58

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Ministerial Member, Department of Agriculture,

Stock and Fisheries

Tei Abal, M.H.A.

Director, Department of Agriculture,

Stock and Fisheries

W. L. Conroy, B.Sc.Agr.

Correspondence on editorial matters should be addressed to the Director, Department of Agriculture, Stock and Fisheries, Konedobu, P.N.G.

ABSTRACTS

GRASS SPECIES EVALUATION AT POPONDETTA IN THE NORTHERN DISTRICT OF PAPUA

H. GALLASCH, *Papua New Guinea agric. J.*, 22 (2) : 63-68 (1971)

A grass species evaluation trial at Popondetta in 1967 yielded production values on ten species of tropical grasses, some of which have potential for use in pastures in the area. There was significant variability in performance of a number of the species, some apparently producing better during the "dry" season, others during the "wet" season. The best grass on the basis of overall dry matter production was Elephant grass (*Pennisetum purpureum*), followed by *Paspalum plicatulum, Panicum maximum* cv. Guinea and *Brachiaria mutica.*

STUDIES ON THE GROWTH OF *LEUCAENA LEUCOCEPHALA*. 2. EFFECT OF LIME AT SOWING ON PRODUCTION FROM A LOW CALCIUM STATUS SOIL OF THE SOGERI PLATEAU

G. D. HILL, *Papua New Guinea agric. J.*, 22 (2) : 69-72 (1971)

Leucaena is difficult to establish on low calcium status, acid soils of the Sogeri family on the Sogeri Plateau. The Peru strain of Leucaena was sown and lime applied at 1, 5 and 10 tons per acre broadcast, and at 1, 2, 4 and 8 cwt per acre drilled in the row. Significant responses were obtained to the application of 5 and 10 tons per acre ($P < 0.05$). As agricultural lime is not at this stage produced in Papua New Guinea, use of these high levels of lime cannot be considered economic.

STUDIES ON THE GROWTH OF *LEUCAENA LEUCOCEPHALA*. 3. PRODUCTION UNDER GRAZING IN THE NEW GUINEA LOWLANDS

G. D. HILL, *Papua New Guinea agric. J.*, 22 (2) : 73-76 (1971)

Under a six-week grazing cycle over a nine-month period at Erap in the Markham Valley, the Peru strain of Leucaena produced an estimated 11,000 lb of dry matter per acre. On the basis of other results from the same site this could be expected to have a crude protein content of 21 per cent. Yield responded markedly to increased rainfall, and during the wet season grazing would need to be more frequent than every 6 weeks to keep Leucaena under control.

[*continued overleaf*]

PROGRESS OF NEW IRELAND FERTILIZER TRIALS 1964 TO 1970

J. H. SUMBAK, *Papua New Guinea agric. J.*, 22 (2) : 77-86 (1971)

Trials on the yellow-brown clay-loam soils of the east coast of New Ireland continued to show responses to potassium fertilizer. The previous recommendation of a biennial application of 5 lb of potassium chloride broadcast evenly over a circle about 20 ft in diameter around the base of the palm as giving the greatest economic response was confirmed.

In a new trial with palms about 30 years old, an estimated average annual increment of at least 3.6 cwt was shown in the 6 years after initial fertilizer application. Additional net profit was estimated at about $A12 per acre per year. Evidence indicated that the actual yield increment would be considerably greater once fertilizer usage was an established practice. A significant yield response to sulphur occurred once the potassium deficiency was corrected and a biennial application would appear appropriate where there is good reason for suspecting low plant sulphur levels.

A single cultivation affected yields adversely for at least 3 years. There were no yield differences detected between palms where fertilizer was broadcast over a circle about 20 ft in diameter around the palm base or where fertilizer was broadcast evenly over the whole area.

Interplanted cacao benefited, in terms of girth increment, from fertilizer applied primarily for coconut palms.

WEED CONTROL IN COFFEE IN THE NEW GUINEA HIGHLANDS

G. H. PRITCHARD, *Papua New Guinea agric. J.*, 22 (2) : 87-115 (1971)

Herbicides available in Papua New Guinea which are suited for use in coffee are briefly discussed. These include the foliar-acting herbicides paraquat, 2,4-D, MCPA, dalapon, amitrole and MSMA, and the soil-acting herbicides diuron, atrazine and simazine. Programmes for weed control, based on paraquat and diuron, are outlined and methods of control are given for specific weeds which are troublesome or can become so under these programmes. These weeds include *Paspalum conjugatum, Cynodon dactylon, Commelina diffusa, Crassocephalum crepidioides, Ipomoea batatas, Lindernia* spp. and *Polygonum* spp.

Two large-scale weed control trials being conducted at the Highlands Agricultural Experiment Station, Aiyura are described and the costs of treatments in the first 2 years of the trials are given. The first trial compares four methods of weed control under three shade situations on two sites. The treatments are (1) based on paraquat, (2) based on diuron, (3) hand-weeded, and (4) hand-weeded with a diuron application during the peak harvest period. Over the two-year period the paraquat-based treatment was the least costly on both sites and under all shade conditions, this being largely due to the large cost advantage of this treatment in the first year. In the second year, there were smaller differences in costs between the treatments and on one site under two shade situations the diuron-based treatment was more economical than the paraquat-based treatment, while the hand-weeded plus diuron treatment was comparable in cost to the

[*continued overleaf*]

paraquat-based treatment. No significant differences in coffee yields between the treatments have been obtained to date. The second trial, in unshaded coffee on one site only, compares treatments based on (1) paraquat and amitrole, (2) MSMA, (3) diuron plus amitrole, and (4) diuron plus paraquat. Treatment (1) was the most economical over the two-year period, but in the second year the costs of treatments (3) and (4) fell below that of treatment (1).

Examples of chemical weed control costs on other coffee blocks at Aiyura are given to further illustrate the large variations in costs that can occur.

NEW RECORDS OF FISH FROM PAPUA

PATRICIA KAILOLA, *Papua New Guinea agric. J.*, 22 (2) : 116-133 (1971)

A series of trawls at Yule Island in Papua produced 22 new species records for Papua, and confirmed the occurrence of one other species. A brief description and photograph of each specimen is provided.

KOKI MARKET IN PORT MORESBY

A. R. McCULLOUGH, *Papua New Guinea agric. J.*, 22 (2) : 134-147 (1971)

Trading at Koki started on the beach where fishermen pulled up their canoes in order to sell their catch to townspeople. Apart from a period during the war, the Market has grown steadily. A Reserve administered by trustees was proclaimed in 1959. The powers of the Trust were increased by legislation in 1969, when the Trust was reconstituted.

The Department of Trade and Industry carried out two series of surveys of Koki Market in 1969-1970.

It was found that the quantity of produce offered for sale fluctuates considerably during the year, due largely to seasonal variations in rainfall in the areas supplying the Market.

The Kairuku and Rigo Subdistricts are the main sources of supply to the Market. There is some evidence of growing regional specialization in the production of certain commodities.

There has been very little change in prices between 1962-1963 and 1969-1970, although the availability of many commodities has increased considerably. Likewise there is little seasonal variation in prices despite marked fluctuations in the quantities available. This may be attributed to the use by sellers of collective bargaining in order to maintain prices at acceptable levels, and their willingness to leave produce unsold rather than lower prices.

Koki Market is peripheral to the market economy in that, with few exceptions, neither sellers nor producers are dependent on market sales for basic livelihood: in other words, they will not starve or suffer major inconvenience if they do not sell their produce.

Increasing monetization of the economy will probably induce the emergence of middlemen and specialized growers producing for sale at the Market. The attitudes to marketing, characteristic of the subsistence farmers who now form the majority of sellers at Koki, will then disappear.

ERRATA

Papua New Guinea Agricultural Journal Volume 22 No. 2 (1971)

p. 102, column 2, lines 34-35 should read" . . . predominantly bare ground, in weeks 70 and 90 on the hillside plot, and in weeks 66 and 85 on the pit-pit plot."

p. 103, *Table* 7, column "Casuarina Hillside Year 2", the seventh entry, No. of applications of 2, 4-D should read "1+1" not "1". The 2, 4-D was applied on two occasions—once on its own at a concentration of 4 pints per 45 gal and once at 2 pints per 45 gal applied in combination with MSMA (also at 2 pints per 45 gal).

Table 7, footnotes 2 and 3 should read "2. Includes $7.20 for an initial slashing." and
"3. Includes $4.86 for an initial slashing".

p. 111, *Table* 11, column "MSMA Year 1", the third entry should read "2. 0-5. 0".

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CONTENTS

GRASS SPECIES EVALUATION AT POPONDETTA IN THE NORTHERN DISTRICT OF PAPUA

H. GALLASCH*

ABSTRACT

A grass species evaluation trial at Popondetta in 1967 *yielded production values on ten species of tropical grasses, some of which have potential for use in pastures in the area. There was significant variability in performance of a number of the species, some apparently producing better during the "dry" season, others during the "wet" season. The best grass on the basis of overall dry matter production was Elephant grass* (Pennisetum purpureum), *followed by* Paspalum plicatulum, Panicum maximum *cv. Guinea and* Brachiaria mutica.

INTRODUCTION

ON the wet lowlands of Papua New Guinea, very little quantitative work has been reported on the productivity of the various tropical pasture species which can grow in these regions. At Bubia, in the Morobe District, an evaluation trial has been in progress for several years and some results are now available (DASF 1969).

In view of an increased interest in cattle, both from among the indigenous people of the area, and several plantations, a grass species evaluation trial was established at Popondetta, on an area typical of the large areas of natural grasslands which are at present of little economic value. The soils of the trial area belong to the Popondetta Land System, Unit 1, and are described as unweathered, sandy volcanic soils with black topsoils; well to excessively drained (CSIRO Aust. 1964). Inherently of very low fertility, the soils support a herbage cover consisting primarily of grasses *Saccharum spontaneum*, commonly called Cane grass, and *Imperata cylindrica* commonly called Kunai, with the following species of minor importance:—

Arundinella setosa;

Coelorhachis rottboellioides;

Ophiuros tongcalingii;

Sorghum nitidum; and

Themeda australis.

*Agronomist, Lowlands Agricultural Experiment Station, Keravat.

The grasslands are periodically burnt by the indigenous population and this maintains the vegetation in the grassland stage of the successional sequence, and reduces the already low fertility of the soil.

The average rainfall at Popondetta is 90 to 100 in per annum with a distinct seasonal variation. The mean monthly rainfall during the "wet" season (November through to March-April) is about 11 in and is double the monthly rainfall during the remainder of the year, or "dry" season. Owing to the loose, sandy nature of the soil, short periods without rain may result in a condition of drought for the plants in the grasslands, but conversely a relatively small amount of rain during the dry season can be quite effective in promoting growth.

METHODS

Ten selected grass species were planted in a randomized block design, with three replications, the individual plot size being 10 x 10 ft. After an initial cultivation, and the hand removal of all grass rhizomes from the plots, cuttings were planted in 5 rows with a spacing of 1 ft between planting positions in the row. The planting material used varied as follows:—

Grass Species	Planting Material per Position
Paspalum plicatulum	1 small clump of stems with roots
P. conjugatum	2 eighteen-inch lengths of rooted stolon
Pennisetum purpureum	1 length of stem containing 3 nodes

Grass Species	Planting material per Position
Panicum maximum cv. Guinea	1 small clump of stems with roots
Setaria sphacelata cv. Kazungula	1 small clump of stems with roots
Brachiaria ruziziensis	3 eighteen-inch lengths of unrooted stolon
B. mutica	3 eighteen-inch lengths of unrooted stolon
Chloris gayana	2 eighteen-inch lengths of rooted stolon ..
Melinis minutiflora	3 eighteen-inch lengths of rooted stolon
Cenchrus ciliaris cv. Nunbank	Seed at rate of 10 lb per acre

After the grasses had become established, fertilizer at the rate of 2 cwt per acre of Nitrophoska (15:15:15) was broadcast over the area.

Harvests were made on six occasions during the first year of growth. Within all the plots, all the grass was harvested at a height of 3 in, with the exception of the Elephant grass plots, where harvest height was 6 in. At each harvest the total plot herbage was weighed to obtain the "green weight" production, while from the three replicates a small combined sample for each species was oven-dried to determine the "dry matter" content. It had been intended to harvest all plots when, on an average, under a system of rotational grazing, they would be ready for grazing, but this was prevented by supervisional difficulties.

The sole maintenance consisted of an occasional hand-weeding.

RESULTS

Initial establishment of all species was good. After the first harvest, however, some of the grasses did not recover well and a little replanting was necessary to achieve a uniform stand. This was particularly the case with Molasses grass (*Melinis minutiflora*). Regrowth of all species was satisfactory after subsequent harvests.

Table 1 summarizes the average green herbage yield per plot of 100 sq. ft, for each of the six harvests, together with the total production over the period of the trial, namely 389 days.

The first three harvests in effect cover production during the wet season of the year, while the next two harvests cover production during the dry season. Examination of rainfall data for 1967 (see *Table* 5) indicates that the last period was wetter than usual. *Tables* 2 and 3 respectively summarize the dry matter

***Table* 1.—Green herbage yield (lb per 100 sq. ft)**

Species	Growing Period						Total	Significant Difference*
	14.11.1966-5.1.1967	5.1.1967-17.2.1967	17.2.1967-21.4.1967	21.4.1967-22.6.1967	22.6.1967-8.9.1967	8.9.1967-8.12.1967		
Paspalum plicatulum	22.4	15.7	10.7	19.0	16.3	51.7	135.8	B
P. conjugatum	10.7	18.7	13.3	11.7	9.3	12.7	76.4	D
Pennisetum purpureum	20.3	18.3	11.3	23.0	27.3	90.5	190.7	A
Panicum maximum	30.8	16.3	12.3	14.3	12.3	38.5	124.5	BC
Setaria sphacelata	14.1	23.7	9.3	17.3	12.3	26.8	103.5	C
Brachiaria ruziziensis	18.6	14.3	9.3	14.3	11.7	38.5	106.7	C
B. mutica	22.8	14.7	11.3	23.3	11.3	21.7	105.1	C
Chloris gayana	45.0	17.0	10.3	9.3	10.0	20.0	111.6	C
Melinis minutiflora	12.9	19.3	9.7	24.0	8.3	10.5	84.7	D
Cenchrus ciliaris	15.5	14.7	16.0	18.7	11.0	21.3	97.2	CD

*A significant difference in yield (at P=5 per cent) exists between species with different letters.

Table 2.—Dry matter production for the "wet" season

Species	Growing Period: 14.11.1966-5.1.1967 (52 days)		5.1.1967-17.2.1967 (43 days)		17.2.1967-21.4.1967 (63 days)		Total (158 days) D.M. (lb per acre)
	D.M. (lb per acre)	per cent D.M.	D.M. (lb per acre)	per cent D.M.	D.M. (lb per acre)	per cent D.M.	
Paspalum plicatulum	1750	18.0	1180	17.3	840	18.0	3770
P. conjugatum	960	20.5	1480	18.2	1030	17.8	3470
Pennisetum purpureum	1120	12.7	1450	18.2	820	16.5	3390
Panicum maximum	2380	17.7	1170	16.4	980	18.3	4530
Setaria sphacelata	1070	17.3	1920	18.6	690	16.9	3680
Brachiaria ruziziensis	1610	19.8	1090	17.5	750	18.5	3450
B. mutica	2720	27.4	1170	18.4	1060	21.4	4950
Chloris gayana	3680	18.8	1160	15.6	910	20.1	5750
Melinis minutiflora	1100	19.6	1380	16.4	820	19.4	3300
Cenchrus ciliaris	1270	18.9	970	15.1	1260	18.1	3500

Table 3.—Dry matter production for the "dry" season

Species	Growing Period: 21.4.1967-22.6.1967 (62 days)		22.6.1967-8.9.1967 (78 days)		"Dry" Season Total (140 days)	8.9.1967-8.12.1967 (91 days)	
	D.M. (lb per acre)	per cent D.M.	D.M. (lb per acre)	per cent D.M.	D.M. (lb per acre)	D.M. (lb per acre)	per cent D.M.
Paspalum plicatulum	1550	18.7	2040	28.6	3590	6060	26.9
P. conjugatum	880	17.3	1300	32.0	2180	1970	35.7
Pennisetum purpureum	1470	14.7	2360	19.8	3830	15020	38.1
Panicum maximum	1260	20.2	1660	31.0	2920	5740	34.2
Setaria sphacelata	1140	15.1	1580	29.5	2720	3510	30.0
Brachiaria ruziziensis	1220	19.5	1490	29.4	2710	5470	32.6
B. mutica	2470	24.3	1580	32.0	4050	3280	34.7
Chloris gayana	1000	24.6	1470	33.7	2470	3290	37.8
Melinis minutiflora	2270	21.7	1060	29.3	3330	1630	35.6
Cenchrus ciliaris	1710	21.0	1710	35.6	3420	3060	36.0

Table 4.—Comparison of "wet" and "dry" season yields

Species	"Wet" Season (158 days)			"Dry" Season (140 days)			6th Harvest (91 days)			Total Production	
	D.M. (lb per acre)	Per cent of Average Yield*	Daily Production of D.M. (lb per acre)	D.M. (lb per acre)	Per cent of Average Yield*	Daily Production of D.M. (lb per acre)	D.M. (lb per acre)	Per cent of Average Yield*	Daily Production of D.M. (lb per acre)	D.M. (lb per acre)	Per cent of Average Yield*
Paspalum plicatulum	3770	96	23.9	3590	115	25.6	6060	124	66.6	13420	112
P. conjugatum	3470	88	22.0	2180	70	15.6	1970	40	21.6	7620	63
Pennisetum purpureum	3390	87	21.5	3830	123	27.4	15020	306	165.1	22240	185
Panicum maximum	4530	109	28.7	2920	94	20.9	5740	117	63.1	13190	110
Setaria sphacelata	3680	94	23.3	2720	87	19.4	3510	72	38.6	9910	83
Brachiaria ruziziensis	3450	89	21.8	2710	87	19.4	5470	112	60.1	11630	97
B. mutica	4950	126	31.3	4050	130	28.9	3280	67	36.0	12280	102
Chloris gayana	5750	139	36.4	2470	79	17.6	3290	67	36.2	11510	96
Melinis minutiflora	3300	82	20.9	3330	107	23.8	1630	33	17.9	8260	69
Cenchrus ciliaris	3500	90	22.2	3420	110	24.4	3060	62	33.6	9980	83

*The yield of each species expressed as a percentage relative to the average yield of all species.

Table 5.—Rainfall at Popondetta

Rainfall	Growing Period					
	14.11.66-5.1.67 (52 days)	5.1.67-17.2.67 (43 days)	17.2.67-21.4.67 (63 days)	21.4.67-22.6.67 (62 days)	22.6.67-8.9.67 (78 days)	8.9.67-8.12.67 (91 days)
Rainfall over growth period (points)	2,132	1,514	2,685	1,047	1,249	3,400
Mean daily precipitation (points)	41.0	35.2	42.6	16.9	16.0	37.4
Approximate average mean daily precipitation for same period over 14 years (points)	41	37	34	20	12	29

production and percentage dry matter for both the wet and dry season. Both the wet and dry seasons production are compared in *Table* 4, while *Table* 5 shows the rainfall received over the period of the trial.

DISCUSSION

An analysis of the green herbage yields (see Appendix), done on individual plot yields, indicated significant differences between yields of some of the species, between the harvest periods, and also an interaction of the species yields with time of harvest. Yield of Elephant grass was superior to all others, followed by *Paspalum plicatulum,* Guinea grass and Rhodes grass (*Chloris gayana* "common" var.). The indigenous *Paspalum conjugatum,* which is used for grazing purposes on several properties, was inferior in yield to most other species.

As the moisture percentage of the herbage varies between species and harvests, a more reliable guide to the actual production is given by the dry matter yields recorded in *Tables* 2, 3 and 4. The production of the different species varies throughout the year; for example, it is noted that yields from Elephant grass were significantly greater than the other species for only the final two harvests. Indications were that this grass needed a longer establishment period and the accumulation of dry matter was favoured by the longer growth periods. However, of prime consideration in pasture production is the palatability of the herbage, and because of this, harvests of Elephant grass should be more frequent, as the palatability of this species in the final harvest was at a low level, as indicated by the hardness of stem and high percentage dry matter. In this regard Elephant grass showed a large degree of variability, with a variation in percentage dry matter from 12.7 at the first harvest to 38.1 per cent at the final harvest. At the final harvest a more accurate indication of digestible herbage would have been given by separating and weighing the leafy foliage as distinct from stemmy material.

Because of the two distinct seasons at Popondetta, production has been considered as "wet" or "dry" season. However, rather exceptionally heavy rains occurred during October, when 13.78 inches of rain were recorded, compared with the average of about 7.25 inches, and this resulted in the mean daily precipitation over the final growth period being equivalent with that usually received during the wet season. Consequently the final harvest has not been included in the total of dry season yield, and is recorded separately.

An examination of the wet season yields (see *Table* 2) indicates a greater than average production from Rhodes grass and Para grass (*Brachiaria mutica*) but this appears to be rather an indication of their more rapid establishment and early growth after planting. With these exceptions, production from all the species is fairly uniform. There are only minor differences between the percentage dry matter for the various species, all being in the range 16 to 21 per cent with the exception of Elephant grass, which has a very low 12.7 per cent, comparable with some of the values obtained at Bubia (DASF 1968), and the Rhodes grass with the rather high value of 27.4 per cent dry matter.

Greater variation between species becomes apparent during the dry season, both with respect to yields and percentage dry matter (see *Table* 3). The yields of Rhodes grass, *P. conjugatum,* Guinea grass, the *Setaria* sp. and *Brachiaria ruziziensis* are considerably reduced in comparison with their wet season production. Although having a much lower relative percentage dry matter content, Elephant grass is the only species showing much improvement in dry season over the wet season yield.

Only in the final harvest, covering the period of an early commencement to the following wet season, have outstanding yield differences between the various species become apparent. This is indicated in comparison with total wet and dry season yields in *Table* 4. Notable increases in yield are shown for Elephant grass and to a lesser degree for *P. plicatulum,* Guinea grass and *B. ruziziensis*. The best comparison of the productive capacity of the grass species in the various periods is given by the "per day" D.M. production figures. This remains substantially the same throughout the year for some species while in other cases there is significant variation between the seasons. Reasons for a substantially larger value in the sixth harvest, for some species, may indicate those species which—

(*a*) need a longer establishment period before their full productive capacity is realized; and

(*b*) perform better under a system of less frequent defoliation.

The high D.M. content of all species at the final harvest, however, indicates that in this case, and also probably for the fifth harvest, harvesting had been delayed beyond the optimum time of cutting.

CONCLUSIONS

The results of this evaluation trial, although derived from values for only one year of production, give some indication of the potential of several tropical grasses for pasture production on the volcanic sands of the Popondetta area. A number of species appear far superior to the volunteer *Paspalum conjugatum* that has been utilized as pasture on several properties. In spite of the low fertility soil and seasonal nature of the rainfall, some of the species have produced quite substantial amounts of dry matter per acre, although yields do not approach the values reported from a similar trial at Bubia near Lae (DASF 1969). Reasons for this may be attributed to Bubia having—

(*a*) a higher initial soil fertility;
(*b*) more uniform rainfall;
(*c*) regular fertilization; and
(*d*) higher planting density of cuttings.

ACKNOWLEDGEMENTS

Thanks are due to Mr Stephenson Ino, Agricultural Assistant, for help with the field work and to Mr C. Edwards, Senior Pasture Agronomist, Bubia, for arranging the dry matter determinations.

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APPENDIX

As the variance of the plot yields was heterogeneous, the plot yields (x) were transformed by obtaining the square root ($\sqrt{x}$), and the analysis of variance was then carried out on this transformed data. The sum of the square roots of the individual plot yields ($\Sigma\sqrt{x}$) for each treatment is tabulated below.

Species	$\Sigma\sqrt{x}$
Paspalum plicatulum	82.3
P. conjugatum	63.6
Pennisetum purpureum	94.6
Panicum maximum	78.3
Setaria sphacelata	73.3
Brachiaria ruziziensis	73.3
B. mutica	74.5
Chloris gayana	74.0
Melinis minutiflora	65.9
Cenchrus ciliaris	70.6

Least significant difference at 5 per cent = 7.4.
Least significant difference at 1 per cent = 9.7.

STUDIES ON THE GROWTH OF LEUCAENA LEUCOCEPHALA

2. EFFECT OF LIME AT SOWING ON PRODUCTION FROM A LOW CALCIUM STATUS SOIL OF THE SOGERI PLATEAU

G. D. HILL*

ABSTRACT

Leucaena is difficult to establish on low calcium status, acid soils of the Sogeri family on the Sogeri Plateau. The Peru strain of Leucaena was sown and lime applied at 1, 5 *and* 10 *tons per acre broadcast, and at* 1, 2, 4 *and* 8 *cwt per acre drilled in the row. Significant responses were obtained to the application of* 5 *and* 10 *tons per acre* ($P < 0.05$)*. As agricultural lime is not at this stage produced in Papua New Guinea, use of these high levels of lime cannot be considered economic.*

INTRODUCTION

THE main industry of the Sogeri Subdistrict is the cultivation of rubber (*Hevea brasiliensis*). A large area of the Subdistrict is not suited to this crop. The soils of this area were described by Mabbutt *et al.* (1965) as members of the Sogeri family. They are very strongly acid, red to brown clays, with total exchangeable metal ions of approximately 5 milliequivalents per 100 g. The calcium status is low. At Ilogo Plantation exchangeable calcium was 1.6 m-equiv. per cent in the 0 to 6 in layer, and 0.8 m-equiv. per cent in the 6 to 12 in layer (Murty, personal communication).

The vegetation on this soil type is open savannah grassland in which *Ophiuros* sp. and *Themeda australis* are dominant grass species. Tree cover is provided mainly by *Eucalyptus tereticornis* and *E. papuana* (Heyligers 1965).

Because of proximity to Port Moresby a possible use for these grasslands is for the production of beef. For maximum productivity the incorporation of a legume is essential. Under suitable conditions Leucaena has the ability to produce a large quantity of highly nutritious forage (Takahashi and Ripperton 1949; Anslow 1959; Hutton and Bonner 1960). Because of its tree habit it also has greater drought resistance than shallow-rooting prostrate legumes. It was decided to investigate the establishment of this legume on a soil of the Sogeri family.

*Formerly Agronomist, Department of Agriculture, Stock and Fisheries, Bubia, via Lae. Present address: Department of Agronomy, University of Western Australia, Nedlands, W.A. 6009.

Leucaena had been reported by local planters to be difficult to establish. They considered that the altitude (about 2,000 ft) was too high for growth. This is unlikely because of the common use of Leucaena as coffee shade in Papua New Guinea up to altitudes of 5,000 ft.

Several workers have reported responses of Leucaena to applied calcium (Takahashi and Ripperton 1949; Dijkman 1950; Wu 1964; Esquivel 1965). Whether calcium is required for improved nodulation, as postulated by Norris (1967), to alter soil pH and thus improve nodulation (Esquivel 1965), or whether the plant itself has a high requirement for the element, is not clear from the available literature.

An experiment was designed to show the effect of lime on the productivity of Leucaena on the soil type in question.

MATERIALS AND METHODS

The experiment was established on a red-brown clay of the Sogeri family at Bisianumu Animal Industry Station on 23rd and 24th February, 1967. It occupied a total area of 102 x 182 ft, plots being 8 x 16 ft. A distance of 10 ft was left between plots within blocks and between blocks, with an 18 ft border at each end and a 20 ft border at each side.

The treatments were 0, 1, 5 and 10 tons of lime per acre broadcast, and 1, 2, 4 and 8 cwt

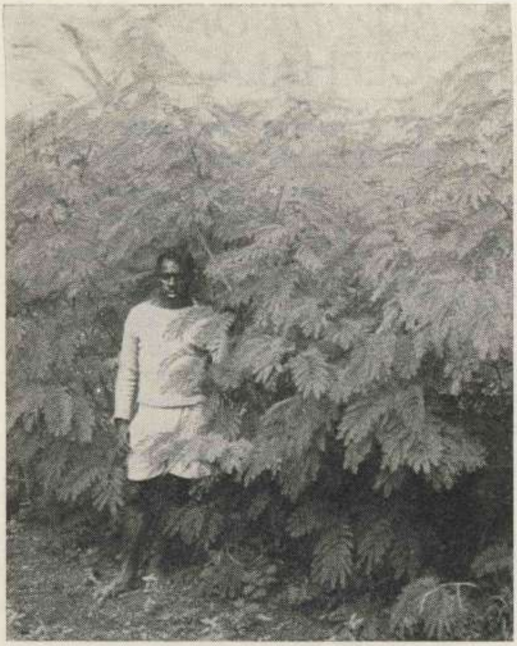

Plate I.—Plot of Leucaena which had received equivalent of 10 tons of broadcast lime per acre, 23rd January, 1968

drilled in the row. A randomized block design with three replicates was used. No other fertilizer was applied.

The trial was sown to the Peru strain of *Leucaena leucocephala* at the rate of 10 lb per acre, each plot comprising four rows 2 ft apart. Prior to sowing, seed was scarified using the method of Gray (1962) and was inoculated with Rhizobium strain NGR 8.

Broadcast lime was worked into the soil with spades. Drilled lime was placed in a shallow furrow directly under the seed.

