweet potato tubers of a white fleshed variety (local name: Giopa). They were washed under running water, topped and tailed, and then sliced. The pigs were offered feed in two, 2 hour feeding periods each day (10.00 to 12.00 and 14.00 to 16.00 hours). About 1.5 and 0.75 kg was offered each period to the older and younger animals respectively. This regime was adopted to facilitate accurate intake measurements. Intakes of sweet potato and faecal outputs were recorded for each of the seven days. In the first feed and first after last, 1 g of ferric oxide was included with a small amount of tuber. When the red brown colour was noticed in the faecal matter the collection commenced or finished. A sample of the tubers was taken each day and all faeces were collected. These materials were dried overnight at 96°C. Any feed residues were also collected and dried similarly so actual intakes were calculated.

The dried feed and faeces were analysed for organic matter (OM) by loss of sample on ignition at 600°C for 2 hours. Nitrogen and crude protein (CP) were determined by the Kjeldahl method using selenium as catalyst. Acid detergent fibre (ADF) method of Van Soest (1963) was used. Energy (E) of sample was determined by bomb calorimetry using a Gallenkamp adiabatic bomb calorimeter.

RESULTS

Table 1 shows the composition of the sweet potato diet. It is low in crude protein. *Table 2* shows mean intake and apparent digestibility for each dietary component analysed for the two groups of animals. Because one pig did not defecate for over 72 hours it was discounted from the final analysis.The apparent digestibility of crude protein was significantly different ($P < 0.05$) for the two groups. This was therefore not pooled. Other component data was combined.

DISCUSSION

Dry matter (DM), organic matter (OM) and energy (E) digestibilities were high compared with 90.4% DM and 89.3% E published by Pond and Maner (1974). This may be due to the low intakes in this experiment and a depression in apparent digestibility might be expected as the level of intake is increased. It could be several percentage units lower with fully fed animals (Schneider and Flatt 1975). Although the intake levels were low, they are comparable with those of pigs fed under Papua New Guinea village conditions. Such animals may gain only 50 g body weight per day when intake includes nutritiously poor grazing of sweet potato fallow. Further trials (Rose, unpublished data) confirm similar levels of sweet potato intake, fed *ad lib.,* where protein supplement is 5% of that recommended by Whittmore and Elsley (1976).

Crude protein (CP) digestibilities for both groups were much higher than that of Pond and Maner (1974), which was 27.6%. If the effects of a low intake were operating, the measurement would be higher for younger animals with a much lower intake. However this is not the case. On either a body weight or metabolic body weight basis the intake of the younger group is higher (15.4 cf. 9.9 g day^{-1} kg body wt^{-1} or 35.7 cf. 30.9 g day^{-1} kg body $wt^{-0.75}$).

The ADF digestibility was not affected by age, so these results have been combined. The level of fibre digestibility was higher than might be expected. With levels of digestibility as high as these, it is unlikely that any significant gains will be made by cooking the tubers. This is in line with the view of Calder (1960). However, it is possible that with the cooking of tubers significant gains may be made in the amount of material that the animal may ingest in a given time, that is, it could affect appetite. If this could be digested as quickly as the uncooked material, then perhaps increased growth rates might be possible. Malynicz and Nad (1975) feeding

Table 1.—**Feed composition on dry matter (DM) basis for organic matter (OM), crude protein (CP), acid detergent fibre (ADF) and energy (E)**

	D.M.	% on dry matter basis			E
	%	OM	CP	ADF	(MJ/kg)
Mean	34.8	97.4	2.54	3.43	16.718
SE*		0.411	0.762		

* Standard error of mean.

Table 2.—**Apparent digestibilities of DM, OM, CP, E and ADF for sweet potato tubers**

	Live weight kg	DM intake g/d	Apparent digestibility %				
			DM	OM	CP	E	ADF
Mean	92.9	925	95.6	96.5	57.2*	94.8	73.6
SE†	13.6	79	0.11	0.17	4.2	0.17	1.70
n = 3							
Mean	29.0	447	95.1	95.8	42.3*	93.8	71.5
SE	6.2	68	0.39	0.35	6.7	0.6	2.81
n = 4							
Mean	—		95.3	96.1	—	94.2	72.40
SE			0.41	0.44	—	0.67	1.69
n = 7							

* Significantly different at $P < 0.05$.
† Standard error of mean.

European pigs doubled consumption of sweet potato by cooking it. This improved intake produced a 36% improvement in liveweight gain but was associated with a reduction of 29% in the food conversion ratio. Therefore further work seems appropriate to determine if cooking of sweet potato for pig feed is worthwhile using the limited resource of firewood.

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REFERENCES

CALDER, A. (1960). Sweet potatoes for pigs. Feeding techniques and management. *Rhodesian Agricultural Journal,* 57(4): 293-299.

LAURIE, E.M.O. and HILL, J.E. (1954). *List of land mammals of New Guinea, Celebes and adjacent Islands, 1758-1952.* British Museum.

MALYNICZ, G. and NAD, H. (1975). A comparison of three ways of feeding sweet potato to pork pigs. Unpublished report, Research Reports and Reviews, D.A.S.F. Pig Research Section.

POND, W.G. and MANER, J.H. (1974). *Swine Production in Temperate and Tropical Environments.* W.H. *Freeman and Co. San Francisco.*

SCHNEIDER, B.H. and FLATT, W.P. (1975). *The Evaluation of Feeds through Digestibility Experiments.* University of Georgia Press, Athens, Ga., USA.

VAN SOEST, P.J. (1963). Use of detergents in the analysis of fibrous feeds. II. A rapid method for the determination of fibre and lignin. *Journal of the Association of Official Agricultural Chemists,* 46: 829-835.

WHITTEMORE, C.T. and ELSLEY, F.W.H. (1976) *Practical Pig Nutrition.* Farming Press.

ZARATE, J.J. (1956). The digestibility by swine of sweet potato vines, and tubers, cassava roots and green papaya fruits. *Philippine Agriculturalist,* 60: 78-83.

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