The experiment was inspected twice prior to harvest. Observations were made on height, colour, establishment and nodulation. At harvest the central 14 ft of the two inside rows of each plot were cut to 3 inches from ground level and the green weight recorded.

RESULTS AND DISCUSSION

Progress of Trial

When inspected on 14th April, 1967, there were no obvious differences among treatments. Average height of plants was 4 in. In a few plots, some plants were yellow. This was not related to treatment and all plots were effectively nodulated. On inspection, roots of yellow plants were found to have been damaged by an insect.

A second inspection was made on 22nd September of the same year. By this time responses to treatment could be seen. Mean height of plants in control plots was 15 in, while mean height of plants which had received 10 tons of broadcast lime was 36 in. In all cases, plots which had received broadcast lime were greener and more even in growth than controls. Plots which had received drilled lime did not respond as well, but no valid comparison can be made as rates were not comparable.

The experiment was harvested on 23rd January, 1968. At harvest it was observed that a fertility gradient ran across the site from block 1 to block 3. The effect was partially taken into account by the randomized blocks design.

Effect of Lime on Forage Production

Plots which had received high rates of lime were taller than controls and darker green (see *Plates* I and II). The effect of treatments on green matter yield was very highly significant $(P < 0.001)$.

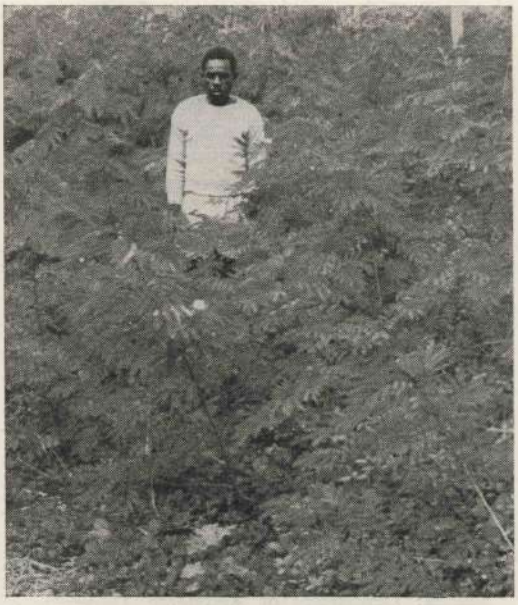

Plate II.—Control plot 23rd January, 1968

The values for the various treatments are shown in the *Table*. A Duncan multiple range test was performed on the results. The responses to 5 and 10 tons were significantly different from each other and all other treatments at the 0.05 level of probability.

Figures 1 and 2 show the regressions of the two methods of lime application. For broadcast lime

$Y = 8{,}552.69 + 1{,}327.89X$ ($t = 9.05^{***}$) (1)

(very highly significant response), while for drilled lime the equation is

$Y = 8{,}248.42 + 215.86X$ ($t = 0.913$N.S.) (2)

(no significant response), where in each case Y = yield of green forage in lb per acre, and X = lime in tons per acre (1) and cwt per acre (2).

The main point of interest that arises from these results is the continued linear response to broadcast lime up to 10 tons per acre. This appears to indicate that it is the plant itself which requires the lime. If lime were required for production some visible response to lower treatment levels would have been expected even

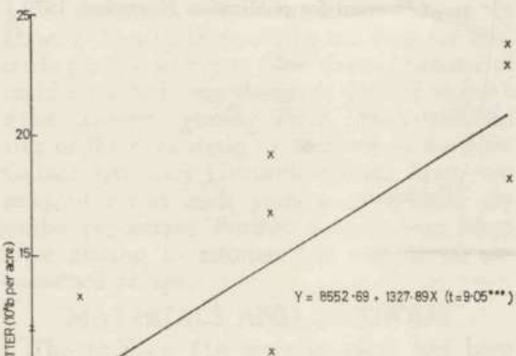

Figure 1.—Response of Leucaena to broadcast lime at 1, 5 and 10 tons per acre

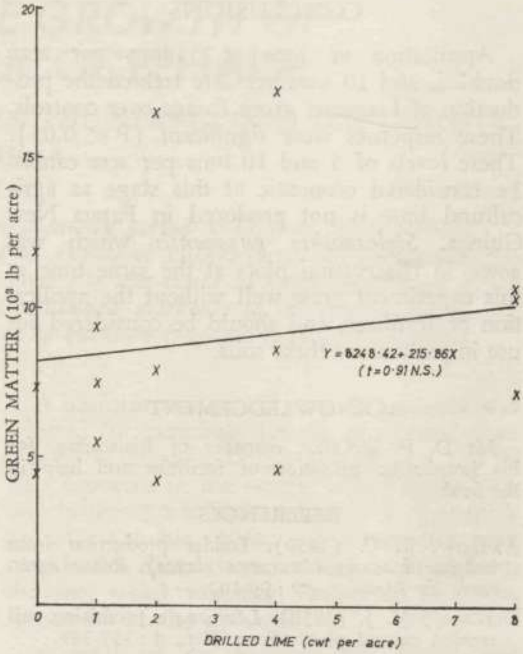

Figure 2.—Response of Leucaena to drilled lime at 1, 2, 4 and 8 cwt per acre (there was no significant increase in production)

Table.—Effect of lime on production of Leucaena at Sogeri

Treatment	Mean Yield Green Mattter (lb per acre)
10 tons broadcast lime per acre	21,560
5 tons broadcast lime per acre	15,660
1 ton broadcast lime per acre	10,291
4 cwt drilled lime per acre	10,120
2 cwt drilled lime per acre	9,536
8 cwt drilled lime per acre	9,365
Control	7,941
1 cwt drilled lime per acre	7,478

Any two means not enclosed by the same brace are significantly different at the 5 per cent level.

if only in the initial stages of the experiment. On the other hand, if the lime were required to change pH and thus improve nodulation, responses to the higher levels could be expected as Leucaena is very tolerant of highly calcareous soils (Mullenax 1963).

CONCLUSIONS

Application of lime at 5 tons per acre doubled, and 10 tons per acre trebled the production of Leucaena green forage over controls. These responses were significant ($P < 0.05$). These levels of 5 and 10 tons per acre cannot be considered economic at this stage as agricultural lime is not produced in Papua New Guinea. *Stylosanthes guyanensis* which was sown in observation plots at the same time as this experiment grew well without the application of fertilizer, and should be considered for use in pastures on these soils.

ACKNOWLEDGEMENT

Mr D. P. McColm, manager of Bisianumu, for his hospitality, provision of facilities and help in the field.

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STUDIES ON THE GROWTH OF LEUCAENA LEUCOCEPHALA

3. PRODUCTION UNDER GRAZING IN THE NEW GUINEA LOWLANDS

G. D. HILL*

ABSTRACT

Under a six-week grazing cycle over a nine-month period at Erap in the Markham Valley, the Peru strain of Leucaena produced an estimated 11,000 *lb of dry matter per acre. On the basis of other results from the same site this could be expected to have a crude protein content of* 21 *per cent. Yield responded markedly to increased rainfall, and during the wet season grazing would need to be more frequent than every* 6 *weeks to keep Leucaena under control.*

INTRODUCTION

NO information is available on the production of Leucaena when grazed by cattle in Papua New Guinea. Studies in Hawaii and Australia have shown the ability of this legume to produce good liveweight gains from cattle (Henke, Work and Burt 1940; Furr 1965; CSIRO Aust. 1968). It was decided, therefore, to estimate the yield of the plant under grazing.

From the literature (Takahashi and Ripperton 1949), harvesting about every 12 weeks gave maximum dry matter production in Hawaii. This cycle would be too long for lowlands grazing in Papua New Guinea because of rapid growth. It was therefore decided to use a fixed six-week grazing cycle. An established area of the Peru strain of Leucaena at the New Guinea Lowlands Livestock Station, Erap, was sampled before each grazing to estimate dry matter production. Further samples were taken after grazing to estimate the amount of unconsumed forage.

MATERIALS AND METHODS

The paddock (16 acres in area) had been sown to the Peru strain in rows 10 ft apart at approximately 10 lb per acre in February, 1967.

Cattle were admitted to the paddock from late 1967, and it was grazed intermittently until the start of the experiment in October, 1968. The companion grass was Buffel (*Cenchrus ciliaris*) and the paddock was moderately infested with *Sida cordifolia.*

*Formerly Agronomist, Department of Agriculture, Stock and Fisheries, Bubia, via Lae. Present address: Department of Agronomy, University of Western Australia, Nedlands, W.A. 6009.

A uniform area of 14 rows of Leucaena was selected for sampling. Length of selected rows was 60 ft, giving a sample area of 60 x 140 ft. The Leucaena in the sample area was cut back into hedges 3.5 ft high and about 0.75 ft thick on 21st October, 1968. All leaves and twig outside this frame were cut and removed from the site, which was then fenced off from the remainder of the paddock.

A total of six harvests was taken. For sampling, each 60 ft of hedge was divided into six sample spaces of 10 ft. At each harvest ten samples were taken prior to grazing. The area was then heavily stocked with cattle until all leaf material was consumed, and a further four samples taken.

At each complete harvest one sample was taken from each row. The position sampled within the row, and the rows to be sampled before and after grazing, were allocated at random with the restriction that each sample space was cut only once during the entire experiment to ensure that the response measured was to grazing and not to cutting.

Estimation of Yield

From each 10 ft sample space the central 5 ft was cut back to the same hedge size as at the start of the experiment. The sample was weighed, and from it a 1 kg subsample was taken and dried to constant weight in a forced draught oven at 85 deg. C. Dried samples were weighed direct from the oven.

Grazing Cycle

Six weeks after the preparatory cutting, pre-grazing samples were taken and cattle admitted. The number varied from harvest to harvest, but was never less than 21 head. This gave a stocking density of 105 beasts per acre. The time taken to graze the area varied from 3 to 5 days. Cattle were removed when no green leaf was visible in the trial area. Post-grazing samples were taken the day the cattle were removed. The next sampling took place six weeks later.

The condition of the trial area after grazing is shown in *Plate* I. Comparison with *Plate* II gives an indication of the volume of forage consumed.

***Plate* I.—Condition of trial area Leucaena grazing trial, Erap, after grazing, 22nd April, 1969**

RESULTS AND DISCUSSION

The first two harvests occurred during the dry season at Erap, harvests three and four during the wet season, five at the end of the wet, and six at the period of the "little wet" (July to August).

It is of interest to note that at the period of the "little wet" there was a considerable increase in the amount of dry matter on offer consumed. At all other harvests the amount of unconsumed forage ranged from 32 to 46 per cent. At the sixth harvest, however, this fell to 19 per cent. This was probably due to increased leaf growth between harvests five and six following the dry period between harvests four and five, thus increasing the amount of leaf relative to unconsumed stems.

Rainfall between harvests is shown in the *Figure*. The response of Leucaena and Buffel to rain was very marked. The condition of the plants at harvest four (18th April, 1969) is shown in *Plate* II.

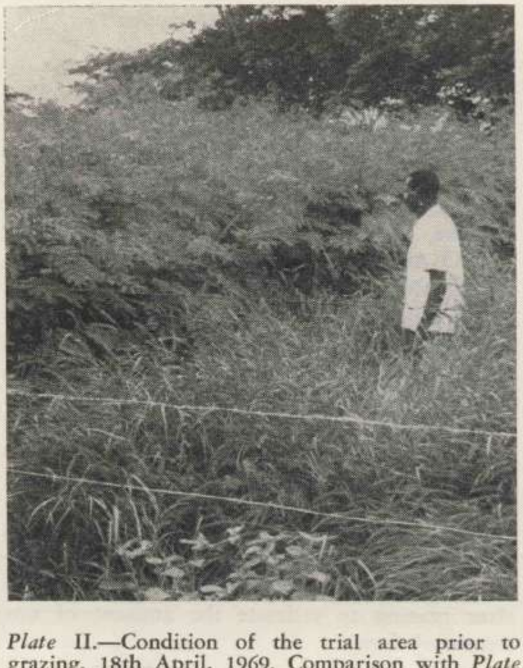

***Plate* II.—Condition of the trial area prior to grazing, 18th April, 1969. Comparison with *Plate* I gives an indication of the amount of forage removed by the cattle**

An interesting feature of the experiment was the effect of the grazing regime on the companion grass. In the rest of the paddock where intensive grazing had not been practised, *Sida cordifolia* was not grazed and tended to dominate the grass. In the experimental area, the high stocking density forced the cattle to graze the Sida. The grass recovered fully after each grazing, and by the second, Sida was no longer a serious weed. The Buffel grass was taller and darker green than that in the remainder of the paddock.

It would thus appear that the grazing regime employed successfully controlled this weed.

Table.—Dry matter production Leucaena grazing—Erap

Harvest Date	Dry Matter (lb per acre)			
	Total	Utilized	Unconsumed	% Unconsumed
2nd December, 1968	861	540	321	37.3
16th January, 1969	892	609	283	31.7
3rd March, 1969	2,941	1,959	982	33.4
18th April, 1969	2,627	1,568	1,059	40.3
2nd June, 1969	1,453	778	675	46.5
17th July, 1969	2,228	1,803	425	19.1

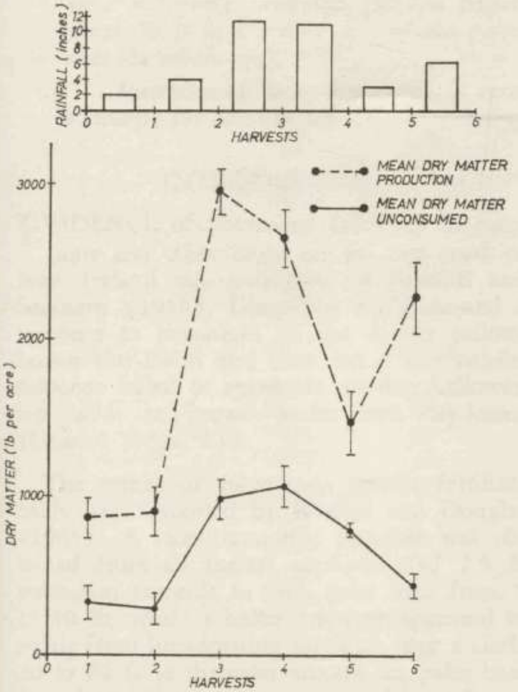

Figure.—Estimated available forage and amount unconsumed (dry matter lb per acre) and rainfall between harvest (Range indicated at each harvest ± Sx (mean))

Dry Matter Production

Mean values for dry matter production are recorded in the *Table,* and are shown in the *Figure*. Maximum dry matter production for any between-grazing period of 2,941 lb per acre was obtained at harvest three.

Estimated total dry matter production over the 289 days of the experiment was 11,000 lb per acre. The amount of utilized forage was estimated at 7,257 lb per acre, or 65.9 per cent. From the results of Hill (1969), six-week-old Peru Leucaena at Erap has an average crude protein content of 21 per cent, giving an estimated crude protein yield of 2,320 lb per acre. These yield estimates do not include production from the companion grass.

When rainfall was adequate, production under a six-week grazing cycle was maintained at high levels. The fixed grazing cycle of 6 weeks did not appear equally suitable for all seasons. During the wet season, grazing clearly needed to be more frequent for efficient utilization and to prevent the hedge from growing out of control.

CONCLUSIONS

The estimated dry matter yield of the Peru strain obtained in this experiment is comparable with that obtained by other workers. Hutton and Bonner (1960) obtained a yield of 11,236 lb dry matter per acre in nine months; and Oakes and Skov (1967) 13,619 lb dry matter per acre in a year, or 10,783 lb per acre if reduced to the same period as the present experiment. From 6 ft hedges, spaced 50 ft apart, Anslow (1959) obtained 2,392 lb per acre using the Mauritius strain. At a 10 ft spacing, assuming no mutual competition, this would give a yield of 11,962 lb, or reduced to the same period as this experiment, 9,471 lb dry matter per acre.

It can be seen that Peru Leucaena because of its high level of production and its very high crude protein content has excellent potential as a forage legume for the lowlands of New Guinea.

ACKNOWLEDGEMENTS

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PROGRESS OF NEW IRELAND FERTILIZER TRIALS 1964 TO 1970

J. H. SUMBAK*

ABSTRACT

Trials on the yellow-brown clay-loam soils of the east coast of New Ireland continued to show responses to potassium fertilizer. The previous recommendation of a biennial application of 5 lb of potassium chloride broadcast evenly over a circle about 20 ft in diameter around the base of the palm as giving the greatest economic response was confirmed.

In a new trial with palms about 30 years old, an estimated average annual increment of at least 3.6 cwt was shown in the 6 years after initial fertilizer application. Additional net profit was estimated at about $A12 per acre per year. Evidence indicated that the actual yield increment would be considerably greater once fertilizer usage was an established practice. A significant yield response to sulphur occurred once the potassium deficiency was corrected and a biennial application would appear appropriate where there is good reason for suspecting low plant sulphur levels.

A single cultivation affected yields adversely for at least 3 years. There were no yield differences detected between palms where fertilizer was broadcast over a circle about 20 ft in diameter around the palm base or where fertilizer was broadcast evenly over the whole area.

Interplanted cacao benefited, in terms of girth increment, from fertilizer applied primarily for coconut palms.

INTRODUCTION

EVIDENCE of potassium deficiency in coconuts and other crops on the east coast of New Ireland was published by Baseden and Southern (1959). Diagnostic trials showed a response to potassium on the deeper yellow-brown clay-loams and clays but a worthwhile response failed to eventuate on the shallower, less acid, red-brown loams and clay-loams (Charles 1959*a*, *b*).

The results of subsequent specific fertilizer trials were reported by Charles and Douglas (1965). A more economic response was obtained from an annual application of 2.5 lb potassium chloride to each palm than from 5 or 10 lb, while a better response appeared to result from broadcasting fertilizer over a circle 20 to 24 ft in diameter around the palm base than from placement over a smaller circle.

There were indications that a biennial application of 5 lb was preferable to annual treatments. A good response to potash fertilizer in coconut seedlings was also demonstrated.

Although potassium applications had increased yields of mature palms it was considered that they had not been brought back to full health. Charles and Douglas examined possible reasons for the absence of a full recovery and mentioned that a new trial had begun on younger palms.

The present paper covers continuation of coconut experimentation in New Ireland from 1964 to early 1970. During this period the Potassium Method of Application Trial and the Potassium Rate of Application Trial were concluded. The trial on younger palms was continued to study the effect of incorporation of fertilizer into the soil by cultivation, the use of NPK fertilizer instead of potassium chloride and two methods of fertilizer placement.

*Agronomist, Lowlands Agricultural Experiment Station, Keravat.

POTASSIUM RATE OF APPLICATION TRIAL

Methods and Results

The progress of this trial from its beginning in 1958 to June, 1964 was described by Charles and Douglas (1965).

Four rates of application of potassium chloride were compared—nil, 1, 2 and 4 cwt per acre per annum, which on a per palm basis was equivalent to 0, 2.5, 5.0 and 10.0 lb per year. The design was a randomized block with four replications and with plots nominally of 16 palms (4 x 4) separated by a single general row. The trial was treated on a typical yellow-brown clay-loam soil in a very variable stand of palms over 40 years old. There was great variability between plot yields and results were adjusted by covariance analysis to reduce random variation by allowing for pretreatment differences.

After fertilizer application in accordance with the original treatments in December, 1964, the following changes were made:—

K0 = Control (unchanged);
K1 = 2.5 lb potassium chloride annually (unchanged);
K2 = 5 lb potassium chloride biennially (previously 5 lb annually); and
K3 = Applications discontinued (previously 10 lb potassium chloride annually).

The K1 treatment was re-applied in May, 1966 (6 months overdue) while K2 was applied in December, 1966.

The treatment changes were designed to examine the indication from the Potassium Method of Application Trial that biennial applications were preferable to annual and to note the residual effect of heavy applications.

Unfortunately, increasing within-treatment variation made result interpretation difficult. The plantation manager suspected that labourers had applied fertilizer in the trial area in his absence and this could have contributed to the increased variability. The trial was concluded in May, 1967.

Table 1 shows average nut counts. Figures from July 1960 to June 1964 are averaged as they had previously been published (Charles and Douglas 1965).

Towards the end of the trial, nut water samples were collected when the trial was visited, provided sufficient suitable nuts were available. Results of analyses are shown in *Table* 2.

Nut characteristics were noted on three occasions and these are shown in *Table* 3.

Discussion

The conclusions drawn by Charles and Douglas (1965) appear confirmed even though increased plot variations prevented the attainment of statistically significant differences between fertilized and unfertilized treatments over the last three years of the trial.

Table 1.—Potassium Rate of Application Trial—average number of nuts per plot, adjusted on pretreatment yields

Date	Control	K1 (2.5 lb per palm)	K2 (5 lb per palm)	K3 (10 lb per palm)	Least Significant Difference 5 %	Least Significant Difference 1 %
Pretreatment*	200.7	200.7	200.7	200.7		
July, 1960 to June, 1964	151	244	258	274		
December, 1964	249	430†	399†	412†	149	217
July, 1965	270	425	422	372	159	232
May, 1966	163	234†	247	252	156	221
November, 1966	185	232	207†	213	98	143
May, 1967	218	305	317	332	143	208
Average December, 1964, to May, 1967	217	325	318	316		

*Average of June and December, 1958, counts.

†Indicates fertilizer application.

Table 2.—Potassium content of nut waters (milli-equivalents per litre)

Treatment	July, 1965	May, 1966	November, 1966
K0	20.5	14.7	23.4
K1	45.9	38.6	45.2
K2	52.9	44.7	42.7
K3	61.0	48.5	56.2

Table 3.—Average husked nut circumference and wet meat plus shell weights

Treatment	Circumference (inches)	Weights (lb)
May, 1966		
K0	13.90	1.11
K1	13.90	1.13
K2	13.97	1.24
K3	14.65	1.34
November, 1966		
K0	13.11	0.94
K1	12.92	0.89
K2	12.85	0.98
K3	13.41	1.01
May, 1967		
K0	12.84	
K1	12.63	
K2	13.19	
K3	13.19	

From June, 1964 onwards the relatively consistent differences in nut production between the three levels of fertilizer were not maintained. However, nut weights in May, 1966, and November, 1966, indicated differences between rates. Despite these differences results indicated that the lowest rate of fertilizer gave the most economic response while at the higher rates the net financial return diminished quickly.

Nut water potassium levels increased with increasing applications of fertilizer. At intervals of about 7, 17 and 23 months after the December, 1964 fertilizer, potassium levels varied according to the amount of fertilizer added. By November, 1966, the 2.5 lb application in May, 1966, had raised the potassium level of the K1 treatment above that of the 5 lb potassium chloride treatment (which had not been fertilized since December, 1964).

Measurements of nut characteristics hinted at fertilizer increasing size but samples were insufficiently large to warrant certainty. Copra cutters could not be kept out of the trial area prior to sampling so it is likely that truly representative samples were not obtained—cutters show a definite tendency to ignore small nuts and concentrate on the larger ones.

POTASSIUM METHOD OF APPLICATION TRIAL

Methods and Results

Charles and Douglas (1965) described this trial from its commencement in 1958 to June, 1964. This trial compared the effect of placement of fertilizer in a narrow band around the base of the palm with broadcasting over a wider area. Application frequencies were also studied.

Treatments were as follows:—

1. Control—no fertilizer.
2. Biennial application of 2 cwt of potassium chloride per acre, broadcast over a narrow band (a circle 6 ft to 10 ft in diameter around the base of each palm).
3. Biennial application of 2 cwt of potassium chloride per acre, broadcast over a broad band (a circle 20 to 24 ft in diameter around the base of each palm).
4. Annual application of 1 cwt of potassium chloride per acre, broadcast over a broad band).

Palms were over 40 years of age and in poor condition with many missing. A randomized block design with six replications was used, with plots nominally of 10 palms (5 x 2) separated by a common guard row. The trial was superimposed on the original cultivation trial in which there had been no treatment response (Charles 1959*b*). It was concluded in May, 1967.

Results after adjustment by covariance analysis are shown in *Table* 4. Figures from July, 1960 to June, 1964 are averaged as they had been previously published (Charles and Douglas 1965).

Discussion

The conclusions drawn by Charles and Douglas (1965) were confirmed. A significant yield response was shown to all fertilizer treatments and the results suggest that the biennial narrow band placement was less effective than the biennial broad band placement. Annual applications were certainly not superior to biennial ones—there is an indication that the reverse may be true. Biennial applications would be recommended provided they are not inferior to annual, because of the saving in application costs.

POTASSIUM-NPK-CULTIVATION TRIAL

Introduction

The possibility of responses to other nutrients on New Ireland soils shown to be deficient in potassium was examined. The use of a compound fertilizer (NPK), which incorporated potassium at the same rate as used in the sole potassium treatments, was included as a treatment.

It is the accepted practice in some coconut-growing countries to incorporate fertilizer into the soil, so cultivation after fertilizer application was included in the trial. There had been reports of palms in New Ireland responding favourably to cultivation so the possibility of this practice improving soil nutrient availability as well as the physical condition of the soil was noted. On the other hand there is a distinct possibility, especially in relatively shallow soils, that cultivation will prove harmful by damaging palm roots.

Fertilizer application over a circle 20 to 24 ft in diameter around the base of the palm had proved superior to applications over a smaller circle in the Potassium Method of Application Trial. It was decided to test whether broadcasting evenly throughout an area of palms might prove equally effective, as it was thought that planters might wish to apply fertilizer by a mechanical fertilizer spreader.

The following treatments were chosen:—

T1 = Control (untreated);

T2 = Cultivation;

T3 = 5 lb potassium chloride biennially;

T4 = 5 lb potassium chloride biennially with cultivation following application; and

T5 = 15 lb NPK biennially with cultivation following application.

The compound fertilizer had a $N : P_2O_5 : K_2O$ ratio of 13 : 13 : 21.

Cultivation consisted of a run up and a run back between each line of palms and the centre line of Leucaena shade with a Ferguson twin

***Table* 4.—Potassium Method of Application Trial—average number of nuts per plot, adjusted on pretreatment yields**

Date	Control	Biennial Narrow Band	Biennial Broad Band	Annual Broad Band	Least Significant Difference	
					5 %	1 %
Pretreatment*	163	163	163	163	....	....
July, 1960 to June, 1964	118	172	206	192	....	....
December, 1964	137	219†	270†	232†	37	51
July, 1965	128	186	267	196	50	69
May, 1966	74	151†	179†	190†	37	51
November, 1966	72	159	181	180	39	54
May, 1967	83	193	195	177	46	64
Average December, 1964 to May, 1967	99	182	218	195	....	....

*Average of seven counts between November, 1955, and November, 1958.

†Indicates fertilizer application.

disc plough set at 4 in. Difficulty was experienced because fairly heavy ground cover and occasional coral outcrops prevented the plough from penetrating evenly. However, the main aim of burying the fertilizer was achieved.

A randomized block design with four replications was used. Plots were nominally of 49 palms (7 x 7) with a common untreated guard row between plots. Only the inner 25 palms were used in assessments so there was at least 90 ft between a recorded palm and the limit of its neighbouring treatment.

Plots of treatments 3, 4 and 5 were split for application method. Palms in three adjacent lines of each plot were fertilized by broadcasting uniformly over that area while three lines on the other side of the plot were fertilized evenly over a circle about 20 ft in diameter around the base of the palms. The centre row of each fertilized plot had fertilizer distributed so as to correspond to the adjacent broadcasting treatment.

The soil of the trial area was a yellow-brown clay-loam soil somewhat variable in depth. The stand was producing poorly and showed symptoms typical of potassium deficiency. Responses would not have been restricted by senility as the stand was only about 30 years old. There were few misses. Palms were planted on a 30ft triangular spacing and were under-planted with cacao which was about two years old when the trial started. Leucaena shade was thinned during the course of the trial.

Pretreatment nut counts were made in May and November, 1963, and treatments were allocated at random but with a few plots interchanged so that the pretreatment mean yields were approximately equal for all treatments.

Cultivation and fertilizer applications were first carried out in November, 1963, and assessments were conducted thenceforth at about six-monthly intervals except between July, 1965, and May, 1966, when a visit was omitted.

Cultivation, with or without fertilizer, proved detrimental and was discontinued after only the one initial ploughing.

Fertilizer was re-applied in May, 1966 (about six months after it was due). Treatments were revised in February, 1968, and again in February, 1970.

By 1968, nut water analyses had indicated low sulphur levels, and as the appearance of the palms suggested the possibility of a sulphur deficiency, treatments were altered to include a potassium sulphate application. A comparison between annual and biennial potash application was also started. Treatments as revised in February, 1968, were:—

- T1 = Control (untreated);
- T2 = 2.5 lb potassium chloride applied annually;
- T3 = 5 lb potassium chloride applied biennially;
- T4 = 6 lb potassium sulphate applied biennially; and
- T5 = 15 lb NPK applied biennially.

Fertilizer was broadcast over circles about 20 ft in diameter around the bases of palms as overall broadcasting had not proved superior and in the experiment situation involved more effort.

In February, 1970, plots were split, one side of each fertilized plot receiving a double application and the other the normal application. The middle row received an intermediate amount.

Nut counts were recorded at roughly six-monthly intervals (except for the interval between July, 1965, and May, 1966) and nut characteristics were recorded on occasions. Cacao girth was measured to see if interplanted cacao benefited.

Nut water samples were taken at regular intervals. Freshly fallen nuts were collected in as large numbers as possible and plots were sampled before any necessary fertilizer application.

Results

Nut counts, after very minor adjustments for pretreatment differences are shown in *Table* 5.

Estimates of annual production based on nut counts are shown in *Table* 6 and illustrated in the *Figure*. Estimates were made by combining two consecutive counts, except for 1965 when only one count was made—in this case the

Table 5.—Number of nuts per plot, adjusted on pretreatment yields

Date	T1	T2	T3	T4	T5	Least Significant Difference	
						5 %	1 %
Pretreatment*	341	341	341	341	341	....	....
June, 1964	436	453	530	552	494	124	175
December, 1964	463	412	585	560	548	165	232
July, 1965	384	241	588	477	471	95	134
May, 1966	341	255	370†	326†	430†	89	126
November, 1966	220	195	359	365	406	97	137
May, 1967	218	216	599	544	516	171	241
February, 1968	356	324†	889†	785†	763†	136	193
August, 1968	416	327	770	758	766	185	261
February, 1969	371	406†	594	703	669	146	206
August, 1969	223	398	510	586	476	87	123
February, 1970	184	399†	548†	607†	523†	55	77
TOTAL	3,612	3,626	6,342	6,263	6,062	....	....
Average June, 1964 to February, 1970	328.4	329.6	576.5	569.4	551.1	....	....

*Average of counts in June, 1963, and November, 1963.
†Indicates fertilizer application.

Table 6.—Estimated annual copra production (cwt) 1964 to 1969 bases on 6,000 nuts per ton of copra

Year	T1	T2	T3	T4	T5
1964	6.71	6.46	8.32	8.30	7.78
1965	5.73	3.60	8.78	7.12	7.03
1966	4.24	3.36	5.44	5.16	6.24
1967	4.29	4.03	11.11	9.92	9.55
1968	5.88	5.47	10.18	10.91	10.71
1969	3.04	5.95	7.90	8.91	7.46
Average	4.98	4.81	8.62	8.39	8.13

July, 1965, recording was doubled. It is estimated that about 6,000 nuts are required to produce one ton of copra. Actually the estimated production for a particular year was really production for the latter half of the year combined with that of the first part of the following year as counts estimate production for approximately the next six months.

Average nut circumferences and weights are shown in *Table* 7.

Table 8 compares methods of fertilizer placement.

Nut water potassium contents are shown in *Table* 9. Sulphur contents of nut waters were determined from May, 1967, onwards and are shown in *Table* 10.

Records of average cacao girth under the various treatments are shown in *Table* 11.

Discussion

Although differences were not statistically significant 7 and 13 months after initial fertilizer application, fertilized palms appeared to be carrying more nuts than control palms. As each nut count represents an estimation of production for the subsequent 6 months some response to fertilizer, in terms of actual copra production, could be expected as early as 12 months and certainly within 18 months of application. It is likely that early responses are due to a reduction in premature nutfall and increased fruit set. Additional responses later will come from increased frond and hence inflorescence production as well as increased fruit set.

Significant responses to potassium were revealed by a nut count 20 months after initial fertilizer application. A substantial increase in copra production could therefore be expected within two years of fertilizer use.

Cultivation depressed yields, no doubt through damage to the root systems of the palms. Unfertilized plots which had been ploughed at the end of 1963 produced consistently fewer nuts than control plots until 1969, a year after they had been fertilized with potassium chloride. There was an indication that cultivation adversely affected yields of fertilized plots as well (*Table* 6).

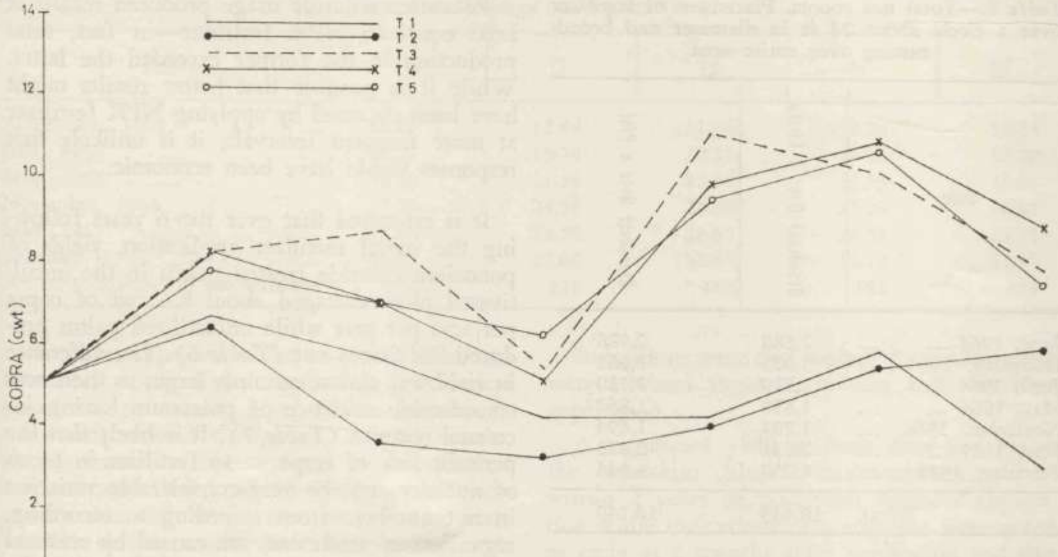

Figure.—Estimated annual copra production

Table 7.—Husked nut circumferences and weights of wet meat plus shell

Date	Weights (lb)					Circumferences (in)				
	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
May, 1963	1.05	1.06	0.96	0.04	0.95	....	....	....	....	....
November, 1963	1.00	0.96	0.98	0.99	0.98	....	....	....	....	....
June, 1964	0.93	0.93	0.71	1.04	0.93	....	....	....	....	....
July, 1965	....	....	....	....	....	13.11	13.09	14.11	13.90	14.15
May, 1966	0.87	0.87	0.89	0.87	0.82	12.61	12.55	11.47	11.81	11.99
November, 1966†	1.27	1.39	1.54	1.38	1.60	13.50	13.97	14.47	14.14	14.98
May, 1967	....	....	....	....	....	14.47	14.40	15.19	14.92	14.88
February, 1968	1.91*	1.98*	2.57*	2.30*	2.75*	14.07	13.78	14.61	15.42	14.59
August, 1968	1.16	1.16	1.27	1.22	1.24	13.92	14.21	14.85	14.46	14.73
February, 1969	1.05	1.16	1.14	1.08	1.07	14.04	14.48	14.37	13.64	13.97
August, 1969	1.05	1.08	1.33	1.25	1.31	13.78	14.13	15.17	14.49	15.01
February, 1970	1.13	1.14	1.31	1.24	1.37	13.83	14.35	14.87	14.61	14.63

†High figures due probably to faulty weighing equipment.

*Weight of husked nut (wet meat and shell plus nut water).

Table 8.—Total nut counts. Placement of fertilizer over a circle about 24 ft in diameter and broadcasting over entire area

Date	Broadcast Over a Circle	Broadcast Over a Plot
June, 1964	2,688	2,586
December, 1964	3,023	2,661
June, 1965	2,519	2,530
May, 1966	1,830	1,862
November, 1966	1,704	1,694
May, 1967	2,621	2,872
February, 1968	4,058	3,944
TOTAL	18,443	18,149

Table 9.—Potassium contents of nut waters (milli-equivalents per litre)

Date	T1	T2	T3	T4	T5
May, 1963	13	17	15	14	14
November, 1963	11	14	12*	12*	13*
June, 1964	12	12	20	14	22
July, 1965	11	13	25	21	26
May, 1966	13	13	21*	20*	20*
November, 1966	14	10	27	21	29
May, 1967	12	14	40	32	41
February, 1968	12	13*	33*	32*	32*
August, 1968	12	14	36	37	34
February, 1969	12	19*	35	34	38
August, 1969	11	19	28	28	33

*Indicates fertilizer application.

Table 10.—Sulphur contents of nut waters (parts per million)

Date	T1	T2	T3	T4	T5
May, 1967	12.0	11.5	8.8	13.5	4.3
February, 1968	5.0	9.4	4.3	4.4	5.3
August, 1968*	2.0	3.9	1.6	3.2	2.8
February, 1969	3.3	3.8	3.1	6.6	2.8
August, 1969	2.4	3.0	2.2	4.2	1.6

*Nut water samples had deteriorated before analysis and this may have affected results.

Potassium chloride usage produced results at least equal to NPK fertilizer—in fact, total production in the former exceeded the latter. While it is possible that better results might have been obtained by applying NPK fertilizer at more frequent intervals, it is unlikely that responses would have been economic.

It is estimated that over the 6 years following the initial fertilizer application, yields of potassium chloride treated palms in the uncultivated plots averaged about 8.6 cwt of copra per acre per year while unfertilized palms produced less than 5 cwt (*Table* 6). The difference in yield was almost certainly larger as there was considerable evidence of potassium having increased nut size (*Table* 7). It is likely that the periodic lack of response to fertilizer in terms of nut size and the very considerable variation in nut numbers from recording to recording, regardless of treatment, are caused by seasonal variations. As yield estimates were based on the assumption that 6,000 nuts were required to produce a ton of copra, regardless of treatment, over-estimates of unfertilized palm yields are likely. Subjective assessments also suggested that unfertilized palms were likely to shed more unripe nuts than fertilized ones.

Even on an average additional return of about 3.6 cwt of copra per acre per year, fertilizing with potassium chloride was worthwhile as it produced an estimated net profit of about \$A12 per acre. This estimate is based on a copra price of \$A150 per ton, fertilizer together with application cost priced at \$A100 per ton and a production cost of \$A50 per ton of copra (excluding fertilizer). It is apparent, as well, that once fertilizer has been used for some time responses would be considerably higher than those from the first few years after initial fertilizer application. Responses to potassium chloride from 1964 to 1969 were 1.61, 3.05, 1.20, 6.82, 4.30, 4.86 cwt per acre respectively. The average response for the first three years was 1.95 cwt as compared with 5.33 cwt for the subsequent three years. Taking this and the probable over-estimation of production from unfertilized palms into account a response well in excess of 3.6 cwt of copra per acre per year could be expected once fertilizer had been used for some time.

Table 11.—Average cacao girth (cm)

Date	T1	T2	T3	T4	T5
November, 1963	12.15	12.44	11.94	12.28	13.34
July, 1965	15.71	15.76	17.55	18.38	18.99
May, 1966	19.36	21.56	22.44	23.39	23.80
November, 1966	22.26	24.59	25.36	27.26	26.85
May, 1967	25.12	25.50	28.55	29.51	29.13
February, 1968	26.77	27.61	31.64	32.16	31.35
Per cent increase on pretreatment	120	122	165	162	139

As there appeared to be no yield differences between application methods, mechanical broadcasting should give similar results to placement around the palms. As this conclusion is based on results from an interplanted coconut-cacao stand where grass growth was greatly reduced it is not possible to state whether similar results could be expected from a sole coconut stand where grass competition is generally severe.

Potassium fertilizer increased potassium nut water levels considerably. Levels generally remained suboptimal (40 to 45 p.p.m. is considered optimal) and had not reached those encountered in the Potassium Rate of Application Trial. It is noted, however, that analyses in the rate of application trial were first conducted more than 6 years after initial fertilizing while the current trial has only just reached this stage. Higher fertilizer rates have been superimposed, but it is doubtful, on the basis of indications from the Rate of Potassium Application Trial, whether they will prove economical.

A fairly consistent pattern of potassium uptake was noted. Seven months after the initial application potassium levels in nut waters had risen in fertilized palms indicating that potassium had been taken up and translocated to well-developed nuts. Levels 18 months after application were higher but still suboptimal—it is possible that levels may have reached their maximum at some intermediate time. Levels 30 months after application and before re-application were lower than at 18 months. Subsequent fertilizer applications resulted in levels considerably higher than after the first application.

It is probable that much of the potassium was initially used in foliar development.

Indications were that highest potassium levels were attained about 12 months after fertilizer application.

A significant yield increase over and above the potassium chloride treatment was evident within 2 years of potassium sulphate application while indications of a response were noted as early as 6 months after application and this was presumably due to the sulphur content of the fertilizer. The February, 1970, inspection indicated that palms supplied with potassium sulphate were yielding the equivalent of 9 cwt of copra per acre per year while those receiving potassium chloride were producing about 8 cwt. The difference was statistically significant at the 5 per cent level. The potassium sulphate treated palms had noticeably greener foliage.

This result is quite important as low sulphur levels in nut waters are common on the east coast of New Ireland. Sulphur may well be a fairly widespread factor limiting production especially where the previously overriding potassium deficiency has been corrected with potassium chloride. A biennial application of 6 lb of potassium sulphate per palm is suggested in areas where fairly obvious deficiency symptoms remain once potassium has been added or where chemical analyses indicate low plant sulphur levels.

Yield responses to sulphur applications in Papua New Guinea have usually been accompanied by rapid rises both in foliar and nut water sulphur contents. In the New Ireland trial, however, nut water contents have to date only risen very slightly despite yield responses. This is the more puzzling because a small pilot trial established on the same plantation showed rapid rises in nut water sulphur levels after potassium and sulphur applications. Pretreatment levels in this case were low to marginal and sulphur was supplied as elemental sulphur.

Girth measurements of interplanted cacao (*Table* 11) indicated a definite response to fertilizer. These measurements failed to reveal any additional response which could be attributed to the nitrogen or phosphorus (or both) supplied in the NPK treatment although the possibility of a production response cannot be excluded. The relatively heavy shade provided by coconuts and Leucaena may have limited responses to nitrogen. An interval of two years between applications was probably too great for nitrogen status to be appreciably improved.

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WEED CONTROL IN COFFEE IN THE NEW GUINEA HIGHLANDS

G. H. PRITCHARD*

ABSTRACT

Herbicides available in Papua New Guinea which are suited for use in coffee are briefly discussed. These include the foliar-acting herbicides paraquat, 2,4-D, MCPA, dalapon, amitrole and MSMA, and the soil-acting herbicides diuron, atrazine and simazine. Programmes for weed control, based on paraquat and diuron, are outlined and methods of control are given for specific weeds which are troublesome or can become so under these programmes. These weeds include Paspalum conjugatum, Cynodon dactylon, Commelina diffusa, Crassocephalum crepidioides, Ipomoea batatas, Lindernia *spp. and* Polygonum *spp.*

Two large-scale weed control trials being conducted at the Highlands Agricultural Experiment Station, Aiyura are described and the costs of treatments in the first 2 *years of the trials are given. The first trial compares four methods of weed control under three shade situations on two sites. The treatments are* (1) *based on paraquat,* (2) *based on diuron,* (3) *hand-weeded, and* (4) *hand-weeded with a diuron application during the peak harvest period. Over the two-year period the paraquat-based treatment was the least costly on both sites and under all shade conditions, this being largely due to the large cost advantage of this treatment in the first year. In the second year, there were smaller differences in costs between the treatments and on one site under two shade situations the diuron-based treatment was more economical than the paraquat-based treatment, while the hand-weeded plus diuron treatment was comparable in cost to the paraquat-based treatment. No significant differences in coffee yields between the treatments have been obtained to date. The second trial, in unshaded coffee on one site only, compares treatments based on* (1) *paraquat and amitrole,* (2) *MSMA,* (3) *diuron plus amitrole, and* (4) *diuron plus paraquat. Treatment* (1) *was the most economical over the two-year period, but in the second year the costs of treatments* (3) *and* (4) *fell below that of treatment* (1).

Examples of chemical weed control costs on other coffee blocks at Aiyura are given to further illustrate the large variations in costs that can occur.

I. INTRODUCTION

Prior to 1967, herbicides such as 2,4-D, dalapon and PCP had been used to a limited extent as a supplement to hand-weeding in coffee plantations but it was not until the introduction of 'Gramoxone' (paraquat) that herbicides began to appear feasible as an economic alternative to hand-weeding. Since then, rising labour costs and in some areas the low availability of labour, have given impetus to the rapid spread in the use of herbicides. While paraquat has been and is the most widely used material, diuron ('Karmex', 'Diurex') has been gaining wider acceptance.

This article gives a brief description of the herbicides currently available, describes various weed control programmes, and gives details and results of trials in progress at Aiyura.

In the naming of herbicides, common names are used except where this would make statements of application rates ambiguous. The use of a brand name does not in any way imply endorsement of that product over a similar product of another manufacturer which is not mentioned, *Table* 1 lists the common and trade names of herbicides mentioned in this article.

*Agronomist, Highlands Agricultural Experiment Station, Aiyura

HERBICIDES

There are a number of herbicides readily available in Papua New Guinea which have been successfully used in coffee. No one material will control all the weed species present in highland plantations, so that while paraquat or diuron is used as the basic treatment, both have to be supplemented in most situations by spot-sprayings with other herbicides for specific weeds.

For descriptive purposes, herbicides may be classified according to whether they are absorbed through the leaves (*foliar-acting*) or through the roots (*soil-acting*). These divisions are often not mutually exclusive and it is not unusual for a herbicide which is mainly active via the foliage to have some effect through root uptake, especially at higher rates, or for a predominantly soil-acting herbicide to have some foliar activity.

1. *Foliar-acting Herbicides*

Since they act through the leaves, they are applied after the weeds emerge. They can be further subdivided according to whether their action depends on contact or translocation.

(*a*) *Contact,* i.e., their effect is predominantly due to a kill of contacted foliage, with little or no translocation (movement) through the plant.

Paraquat (Gramoxone) is the only herbicide in this category which is of present interest. It is active against a wide range of weed species, both grasses and broadleafs. While it kills most annual weeds, the exceptions being a few broadleaf species, it has only a transitory effect on perennial weeds, because they are able to regenerate from undamaged rootstocks. Paraquat acts very rapidly, and rain falling shortly after application will not inhibit its action. It is applied at concentrations of ½ to 2 pints (of Gramoxone) per 45 gallons of spray. The formulation marketed in Papua New Guinea contains 2 lb of paraquat per gallon plus 10 per cent surfactant (wetting agent).

Paraquat has no action through plant roots because it is rapidly adsorbed onto the soil particles where it is tightly held and unavailable to plant roots. In mature coffee, paraquat is unlikely to cause toxicity problems. The killing of a few lower leaves by direct contact will be of little importance. It is only when blanket applications are being made at the beginning of a spray programme that the possibility exists of contacting the green stems of suckers and incurring more serious damage. Once spraying has been reduced to spot applications, this danger should no longer exist if the sprayers take reasonable care. The other situation where care should be exercised is where, for any reason, large amounts of coffee feeder roots lie exposed on the soil surface. Without the protection of the soil, root uptake and subsequent damage to the tree is possible.

In young coffee in its first year or two in the field, there have been a number of cases where the paraquat spray has penetrated the thin bark and killed the underlying green tissue a few inches above the ground. This has a ringbarking effect which results in the death of the tree. The symptoms usually appear only after a number of applications have been made. For spraying in young coffee, there are three alternatives which avoid possible paraquat damage.

(i) Spray along the middle of the rows with paraquat and hand-weed along the tree line.

(ii) Spray along the middle of the rows with paraquat and use diuron along the tree line.

(iii) Spray overall with diuron, but note the comments below concerning diuron.

(*b*) *Translocated,* i.e., herbicides which are absorbed into the plant (in this case through the leaves) and move through it to their site of action—the growing points of leaves or roots.

2,4-D ('Weedkiller D', 'Amoxone-50') is active against most broadleaf weeds. It has no effect when applied to the foliage of grasses. It is available in a number of formulations. The two products mentioned above are amine formulations, which with reasonable care are completely safe in older coffee. Both products contain 5 lb of active ingredient per gallon and are used in spot-spraying at concentrations of 1 to 4 pints per 45 gallons of spray. 2,4-D

Table 1.—Herbicides common, trade and chemical names

Common Name	Trade Name	Amount of Active Ingredient in Commercial Formulation	Chemical Name
Amitrole	Weedazol TL Plus	2.5 lb per gal	3-amino-1,2,4-triazole
Amitrole plus dalapon	Weedazol Total	10 per cent amitrole + 57.2 per cent dalapon on a weight basis	see amitrole and dalapon
Atrazine	Gesaprim-50	50 per cent on a weight basis	2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine
2,4-D	Amoxone-50; Weedkiller D	5.0 lb per gal (amine salt)	2,4-dichlorophenoxyacetic acid
Dalapon	Basfapon; Dowpon; Gramevin	85 per cent on a weight basis (as the sodium salt)	2,2-dichloropropionic acid
Diuron	Diurex; Karmex	80 per cent on a weight basis	N'-(3,4-dichlorophenyl)-NN-dimethylurea
Fluometuron	Cotoran	80 per cent on a weight basis	N'-(3-trifluoromethylphenyl)-NN-dimethylurea
MCPA	Methoxone-30	2.42 lb per gal (as the sodium salt)	4-chloro-2-methylphenoxyacetic acid
Metobromuron	Patoran	50 per cent on a weight basis	N'-(4-bromophenyl)-N-methoxy-N-methylurea
MSMA	Ansar 529; Daconate	6.0 lb per gal; 4.98 lb per gal	monosodium methanearsonate
Paraquat	Gramoxone	2.0 lb per gal (of paraquat cation)	1,1'-dimethyl-4,4-bipyridylium dichloride
PCP	Weedkiller Q	1.0 lb per gal	pentachlorophenol
Simazine	Gesatop-50	50 per cent on a weight basis	2-chloro-4,6-bisethylamino-1,3,5-triazine

has some activity on weed seedlings from root uptake, but it only persists in the soil for a few weeks.

In mature coffee, if leaves on a lower lateral are contacted the only symptom that is observed is the twisting of the youngest leaf-pair on the lateral. Deliberate overall spraying of mature trees has caused defoliation and deliberate spraying of young suckers caused some twisting and limpness of stems and fairly severe twisting, limpness and yellowing of leaves, followed by slow death if the treatment was repeated. Damage from root uptake at least at the concentrations used (up to 4 pints per 45 gallons) is not likely.

MCPA ('Methoxone-30') is similar to 2, 4-D and also has no effect on grasses as a foliar spray. The product mentioned contains 2.4 lb of active ingredient per gallon and is usually used in spot-sprays at concentrations between 2 and 4 pints per 45 gallons.

Dalapon ('Gramevin', 'Dowpon', 'Basfapon') is a grass-killer effective against a number of hard-to-kill perennial grasses. It is used as a spot-spray at concentrations of 5 to 10 lb per 45 gallons. It is more effective applied in two equal applications about four weeks apart than as a single application at double the concentration. The three products listed above all contain 85 per cent of dalapon as the sodium salt.

While uptake is mainly through the leaves, root uptake can occur. Reasonable care in its use is required because excessive doses could cause damage to coffee through root uptake. This possibility is greater on lighter-texture soils. Spray concentrations should not exceed 10 lb (of product) per 45 gallons and concentrations of about 5 lb would be preferable, particularly in young coffee. In Kenya, applications of up to 8 lb of dalapon per acre (i.e., 9.4 lb of Gramevin or equivalent product) did not harm coffee provided the foliage was not sprayed (Wallis 1961), while toxicity symptoms from root uptake were recorded three months after an application of 10 lb dalapon per acre in bearing coffee (Wallis 1959), and three and a half months after an application of 13.6 lb dalapon (16 lb Gramevin or equivalent) in coffee which had recently been stumped (Wallis 1958).

It should be remembered that in spot-spraying it would be possible for a spray operator to spray double the intended rate to a given patch of ground. Thus, a spray containing 10 lb of Gramevin per 45 gallons could be applied to particular spots at a rate equivalent to 20 lb per acre.

In normal field use, damage to coffee from foliar contact has not been observed. However, deliberate overall spraying of mature trees has caused complete defoliation and, when young suckers on stumped coffee were sprayed, all suckers contacted were completely killed. Thus, contact with the foliage of young coffee should be carefully avoided, and reasonable care taken in older coffee.

Amitrole ('Weedazol TL Plus') has some effect on a wide range of grass and broadleaf weeds, although at the relatively low rates used in coffee it often only retards weed growth rather than achieving a complete kill. It is particularly effective against the perennial grass *Paspalum conjugatum* (thurston grass), and this has been its main use in the highlands. The Weedazol TL Plus formulation contains 2½ lb of amitrole per gallon plus an activator, ammonium thiocyanate. At the concentrations used—1 to 4 pints per 45 gallons—it appears to be safe in mature coffee, although contacted foliage will turn white and white leaves may also appear higher up the tree. This can look rather serious and it persists for a considerable period, but even on a block at Aiyura where amitrole has been the only herbicide used for 18 months, there has been no appearance of more advanced toxicity symptoms. However, in young coffee, more care is required. Fairly serious damage was caused at Aiyura from foliar contact. The herbicide accumulates at the growing points of the plant and can kill or seriously retard young suckers. The young trees that were damaged at Aiyura had been bent over in the Agobiada system to induce suckering, so that much of the foliage was at ground level and was contacted by the spray. In this instance, recovery occurred a few months after spraying had been suspended.

While root uptake is possible and was apparently the cause of toxicity symptoms reported in Kenya (Wallis 1958) from plots receiving 2 or 4 lb of amitrole (equivalent to 6.4 and 12.8 pints respectively of Weedazol

TL Plus), the main cause of all damage observed to date at Aiyura is considered to have been from foliar contact. The possibility of damaging mature coffee from root uptake when occasional spot-sprays are used would be very slight.

Another formulation, 'Weedazol Total', which is a mixture of amitrole and dalapon, is also active against a wide range of weed species and is more effective against most perennial grasses than amitrole alone.

MSMA ('Ansar 529', 'Daconate') is active against a number of grasses and broadleafs, although it is not effective against as wide a range of species as paraquat. It is particularly effective against several *Paspalum* species, including *P. conjugatum*. The Ansar 529 formulation contains 6 lb MSMA per gallon and the Daconate formulation 5 lb per gallon.

MSMA is an organic arsenical which, unlike inorganic arsenicals such as sodium arsenite, can be considered fairly safe to the user. Its use in food crops in developed countries is fairly strictly controlled and tolerance levels for arsenic residues in these crops have been established. It seems unlikely at present that any arsenic residues in coffee beans arising from the foliage being contacted with spray (root uptake is improbable) would exceed levels permitted elsewhere in food crops. However, as there is no set-up in Papua New Guinea for monitoring residues appearing in export produce, the indiscriminate use of MSMA would be unwise until further information is available. In non-bearing coffee or as a spot-spray under supervision, it should present no problems.

2. *Soil-acting Herbicides*

These materials are taken up from the soil by the weed seedling soon after germination and may be ineffective if applied after the seedling has emerged, although depending on the herbicide, the rate used and the weed species, larger seedlings may be killed. Soil-acting herbicides remain active in the soil for some time, and the longer-lasting materials are sometimes referred to as residual herbicides.

Diuron (Karmex, Diurex) is effective against a wide range of annual broadleafs and grasses and also some perennial grasses. Its action against perennial grasses is unusual for a soil-acting herbicide, and even occurs with established plants of thurston grass, and in certain circumstances with couch grass. Both commercial products are wettable powders containing 80 per cent active ingredient (diuron). If used as recommended, i.e., at no more than 4 lb (of commercial product) per acre at the first application with subsequent applications at 2 lb per acre to give a total in the first year of use of about 8 lb per acre and about 4 lb per year thereafter, then there seems to be little likelihood in highland soils of residues ever accumulating to the point where they will become toxic to coffee. Occasional spray contact with the lower leaves has not been observed to cause any damage.

In young coffee, as an extra precaution, the maximum individual dose could be limited to 3 lb per acre, but with soil-applied treatments damage is unlikely. However care should be taken to avoid contacting the foliage. While contact may not kill the young coffee, it could, depending on the amount of foliage sprayed, cause a severe setback to growth. Symptoms of contact are a severe yellowing of leaves, except for the midrib and main veins, yellowing of sucker stems, death of tissue along the leaf margins and leaf-fall. This damage occurs even if the spray contains no added surfactant.

Simazine ('Gesatop') is active against a wide range of annual grasses and broadleaf weeds. It has no effect if applied to emerged weeds.

Atrazine ('Gesaprim') is similar to simazine, but has some foliar activity, so it can be applied successfully to small seedlings of annual weeds.

There are no other soil-acting herbicides available commercially in Papua New Guinea at present, although some which are undergoing evaluation in coffee are commercially available in Australia.

Some care should be exercised in the use of persistent soil-acting herbicides. If used at recommended rates, the annual rate of breakdown and loss from the soil will approximately balance the amount applied, so that there will be little likelihood that residues will build up in the soil to levels high enough to harm coffee. However a constant check should be kept on how much is being applied, both over the whole plantation and also on smaller sections of it, to prevent overdoses being made.

II. HERBICIDE PROGRAMMES

At present there are two main alternative methods of chemical weed control. One is based on the use of the contact herbicide paraquat and the other on the soil-acting, residual herbicide diuron. These methods and some variations are discussed below. Whatever method is used, regular attention and treatment will be required if the programme is to be effective and economic.

1. *Based on Paraquat*

This is the herbicide programme with which most plantations have had some experience. In most situations it will be the least expensive method in the first year or so, and will probably remain so in the longer term. However, it does require regular applications at fairly short intervals, and can involve management difficulties when resistant weeds appear.

Initially blanket applications are made with a spray containing 1 pint of Gramoxone plus ½ pint of non-ionic surfactant (such as 'Agral 60' or 'Nonidet WK') per 45 gallons of spray. This volume is sufficient to cover about one acre if spray nozzles giving a wide, coarse pattern are used. Respraying is carried out when the majority of the weeds from the next batch of germinating seeds reach a height of six to eight inches, but before they commence seeding. This usually results in an interval of about six weeks between sprayings, but can vary with rainfall and weed species. After two or three blanket applications, the weed germinations become patchy and it becomes feasible to spot-spray rather than apply a blanket application. At the same time, provided an adequate coverage of the weeds' foliage is made with the spray, it is usually possible to reduce the concentration of the spray from the initial 1 pint down to ½ pint per 45 gallons of spray (the surfactant being retained at the initial concentration). After some time the ½ pint of Gramoxone may be covering 2½ acres or more, so that the amount being applied to each acre of plantation may only be 1/5th pint.

In most cases some resistant or partially resistant weeds will be present, and these will start to become more prominent once the ground has become partly cleared of weeds. If action against the resistant weeds is delayed until they become firmly and widely established, then eradication becomes a more lengthy and costly process. The biggest problem is usually the perennial grasses *Cynodon dactylon* (couch grass) and *Paspalum conjugatum* (thurston grass). Other weeds which are less serious generally through the highlands, but which may become troublesome in particular areas, include the grasses *Paspalum orbiculare, Paspalum paniculatum, Pennisetum clandestinum* (kikuyu), *Pennisetum purpureum* (elephant grass), *Imperata cylindrica* (kunai), the sedges *Cyperus brevifolius* and *C. kyllingia,* and the broadleafs *Lindernia crustacea, L. anagallis, Portulaca oleracea* (pigweed) and *Commelina diffusa* (wandering jew—it is a monocotyledon so is not strictly a broadleaf weed, but by its superficial appearance and response to herbicides it is convenient to include it in this category).

Treating these weeds with other herbicides while continuing to apply paraquat at regular intervals to the susceptible weeds can involve difficulties, because if the other herbicide is slow-acting then it is necessary to avoid any contact of the treated weeds with paraquat until the other herbicide has had time to act. For example, when couch grass is treated with two applications of dalapon applied four weeks apart (and this gives better results than one application at double the rate), the couch grass should not be contacted with paraquat for at least a month after the second application. There is thus a period of up to 12 weeks (from the previous paraquat application 3 to 4 weeks before the first dalapon treatment until 4 weeks after the second dalapon treatment) when contact of couch grass with paraquat should be avoided. Where the couch grass is present in well-defined patches to the exclusion of all other weeds, the alternative spraying is relatively straightforward, but if the grass is more thinly distributed and in close association with other weeds, some modification of the spray programme may be necessary. Thus, if it is thought that ceasing paraquat treatments during the period, thereby allowing weeds to mature and produce seed, will not seriously increase the weediness of the block and the subsequent control costs, then this could be a feasible solution. Alternatively the couch could be sprayed with paraquat at the same time as it becomes necessary for the other weeds. This would result in a poorer kill of couch grass and would necessitate further treatments, but control of all weeds would be maintained while the couch grass was being gradually eradicated. Another possibility would be to replace the paraquat treatment during the period around the dalapon applications with a herbicide which, if it contacts the couch grass, does not interfere with the action of dalapon. For example, 2,4-D or MCPA could be used to replace paraquat if broadleaf weeds predominated.

2. *Based on Diuron*

As generally practised, blanket applications of diuron are made at intervals of three to five months, and spot-spraying as necessary is carried out with the appropriate herbicides between the diuron applications. The initial diuron application is made at 4 lb of commercial product (Karmex, Diurex) per acre, and subsequent applications at 2 lb per acre. The first application can be made either to freshly weeded ground or to standing weeds. In the latter case it is necessary to include in the spray a suitable non-ionic surfactant at a concentration of 0.5 per cent of the spray volume, or a foliar-acting herbicide such as paraquat or amitrole. The later diuron applications are usually made to substantially weed-free ground so that additions of surfactant or foliar-acting herbicides are unnecessary. However, if a considerable amount of weed is present then a surfactant could be added, or alternatively the diuron could be applied alone and any weeds which were not killed could be spot-sprayed a few weeks after with a foliar-acting herbicide.

The weeds likely to require most attention on diuron-treated areas are couch grass, wandering jew, and the composite, thickhead (*Crassocephalum crepidioides*). Spot-treatments of specific weed species do not raise the difficulties which can occur under a paraquat programme, since there will be no regular paraquat applications to interfere with the action of translocated herbicides.

An alternative method of using diuron to that described above is to apply the first treatment as a blanket application and then all subsequent treatments as spot-sprayings of diuron as necessary. For these spot-sprayings, as for blanket applications to standing weeds, either a non-ionic surfactant at 0.5 per cent of the spray volume, or paraquat or amitrole is added. A spray mixture of 3 lb Karmex (or Diurex) plus 1 pint of Gramoxone or 3 pints of Weedazol TL Plus with the appropriate amount of surfactant ($\frac{1}{2}$ pint per 45 gallons for Gramoxone or 1/3rd pint per 45 gallons for Weedazol TL Plus, i.e., the same amount that would be required if the foliar-acting herbicide was being applied alone), in 45 gallons of spray gives a fairly rapid knockdown and residual control of a wide range of weeds. The combination of diuron with amitrole or paraquat is quicker-acting and usually more effective than the diuron-surfactant mixture.

The spot treatments with the diuron-based spray are required at shorter intervals than the blanket applications, but the total number of treatments applied has been found to be no more than is required in the method which employs spot applications of other herbicides between the blanket applications of diuron. Although spot-spraying diuron reduces the need for spot treatments with other herbicides, in most cases they cannot be completely eliminated. Couch grass and wandering jew, if present, are likely to require additional treatment. The overall cost of this method can be considerably lower, particularly in the first year, than the method employing regular blanket applications, but it does have the disadvantage that excessive amounts of diuron could be applied to localized areas of ground.

3. *Based on Other Soil-acting Herbicides*

As yet, insufficient experience has been gained with other soil-acting herbicides such as simazine, atrazine, fluometuron ('Cotoran') or metobromuron ('Patoran') to make recommendations concerning their use. In overseas trials, diuron has usually given more consistent results, but in a particular area and weed situation, one or more of these materials may be more suitable than diuron. For example, it has been observed at Aiyura that simazine gives good control of thickhead (*Crassocephalum crepidioides*), which is not controlled by soil applications of diuron, and in a situation where this weed is prominent, simazine may be the preferred treatment. Against this, however simazine gives no control of a number of weeds, for example, thurston grass and *Amaranthus lividus,* which are controlled by diuron.

The possibility of increasing the spectrum of weeds controlled by using mixtures of soil-acting herbicides is presently being examined.

PROBLEM WEEDS

As indicated above, there are a number of species which are not adequately controlled by one or both of the basic treatments and which therefore require additional treatment.

Paspalum conjugatum (Thurston Grass)

A number of different treatments will control and fairly quickly eliminate this grass. The most appropriate in a given situation will depend on the proportion of this weed in the total weed population, the herbicide being used as the basic treatment, and the importance placed on rapid elimination—which will generally be more costly than slower eradication.

(*a*) The cheapest method is to use only amitrole. Two applications of between 2 and 4 pints of Weedazol TL Plus per 45 gallons of spray, applied four weeks apart, with a follow-up treatment two to three months later on any patches which are recovering, give excellent results at low cost. While such a treatment is possible where thurston grass is the predominant weed, or where a soil-acting herbicide is being used as the basic treatment, it may not be possible if paraquat is the basic treatment, since it would not be feasible to cease using paraquat during the long period that amitrole takes to kill the grass. One way out of this difficulty, if it is not possible to avoid contacting the thurston grass with paraquat sprays, is to apply amitrole to all the weeds. Although a number of species may not be killed by this treatment, their growth and development will be retarded sufficiently to prevent them spreading while the thurston grass is being eradicated.

(*b*) However, where paraquat is the basic treatment and thurston grass is not a dominant species in the weed population, it is probably preferable to use amitrole in conjunction with paraquat. This method may take longer to achieve complete eradication and may be more costly but it does bring about a rapid decrease in the amount of grass. Weedazol TL Plus is spot-sprayed to the thurston grass at a strength of 2 to 4 pints per 45 gallons of spray (depending on the height and density of the grass) and four weeks later the regular Gramoxone application, at 1 pint per 45 gallons, is made to all weeds, including thurston grass. There will be some recovery of thurston grass from this first "split application" treatment, but repeat treatments will eventually give complete eradication.

(*c*) As mentioned previously, diuron is effective against thurston grass, and where this herbicide is the basic treatment it will give good control, although there will probably be some patches of the grass which persist. These can either be eradicated with amitrole as described in (*a*) above, and this would be the less costly treatment, or by spot-spraying with diuron. A non-ionic surfactant at 0.5 per cent of the spray volume or amitrole or paraquat should be included with the diuron for spot treatments.

(*d*) The fourth method of treating thurston grass is with MSMA, but note the previous comment concerning MSMA. Two applications containing 2.25 to 3.75 lb of active ingredient (i.e., 3 to 5 pints of a formulation containing 6 lb active ingredient per gallon) per 45 gallons of spray applied about four weeks apart, with follow-up treatments to regrowth, will give good control. Applying paraquat after MSMA results in less satisfactory control.

Cynodon dactylon (Couch Grass)

Paraquat will "burn-off" the top growth of the grass but regeneration is rapid and even repeated doses fail to control it. Diuron at normal rates is usually ineffective and on diuron-treated areas, the grass can be expected to spread.

The most satisfactory method of treatment is with two applications of dalapon applied four weeks apart. Two applications give better results than one application using the same total amount of herbicide. The amount of herbicide required to give a high percentage kill will vary with the growing conditions of the weed. Applications made when the movement of the sap within the grass is predominantly downwards into the roots will give better results than when the sap movement is predominantly upwards from the roots, since regrowth is only prevented if the dalapon enters the rhizomes and roots.

Under markedly seasonal conditions, considerable downward movement of sap can be expected towards the end of a period which has been favourable to growth, just prior to the onset of a period which is unfavourable to growth, such as a dry season. At this time the plant is laying down root reserves to carry it over the unfavourable season. In many highland areas, including Aiyura, the seasonality is not particularly marked or constant, with the "wet season" being broken up by periods of dry weather and the "dry season" not being dry enough to interfere greatly with plant growth. Under these conditions the phasic growth of a perennial grass, as outlined above, may be ill-defined or it may be occurring but be difficult to predict because of the lack of predictability in the onset of dry periods.

In general, then, a dalapon spray containing 5 to 10 lb (of commercial product) per 45 gallons with 0.1 to 0.2 per cent wetting agent, applied twice with four weeks between the treatments, should be used. This range of spray concentration is given on the assumption that the spray is being applied at a rate of about 45 gallons per acre of treated ground. If spot-sprays are being applied at higher volumes, or are likely to be so applied, then the spray concentration should be adjusted so that the upper rate limit does not exceed the equivalent on any patch of grass of 10 lb per acre. If conditions are favourable for the downward translocation of herbicide, then the concentration of 5 lb per 45 gallons should be sufficient to give a high percentage kill. Even at the highest rate complete eradication may not be achieved after one double treatment, although initially all the aboveground growth will appear to be dead. Prompt retreatment of regrowth will result in eventual eradication at the lowest cost.

In an area in which paraquat is being used, double applications of dalapon can be difficult, as mentioned previously. As with amitrole on thurston grass, a split application method can be used in which a spot-spraying of couch grass with dalapon at 5 to 10 lb per 45 gallons precedes by about four weeks the regular overall treatments with paraquat. This treatment gives less satisfactory results than the double application of dalapon, and the eradication of the couch grass would be a lengthier process.

As already mentioned, care should be taken to prevent overdoses of dalapon being applied, as damage to the coffee could result from root uptake.

Repeated doses of amitrole will control the grass better than does paraquat alone, but even where several applications have been used, eradication has not been achieved and when treatment ceased the grass recovered. Repeated applications at higher rates (around 8 pints of Weedazol TL Plus per 45 gallons of spray) may be more successful, but would be more expensive than dalapon and would introduce the possibility of affecting the coffee.

A mixture of dalapon and amitrole (a commercial formulation containing these ingredients is marketed as Weedazol Total) is effective, but no more so than dalapon treatments of equal cost.

Commelina diffusa (Wandering Jew)

This weed is likely to become troublesome under a diuron programme. With paraquat, repeated sprayings will usually control it, although additional treatment may be required for very thick infestations, or if relatively low rates of paraquat (less than 1 pint of Gramoxone) are being used, or in exposed areas.

Repeated spot-sprayings with 2,4-D amine at 3 to 4 pints per 45 gallons (of formulations containing 5 lb active ingredient per gallon) have been successful in eliminating the weed at Aiyura. However, a recent trial has indicated that MCPA at 4 pints (of Methoxone-30) is a more effective and cheaper treatment, although two applications were still not sufficient to completely eradicate a dense infestation. In the same trial, some newer herbicides were superior to MCPA, but their cost seems likely to be considerably higher than that of MCPA.

Crassocephalum crepidiodes (Thickhead)

This composite is resistant to soil applications of diuron and usually becomes prominent in an area soon after diuron treatment commences. Foliar applications of diuron with surfactant, or paraquat, will kill established plants, but will have no residual effect on plants which subsequently appear from seed. The cheapest treatment is spot-spraying Gramoxone at 1 pint per 45 gallons of spray. 2,4-D has some effect on the weed, but although growth may be retarded, recovery often occurs, even from sprays containing 3 pints (of commercial formulation) per 45 gallons. MCPA gives similar results.

Ipomoea batatas (Sweet Potato)

Sweet potato regrowth is resistant to paraquat and only slightly affected by diuron. 2,4-D or MCPA at 2 pints (of commercial formulation) per 45 gallons of spray will kill it.

Lindernia spp.

There are two species of *Lindernia* occasionally present in coffee. They are small prostrate plants which are usually inconspicuous until other weed growth is eradicated. Both species have purplish pigmentation on the upper surface of their leaves and stems. The flowers are purple and white, or purple with a yellow spot. They are resistant to paraquat and possibly also to diuron. However, both species spread relatively slowly and seem unlikely to become a problem. Control is achieved with 2,4-D at 2 pints (of commercial formulation) per 45 gallons of spray.

Polygonum spp.

Polygonum minus and *Polygonum dichotomum* are occasionally seen in plantations, usually in or adjacent to drains. Both are resistant to paraquat. *P. dichotomum* grows fairly prostrately and has firm, dark green leaves and small white and pink flowers in short clusters. It can be controlled with 2,4-D at 2 pints per 45 gallons of spray. *P. minus* grows more upright, has longer, narrower leaves, and small pink or white flowers on flowering branches (racemes). 2,4-D at 2 pints (of commercial formulation) per 45 gallons has not controlled it, but it is likely that higher concentrations would do so.

P. nepalense is a common weed in coffee. It has thin, light green leaves, often with a darker patch near the centre, stems which are usually reddish, and small pink flowers in small clusters. Paraquat is less effective on it than on most annual weeds, and if it is not being adequately controlled, 2,4-D at 2 pints (of commercial formulation) per 45 gallons can be used.

III. ECONOMICS OF VARIOUS METHODS OF WEED CONTROL

Several trials at Aiyura are examining the economics of various systems of weed control. The two which have been in existence for the longest period are discussed here in some detail.

TRIAL AWC2a

The first, designated AWC2a, commenced in March, 1968. It compares the costs of the following four weed control treatments:—

(1) Basically paraquat (Gramoxone);
(2) Basically diuron (Karmex or Diurex);
(3) Hand-weeded; and
(4) Hand-weeded during most of the year with diuron used during the peak harvest period.

The trial was laid out over an existing shade-spacing-pruning trial, ACA1, with each weed control treatment being applied to a complete replicate of ACA1. Thus, each herbicide treatment is evaluated under three shade conditions, namely dense Casuarina shade, medium Albizia shade and Unshaded, at each of two sites—the hillside block B15/16 and the "pit-pit" blocks C6-D6. Each shade plot is $\frac{5}{8}$ acre in size. Under each shade the coffee is grown at three spacings (7, 8 and 9 ft triangle) and with two pruning systems (single stem and multiple stem). The weed control costs given for a shade plot are thus an average of the costs in six different growing situations. This is mentioned because in mature coffee, weed growth in different plantings systems varies considerably, as shown in *Table* 2. *Table* 3 shows how weed growth is influenced by overhead shade.

Details of the soil types at the two sites are given in *Table* 4.

The weed problem in the trial area was worse than that existing on most highland plantations, with perennial grasses forming a high proportion of the weed population. On the pit-pit site, the perennial grass problem was accentuated by the heavy, poorly drained soil.

Costs of weed control, both by chemical and manual means, will vary greatly between properties, depending on such factors as rainfall, soil type and weed species. The costs incurred in this trial cannot be directly transposed to different situations elsewhere in the highlands. In fact, for reasons mentioned above, the costs of all treatments in the trial are higher than would be expected on most plantations. However, the relative costs of the different treatments can be usefully compared, and along with results from other current trials, which are discussed later, help to provide a reasonable indication of the likely costs of a particular programme in a given situation.

Table 5 gives the per acre cost of each treatment for the first two years. Details of each treatment follow.

1. *Basically Paraquat*—with no soil-acting residual herbicides

A summary of the applications made under each shade appears in *Table* 6. The main weeds at which the various additional herbicides used were aimed are indicated, and a breakdown of the total costs due to paraquat and to 'other' herbicides is given.

The weed species are given according to the following code:

A *Paspalum conjugatum* (thurston grass)
B *Cyperus brevifolius* and *C. kyllingia*
C *Cynodon dactylon* (couch grass)
D *Paspalum orbiculare*
E *Paspalum paniculatum*
F *Pennisetum purpureum* (elephant grass)
G *Pennisetum clandestinum* (kikuyu grass)
H *Brachiairia mutica* (para grass)
I *Polygonum dichotomum*
J *Rumex crispus* (dock)
K *Ipomoea batatas* (sweet potato)
L *Lindernia* spp.
M *Commelina diffusa* (wandering jew)
N *Crassocephalum crepidioides* (thickhead)
O *Dichrocephala bicolor*

For most of the first year the old Gramoxone formulation which contained no added surfactant was used. Agral 60 was added to the spray mix at the manufacturer's recommended concentration of 1.5 pints per 100 gallons of spray. With the new formulation which contains 10 per cent surfactant, 0.5 pints of Agral 60 was added to each 45 gallons of spray. The concentration of Agral 60 used with the other foliar-acting herbicides varied from 0.06 to 0.1 per cent.

***Table* 2.—Trial AWC2a. Comparison of quantity of weeds growing in the six different spacing-pruning arrangements of each site, prior to the commencement of the control programme**

Shade	Site	Weed Weight (lb dry matter per acre) (1)					
		MS 9 x 9	SS 9 x 9	MS 8 x 8	SS 8 x 8	MS 7 x 7	SS 7 x 7 (2)
Casuarina (3)	Hillside	311	402	50	119	42	102
	Pit-pit	100	202	122	116	62	115
	Mean	206	302	86	118	52	109
Albizia	Hillside	1,737	1,368	1,311	389	256 (4)	833
	Pit-pit	588	827	1,198	504	257	498
	Mean	1,163	1,098	1,255	447	257	664
Unshaded	Hillside	4,059	3,052	3,512	2,499	2,418	1,187
	Pit-pit	1,282 (5)	2,505 (4)	1,923	1,639 (4)	2,060	396 (4)
	Mean	3,133	2,817	2,718	2,069	2,264	849

(1) The figures for each site are derived from 16 samples (4 samples from each of 4 shade plots), each sample being from an area of 2 ft^2.

(2) Pruning system and spacing (in ft) of coffee. The coffee is planted on a triangular spacing. MS = Multiple stem. SS = Single stem.

(3) The weed weights under Casuarina shade include coffee seedlings, which often formed a high proportion of the total weight of samples—100 per cent in a number of instances.

(4) Derived from 12 samples only.

(5) Derived from 8 samples only.

Table 3.—Trial AWC2a. Comparison of quantity of weeds growing, and percentage ground covered by weeds, under different shade conditions, prior to the commencement of the control programme

Shade	Site	Weed Weight(1) (lb dry matter per acre)					% Cover(1)				
		1	2	3	4	Mean	1	2	3	4	Mean
Casuarina	Hillside	130	88	388	79	171(2)	9	6	17	9	10
	Pit-pit	92	119	83	182	119(3)	6	13	7	13	10
	Mean	....	....	....	....	145	....	....	....	....	10
Albizia	Hillside	1,323	489	1,441	759(4)	1,003	50	43	49	55	49
	Pit-pit	975	929	300	375	645	52	48	31	28	40
	Mean	....	....	....	....	824	....	....	....	....	45
Unshaded	Hillside	2,407	2,077	3,952	2,959	2,849	91	76	89	91	87
	Pit-pit	1,483(4)	2,131	....	1,322	1,645	77	75	....	73	75
	Mean	....	....	....	....	2,333	....	....	....	....	82

1 Plot to receive paraquat treatment.

2 Plot to receive diuron treatment.

3 Plot to receive hand-weeding treatment.

4 Plot to receive hand-weeding plus diuron treatment.

(1) Derived from 24 samples of 2 ft² in each shade plot.

(2) 38 per cent of this weight was due to coffee seedlings, the percentage ground cover includes coffee seedlings.

(3) 63 per cent of this weight was due to coffee seedlings, the percentage ground cover includes coffee seedlings.

(4) Derived from 20 samples only.

Table 4.—Representative analyses of soils in AWC2a

Site	Soil Type	Percentage Clay (0 to 6 in)	Organic Matter (0 to 6 in)	pH (0 to 6 in)
Hillside	Clay	34.8	14.3	5.1
Pit-pit	Clay	65.9	13.1	5.0

(*a*) *Unshaded*.—On the hillside plot prior to the first application, *Paspalum conjugatum* (thurston grass) constituted 50 per cent (by weight) of the weeds present, the broadleaf *Drymaria cordata* 12 per cent and *Commelina diffusa* (wandering jew) 10 per cent. On the pit-pit plot, thurston grass accounted for 85 per cent (by weight) of the weeds, *Cynodon dactylon* (couch grass) 5 per cent and *Cyperus brevifolius* 1½ per cent. The heavy weed infestation, dominated by thurston grass, can be seen in *Plate* I.

After seven applications of paraquat on both plots, it became apparent that paraquat on its own, although achieving a reduction in the amount of thurston grass, particularly on the hillside plot, was not going to eradicate it. Because of the rapid recovery of the grass after treatment, the intervals between these seven sprayings ranged from three to five weeks. Amitrole was then applied as a split application in conjunction with paraquat, and after a second such double application the grass was largely eradicated. *Plate* II shows a section of the unshaded pit-pit plot one month after the first amitrole-paraquat split application.

During the second year, the sedge *Cyperus brevifolius,* and to a lesser extent a similar sedge, *C. kyllingia,* and couch grass became serious weeds on the pit-pit site. *C. brevifolius* had initially been present as an insignificant plant a couple of inches high, usually hidden by taller vegetation. With the elimination of other weeds (mainly thurston grass), it became larger (up to 8 in or more high), and spread to form a dense continuous mat of growth, which completely covered about one third of the plot (see *Plate* III). On the hillside plot, it persisted as a low plant growing in small discrete patches, and was held in reasonable check by paraquat. The sedge has been observed occasionally elsewhere in the highlands, but only growing as small individual

Table 5.—Costs per acre of herbicide treatments in AWC2a

Treatment	Shade	Site	Total Cost (Herbicide, Wetting Agent, Labour)		
			1st Year	2nd Year	Total
Basically paraquat	Casuarina	Hillside	12.23	6.08	18.31
		Pit-pit	9.74	3.25	12.99
	Albizia	Hillside	26.84	10.67	37.51
		Pit-pit	33.22	21.55	54.77
	Unshaded	Hillside	36.72	18.43	55.15
		Pit-pit	39.13	33.11	72.24
Basically diuron	Casuarina	Hillside	20.50	10.96	31.46
		Pit-pit	10.49	7.59	18.08
	Albizia	Hillside	47.58	22.80	70.38
		Pit-pit	50.01	15.98	65.99
	Unshaded	Hillside	61.04	25.98	87.02
		Pit-pit	63.92	23.48	87.40
Hand-weeded plus diuron	Casuarina	Hillside	14.55	13.28	27.83
		Pit-pit	19.47	10.37	29.84
	Albizia	Hillside	35.86	22.80	58.66
		Pit-pit	37.53	20.24	57.77
	Unshaded	Hillside	70.21	35.71	105.92
		Pit-pit	60.00	32.25	92.25
Hand-weeded	Casuarina	Hillside	20.21	11.42	31.63
		Pit-pit	18.61	9.00	27.61
	Albizia	Hillside	49.83	29.16	78.99
		Pit-pit	42.85	28.24	71.09
	Unshaded	Hillside	74.15	42.63	116.78
		Pit-pit	81.50	45.19	126.69

Prices used in compiling costs:
Agral 60 $6.20 per gallon
Ansar 529 $8.00 per gallon
Gramevin $0.55 per lb
Gramoxone $21.50 per gallon
Karmex 3.25 per lb
Methoxone-30 $3.40 per gallon
Teepol $1.18 per gallon
Weedazol TL Plus $7.50 per gallon
Weedkiller D
(and Amoxone-50) $5.19 per gallon
Labour 9c per man-hour

plants, and it seems unlikely that it would become a problem on reasonably well-drained soils.

Much of the difference in costs between the two plots can be attributed to this sedge, although couch grass on the pit-pit plot was also a factor, as can be seen by the quantities of dalapon applied (*Table* 6). Control of the sedge was attempted with amitrole and with MSMA, but at the concentrations used (3 and 5 pints of 60 per cent w/v MSMA formulation per 45 gallons and 4 pints of Weedazol TL Plus per 45 gallons) they were only successful against smaller plants, the bulk of the growth being only temporarily checked. Higher concentrations have subsequently been more successful.

(*b*) *Albizia Shade*.—At the beginning of the trial, thurston grass constituted 50 per cent (by weight) of the weeds present on the hillside plot, while on the pit-pit plot it formed 67 per cent and couch grass 18 per cent of the weeds present.

The first paraquat treatments removed much more of the thurston grass than had been the case on the unshaded plots, but dense residual clumps remained, and on a poorly shaded section of the pit-pit plot almost no reduction was achieved. The amitrole-paraquat split applications resulted in the virtual eradication of the grass.

In the second year the pit-pit plot required considerable attention for *C. brevifolius* and couch grass, which infested, in particular, a

Table 6.—Summary of tne paraquat-based treatment of AWC2a
Quantities of herbicides in lb or pints of commercial product per acre

Herbicide		Unshaded				Albizia				Casuarina			
		Hillside		Pit-pit		Hillside		Pit-pit		Hillside		Pit-pit	
		Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Paraquat	No. of applications	9	7	9	4	8	7	9	4	6	7	6	4
	Total quantity	9.1	3.5	9.5	2.8	6.6	1.5	8.2	1.8	2.7	1.0	2.3	0.5
	Spray concentration (pints per 45 gal)	0.7-1.6	1.0	0.7-1.8	1.0	0.7-1.7	0.5-1.0	0.7-1.8	1.0	0.7-1.8	0.5-1.0	0.7-1.8	1.0
Amitrole	No. of applications	2	2	2	3	2	2	2	3	2	2	2	2
	Total quantity	2.8	3.4	4.2	7.0	2.1	2.7	3.0	4.6	1.4	0.9	0.7	0.3
	Spray concentration (pints per 45 gal)	2.0-3.4	2.0-8.0	2.0-4.0	2.0-4.0	2.0-3.4	2.0-8.0	2.0-4.0	2.0-4.0	2.0-3.4	2.0-8.0	2.0-4.0	2.0-4.0
	Main weeds treated	A	A, B	A, B	A, B	A	B	A	A, B	A	B	A	B
Dalapon	No. of applications	1	1	1	3	1	1	1	3	1	1	1	3
	Total quantity	1.8	1.9	1.9	7.2	0.85	1.3	1.5	5.0	0.5	1.3	0.2	0.9
	Spray concentration (lb per 45 gal)	6.0	6.0	5.0	5.0-7.5	6.0	6.0	5.0	5.0-7.5	6.0	6.0	5.0	5.0-7.5
	Main weeds treated	C, D	D, E	C, D	C, D	D, F	D, F	C, D	C, D	D	D	C, D	C, D
Dalapon plus amitrole	No. of applications			....	2			....	2				
	Total quantity			....	3.1d+1.2a			....	2.2d+0.9a				
	Spray concentration (lb + pints per 45 gal)			....	5.0d+2.0a			....	5.0d+2.0a				
	Main weeds treated			....	C			....	C				
2,4-D	No. of applications	....	1	1	1			1	1				
	Total quantity	....	0.1	0.5	0.6			0.4	0.1				
	Spray concentration (pints per 45 gal)	....	2.0	2.0	2.0			2.0	2.0				
	Main weeds treated	....	K	I, J, K	I, J, K, L			I, J	I, J, L				
MSMA	No. of applications	....	1	....	3	....	1	....	3	....	1	....	2
	Total quantity	....	0.9	....	6.2	....	0.4	....	3.4	....	0.3	....	0.3
	Spray concentration (pints per 45 gal)	....	3.0	....	3.0-5.0	....	3.0	....	3.0-5.0	....	3.0	....	3.0-5.0
	Main weeds treated	....	B, D, E	....	B, D	....	B	....	B, D	....	B	....	B
Cost of paraquat applications (including labour)	$	31.92	12.17	32.50	9.84	23.41	6.26	28.32	6.53	10.14	3.88	8.72	1.88
Cost of all non-paraquat applications (including labour)	$	4.80	6.26	6.63	23.27	3.43	4.41	4.90	15.02	2.09	2.20	1.02	1.37
TOTAL COST	$	36.72	18.43	39.13	33.11	26.84	10.67	33.22	21.55	12.23	6.08	9.74	3.25

Plate I.—A section of the unshaded paraquat plot on the pit-pit site of trial AWC2a at the time of the second application of paraquat. The dominant weed species is thurston grass (*Paspalum conjugatum*)

poorly shaded area, after the original cover of thurston had been removed. However, the sedge remained as small clumps and did not spread to form a continuous cover as it had on the adjacent unshaded plot. The presence of couch grass and sedge was the main reason for the considerable difference in cost between the hillside and pit-pit plots. On the hillside plot, the weeds had been reduced by the end of the first year to a patchy cover of predominantly annuals. This allowed the use of low concentrations of paraquat during much of the second year and a small number of applications with other herbicides.

(*c*) *Casuarina Shade*.—The weed growth under the dense shade in these plots was very slight. A large proportion of the costs incurred was due to treatments around the perimeter of the plot. Thus, on large scale plantings under such shade, the weeding costs would be considerably less than is indicated for these $\frac{5}{8}$ acre plots. Weeds were more prevalent in the multiple stem coffee at the widest spacing (9 x 9 ft). Inside the plot, the main weeds, excluding coffee seedlings, were *Crassocephalum crepidioides* (thickhead), *Drymaria cordata* and *Ageratum conyzoides*. On each site in the first year, $1\frac{1}{2}$ pints of the total Gramoxone

Plate II.—View of part of the unshaded paraquat plot on the pit-pit site of Trial AWC2a 38 weeks after the trial commenced. Photo taken one month after the first amitrole-paraquat split application. The clumps of thurston grass (*Paspalum conjugatum*) are still white from the amitrole treatment. The taller, tufted grass which is not showing obvious amitrole symptoms is *Paspalum orbiculare*

used was applied in the first spraying. This blanket application was probably unnecessary but it did remove the very numerous small coffee seedlings.

2. *Basically Diuron*

Table 7 summarizes the applications made under each shade and indicates the main weeds spot-treated with herbicides other than diuron. The total costs of the spot-sprayings and of

Plae III.—Severe infestation of the sedge *Cyperus brevifolius* in a section of the unshaded paraquat plot on the pit-pit site in trial AWC2a. The sedge invaded this area after the thurston grass shown in *Plate* I had been eradicated

the diuron applications are also given. The wetting agent used in the spot treatments was either Agral 60, usually at a concentration of less than 0.1 per cent, or 'Teepol' at a concentration of 0.1 to 0.2 per cent of the spray volume.

(*a*) *Unshaded.*—At the commencement of the trial, the main weeds on the hillside plot were thurston grass which made up 31 per cent (by weight) of the weed vegetation, and *Drymaria cordata* which formed 25 per cent. On the pit-pit plot, thurston grass formed 31 per cent, *Cyperus* spp. 25 per cent, couch grass 21 per cent and wandering jew 12 per cent.

All diuron applications were made as blanket treatments, that is, applied to the total ground area. The initial treatment on the two sites differed in that the first application of diuron was applied to standing vegetation (8 to 10 inches high) on the hillside plot, while on the pit-pit plot the knee-high growth was slashed to within a couple of inches of the ground one week before the first application. On each site the first application was at 5 lb Karmex (i.e., 4 lb diuron) per acre with 1 per cent non-ionic surfactant, the second at $2\frac{1}{2}$ lb Karmex with $\frac{1}{2}$ per cent non-ionic surfactant, and the third at $2\frac{1}{2}$ lb Karmex without surfactant. These applications were made at 0, 28, and 49 weeks on the hillside plot and at 1, 22 and 44 weeks on the pit-pit plot. The ground cover on both plots at the time of the second diuron application was about 30 per cent, while at the third application the ground was predominantly bare.

By the end of the first year, thurston grass had been virtually eradicated and the most prominant weed was *Cyperus brevifolius,* although it did not constitute a serious problem. The sedge is affected by diuron, but larger plants usually recover (at least from lower rates), and there is also reinfestation from the seed of roadside plants.

The elimination of the thurston grass was due almost entirely to the diuron treatments. Amitrole was not used until near the end of the first year (mainly for *C. brevifolius*), and by this time the thurston grass was almost non-existent. The dalapon treatments, if applied to the grass, had only a very slight effect.

In the second year, both plots received two applications of diuron without surfactant, at 2 lb (of Karmex) per acre, plus additional spot-sprayings, as indicated in *Table* 7. The diuron applications were made to predominantly bare ground, in weeks 66 and 85 on the hillside plot, and in weeks 70 and 90 on the pit-pit plot. Throughout the second year, both plots remained substantially weed-free. The main species present at the end of the second year were *Cyperus brevifolius, Paspalum orbiculare* and thickhead on the hillside plot, and *C. brevifolius* and *C. kyllingia* on the pit-pit plot.

(*b*) *Albizia Shade.*—Of the weeds present on the hillside plot at the beginning of the trial, *Drymaria cordata* formed 29 per cent (by weight) and thurston grass 10 per cent. On the pit-pit plot, thurston grass constituted 33 per cent (by weight) of the weeds, *D. cordata* 15 per cent and *Cyperus* spp. 9 per cent.

The applications made to these plots were substantially the same as for the unshaded plots. One difference, however, was that the

Table 7.—Summary of the diuron-based treatment of AWC2a
Quantities of herbicide in lb or pints of commercial product per acre

Herbicide		Unshaded				Albizia				Casuarina			
		Hillside		Pit-pit		Hillside		Pit-pit		Hillside		Pit-pit	
		Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Diuron	No. of applications	3	2	3	2	3	2	3	2	2	2	1	2
	Total quantity	10.0	4.0	10.0	4.0	9.0	4.0	9.0	4.0	4.7	1.8	1.3	1.8
Dalapon	No. of applications	4	3	4	5	4	3	4	3	3	3	4	5
	Total quantity	14.8	3.5	16.7	8.7	7.6	3.7	7.9	1.2	1.3	1.4	2.8	1.7
	Spray concentration (lb per 45 gal)	5.6-7.5	5.0	7.0-7.5	5.0-15.0	5.6-7.5	5.0	7.0-7.5	5.0-15.0	5.6-7.5	5.0	7.0-7.5	5.0-15.0
	Main weeds treated	C, D, G	C, D, G	C, D	C, D	C, D, G	C, D, G	C, D	C, D	D, G	D	C, D	C, D
2,4-D	No. of applications	4	1	2	1	4	1	2	1	3	1[1]	2	1
	Total quantity	5.5	0.9	3.1	0.6	4.5	0.7	2.1	0.1	1.9	1.1	2.4	0.1
	Spray concentration (pints per 45 gal)	3.4-4.5	4.0	4.0-4.5	3.0	3.4-4.5	4.0	4.0-4.5	3.0	3.4-4.0	2.0-4.0	4.0-4.5	3.0
	Main weeds treated	M, N	M	J, K, M, O	M, N	M, N	M	M, O	M, N	M, N	M, N, O	J, M, O	M, N
MCPA	No. of applications			....	1			....	1				
	Total quantity			....	0.6			....	0.5				
	Spray concentration (pints per 45 gal)			....	4.0			....	4.0				
	Main weeds treated			....	M, O			....	M, N				
Amitrole	No. of applications	1	2	2	....	1	2	2	....	1	2	2	....
	Total quantity	1.8	3.8	3.6	....	0.4	2.1	1.9	....	0.4	1.3	1.3	....
	Spray concentration (pints per 45 gal)	4.0	4.3-8.0	4.0	....	4.0	4.3-8.0	4.0	....	4.0	4.3-8.0	4.0	....
	Main weeds treated	B	B	B	....	B	B	B	....	B	B	B	....
Paraquat	No. of applications	1	1			1	1			....	1		
	Total quantity	1.5	0.3			0.5	0.2			....	0.2		
	Spray concentration (pints per 45 gal)	1.8	1.0			1.8	1.0			....	1.0		
	Main weeds treated	M	B			M	B, D			....	N		
MSMA	No. of applications	....	2	....	3	....	2	....	2	....	1[1]	....	2
	Total quantity	....	3.0	....	2.7	....	2.3	....	0.9	....	0.6	....	0.3
	Spray concentration (pints per 45 gal)	....	3.0-4.0	....	3.0-4.0	....	3.0-4.0	....	3.0-4.0	....	2.0	....	3.0-4.0
	Main weeds treated	....	B	....	B, D	....	B	....	B	....	N, O	....	B
Cost of diuron applications (including labour)	$	39.98	13.73	39.50	13.51	36.38	13.79	36.19	13.50	17.52	6.22	5.27	6.02
Cost of spot-sprayings (including labour)	$	21.06	12.25	17.22	9.97	11.20	9.01	8.96	2.48	2.98	4.74	5.22	1.57
TOTAL COST	$	61.04	25.98	63.92[2]	23.48	47.58	22.80	50.01[3]	15.98	20.50	10.96	10.49	7.59

1. This application was a combined treatment of MSMA and 2,4-D.
2. Includes $4.86 for an initial slashing.
3. Includes $7.20 for an initial slashing.

second and third diuron applications were at 2 lb (of Karmex) per acre and not 2½ lb. At the second diuron application the weed cover was 10 to 15 per cent, and at the third application it was less than 5 per cent. At the end of the second year the weed cover on both plots was less than 1 per cent. Thickhead was the main weed on the hillside plot and *C. brevifolius* the main weed on the pit-pit plot.

(*c*) *Casuarina Shade.*—As *Table* 3 shows, the weed cover within the coffee at the commencement of the trial was low on both sites, although it was somewhat higher around the plot perimeters. The main weeds on the hillside plot were wandering jew and thurston grass, while thickhead, *D. cordata* and *Isachne myosotis* (a small prostrate-growing grass) were the most common weeds on the pit-pit plot.

The weed growth was really too slight to justify the use of an expensive herbicide such as diuron, and apart from an initial blanket application on the hillside plot, all applications of diuron on both plots were made as spot-sprayings within the coffee with a blanket spray around the perimeters. Of the total of 4.7 lb Karmex applied to the hillside plot in the first year (see *Table* 7), 4.0 lb was in the first blanket application. Although there were a considerable number of spot-sprayings with other herbicides, which were generally applied at the same time as the other shades were being treated, the amount of weeds present was always small. The average volume of spray required per application (on a per acre basis) in the second year was 8.4 gallons on the hillside plot and 4.6 gallons on the pit-pit plot.

3. *Hand-weeded*

(*a*) *Unshaded.*—At the beginning of the trial, which was about 16 weeks after the area had previously been hand-weeded, the main weeds on the hillside plot were thurston grass which formed 37 per cent (by weight) of the weeds present and *Pennisetum clandestinum* (kikuyu) which formed 18 per cent. On the pit-pit plot the main weed was thurston grass, but no figures were obtained because part of the plot was inadvertently weeded about two weeks before the trial was due to commence. The commencement date for the hand-weeded treatment was taken from the date of this partial weeding and its cost was included in the total cost for this treatment.

In the first year the hillside plot was weeded, with hoes, seven times and the pit-pit plot seven and a half times (the "half" being the accidental partial weeding referred to above). In the second year both plots were weeded six times—four times with hoes and the last two weedings with spades. As much as possible, weeding was done during periods of dry weather in an attempt to obtain a reasonable kill of the perennial grasses. Weeding perennial species at other times is little more than a transplanting operation.

At the end of the second year the main weeds on the hillside plot were thurston grass and kikuyu, and the weed cover 6 weeks after the last weeding was 29 per cent. On the pit-pit plot the main weeds present were thurston grass, couch grass, *Dichrocephala bicolor* (a broadleaf), *C. brevifolius* and wandering jew, and the weed cover nine weeks after the last weeding was 52 per cent.

(*b*) *Albizia Shade.*—At the start of the trial the main weeds were thurston grass, kikuyu grass and wandering jew on the hillside plot, and *Stellaria media* (chickweed), *Cyperus* spp., thurston grass and *Isachne myosotis* on the pit-pit plot.

Both plots were weeded seven times with hoes in the first year, and four times with hoes and twice with spades in the second year. At the end of the second year the main weeds on the hillside plot were thurston grass, *I. myosotis* and *D. cordata,* and the weed cover 6 weeks after the last weeding was 10 per cent. On the pit-pit plot the main weeds at that time were thurston grass, *I. myosotis* and wandering jew and the weed cover 9 weeks after the last weeding was 14 per cent.

(*c*) *Casuarina Shade.*—The most common weeds present at the start of the trial were *Paspalum orbiculare,* thickhead and *Digitaria pruriens* on the hillside plot and wandering jew, *Dolichos* sp. and thurston grass on the pit-pit plot. On both sites the weed cover around the perimeter of the plots was considerably more than it was within the plots, where coffee seedlings were more abundant than weeds.

In the first year the hillside plot was weeded (with hoes) five times and the pit-pit plot seven times. In the second year both plots received four weedings with hoes and two with spades.

Decrease in labour requirements.—The decrease in labour requirements for the hand-weeded treatments under all shade situations in the second year (see *Table* 5) was not due to a reduction in the weeds present.

Although the figures for weed cover at the end of the second year are less than those obtained at the commencement of the trial, this can be accounted for by the difference in the time intervals between the assessment and the previous weeding (16 weeks in the case of the first assessment and 6 or 9 weeks in the case of the final assessment). Some of the decrease in labour in the second year can be attributed to the changeover from hoes to spades for the last two weedings, and some to the fact that there was one less weeding in the second year. In the unshaded coffee on both sites, allowance for these two factors still leaves about 20 per cent of the decrease in labour requirements for the second year unaccounted for. Corresponding allowances for the Albizia shade leave 18 per cent and 9 per cent of the decrease not accounted for on the hillside site and pit-pit site respectively. The most likely explanation is that the closer supervision which was given to the labour in the second year resulted in an increase in work output.

This, of course, immediately brings into question the value of the costs given for the hand-weeding treatment (and for the diuron plus hand-weeding treatment). A series of measurements made on a plantation (using plantation labour) on an area of coffee under light Albizia shade, heavily infested with annual weeds (almost no perennial grasses) and on a lighter soil type than Aiyura, gave a labour requirement, using spades, of between 32 and 47 man-hours per acre for one weeding. Considering how much worse the weed situation is at Aiyura, the labour requirements under Albizia shade could be expected to be above the upper limit of that range, while the requirement in unshaded coffee at Aiyura might be one third higher again. In fact, the labour usage in the last two weedings with spades was lower than this, averaging 32 man hours under Albizia shade and 51 man-hours in the unshaded plots.

In view of the discrepancy in labour requirements between the two years, perhaps a more realistic comparison with the costs of the other weed-control treatments may be obtained by using the plantation figures as guide in forming an estimate of hand-weeding costs in the present trial. If it is assumed that an average of 47 man-hours per acre is required for each weeding under Albizia shade, and 63 man-hours per acre in unshaded coffee, then with seven weedings in the first year and six in the second, the costs over the 2 years (at 9c per man-hour) would be as given in *Table* 8.

A comparison of these estimated costs with the costs of the other treatments as given in *Table* 5 shows that the hand-weeding treatment in Albizia and unshaded plots would then be about equal in cost to the paraquat treatment in the first year (and less than the diuron and the unadjusted diuron plus hand-weeding costs), while in the second year it would be more expensive than either the paraquat or diuron treatments.

An alternative method of obtaining an estimate of the labour requirements would be to assume that the labour requirements in the first year were the same as that recorded in the second year. This estimate would give a hand-weeding cost in the first year that was less than the cost of the paraquat treatment under Albizia shade and above the cost of the paraquat treatment in the unshaded plots.

4. *Hand-weeded plus Diuron*

In this treatment diuron is used during the peak harvest period, when labour is likely to be scarce, and hand-weeding is used during the remainder of the year.

Table 9 gives a summary of the operations in this treatment and a breakdown of the costs into those due to hand-weeding and those due to herbicide applications (including labour).

(*a*) *Unshaded*.—The trial commenced about 16 weeks after the area was last hand-weeded. Thurston grass constituted 40 per cent (by weight) of the weeds present on the hillside plot, and 82 per cent of those on the pit-pit plot. As in the 'hand-weeded only' treatment, *Table* 8.—Adjusted costs per acre of the hand-weeded treatment of AWC2a

Shade	First Year			Second Year		
	Adjusted Cost ($)	% of Actual Cost		Adjusted Cost ($)	% of Actual Cost	
		Hillside	Pit-pit		Hillside	Pit-pit
Albizia	29.61	59.4	69.1	25.38	87.0	89.9
Unshaded	39.69	53.5	48.7	34.02	79.8	75.3

an endeavour was made to weed when weather conditions were conducive to achieving a reasonable kill of perennial grasses.

On the hillside plot there was a considerable amount of weed growth present at the time of the spray treatment in the first year, so amitrole was added to the diuron to improve the "knockdown" effect. The application rate was 4 lb Karmex plus 3 pints Weedazol TL Plus per acre in 38 gallons. On the pit-pit plot the ground was predominantly clean, so only Karmex was applied at 4 lb per acre. In the second year both plots received Karmex alone at 4 lb per acre.

At the end of the second year the main weeds present on the hillside site were wandering jew and *Paspalum orbiculare* and the weed cover (11 weeks after the last hand-weeding) was 27 per cent. On the pit-pit plot the main weeds present were thurston grass, *Cyperus brevifolius* and wandering jew, the weed cover (13 weeks after the last hand-weeding) being 23 per cent. On both plots there had been a considerable reduction in the total amount and the proportion of thurston grass—from 40 per cent to 1 per cent of the total weeds on the hillside plot, and from 82 per cent to 60 per cent on the pit-pit plot. The proportion of wandering jew had increased on both plots and on the hillside plot *Paspalum orbiculare* had increased from an initial 8 per cent to 25 per cent of the total weeds.

(*b*) *Albizia Shade*.—At the beginning of the trial, the main weeds on the hillside plot in order of abundance were *Drymaria cordata, Bidens pilosa* (cobbler's peg) and thurston grass, while thurston grass, chickweed and *D. cordata* were the most common weeds on the pit-pit plot.

On both plots the herbicide application was at 4 lb Karmex per acre in the first year and 3 lb Karmex per acre in the second year.

During the two-year period there was a large increase in the proportion of *D. cordata* on both plots, a decrease in thurston grass on the hillside plot but not on the pit-pit plot, and an increase in the proportion of *Isachne myosotis* on the hillside plot. The total weed

Table 9.—Summary of treatments and costs for the 'hand-weeded plus diuron' treatment of AWC2a

Shade	Site	First Year				Second Year			
		No. of hand-weedings	No. of herbicide applications	Cost of H.W. ($)	Cost of herbicide applications ($)	No. of hand-weedings	No. of herbicide applications	Cost of H.W. ($)	Cost of herbicide applications ($)
Casuarina	Hillside	5	0	14.55		5	1	9.30	3.98
	Pit-pit	6	1	18.55	0.92	5	1	7.36	3.01
Albizia	Hillside	6	1	22.63	13.23	5	1	12.59	10.21
	Pit-pit	6	1	24.22	13.31	5	1	10.17	10.07
Unshaded	Hillside	6	1	54.08	16.13	5	1	22.33	13.38
	Pit-pit	6	1	46.52	13.48	5	1	18.94	13.31

cover had decreased from the initial 46 per cent and 21 per cent on the hillside and pit-pit plots respectively to 6 per cent on the hill-side plot (determined 11 weeks after the last weeding) and 3 per cent on the pit-pit plot (determined 9 weeks after the last weeding).

(*c*) *Casuarina Shade*.—As on the other Casuarina plots, weed cover was slight within the plot and somewhat greater around the margins. Thickhead, *Drymaria cordata* and *Isachne myosotis* were the most common weeds on the hillside plot and *I. myosotis, Dolichos* sp. and thurston grass the most prevalent on the pit-pit plot.

In the first year no herbicide application was made on the hillside plot because throughout the peak harvest period no weed control measures were necessary. The pit-pit plot was only spot-sprayed with Karmex at a concentration of 2½ lb per 45 gallons. The weed growth had been too slight to warrant a blanket application. In the second year the herbicide treatment on both plots was a spot-spraying with Karmex at a concentration of 4 lb per 45 gallons.

Decrease in hand-weeding costs.—There has been a marked decrease in the hand-weeding costs of this treatment in the second year—greater than 50 per cent in most cases. However, as there has been a decrease in the total weed cover, part at least of the decreased hand-weeding costs may be attributable to the diuron applications. It is thus not possible to assume, as could be assumed in the 'hand-weeded only' treatment, that all the difference in labour costs in the 2 years is due to less efficient labour in the first year. Nevertheless, the labour costs in the first year, as shown in *Table* 9, do seem excessively high.

In the 'hand-weeded only' treatment the labour used in the second year was lower than that used in the first year by amounts varying from 34 per cent on the pit-pit plot under Albizia shade to 52 per cent on the pit-pit plot under Casuarina shade. If it is assumed that these differences were due to greater labour efficiency in the second year and that the same differences apply to the hand-weeding of the 'hand-weeded plus diuron' treatment, then the labour costs of hand-weeding given for the first year of this treatment should be reduced in each plot by the appropriate proportion, as indicated by the labour usage in each plot of the 'hand-weeded only' treatment. When this is done, the adjusted costs are given in *Table* 10.

The adjusted costs of this treatment for the first year are comparable with the adjusted costs of the 'hand-weeded only' treatment over the same period, are lower than those for the diuron-based treatment, and are lower than the costs of the paraquat-based treatment under Albizia shade, while remaining higher under no shade. In the second year the costs (actual) of the 'hand-weeded plus diuron' treatment were less than the actual cost of the 'hand-weeded only' treatment and about the same as or slightly better (depending on shade) than the adjusted costs for that treatment. Over this period, however, it was more expensive than both the paraquat and diuron-based treatments, whose costs had decreased considerably in the second year.

Discussion

As *Table* 5 shows, the paraquat-based treatment overall was the least costly in both years of the trial. However, the hand-weeded treatment was very expensive, even when the adjusted labour figures were used, and it is probable that in situations where perennial grasses are uncommon and hand-weeding is therefore less expensive, paraquat in the first year of its use would be more costly than hand-weeding. Any difference is likely to be small, and after the first year, the paraquat-based treatment could be expected to be cheaper by a considerable margin.

As already mentioned in the section which gave details of the paraquat-based treatment, there was a large difference between the costs of the treatment on the two sites in the second year. This difference illustrates how greatly the weed species present can influence control costs as well as showing the effect the site can have on weed vigour. On the pit-pit site in both Albizia and unshaded plots, the problem weeds resulted in the costs of the paraquat-based treatment remaining relatively high in the second year, while the diuron-based treatment dropped so much that on these plots it was less costly than the paraquat-based treatment.

It can be seen by comparing *Tables* 6 and 7 that the use of diuron need not necessarily result in a reduction in the total number of

Table **10.—Adjusted costs ($ per acre) for the first year of the 'hand-weeded plus diuron' treatment of AWC2a**

Shade	Site	Actual Total Cost	Adjusted Cost of Hand-weeding	Cost of Herbicide Applications	Adjusted Total Cost
Casuarina	Hillside	14.55	8.29	0.0	8.29
	Pit-pit	19.47	8.90	0.88	9.78
Albizia	Hillside	35.86	13.35	13.23	26.58
	Pit-pit	37.53	15.99	13.31	29.30
Unshaded	Hillside	70.21	30.83	16.13	46.96
	Pit-pit	60.00	25.59	13.48	39.07

treatments over that required in a paraquat-based programme. In the first year of the trial, in both Albizia and unshaded plots, the paraquat-based treatment received 12 or 13 separate applications and the diuron-based treatment received 11 or 13 separate applications. In the second year, it was only on the pit-pit site that the diuron-based treatment required appreciably fewer applications than the paraquat-based treatment.

In a situation where weeds that are resistant to diuron are absent or rare, it is possible that the cost of a diuron-based treatment over the first couple of years would more closely approach the cost of a paraquat-based treatment than was the case in this trial. As can be seen from *Table* 7, if the applications of diuron had been all that was required, the cost of this treatment would have been comparable to the total cost of the paraquat-based treatment. Of course, under equally favourable conditions (i.e., no resistant weeds) the cost of the paraquat treatment would also be lower although the difference in cost between the two treatments would then be less than was the case in AWC2a. In such favourable situations, the diuron-based treatment, although almost certainly more expensive in the first year (and possibly also in later years) than a paraquat-based treatment, may be preferred because of the fewer numbers of applications required. Against this, however, is the fact that the correct use of diuron requires closer supervision than does paraquat.

It is suggested above that paraquat, even in the longer term, is likely to remain the cheaper of the two treatments at present prices. This will be so unless it becomes possible to use less than 4 lb of Karmex per acre per year and almost no additional herbicides. In the longer term it should be possible to reduce the annual cost of a paraquat-based treatment to less than $10 per acre even in unshaded conditions. (Note that the cost in the second year of the paraquat-based treatment under Albizia shade is already approaching $10.) A cost of $10 is approximately equivalent to 3 lb of Karmex at present prices.

The 'hand-weeded plus diuron' treatment, while offering some cost advantage over the hand-weeded treatment, seems unlikely ever to attain the lower costs of the treatments which depend solely on herbicides, even assuming that rural wages remain constant.* It is likely that in subsequent years the cost of this treatment will not decrease much below the cost incurred in the second year. If paraquat had been used instead of diuron, the total costs in the first year would have been lower, even if, as is likely, two applications were required to maintain weed control for the duration of the peak harvest period. In the second year, however, the costs with paraquat probably would not have decreased because it seems unlikely that one or two paraquat applications per year

*This was written before the publication of the findings of the Rural Wages Board and the granting of the interim increase of 50 cents per week in the minimum rural wages, which took effect from 1st January, 1971.

In compiling the costs of labour used in the treatments, labour was costed at 9 cents per man-hour. The 50 cent increase in the minimum rural wage has raised the cost of labour to 10 cents per man-hour. This increases the cost of the 'hand-weeded only' treatment by 11 per cent, but has considerably less effect on the herbicide treatments. For example, the paraquat-based treatment on the hillside plot (see *Table* 6) would increase by 71 cents from $36.72 to $37.43.

would bring about any permanent decrease in the weed population. The costs would then be at a level approximating to that actually obtained in the second year of the 'hand-weeded plus diuron' treatment.

A method which uses both hand-weeding and herbicides is perhaps a possibility where the difficulty of obtaining casual labour during periods of high labour requirements makes it necessary to maintain a large permanent labour force throughout the year.

Effect of Shade on Weed Control Costs

Table 3 shows the effect of the three shade conditions in the trial AWC2a on weed growth and *Table* 5 records the considerable effect of shade on weeding costs in AWC2a. As well as the effect of the shade tree on weed growth, the ground shade produced by the coffee itself also influences weed growth. Thus in young coffee or unhealthy coffee which is partly defoliated, weed growth is invariably more vigorous. Spacing and pruning systems, by varying the ground shade, affect weed growth, as shown in *Table* 2.

In some situations in some years, the extra cost incurred in weeding unshaded coffee may not be covered by the higher yields that unshaded coffee normally produces. However, the long-term average yields at Aiyura show that yields from unshaded coffee are so much higher than from shaded coffee, that the higher weeding costs become unimportant. Over the 11 years 1959-1960 to 1969-1970, the average annual yield of clean coffee from unshaded coffee in trial ACA1 (the area used in the herbicide trial AWC2a) has been 600 lb higher than from coffee under Albizia shade and 500 lb higher than coffee under Casuarina shade. With yield differences of this magnitude there is a substantial net increase in return from unshaded coffee at Aiyura.

Where shade is being thinned or removed, some increase in the costs of weed control can probably be expected. However, if herbicides have been used for a number of years and the weed population has been reduced to a low level, the increase in cost should be relatively minor. Perennial grasses present at the time of shade thinning can be expected to require more attention. Thus it would be preferable to have as weed-free a condition as possible, and preferably no perennial grasses, at the time of thinning or eliminating shade. But as higher yields can be expected after reducing or removing the shade, delaying this operation until near perfect weed control is obtained may not be profitable.

TRIAL AWC2b

The second costing trial at Aiyura, although not as comprehensive as AWC2a, is of interest because it includes variations in the paraquat and diuron treatments of that trial which have been less expensive, particularly in the first year of use.

The trial (designated AWC2b) is on the pit-pit site immediately adjacent to the pit-pit plots of AWC2a. It compares four herbicide treatments on plots which are again $\frac{5}{8}$ acre in size. The treatments were selected as a result of their effectiveness against thurston grass in a small-plot trial on this grass. The evaluation on the larger scale was to allow comparisons of costs and performance to be made against a wider range of weeds over an extended period. The plots are unshaded and, as in each plot of AWC2a, have coffee growing under six different cultural methods, namely single and multiple stem each at spacings of 7, 8 and 9 ft triangle. The trial is unreplicated, that is, there is only one plot for each treatment. The dominant weed on all four plots at the beginning of the trial was thurston grass.

The four treatments are:—

(1) *Paraquat and amitrole,* the latter being retained for as long as is considered necessary. Amitrole applications precede paraquat by 4 weeks.

(2) *MSMA* applied as necessary, usually as a double treatment with the two applications about 4 or 5 weeks apart.

(3) *Diuron plus amitrole* applied together, the first application as a blanket spray (to existing weeds) and all subsequent applications as spot-sprays when required.

(4) *Diuron plus paraquat* applied together, the first application as a blanket spray (to existing weeds) and all subsequent applications as spot-sprays when required.

As in AWC2a, it was not feasible to use exclusively only the prescribed treatment, and all plots required supplementary treatment with dalapon (for couch and para grass (*Brachiaria mutica*)) and with 2,4-D (for such weeds as wandering jew and sweet potato).

Table 11 summarizes the herbicide applications and gives the cost of each treatment, adjusted to a per acre basis, for the first 2 years. Additional details of the four treatments are given below.

The dense weed growth on all plots was slashed to ground level about three weeks before the first applications. The trial was considered to begin with the first herbicide applications, so the cost of the slashings is not included in the costs given in *Table* 11.

1. *Paraquat and Amitrole*

At the first spraying about 50 per cent of the ground area was covered by weeds, the main species being thurston grass, wandering jew, *Polygonum nepalense, Leersia hexandra* (rice grass), *Drymaria cordata,* couch grass and para grass.

The first amitrole application was at 3.75 pints (of Weedazol TL Plus) per 45 gallons of spray (4 pints per acre in 48 gallons) with 0.1 per cent surfactant. Subsequent Weedazol applications were at spray strengths of 4.5, 2, 2, 4, 4, 8 and 8 pints per 45 gallons. The higher concentrations used in the second year were made necessary by *Cyperus brevifolius,* which had become prominent, and not by thurston grass, which by this time had been eliminated. All paraquat applications were with sprays containing 1 pint of Gramoxone plus ½ pint of non-ionic surfactant per 45 gallons. Although there was a total of 12 separate applications in the first year, and 14 in the second year, most were spot-sprayings which used relatively small quantities of herbicide, so the total cost was not high. In the first year the volume applied per application averaged 25.5 gallons per acre, and in the second year, 15.8 gallons.

In the second year, two of the dalapon applications to couch grass were made 3 or 4 weeks prior to a paraquat application and not as a double dalapon application. This fitted in more readily with the paraquat applications than the double sprayings of dalapon. However, although the dalapon-paraquat treatment gave a high percentage kill initially, regrowth of couch grass subsequently appeared.

During the second year, *C. brevifolius* became the main weed, although it was mainly confined to one large patch and was not as bad as the infestation previously described on the unshaded pit-pit plot of AWC2a. Two applications of Weedazol TL Plus at 4 pints per 45 gallons were generally ineffective, but two applications at 8 pints per 45 gallons (applied four weeks apart) eradicated the dense area of weed. Some seedling plants have since appeared, but these can be killed with lower rates of Weedazol.

At the end of the second year the plot was substantially clean.

2. *MSMA*

At the first spraying the weed cover was about 60 per cent, the main weeds being thurston grass, para grass, couch grass, sweet potato, *Rumex crispus* (dock) and *Dichrocephala bicolor.*

Sprayings with MSMA were mostly as double treatments applied about four weeks apart. This method of application has given better results, particularly on perennial weeds, than single applications applied at longer intervals. Spray concentrations of Ansar 529 varied between 5 and 2 pints per 45 gallons, with most treatments at 3 or 4 pints. The formulation contains an adequate amount of surfactant and no additional surfactant was used. MSMA gave no control of the couch grass, and para grass, which was more prevalent initially on this plot than on the others, was also not controlled by MSMA. These two grasses necessitated the large number of dalapon applications. The broadleaf weed *Dichrocephala bicolor* was not controlled by MSMA and it spread to become a major weed, before being controlled with 2,4-D. At the end of the second year, the main weeds present were *Dichrocephala bicolor, C. brevifolius* and *C. kyllingia* (both sedges present as individual plants, not dense mats) and couch grass. At this time the plot was unacceptably weedy over most of its area.

3. *Diuron plus Amitrole*

The weed cover at the first spraying was about 20 per cent, the main weeds being thurston, para and couch grasses, wandering

Table 11.—Summary of treatments and costs per acre in AWC2b
Quantities of herbicides in lb or pints of commercial product per acre

Herbicide		Paraquat and Amitrole		MSMA		Diuron + Amitrole		Diuron + Paraquat	
		Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Amitrole	No. of applications	4	4						
	Total quantity	8.2	9.5						
	Spray concentration (pints per 45 gal)	2.0-4.5	4.0-8.0						
	Main weeds treated	A, B	B						
Paraquat	No. of applications	4	6						
	Total quantity	2.8	2.2						
	Spray concentration (pints per 45 gal)	1.0	0.67-1.0						
	Main weeds treated								
MSMA	No. of applications			8	6				
	Total quantity			18.1	10.5				
	Spray concentration (pints per 45 gal)			1.0-5.0	3.0-4.0				
	Main weeds treated			A, B	A, B				
MSMA + 2,4-D (combined)	No. of applications			....	1				
	Total quantity			....	2.1+2.1				
	Spray concentration (pints per 45 gal)			....	3.0+3.0				
	Main weeds treated			....	A, B, O				
Diuron + amitrole	No. of applications					3	5		
	Total quantity					5.3d+7.1a	3.4d+4.3a		
	Spray concentration (lb+pints per 45 gal)					3.1d+4.2a	(3.1d+4.2a)—(2.0d+2.0a)		
	Main weeds treated					A, B	B		
Diuron + paraquat	No. of applications							4	6
	Total quantity							7.0d+2.3p	4.0d+1.3p
	Spray concentration (lb+pints per 45 gal)							3.1d+1.0p	(3.1d+1.0p)—(2.0d+0.67p)
	Main weeds treated							A, B	B, N
Dalapon	No. of applications	3	4	8	6	4	3	4	....
	Total quantity	7.8	5.4	24.3	22.8	7.3	2.6	7.8	....
	Spray concentration (lb per 45 gal)	5.0-5.6	5.0-8.0	5.0-5.9	5.0-10.0	5.0-5.6	8.0-10.0	5.0-5.6	....
	Main weeds treated	C, H	C, D	C, H	C, H	C, D, H	C, D, H	C, D, H	....
2,4-D	No. of applications	1	....	2	5	2	....	1	1
	Total quantity	0.7	....	3.8	6.8	1.3	....	1.6	0.1
	Spray concentration (pints per 45 gal)	5.0	....	3.0-6.0	2.0-3.0	2.3-4.5	....	4.5	2.0
	Main weeds treated	J, K	....	J, O	J, M, O	J, K, M,	....	J, K	K
TOTAL COST $		24.99	21.86	39.28	33.74	33.35	17.99	39.29	18.25

jew and *Polygonum nepalense*. The first blanket application was at the rate of 3 lb Karmex plus 4 pints Weedazol TL Plus per acre (in 43 gallons) with 0.5 per cent non-ionic surfactant. (This high concentration of surfactant was used in the first three applications, but is unnecessary when the spray mixture contains a foliar-acting herbicide, and it was subsequently reduced to 0.1 per cent.) All diuron plus amitrole treatments after the initial one were as spot-sprayings. For the first 18 months these sprays contained the same concentration of herbicides as the blanket spray. After that period the spray concentration was reduced to 2 lb Karmex plus 2 pints Weedazol TL Plus per 45 gallons. Two spot-sprayings were applied in the first year and six more in the second year. The other herbicides used are given in *Table* 11.

The plot has remained substantially weed-free from shortly after the first spraying and there has been little difficulty in maintaining it in this condition. At the end of the second year, weeds occupied only about 1 per cent of the ground area. Thurston grass is no longer present and no potentially troublesome weeds have appeared, although small patches of couch have required regular attention. *Cyperus brevifolius* and *C. kyllingia* and thickhead plants continue to appear, but are killed by the diuron-amitrole spray.

4. *Diuron plus Paraquat*

The weed cover at the first spraying was about 30 per cent and the main weeds were thurston, para and couch grasses. The first application was a blanket spraying at 3 lb Karmex plus 1 pint Gramoxone per acre (in 43 gallons) with 0.5 per cent non-ionic surfactant. [As mentioned in the previous treatment, this high rate of surfactant is unnecessary and it was reduced, firstly to 0.14 per cent and then to 0.1 per cent.] All subsequent applications of the mixture during the first 18 months were as spot-sprays containing the same concentration of herbicides as the initial treatment. After this period the concentration of the spray mixture was reduced to 2 lb Karmex plus 2/3 pint Gramoxone per 45 gallons. Three spot-sprays of the mixture were applied in the first year and six further sprays in the second year.

Weed control has been excellent throughout the two years, and at the end of the period the weed cover was about 1 per cent. Thurston grass has been eradicated but a small amount of couch grass remains. *C. brevifolius, C. kyllingia* and thickhead plants which appear are killed by the diuron-paraquat spray. No other potentially troublesome weeds have appeared.

Discussion

In the first 12 months the paraquat-amitrole treatment was the most economical (see *Table* 11), followed by diuron plus amitrole. Diuron plus paraquat and MSMA were the most expensive. Considering weed control, only the MSMA treatment was not completely satisfactory. It required the highest number of treatments and the plot was weedier at all times than the other three plots. This was partly because MSMA was active against a narrower range of weeds than the other three treatments. However, as mentioned above, the plot initially had more para grass than the other plots and the high costs in the first year can partly be attributed to this weed, although the fact that MSMA did not give even temporary control of couch grass would also have been a factor. The para grass was mostly eradicated by the end of the first year and was not an important weed after that time. The cost of the MSMA-based treatment remained high, however, and as long as *C. brevifolius* and *C. kyllingia* are present, higher concentrations of MSMA (i.e., about 4 pints of Ansar 529 per 45 gallons) will be necessary and this will keep costs relatively high. Spraying with 2, 4-D will continue to be necessary for some broadleafs, in particular *Dichrocephala bicolor*.

Again, as in AWC2a, there was a decrease in costs in the second year. The paraquat-amitrole treatment has remained the cheapest treatment overall for the two-year period, but in the second year, the two diuron-containing treatments were less expensive than the paraquat-amitrole treatment. Both the diuron-containing treatments are giving excellent control and although the diuron-amitrole treatment was cheaper in the first year, there was no difference between them in the second year. Figures given with the details of the treatments above indicated that the initial weed cover on the diuron plus amitrole plot was a little less than on the diuron plus paraquat

Table 12.—Costs per acre for the first two years of herbicide treatments in AWC2a and AWC2b

Trial	Treatment	Cost ($)	
		Year 1	Year 2
AWC2a	Basically paraquat (on pit-pit site, unshaded)	39.13	33.11
AWC2b	Paraquat and amitrole	24.99	21.86
AWC2a	Basically diuron (on pit-pit site, unshaded)	63.92	23.48
AWC2b	Diuron plus amitrole	33.35	17.99
AWC2b	Diuron plus paraquat	39.29	18.25
AWC2b	MSMA	39.28	33.74

plot. It is possible that the difference in cost between the two treatments in the first year, which is due almost entirely to the extra diuron used on the diuron plus paraquat plot (see *Table* 13), may have been brought about by the heavier initial weed infestation on the latter plot.

COMPARISON OF RESULTS IN TRIALS AWC2a AND AWC2b

A comparison can be made between the four treatments described above and the herbicide treatments on the unshaded pit-pit plots of AWC2a. The costs of the treatments are collated in *Table* 12.

The considerable reduction in the cost of the paraquat-amitrole treatment of AWC2b over that of the paraquat treatment of AWC2a can be attributed to three factors. Firstly, the spray treatments in AWC2b commenced on fairly low vegetation—it had been slashed to ground level three weeks before the initial amitrole application—whereas in AWC2a the weed growth had been undisturbed for about 16 weeks, and in places was knee-high. [If the cost of the slashing was included, it would add about $6 per acre to the first year costs of the AWC2b paraquat-amitrole treatment.] Secondly, the use of the amitrole-paraquat split applications from the beginning resulted in a quick reduction and eventual eradication of the thurston grass. This eliminated the need for frequent and relatively high doses of paraquat which had been needed in the AWC2a treatment. Thirdly, the coffee in some sections of the paraquat treatment of AWC2a was unhealthy and so provided little ground shade. This permitted more vigorous grass growth.

In *Table* 13, the quantities of individual herbicides used in the diuron treatment of AWC2a are compared with those used in the diuron plus amitrole and diuron plus paraquat treatments of AWC2b. This breakdown indicates the main source of the difference in costs between the diuron treatments in the two trials. Thus, of the difference in the first year of $24.63 between the cost of the diuron plus paraquat treatment of AWC2b and the diuron treatment of AWC2a, $13.38 is due to the difference in the amount of Karmex used (and the surfactant used with the Karmex), and $4.90 to the difference in the amount of Gramevin used (there was more couch grass on the AWC2a plot). Most of the remaining difference is due to the cost of the initial slashing ($7), being included in the costs of the AWC2a treatment and not in those of the AWC2b treatment. Similarly in the diuron plus amitrole treatment, the main source of cost reduction over the cost of the diuron treatment in AWC2a is the reduced amount of Karmex used. While the amount of Karmex used in

Table 13.—Comparison of amounts of herbicide used in different diuron-based treatments during first 12 months

Herbicide	Treatment		
	Basically Diuron (AWC2a, pit-pit site)	Diuron plus Amitrole (AWC2b)	Diuron plus Paraquat (AWC2b)
Karmex	10.0 lb	5.3 lb	7.0 lb
Weedazol	3.6 pints	7.1 pints	....
Gramoxone	....	....	2.3 pints
Gramevin	16.7 lb	7.3 lb	7.8 lb
Amoxone-50 or Weedkiller D	3.1 pints	1.3 pints	1.6 pints
Surfactant	8.7 pints	3.6 pints	4.2 pints
No. of treatments	11	9	9

the AWC2a treatment could probably have been reduced to 8 lb (applications of 4 + 2 + 2 lb), this could have been expected to increase the requirements for other herbicide treatments, while only partly reducing the difference in costs attributable to Karmex.

In spot-spraying, diuron is only applied where it is needed and thus a considerable saving is made in this expensive material. However, it was rather unexpected that, following the initial blanket application, only two spot-sprayings containing diuron were required on the diuron plus amitrole treatment and three spot-sprayings on the diuron plus paraquat treatment of AWC2b in the first year. In the second year, six diuron-containing spot-sprays were applied in both treatments.

The method of spot-spraying diuron to emerged weeds, either combined with one of the foliar-acting herbicides used here, or with a non-ionic surfactant, would appear to offer distinct possibilities of reducing the costs of a diuron-based treatment, particularly in the first year of use. However, as this conclusion is based on the data of one unreplicated trial and a not strictly valid comparison with another trial, some caution is necessary in interpreting the results. Further trials have begun comparing the two methods of applying diuron (blanket and spot-sprays).

With the spot-spraying method there is the disadvantage that it is not possible to know how much diuron is being applied over a period to specific small areas. This means that without due care it is possible that in localized areas diuron could accumulate in the soil to levels which are toxic to coffee. Obviously, if over a period a patch of weeds is not being killed by diuron, it would be unwise to continue pouring diuron onto that area. Sufficient attention must therefore be given to the spraying programme to enable the appearance of any such weed patches to be detected early and appropriate action taken.

VARIATIONS IN WEED CONTROL COSTS

As already mentioned, the costs of weed control in the trial AWC2a were fairly high. Those of AWC2b were somewhat lower but they were also obtained from a problem area. Weed control costs for several coffee blocks at Aiyura, some of which have weed populations nearer the norm for the highlands, are given in *Table* 14, along with a brief description of the blocks and the herbicide treatments. The Table brings out the large variations in costs which can occur. These differences in costs are due both to differences in weed populations and in herbicide treatment.

Block A6 had large areas of thurston grass when herbicide treatment started, mainly in the multiple stem coffee; blocks A15/16 and B14 contained predominantly annual weeds. The difference in control costs between A15/16 and B14 can be attributed to the different herbicide treatments used. If control in B14 had been based on paraquat, the costs could have been expected to be lower than those in the unshaded A15/16 block. That the weed infestation in B14 was less severe than in A15/16 is indicated by the hand-weeding costs of the two blocks in previous years. In block E6, the comparatively low cost was also due to the treatment rather than the weed population. The block initially contained a large amount of thurston grass and was probably more heavily weed-infested than block A6, being somewhat comparable to the Albizia plots on the pit-pit soil of AWC2a.

YIELD INCREASES FROM CLEAN WEEDING

Good weed control can be expected to produce substantially higher yields. This has been shown both at Aiyura and in Kenyan trials. At Aiyura in the cover crop trial ACA3 (Schindler and Fraser 1964), a weed-infested cover crop decreased yields of saleable beans by an average of 300 lb per acre per year compared with the clean-weeded treatment over the first 3¼ years of bearing. In Kenya, in a ten-year trial in unshaded coffee, in 41 inch rainfall, thorough weed control gave a mean annual yield increase over minimal weeding (two hand-weedings per year) of 350 lb of clean coffee (Wallis and Blore 1964). Another trial over a four-year period, in unshaded coffee in 67 inch rainfall, gave a mean increase per year of 412 lb of clean coffee per acre (Reynolds 1967). However, trials in two other areas in Kenya with 59 inch and 55 inch mean annual rainfall and over five and four years respectively, did not show significant yield increases from clean-weeding. The coffee in both cases

Table 14.—Variation in costs of chemical weed control at Aiyura

Block	Size	Description of block	Summary of herbicide treatment for first 12 months	Cost per acre in first 12 months ($)	Cost of hand-weeding (per acre)* ($)
A6	5 acres	Mature coffee under Albizia shade; half is multiple stem, half single stem, both at 8 x 8 ft spacing; on pit-pit soil	Initially blanket application of diuron plus paraquat, then 2 further blanket applications of diuron, and spot-sprayings with paraquat, dalapon and amitrole as necessary	39.77	40
A15/16	5 acres	Mature single stem coffee on 9 x 9 ft spacing; unshaded; on shallow hillside soil	Paraquat (9 applications, from 1 to 2/3 pint Gramoxone per 45 gallons) plus 2 applications of dalapon	17.97	40
B14	5 acres	Mature multiple stem coffee at various spacings (5 x 5 ft to 9 x 7 ft) under dense Albizia shade; hillside soil	3 blanket applications of diuron (3, 2, and 2 lb Karmex per acre) plus spot-sprays with paraquat as necessary	30.73	22½
E6	1.5 acres	Mature multiple stem coffee, spaced at 9 x 9 ft; Albizia shade; pit-pit soil	9 applications of amitrole at 4.7 to 1.5 pints (Weedazol TL Plus) per 45 gallons	13.91	

* Means of costs for the 3 previous 12-month periods.

was growing under shade and this was thought to be the possible reason for the lack of response (Wallis and Blore 1964).

Theoretically it might be expected that, even where previous weed control by hand-weeding has been good, the introduction of herbicides with the accompanying end to the disturbance of feeder roots, would result in higher yields. However, yield increases due to this factor may not eventuate owing to other balancing factors. If (as in most cases), the use of herbicides leads to greatly improved weed control, then, as indicated by the evidence quoted above, increases in yield should result. To date, it has not been possible to show any yield increases from improved weed control in the trial AWC2a, and the large variations in yield which occur between replicates both in the same year and from year to year may mean that any differences will not be detected. In Kenya, over the first 4 years of a long-term weed control trial there has been no significant difference in yield between herbicide-treated plots and mechanically or hand-weeded plots (Mitchell 1967). It would seem that the main tangible benefit likely to result from the use of herbicides in coffee is a decrease in weeding costs.

ACKNOWLEDGEMENTS

The assistance of the following people is gratefully acknowledged: Mr A. E. Charles for advice during the preparation of the manuscript, Mr Tomagao Awang for assistance in the recording and supervision of the field work, Mr J. Brigatti of the Land Utilization Section for the soil analyses and Mr E. E. Henty of the Division of Botany, Department of Forests, Lae, for identification of weed species.

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NEW RECORDS OF FISH FROM PAPUA

PATRICIA KAILOLA*

ABSTRACT

A series of trawls at Yule Island in Papua produced 22 new species records for Papua, and confirmed the occurrence of one other species. A brief description and photograph of each specimen is provided.

INTRODUCTION

BETWEEN November, 1969, and the end of January, 1970, a series of experimental trawls was made by the Department of Agriculture, Stock and Fisheries' Research and Surveys Division at Yule Island in Papua (146° 30' E., 8° 50' S.) (*Figure*). Over this period, two sunk nets were set and 24 trawls made, to the south-west of the island at depths between $2\frac{3}{4}$ fathoms and 26 fathoms over a sandy-mud bottom.

A representative collection of the fishes trawled was kept for identification. Besides the 80 known Papuan species identified, the collection contained 22 Indo-Australian species not previously recorded from Papua New Guinea and confirmed the occurrence of one other species in Papua. Of these 22 species, eight have been recorded previously from, or near, West Irian.

The purpose of this paper is to record these species as new for Papua and also to provide a brief description of each.

FAMILY BOTHIDAE

Genus *Bothus* Rafinesque

Bothus myriaster (Temminck and Schlegel) (*Plate* I, A and B)

Rhombus myriaster Temminck and Schlegel, Fauna Japonica, Poissons, 1846, p. 181.

D. 89-95. A. 60-70. P. sin. 9. P. dextr. 8-9. L. lat. 93-105.

Depth 1.4-1.5, 1.7-1.8 in length with caudal. Head 3.6-3.8, 4.2-4.5 in length with caudal. Eye 3.0, 1.0-1.3 in interorbital space. Maxilla 3.6 in head, reaching to below front border of eye. Rostral spines present in some. Each eye with a round flat tentacle. Second to fifth pectoral rays produced into long filaments in 5 of the 7 specimens.

Colour of preserved specimens reddish-brown, with numerous black-centred white ocelli and a large black blotch in middle of lateral line. A variable number of bent brown cross-bars separate the pale anterior from the brown posterior section of the blind side. The blind sides of the two remaining specimens are pale with no cross-bars. (*Note*: Perhaps these two represent a different sex to the others as they have neither developed rostral spines nor filamentous pectoral rays.)

Seven examples, 73-103 mm total length.

Previously unknown from Papua New Guinea, although recorded from West Irian (Munro 1967). A new record for Papua.

Genus *Engyprosopon* Gunther

Engyprosopon grandisquamma Schlegel (*Plate* I, C)

Rhombus grandisquamma Temminck and Schlegel, Siebold's Fauna Japonica, Pisces, 1842-1850, p. 183.

D. 87-95. A. 65-70. P. sin. 11. P. dextr. 9. V. 6. L. lat. 44-48.

Depth 1.8-1.86, 2.2 in length with caudal. Head 3.9-4.2, 4.6-5.0 in length with caudal. Eye 3.0-3.6, equal to interorbital in two specimens (male) and 2.5 times interorbital in the other. Snout about half as long as eye. Maxilla reaching to below pupil of lower eye. Longest dorsal and anal rays equal to postorbital head length. Pectorals nearly as long as head, shorter in female. Origin of right ventral just behind fourth ray of left ventral.

*Biologist, Fisheries Research Station, Kanudi

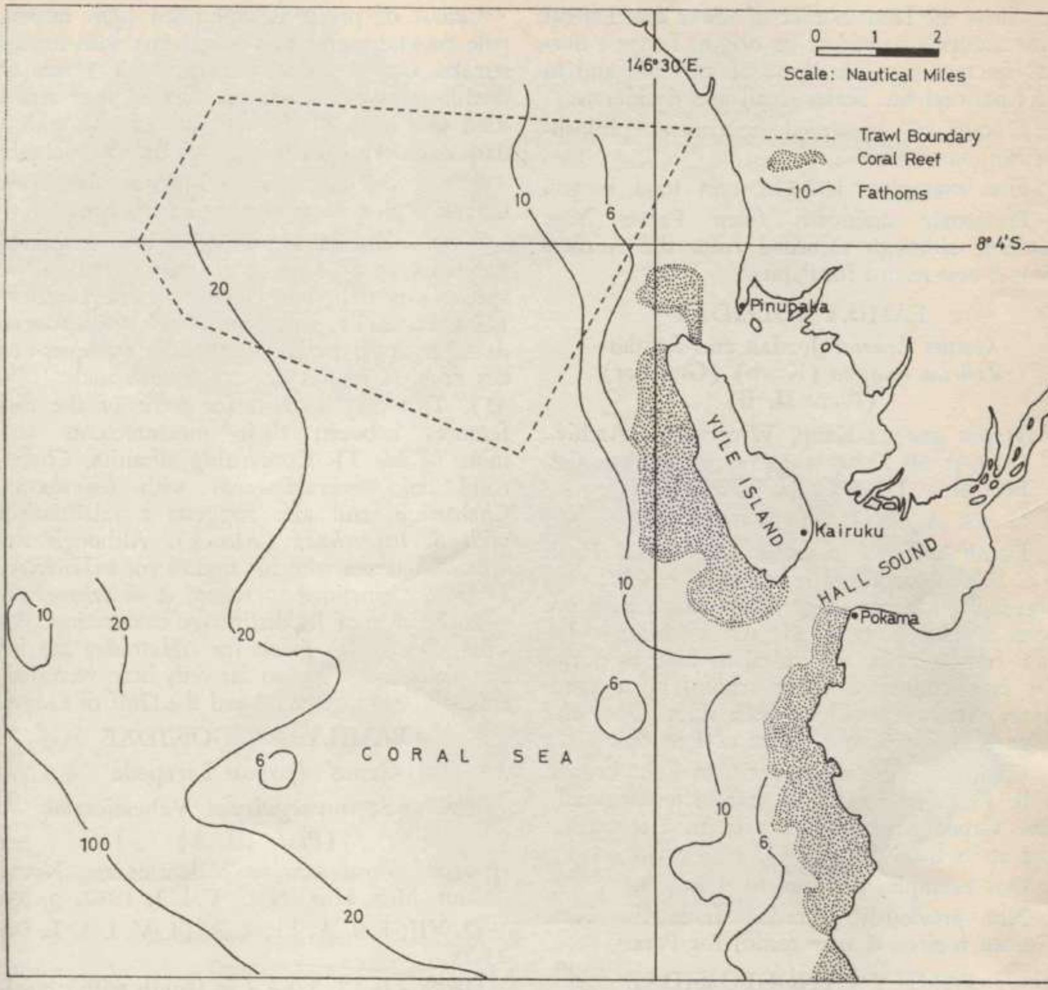


Figure.—Map of Yule Island with the trawling area marked

Colour of preserved specimens brown. Blind side with a longitudinal orange band below dorsal and another above anal. Caudal with a black spot at middle of upper and lower margin. Anal, dorsal and pectorals finely banded with numerous brown spots.

Three examples, 78-91 mm total length.

Previously unknown from Papua New Guinea, although recorded from West Irian and south of New Guinea. A new record for Papua.

Genus *Laeops* Gunther
Laeops parviceps Gunther
(*Plate* II, A)

Laeops parviceps Gunther, Challenger Rep. Zool., I, Part VI, Shorefishes, 1880, p. 29.

D. 94-107. A. 76-85. P. sin. 13-14. P. dextr. 11-12. L. lat. 85-98.

Depth 2.5-2.65, 2.9-3.2 in length with caudal. Head 5.6-6.5, 6.8-7.0 in length with caudal. Eye 2.1-2.6, and close together, the lower eye a little in front of the upper. Maxilla reaching the front border of lower eye. Lateral line abruptly curved at its origin. Longest dorsal fin rays equal to those of anal fin, and to left pectoral fin. Scales small and deciduous.

Colour of preserved specimens pinkish-brown; fins brown.

Five examples, 100-112 mm total length.

Previously unknown from Papua New Guinea, although recorded from the Arafura Sea. A new record for Papua.

FAMILY SOLEIDAE

Genus *Zebrias* Jordan and Snyder

Zebrias quagga (Kaup) (Gunther) (*Plate* II, B)

?Aesopia quagga Kaup, Wiegmann's Archiv., 1858, p. 98. *Synaptura quagga* Gunther, Cat. Brit. Mus., IV, 1862, p. 485.

D. 68. A. 58. L. lat. 99.

Depth 2.68, 3.1 in length with caudal. Head 5.6, 6.6 in length with caudal. Eye 4.25, contiguous, 2.5 times longer than snout. Each eye with a short tentacle. Maxilla reaching to below front of pupil. Pectoral as long as dorsal fin rays, connected to operculum by a membrane. Scales ctenoid on both sides. Opercular edge on left side has fringe of tentacles.

Colour of preserved specimen light brown, with 11 transverse double bars extending onto fins. Caudal dark brown, with another smaller bar at its base.

One example, 120 mm total length.

Not previously recorded from the New Guinea region. A new record for Papua.

FAMILY CYNOGLOSSIDAE

Genus *Symphurus* Rafinesque

Symphurus microrhynchus (M. Weber) (*Plate* II, C)

Aphoristia microrhynchus M. Weber, Siboga Exped. Fische, 1913, p. 444.

D. 87. A. 76. V. 4. C. 12. Sc. 86. Tr. 33.

Depth 3.76, 4.17 in length with caudal. Head 4.41, 4.9 in length with caudal. Eye 8.5, contiguous, the upper slightly in advance of the lower. Maxilla reaches to below hind half of eye. Body depth 1.2 times head length. Dorsal and anal fin heights 2.0 in head length and 2.4 in body depth. Scales ctenoid on both sides. Scales with 7 or 8 basal radiating striae, and 16 slender apical denticles.

Colour of preserved specimen light brown, pale on undersurface. Vertical fins with brown streaks. Upper surface crossed with 5 sets of double transverse bars; possibly another across hind half of head. Base of caudal also with a dark bar. One example, 71 mm total length.

Not previously recorded from the New Guinea region. A new record for Papua.

Note.—Chabanaud (1955) has examined the holotype of *S. microrhynchus* used in the species' description by Weber and de Beaufort (1929, p. 211), and found that it "depourvu de sa nageoire caudale et aussi de quelques-uns des derniers rayons de sa nageoire anale." (p. 45). This may account for some of the differences between their measurements and mine (*Table* 1). Concerning affinities, Chabanaud links *microrhynchus* with *holothuriae* Chabanaud, and also suggests a relationship with *S. trifasciatus* (Alcock). Although my specimen agrees with his figures for *trifasciatus*, I am more inclined to regard it as *microrhynchus*, because of its distinctive colouration. Besides, the figures given for *trifasciatus* are incomplete, and it has so far only been recorded from the Bay of Bengal and the Gulf of Oman.

FAMILY APOGONIDAE

Genus *Apogon* Lacepede

Apogon novaeguineae Valenciennes (*Plate* III, A)

Apogon Novae-guineoe Valenciennes, Nouv. Ann. Mus. Hist. Nat., Vol. I. 1832, p. 53.

D. VII; I, 9. A. 11, 8. P. 14. V. I, 5. L. lat. 23-25.

Depth 2.6-2.7, 3.3-3.4 in length with caudal. Head 2.4-2.5, 3.0 in length with caudal. Eye 3.2-3.7, 1.5 times interorbital. Maxilla reaching posterior margin of pupil. Outer margin of preoperculum finely serrated, preopercular ridge entire. Predorsal and body scales ctenoid.

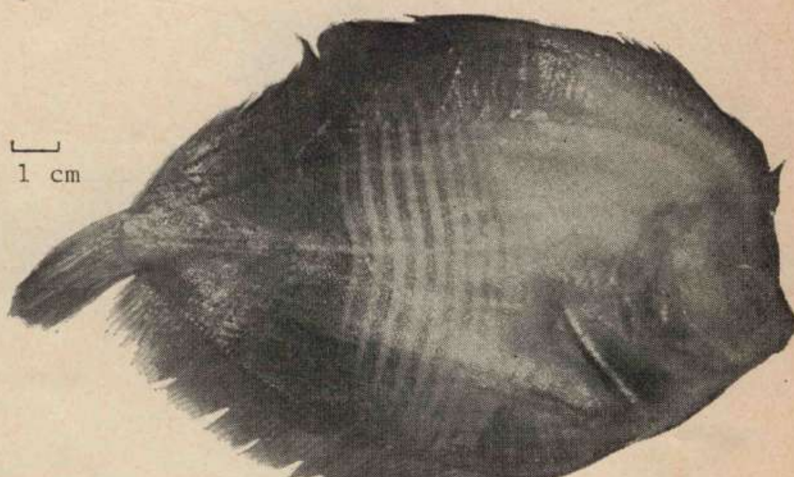
Colour of preserved specimens brownish, with 7 to 15 distinct vertical brown bars across back and sides. Sometimes a brown diagonal bar from eye to preopercular angle. Subbasal brown bar on soft dorsal; anal hyaline. Upper part of first dorsal dusky.

Eleven examples, 45-83 mm total length.

Previously unknown from Papua New Guinea, although recorded from West Irian. A new record for Papua.

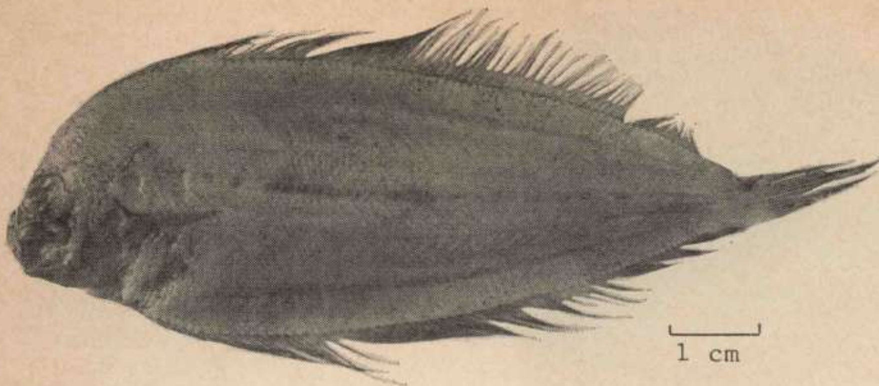
Plate I.—

A. *Bothus myriaster* (Temminck and Schlegel). 77 mm.



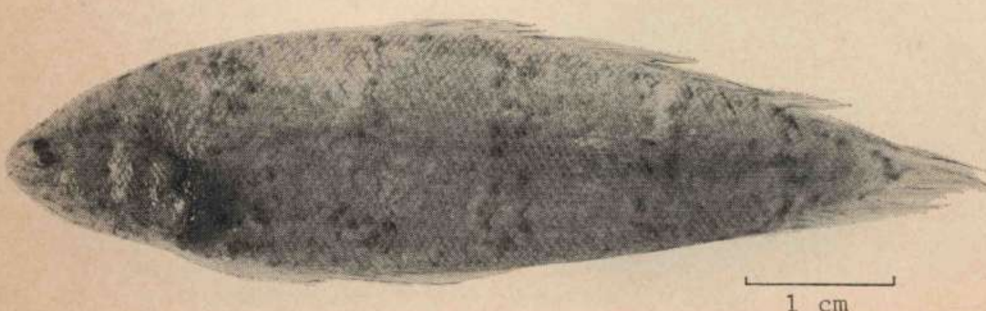
B. *Bothus myriaster* (Temminck and Schlegel). 103 mm. Blind side.

C. *Engyprosopon grandisquamma* Schlegel.



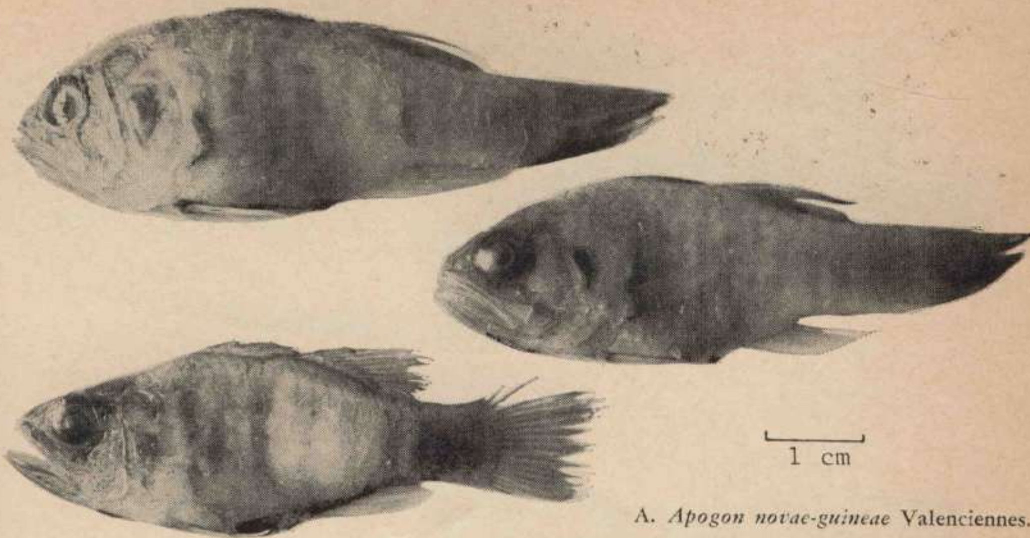
A. *Laeops parviceps* Gunther.

B. *Zebrias quagga* (Kaup) (Gunther).

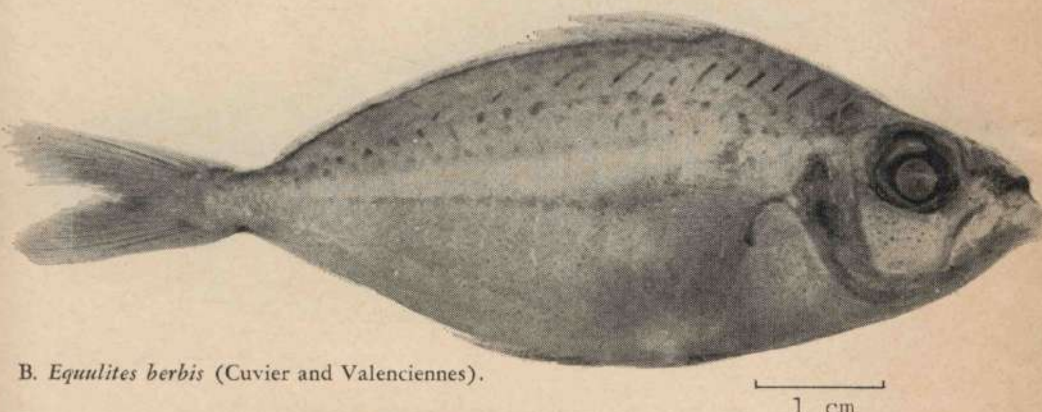


C. *Symphurus microrhynchus* (M. Weber).

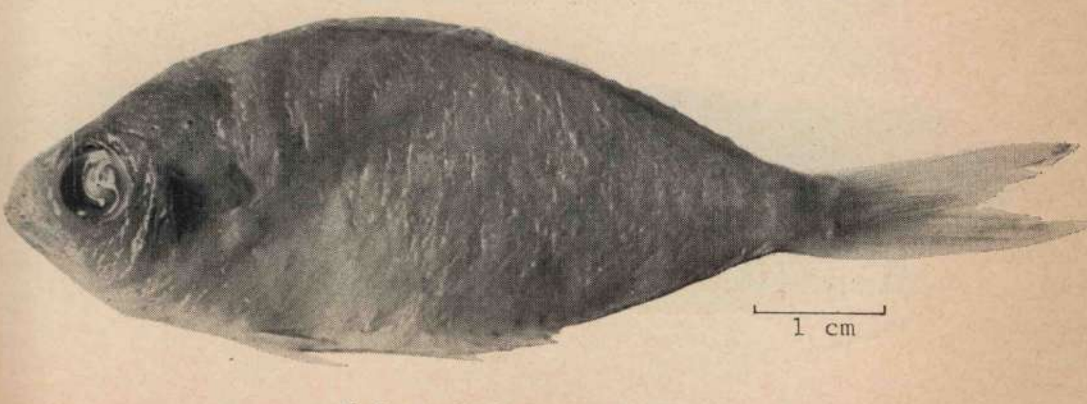
Plate III.—



A. *Apogon novae-guineae* Valenciennes.

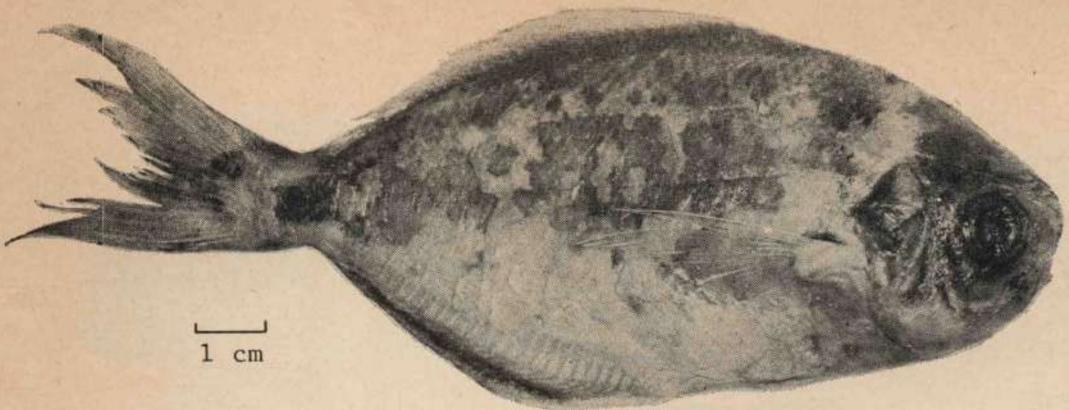


B. *Equulites berbis* (Cuvier and Valenciennes).

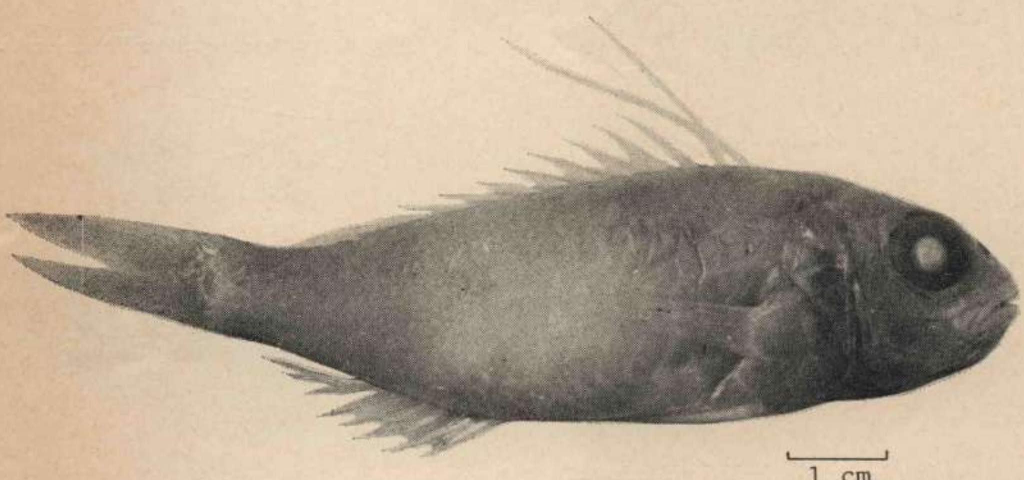


C. *Pentaprion longimanus* (Cantor).

Plate IV.—



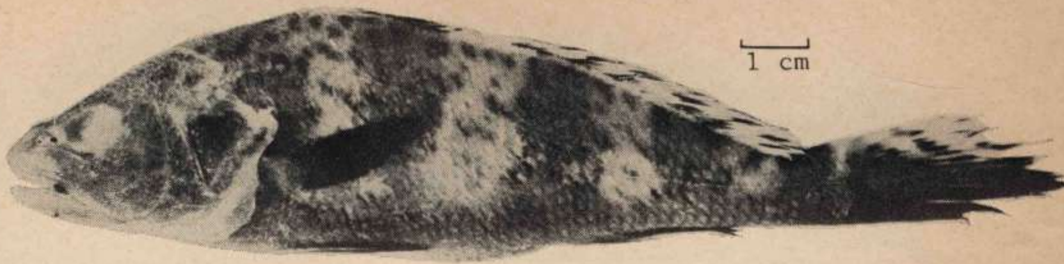
A. *Psenopsis humerosus* Munro.



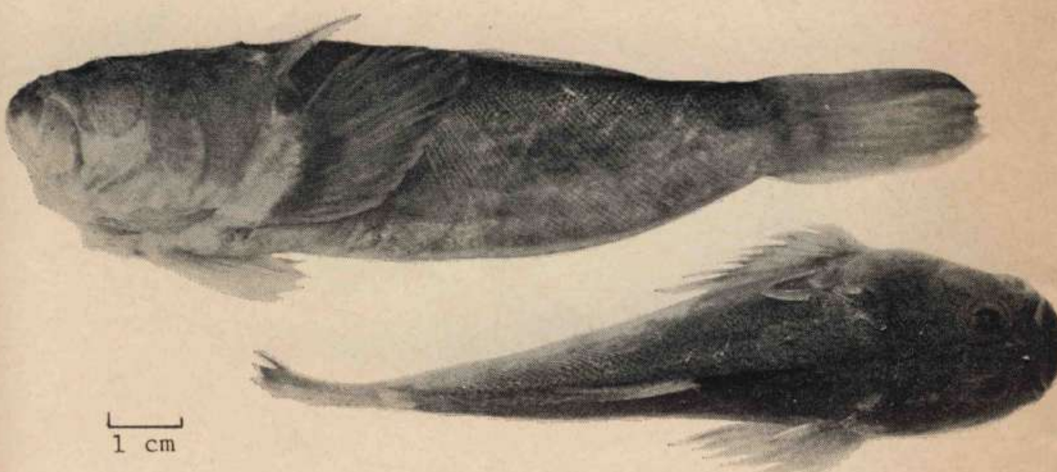
B. *Nemipterus nematophorus* Bleeker.

C. *Upeneus moluccensis* (Bleeker).

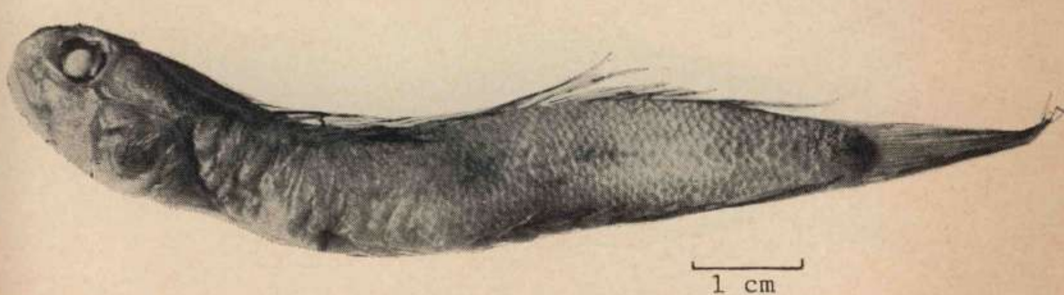
Plate V.—



A. *Pseudosciaena diacanthus* (Lacepede).

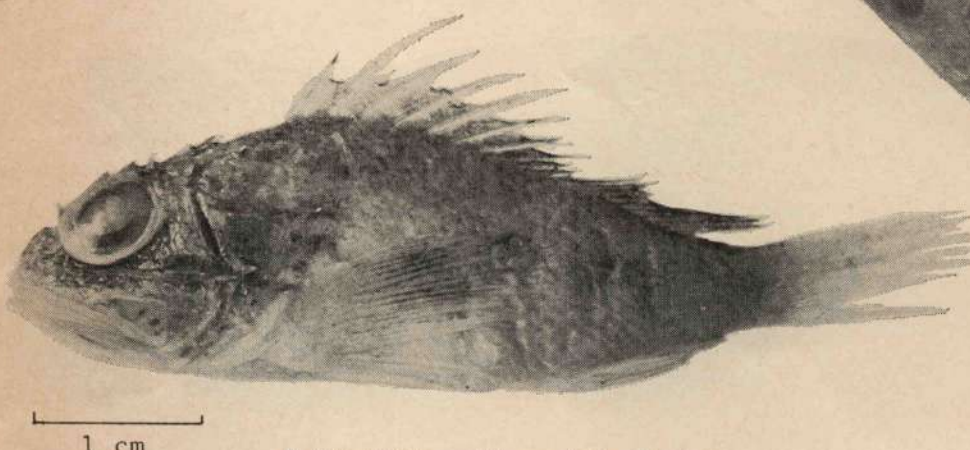


B. *Uranoscopus cognatus* Cantor. 140 mm and 113 mm.



C. *Oxyurichthys papuensis* (Cuvier and Valenciennes).

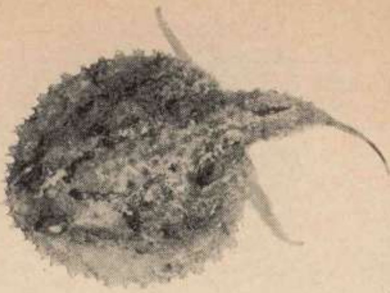
A. *Elates ransonneti* (Steindachner). 164 mm.



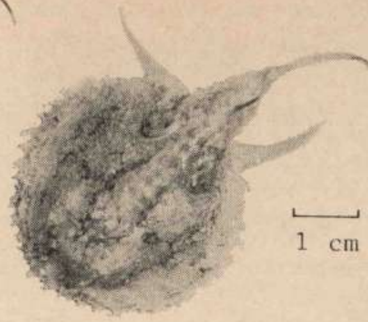
B. *Sebastapistes amplisquamiceps* (Fowler).

C. *Minous trachycephalus* (Bleeker).

Plate VII.—



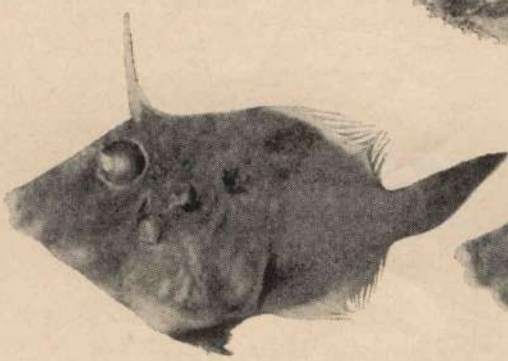
A. *Halieutaea indica* Ann. and Jenk.

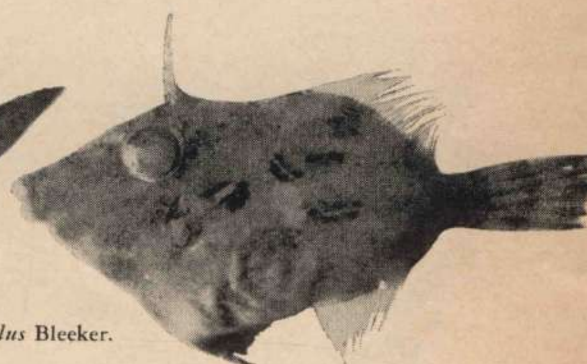


B. *Halieutaea coccinea* Alcock.

C. *Halieutaea stellata* (Vahl).

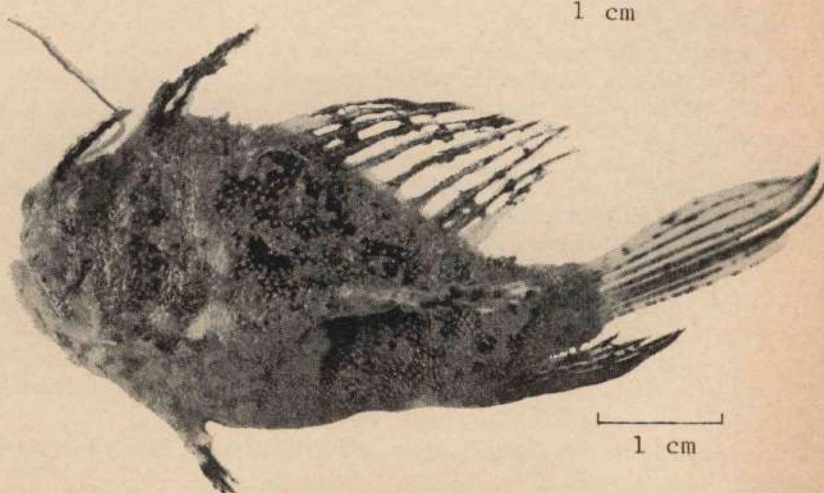
1 cm





D. *Monacanthus choirocephalus* Bleeker.

1 cm



1 cm

E. *Tathicarpus butleri* Ogilby.

Table 1.—A comparison between different *Symphurus* spp. based on Chabanaud (1955)

Character	S. regani (Weber)	S. microrhynchus (Weber)	S. holothuriae (Chabanaud)	S. trifasciatus (Alcock)	Yule I. Specimen
Dorsal Fin	101-104; 100*	84; about 88-90*	80	84-91	87
Anal fin	89-92	72; about 68*	70	70-75	76
Ventral fin	4	4	....	....	4
Caudal fin	14	?	11	10-12	12
Scutes	± 100; 80-90*	68*	± 70	79-88	86
Depth:					
Ratio	4.3*	4.5*	....	....	3.76
Per cent standard length	22-27	....	....	....	26.5
Head:					
Ratio	Almost 6*	4.5*	....	....	4.41
Per cent standard length	16-18	23.3	....	....	21.9
Eye:					
Ratio	7*	7*	....	....	8.5
Per cent head length	14-16	10	....	....	12.14
Caudal:					
Per cent head length	± 65	47	....	....	50
Locality	Flores Sea	Java Sea	NW. coast of Australia	Bay of Bengal, Gulf of Oman	Papua

*Figures from Weber and de Beaufort (1929), pp. 210-211.

FAMILY LEIOGNATHIDAE

Genus *Equulites* Fowler

Equulites berbis (Cuvier and Valenciennes) (*Plate* III, B)

Equula berbis Cuvier and Valenciennes, Hist. Nat. Poiss., X. 1835, p. 85.

D. VIII; 16. A. III, 14.

Depth 2.3-2.5, 2.9-3.2 in length with caudal. Head 3.2-3.4, 4.0-4.3 in length with caudal. Eye 2.7-2.8, 1.1-1.2 longer than snout. Maxilla reaches to below front border of pupil. Body scales small to moderate sized; breast fully scaled. Lateral line 40-43, terminating below end of soft dorsal fin. Second dorsal spine longest, 1½-2 times in body depth. Longest anal spine three quarters of length of second dorsal spine.

Colour of preserved specimens pinkish-grey, back darker with series of angulated vertical lines from nape to end of dorsal. Snout black-tipped.

Eight examples, 64-83 mm total length.

Not previously recorded from the New Guinea region. A new record for Papua.

FAMILY GERRIDAE

Genus *Pentaprion* Bleeker

Pentaprion longimanus (Cantor) (*Plate* III, C)

Equula longimana Cantor, J. Asiat. Soc. Bèng., XVIII, 1850, p. 1134.

D. IX-X, 14-15. A. V-VI, 12-13. L. lat. 44-46.

Depth 2.5, 3.3 in length with caudal. Head 3.1, 4.2 in length with caudal. Eye 3.0, 1.4 times longer than snout and subequal to interorbital. Maxilla reaches to below front border of eye. Third dorsal spine longest, as long as head without postorbital. Pectorals reaching first or second anal ray, 2.6 in standard body length.

Colour of preserved specimens pinkish-white to silvery, with white median lateral streak through eye to tail base. Another dark streak just below dorsal, following dorsal profile.

Four examples, 73-103 mm total length.

Not previously recorded from the New Guinea region. A new record for Papua.

FAMILY STROMATEIDAE

Genus *Psenopsis* Gill

Psenopsis humerosus Munro

(*Plate* IV, A)

Psenopsis humerosus Munro, Handbook of Australian Fishes, No. 29, p. 18. Canberra, 1958.

D. VII, 29. A. III, 26. P. 22. L. lat. 51 or 52. L. Tr. 9 + 15. G.R. 6-12 or 13.

Depth 2.17, 2.8 in length with caudal. Head 3.3, 4.3 in length with caudal. Eye 3.5, 1.34 times snout. Snout blunt; maxilla reaches to below anterior of eye, 4.0 in head length. Operculum pointed with entire edges. Dorsal spines short and almost embedded in skin, graduating to the dorsal rays. Pectoral fin falcate, subequal (0.9) to head length. Ventral fins 0.81 times eye, inserted below pectoral base. Scales moderate, deciduous.

Colour of preserved specimen dark reddish-brown above, mottled in places, and cream below. Indications of a large dark humeral blotch. Fins pale, vertical fins dark brown at base.

One example, 155 mm total length.

Not previously recorded from the New Guinea region. A new record for Papua.

Note.—More recently, two specimens of *P. humerosus* have been received from Orangerie Bay in Papua. *Table* 2 compares counts and measurements of the three Papuan fish with those given by Munro (1958) for *P. humerosus* and those given by Tate Regan (1902) and by Ochiai and Mori (1965) for *Psenopsis anomala* (Temm. & Schl.).

No appreciable difference between *P. humerosus* and *P. anomala* on the basis of body counts and proportions is apparent from this table. Although neither Tate Regan nor Ochiai and Mori specifically mention a humeral blotch for *P. anomala,* it can be discerned on the specimens in *Plate* I of the latters' paper. In the Japanese Encyclopaedia Zoologica II, *P. anomala* is again depicted with a humeral blotch.

Obviously, many more specimens need to be examined. However, it seems probable that any definite distinction between the two described species of *Psenopsis* is only due to geographical variation.

FAMILY NEMIPTERIDAE

Genus *Nemipterus* Swainson

Nemipterus nematophorus (Bleeker)

(*Plate* IV, B)

Dentex nematophorus Bleeker, Nat. Tijdschr. Ned. Indie, V, 1853, p. 500.

D. X, 9. A. III, 7. P. 2, 15. L. lat. 47.

Depth 3.1-3.25, 4.0-4.2 in length with caudal. Head 3.0-3.1, 4.0 in length with caudal. Eye 2.8-2.9, nearly 1.5 times snout. Suborbital narrow, more than twice in vertical eye diameter, its hind border when produced reaching dorsal profile 6-7 scales before dorsal origin. Four curved canines anteriorly on each side of upper jaw; none in lower jaw. First and second dorsal spines longest, extending at least length of spinous dorsal (probably broken near tips). Pectorals as long as head. Caudal deeply forked.

Colour of preserved specimens pinkish-brown, the fins hyaline.

Three examples, 96-103 mm total length.

Not previously recorded from the New Guinea region. A new record for Papua.

FAMILY MULLIDAE

Genus *Upeneus* C.V.

Upeneus moluccensis (Bleeker)

(*Plate* IV, C)

Upeneoides moluccensis Bleeker, Nat. Tijdschr, Ned. Indie, VIII, 1855, p. 409.

D. VIII; I, 8. A. I, 6. L. lat. 35-36. L. Tr. $2\frac{1}{2}$ + 5-6. G.R. 7 + 19-20 (last 5-6 rudimentary).

Depth 3.67-4.21, 4.67-5.3 in length with caudal. Head 3.19-3.4, 4.0-4.3 in length with caudal. Eye 3.8-4.0, equal to interorbital and less than snout. Maxilla reaching to origin of pupil. Barbels falling just short of vertical through posterior edge of preopercle, 1.6 in head length. Longest dorsal spine 1.4 in head. Caudal forked, the lobes pointed.

Colour of preserved specimens pinkish-brown above and pale below. A yellow band from eye to caudal base. Dorsal fins and upper lobe of caudal barred with dark brown; other fins and lower caudal lobe hyaline.

Five examples, 99-150 mm total length.

Not previously recorded from the New Guinea region. A new record for Papua.

FAMILY SCIAENIDAE

Genus *Pseudosciaena* Bleeker

Pseudosciaena diacanthus (Lacepede)

(*Plate* V, A)

Lutjanus diacanthus Lacepede, Hist. Nat. Poiss., IV, 1802, pp. 195, 240.

D. XI, 22-24. A. II, 7. P. 2, 17. L. lat. 52. L. Tr. 7-8 + 14.

Table 2.—A comparison between Papuan specimens of *Psenopsis humerosus* and recorded descriptions

Character	Description					
	C. Tate Regan's P. anomala	Ochiai's & Mori's P. anomala (1)	Munro's P. humerosus (2)	Yule I. Specimen	Orangerie Bay Specimen No. 1	Orangerie Bay Specimen No. 2
Dorsal fin	V-VI, 29-30	?, 27-31	VII, 28	VII, 29	VII, 29	VII, 30
Anal fin	III, 26	?, 25-28	III, 25	III, 26	III, 25	III, 25
Pectoral fin	22	20-22	22	22	22	22
Lateral line	"about 50"	55-63	55	51 or 52	49	48
L. Tr.	....	....	9 + 14	9 + 15	9 + 15	9 + 15
Gill rakers	....	19-21	(lower) 12	6 + 12	6 + 12	6 + 11 or 12
Depth	(2.25)	2.0-2.4	1.9	2.17 (2.8)	2.1 (2.69)	1.9 (2.69)
Head	(3.6)	3.0-3.5	3.4	3.3 (4.3)	3.2 (4.17)	3.0 (4.15)
Eye	4.5	3.6-5.0	3.5	3.5	3.9	3.7
Eye/snout	"as long as"	....	1.4	1.34	1.25	1.2
Eye/ventral fin	....	....	"about as long as eye"	0.81	0.9	0.83
Standard length/caudal peduncle depth	....	7.8-11.0	....	8.7	7.8	7.4
Head/pectoral	"as long as"	0.94-1.2	"about as long as head"	0.9	0.85	0.88
Head/snout	....	3.9-5.0	....	4.0	4.3	4.9
Head/interorbital width	2.6	2.1-2.9	....	2.7	2.6	2.6
Head/maxillary	....	3.2-4.2	....	4.0	4.3	4.4
Standard length	....	....	....	113 mm	125 mm	133 mm
Total length	190 mm	Over 100 mm	177 mm	155 mm	167 mm	183 mm
Colouration						
Shoulder patch	....	present in plates	present	present	present	present
Back	"dark gleaming purple"	dusky/pale (3)	darker	brown	brown	brown
Vertical fins	....	darker/pale	....	brown basally	dusky	dusky
Mouth cavity	....	darkish/pale	dusky	dusky	brown	brown
Locality	Japanese Seas	Around Japan, east China seas	NW. Australia	Papua	Papua	Papua

(. . .) In total length.

(1) Based on measurements from 22-57 specimens over 100 mm long.

(2) Based on measurements from one specimen only.

(3) Ochiai and Mori distinguish pale and dark varieties.

Depth 3.76-3.43, 4.3-4.7 in length with caudal. Head 2.9-3.1, 3.7-3.94 in length with caudal. Eye 5.3-5.6, equal to interorbital. Mouth slightly oblique, maxilla reaching to below hind half of eye. Two pores on each side of groove containing symphysial tubercle. Preopercular margin denticulate. Anal base 3.5 times in soft dorsal base. Caudal wedge-shaped.

Colour of preserved specimens light brown. Five dark brown bars on back reaching to lower part of sides, with white interspaces as wide as bars. First bar on nape, second to fourth below dorsal, and fifth on caudal peduncle. Back, sides, dorsal and upper half of caudal with scattered brown spots. Other fins and lower half of caudal dark brown.

Two examples, 167-201 mm total length.

Not previously recorded from the New Guinea region. A new record for Papua.

FAMILY CALLIONYMIDAE

Genus *Callionymus* Linne

Callionymus japonicus var. *japonicus* Houttuyn

Callionymus japonicus Houttuyn, Ver. Holl. Maatsch. Wet. Haarlem, XX, 1782, p. 311.

D. IV, 9. A. 8. P. 19. V. I, 5.

Depth 12.0-13.5, 24.3 in length with caudal. Head 5.1-5.3, 9.7 in length with caudal. Eye 3.0-3.2, 1.0-1.4 in snout. preopercular process slender, straight, and pointed, with 10 antrorse barbs along inner border. Lateral line bifurcates on head, one branch continuing forward, the other running down the operculum. This latter branch bifurcates again, one branch bending forwards over the preopercular spine, and the other continuing to the posterior opercular edge. First dorsal spine longer than snout plus eye. Caudal very long and pointed, 1.12 times in standard length.

Colour of preserved specimen pinkish-brown above and mottled with brown spots, forming distinct rows along sides. Underside creamy, throat mauve-shaded, with a large triangular black blotch. First dorsal with a large black blotch superiorly on membrane between third and fourth spines. Second dorsal with three rows of dark spots. Anal white with submarginal brown band. Lower half of caudal dusky, upper half with transverse rows of dark spots.

One example, 225 mm total length. (One other specimen, 340 mm total length, was found in our Museum. It was trawled in the Gulf of Papua, May, 1967.)

Note.—In both specimens, the chest colouration is as that described for *Calliurichthys lineathorax* Fowler (cited in de Beaufort and Chapman 1951).

Previously unknown from Papua New Guinea, although recorded from West Irian and "south of New Guinea". A new record for Papua.

FAMILY URANOSCOPIDAE

Genus *Uranoscopus* Linne

Uranoscopus cognatus Cantor

(*Plate* V, B)

Uranoscopus cognatus Cantor, J. Asiat. Soc. Beng., XVIII, Part II, 1850, p. 1003.

D. III, 14. A. 13. P. 17. V. I, 5. L. lat. 57-62.

Depth 3.3-4.1, 4.3-5.5 in length with caudal. Head 2.5-3.1, 3.7-4.3 in length with caudal. Eye 4.8-6.4, 0.5-0.8 in snout, and 1.0-1.2 in interorbital. Four spines along preopercular margin. Humeral spine well developed. Two small tentacles before eyes. First dorsal short. Longest dorsal rays anteriorly, about as long as postorbital head length. Pectorals equal to head without snout. Body scaled, except for area on the back from nape to lateral line, extending past dorsal fin origin.

Colour of preserved specimens brownish-grey; back, sides and head reticulated with fine brown lines and spots. First dorsal black, with white patches on lower part of membrane around first dorsal spine and behind third spine. Dorsal rays with rows of dark streaks. Other fins brown, their fin edges white.

Thirteen examples, 43-140 mm total length.

Not previously recorded from the New Guinea region. A new record for Papua.

FAMILY GOBIIDAE

Genus *Oxyurichthys* Bleeker

Oxyurichthys papuensis (C.V.)

(*Plate* V, C)

Gobius papuensis Cuvier and Valenciennes, Hist. Nat. Poissons, 12, 1837, p. 106.

D. VI; I, 12. A. I, 13. P. 21. L. lat. 78. L. Tr. 19.

Depth 6.5, 9.2 in length with caudal. Head 4.0, 5.2 in length with caudal. Eye 3.5 in head, equal to snout. Maxilla reaches to below the middle of eye. 16 curved pointed teeth on each side of upper jaw. Head scaled; median crest on nape naked. Membrane of first dorsal reaches only a short distance up spines. Pectorals one, and caudal one and a half times head length.

Colour of preserved specimen faded; indications of five dark blotches along middle of sides.

One example, 109 mm total length.

Previously unknown from Papua New Guinea, although recorded from West Irian. A new record for Papua.

FAMILY PLATYCEPHALIDAE

Genus *Elates* Jordan and Seale

Elates ransonneti (Steindachner)

(*Plate* VI, A)

Platycephalus ransonneti Steindachner, Sber. Akad. Wiss. Wien, LXXIV, I. Abth., 1876, p. 209.

D. VI; 13. A. 13. P. 22. V. 1, 5. L. Lat.90.

Depth 13.6, 16 in length with caudal. Head 3.45, 4.0 in length with caudal. Eye 5.0, 2.0 in snout. Interorbital 7.0 times eye. Preopercular spine one quarter of head length, reaching pectoral base. Second spine of dorsal longest, 1.5 times body depth. First four rays of second dorsal elevated, height of rays decreasing posteriorly. Caudal forked, upper lobe longest, produced into a filament as long as caudal itself.

Colour of preserved specimen yellowish, large brown spots on sides, orange spots over head and back. Dorsals and caudal black-spotted, other fins hyaline.

One example, 164 mm total length.

Not previously recorded from the New Guinea region. A new record for Papua.

FAMILY SCORPAENIDAE

Genus *Sebastapistes* Streets

Sebastapistes amplisquamiceps (Fowler)

(*Plate* VI, B)

Scorpaena amplisquamiceps Fowler, Proc. U.S. natn. Mus., 85, 1938, p. 55.

D. XII, 9-10. A. III, 5. P. I, 9, 9. V. I, 5. Sq. l. 37. L. Tr. 5 + 9-10.

Depth 3.0, 3.8-3.9 in length with caudal. Head 2.2, 2.7-2.9 in length with caudal. Eye 3.4. Maxilla reaches to below hind border of eye. Head fairly spiny and ridged; filaments on anterior nostrils, supra-orbital spines, and on preorbital spines. Head scaled over cheeks and opercles, encroaching on interorbital space from nape. First dorsal spine nearly twice in eye, third and fourth spines longest. Anal begins opposite last dorsal spine. Scales ctenoid.

Colour of preserved specimens pinkish-brown. Pectorals, dorsal and anal with traces of dark brown.

Two examples, 46 and 78 mm total length.

Not previously recorded from the New Guinea region. A new record for Papua.

FAMILY SYNANCEIDAE

Genus *Minous* C.V.

Minous trachycephalus (Bleeker)

(*Plate* VI, C)

Aploactis trachycephalus Bleeker, Nat. Tijdschr. Ned. Indie, VII, 1854, p. 451.

D. X-XI, 12. A. 10-11. P. 11 + 1. V. I, 5. L. lat. 19-20. G.R. 2-4 + I + 9.

Depth 2.7-3.0, 3.6-3.9 in length with caudal. Head 2.4-2.6, 3.1-3.5 in length with caudal. Eye 4.0-4.4, 1.0-1.25 in snout. Deep transverse groove across nape. Spine on preopercular margin almost as long as eye. Row of eight to ten tentacles along upper edge of eye, longest in centre, becoming very small and knob-like toward the extremities. Chin with two tentacles on each side, the posterior one larger, 1.8 in eye. First spine of dorsal very small, 3.5 in second spine, which is 1.5 times eye diameter. Pectoral reaches to middle of anal. Caudal rounded.

Colour of preserved specimens cream variegated with brown. Dorsal with oblique brown bars. Caudal cream. Other fins dark brown.

Five examples, 51-90 mm total length.

Not previously recorded from the New Guinea region. A new record for Papua.

FAMILY OGCOCEPHALIDAE

***Halieutaea indica* Ann. & Jenk.**
(*Plate* VII, A)

Halieutaea indica Annandale and Jenkins, Mem. Indian Mus., III, No. I, 1910, p. 19.

D. I, 4. A. 4. P. 13.

Depth 5.0, 6.6 in length with caudal. Head 1.7, 2.2 in length with caudal. Eye 5.5, 1.0 in interorbital space. Snout in eye 2.0. Disc flat to convex in front. Roof of rostral cavity extends to edge of body disc. Maxilla extends to below hind half of eye. Dorsal origin halfway between gill opening and tail base. Anal fin originates opposite end of dorsal. Origin of ventrals slightly nearer symphysis of lower jaw than anal fin origin.

Colour of preserved specimen pinkish, with patches of reticulated brown lines on upper surface. Dorsal fin brown, others hyaline.

One example, 66 mm total length.

Previously unknown from Papua New Guinea, although recorded from near the west coast of West Irian. A new record for Papua.

***Halieutaea coccinea* Alcock**
(*Plate* VII, B)

Halieutaea coccinea Alcock, Ann. Mag. nat. Hist., (6) IV, 1889, p. 382—Descr. Cat. Indian Deep-Sea Fishes, 1899, p. 61.

D. I, 5. A. 4. P. 13.

Depth 4.5, 5.9 in length with caudal. Head 1.8, 2.3 in length with caudal. Eye 6.2, 1.1 in interorbital, and twice the snout. Rostral cavity roof does not extend to the front of the body disc; illicium can be seen from above. Maxilla reaches to below middle of eye. Dorsal origin nearer gill opening than tail base, longest dorsal ray 1.3 times eye. Longest anal ray 1.6 times eye. Ventral origin nearer lower jaw symphysis than anal fin origin. Disc convex behind eyes.

Colour of preserved specimen same as in *H. indica* Ann. & Jenk.

One example, 65 mm total length.

Not previously recorded from the New Guinea region. A new record for Papua.

Genus *Halieutaea* Valenciennes
***Halieutaea stellata* (Vahl)**
(*Plate* VII, C)

Lophius stellatus Vahl, Skr. Naturh, Kjobenh., IV, 1797, p. 214.

D. I, 4. A. 4. P. 12.

Depth 5.3, 7.0 in length with caudal. Head 1.75, 2.3 in length with caudal. Eye 6.8, a little more than interorbital space.

One example, 46 mm total length.

Previously recorded from near the west coast of New Guinea. Munro (1967) records it from the "continental shelf of New Guinea" (p. 586). Confirmation of occurrence in Papua.

FAMILY MONACANTHIDAE

Genus *Monacanthus* Cuvier, Oken
***Monacanthus choirocephalus* Bleeker**
(*Plate* VII, D)

Monacanthus choirocephalus Bleeker, Verh. batav. Genoot. Kunst. Wet., XXIV, 1852. Bijdr. kennis Balistini, p. 11, p. 19.

D. II; 28-30. A. 29-31. P. 12.

Depth 2.0-2.4, 2.4-3.0 in length with caudal. Head 2.7-3.2, 3.4-4.0 in length with caudal. Eye 2.5-3.2, 1.75-2.2 in snout. Pectoral fin equal to two thirds of snout. Caudal rounded.

Colour of preserved specimens pinkish-brown, with two oblique bands from second dorsal and caudal. Caudal with two transverse bands.

Four examples, 62-78 mm total length.

Note.—According to de Beaufort and Briggs (1962), *M. choirocephalus* is synonymous with *Paramonacanthus horae* Fraser-Brunner.

Previously unknown from Papua New Guinea, although recorded from West Irian (Munro 1967). A new record for Papua.

FAMILY ANTENNARIIDAE

Genus *Tathicarpus* Ogilby
Tathicarpus butleri Ogilby
(*Plate* VII, E)

Tathicarpus butleri Ogilby, Proc. R. Soc. Qd, XX, 1907. pp. 17-25.

D. I; I; I; 11. A. 7. P. 7. V. 5. C. 9.

Depth 1.9, 2.9 in length with caudal. Head 1.8, 2.68 in length with caudal. Eye 6.25 in head, equal to interorbital. Snout 7.3 in head. Maxilla ends opposite hind border of eye, its length 2.4 in head. Illicium long and thin, 1.4 in head, extending to midway between last dorsal spine and first dorsal ray. Second spine 1.75 in illicium; third spine 1.6 in head. Length of second dorsal base 1.3 in head. Second dorsal elevated; depressed rays reach just past caudal base. Length of anal base 3.84 in head. Depressed pectoral fin reaches caudal base. Skin densely prickled, even extending onto fin rays.

Colour of preserved specimen marbled and irregularly spotted with brown over pinkish-white background. Fins irregularly barred with dark brown. Dermal filaments brown or pale. Illicium alternately barred with brown and white. Brown lines radiate from eyes.

One example, 67 mm total length.

Not previously recorded from the New Guinea region. A new record for Papua.

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KOKI MARKET IN PORT MORESBY

A. R. McCULLOUGH*

ABSTRACT

Trading at Koki started on the beach where fishermen pulled up their canoes in order to sell their catch to townspeople. Apart from a period during the war, the Market has grown steadily. A Reserve administered by trustees was proclaimed in 1959. The powers of the Trust were increased by legislation in 1969, when the Trust was reconstituted.

The Department of Trade and Industry carried out two series of surveys of Koki Market in 1969-1970.

It was found that the quantity of produce offered for sale fluctuates considerably during the year, due largely to seasonal variations in rainfall in the areas supplying the Market.

The Kairuku and Rigo Subdistricts are the main sources of supply to the Market. There is some evidence of growing regional specialization in the production of certain commodities.

There has been very little change in prices between 1962-1963 and 1969-1970, although the availability of many commodities has increased considerably. Likewise there is little seasonal variation in prices despite marked fluctuations in the quantities available. This may be attributed to the use by sellers of collective bargaining in order to maintain prices at acceptable levels, and their willingness to leave produce unsold rather than lower prices.

Koki Market is peripheral to the market economy in that, with few exceptions, neither sellers nor producers are dependent on market sales for basic livelihood: in other words, they will not starve or suffer major inconvenience if they do not sell their produce.

Increasing monetization of the economy will probably induce the emergence of middlemen and specialized growers producing for sale at the Market. The attitudes to marketing, characteristic of the subsistence farmers who now form the majority of sellers at Koki, will then disappear.

INTRODUCTION

KOKI Market is the main selling place for indigenous produce in Port Moresby, and is also an important centre for indigenous social activity. The Market occupies most of the land known as the "Koki Market Landing Place and Recreation Reserve", on the shore of Walter Bay, about 2 miles east of the business centre of Port Moresby.

It is not possible to establish when trading first began at Koki. One of the earliest European visitors, who spent three months in Port Moresby in 1875-1876 and who described the area in some detail, made no mention of a settlement at Koki (Stone 1880). An early missionary also made no reference to a settlement there (Chalmers 1887). It seems that, prior to the coming of the white man, indigenous settlements in the area were all on the shores of what are now known as Port Moresby and Fairfax Harbours.

Seligman (1910, pp. 92-95) described pre-contact trading in the Central District but did not mention Koki as a trading centre.

He wrote:

"By far the greater part of the Koita trade (the trade of the Motu was practically the same) has been water borne by the inhabitants of the coastal villages, from Toaripi in the Papuan Gulf to Aroma in the east", but

*Department of Trade and Industry, Port Moresby

that "markets, called by the Koita 'Wotogo', Motu 'utuka' are not held at the present day and never seem to have played any important part in the Koita economy."

The Papuan Annual Reports omit any reference to trading at Koki, but this is not significant as the Reports rarely described indigenous trading activities.

Koki was considered by officers of the prewar Papuan service to be a "traditional meeting and trading place"[1] and trading has certainly been carried on at Koki Beach for many years. A reliable informant stated that when he first went to live at Koki in 1935, indigenous fishermen sometimes pulled their canoes up on the beach and sold their catch to the townspeople. This trade was discontinued during the war when the villagers from around Port Moresby were evacuated, and did not resume until about 1947 when the evacuees returned. The market was still an *ad hoc* affair, and supplies, especially of fish, were irregular, as few fishermen owned outboard motors or used imported fishing nets. It was not until 1949 that, in the words of one informant, "you could really call it a market".

In 1950, the then Minister for External Territories, Mr P. C. Spender, referred to Koki Market when he directed that "steps be taken to get rid of the unsatisfactory and dangerous waterfront area where canoes from up and down the coast traditionally anchor". It was later resolved by the Executive Council that "a sea wall be built, the area enclosed to be reclaimed, and that the area together with the small area along the beach on which coconuts are at present growing, be made into a park area for use by the public".[2]

A sea wall was built, but the work of reclamation still continues (January, 1971) and the area was not developed as a public park.

In 1951 Koki Beach was described as a "minor market where traders set up selling points, which we christened 'stalls' on the beach" (Belshaw 1952, p.26). There were usually four or five stalls, but sometimes there were only one or two and, on one occasion, 24.

In November, 1952, the Port Moresby Advisory Council appointed a subcommittee to consider and make suggestions concerning the establishment of a Municipal Market in Port Moresby. The subcommittee submitted a report in January, 1953 and recommended that any one of three sites in the town be developed as a municipal market. It also recommended that "the Government Secretary be asked to build a market site in Coconut Grove at Koki . . .".

The Administration decided that the three sites recommended by the Advisory Council were unsuitable (no reason was given) and that the Koki site should be improved. £1,500 was allocated to build one or two sheds, to install a water supply, and to improve drainage. This work was duly carried out. The Market was placed under the control of the District Commissioner in Port Moresby and an overseer was employed to supervise the market.[3]

It was then discovered that the market site was not a native reserve as had been assumed, that the land had never been purchased, and was therefore still native land.

The Administration purchased the land from the Hohodae people in June, 1955. £640 was paid for 16 acres of land comprising the foreshore at Koki and Gabutu Motu Motu Island.[4]

In October, 1956, the Hanuabada Local Government Council applied for a lease of the land in order to control the native market and canoe anchorages and for Local Government Council functions. The application was withdrawn in 1957 on the advice of the Department of Native Affairs "until the future of the Greater Port Moresby Native Local Government Council is determined".[5]

In August, 1959, following a recommendation from the District Officer in Port Moresby, the market area was proclaimed as a reserve for native business and recreation with the District Officer and Assistant District Officer as trustees. The number of trustees was increased in 1962 and 1964 when Papuans were appointed.

In July, 1968, the trustees wished to borrow $30,000 from a bank in order to improve the Market. However the reservation proclamation of 1959 did not provide acceptable security for a bank loan, and it was decided to revoke the reservation and declare a Trust by legislation.[5]

A Bill to this effect was passed by the House of Assembly in April, 1969, and new trustees were appointed. The Chairman *ex officio* is the

District Commissioner of the Central District and the other members are Mr Frank Griffin, a foreman mechanic, Mrs Stephanie Maino, a welfare assistant, Mr Dirona Abe, President of the Rigo Local Government Council, Mr Oala Oala Rarua, Member of the House of Assembly and Mr Willie Gavera, a Councillor on the Hiri Local Government Council.

In recent years the Trust has concentrated efforts on reclaiming land adjoining the Market and has considerably enlarged its area. Light shelters have been erected to protect vendors and their produce from the tropical sun. However, the Market is still badly overcrowded, especially at weekends, and there is little protection from rain or dust. Produce deteriorates rapidly, and the Market is considered by many to be unattractive, uncomfortable and unhygienic.

MARKET SURVEYS

Several surveys have been made of Koki Market. Belshaw recorded prices and quantities of commodities sold during part of 1951. Spinks organized a survey of sellers over three periods each of one week in 1962-1963 for the Department of Agriculture, Stock and Fisheries. Some of the results of his surveys are published in this paper for the first time. Epstein surveyed buyers and sellers in May, 1968, and a follow-up survey was carried out by the Department of Trade and Industry in February, 1969. The results of the follow-up survey were sent to Dr Epstein for processing.

The present surveys consisted of two series. Series A was composed of systematic samplings of sellers during the periods 20th August to 2nd September, 1969, 3rd to 16th December, 1969, and 15th to 28th April, 1970. The sampling was made each afternoon for 14 days by two groups, each usually consisting of an expatriate and a fluent speaker of police Motu, the lingua franca of most sellers at the Market. Every tenth seller was asked questions concerning his name, village, means of transport to the market, whether the goods were specially grown for selling, how he would use the money obtained from selling the goods, how he would dispose of unsold produce at the end of the day, and how long he would stay at the market. The quantities of produce offered for sale were weighed and sample bundles of each commodity weighed and prices recorded. The total quantity available during each survey of most commodities was estimated using a scale-up factor.

The second series (B) consisted of five counts of all sellers classified according to tribe and commodity sold. The counts were made each afternoon from 28th May to 10th June, from 23rd July to 5th August, 1st to 14th October, 3rd to 16th December, 1969, and 4th to 17th February, 1970. The numbers of sellers recorded during the April, 1970, sample survey were scaled-up to complete the series.

RESULTS OF THE SURVEYS

Seasonality of Supply

Table 1 records the total number of sellers of different commodities from all areas as counted in each survey of Series B. It is an indication of seasonal variations in the quantities supplied, as, within broad limits, the quantities supplied vary directly with the number of sellers of a particular commodity.

Seasonal variations in the number of sellers in the classifications "bananas", "yams", "taro", "sweet potatoes", "betel nut, peppers, etc.", and "other commodities" are shown in the following graph (*Figure* 1) which is based on *Table* 1.

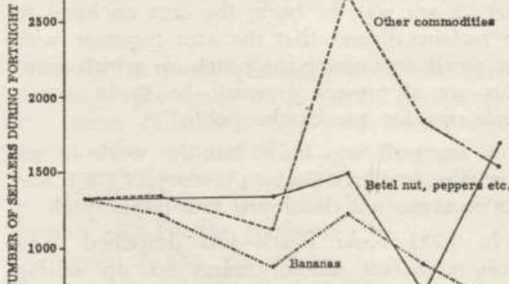


Figure 1.—Total numbers of sellers of various commodities during survey fortnights

Table 1.—**Total number of sellers of various commodities during survey fortnights**

Commodity	May 1969	July 1969	Oct. 1969	Dec. 1969	Feb. 1970	April 1970
Betel nut, peppers, etc.	1325	1323	1353	1506	712	1693
Lime	334	289	341	237	236	294
Fish and crabs	501	420	359	591	261	....
Meat	139	151	147	147	85	25
Sago	24	47	87	109	32	12
Sweet potatoes	455	245	297	395	438	516
Bananas	1328	1240	871	1234	897	637
Taro	357	501	483	460	68	98
Yams	287	549	484	90	23	37
Other	1327	1352	1127	2710	1848	1558
Total number of sellers*	3993	3876	3565	5238	2776	3569

*Many sellers sold more than one commodity and were therefore counted several times. The sum of the numbers of sellers of the different commodities is therefore not equal to the total number of sellers.

The numbers of sellers in the classification "other commodities", "fish and crabs", and "betel nut, peppers, etc.", were at a maximum in December. This may be attributed to the need for cash at Christmas, the calm seas of the doldrums before the north-west season which facilitate carriage by sea of supplies from areas lacking road access to Koki, and the peak flush of the mango and pineapple seasons.

The numbers of sellers of some starchy staples—bananas, yams and taro—declined markedly in February and April. The decline was probably caused by the low rainfall in the main supply areas 6 months before (*Table* 2). Only 226 points of rain were recorded at Kapogere in the Rigo Subdistrict and 526 points at Bereina in the Kairuku Subdistrict in the four months July to October, 1969. These two areas supply most produce to Koki Market (*Table* 3).

In contrast there was much less variation in the number of sellers of sweet potatoes. Large quantities of sweet potatoes were grown in the Sogeri and Brown River areas which were not affected by dry conditions to the same extent as Rigo and Kairuku.

Sources of Supply

Table 3 shows the sources of supply of ten of the more important products sold at Koki Market, and the changes in quantities supplied from each of the main producing areas which have occurred since 1962-1963.

The 1969-1970 surveys measured the quantities available each day in the market-place and the quantities shown in *Table* 3 may be overstated due to double counting. This is most likely for betel nut, peppers and coconuts, from Kairuku.

Subject to the reservation, *Table* 3 indicates that the quantities available at Koki increased

Table 2.—**Monthly rainfall in areas supplying Koki Market, November, 1968 to December, 1969***

Met. Station	1968		1969											
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Bereina (DASF)	25	178	830	738	263	914	138	153	22	0	453	51	826	615
Kapogere	23	1040	1011	301	547	1109	60	204	33	30	47	116	33	2610
Brown River	188	1782	682	1158	647	1509	144	790	31	63	487	409	662	704†
Itikinumu	661	2161	1687	1308	1069	1492	527	942	199	....	578	1052	1061	1357

Note.—Bereina is in the Kairuku Subdistrict, Kapogere in the Rigo Subdistrict, Brown River in the Brown-Vanapa Area of the Port Moresby Subdistrict and Itikinumu in the Sogeri Area of the Port Moresby Subdistrict.

*Source: Bureau of Meteorology, Port Moresby.

†Incomplete.

1½ times in 7 years. Of the ten commodities in the table, only the quantity of oranges declined. The greatest relative increase was in the quantity of pumpkins, which increased from 10 to 110 tons. The quantities of coconuts, yams, pineapples and betel nut also increased substantially. The availability of bananas showed a comparatively small increase of 30 per cent.

The greatest relative increase in the quantity available from any area came from Marshall Lagoon/Abau, viz., 14 to 105 tons. The greatest absolute increase came from Kairuku whilst much larger quantities were also received from the Gulf District. The use of large double-hulled dugout canoes powered by outboard motors and the availability of regular shipping services (regularly twice per week from Kairuku) have facilitated the transport of produce from these areas to Koki (see *Table* 4).

Table 3.—**Sources of supply to Koki in 1962-1963 and 1969-1970**

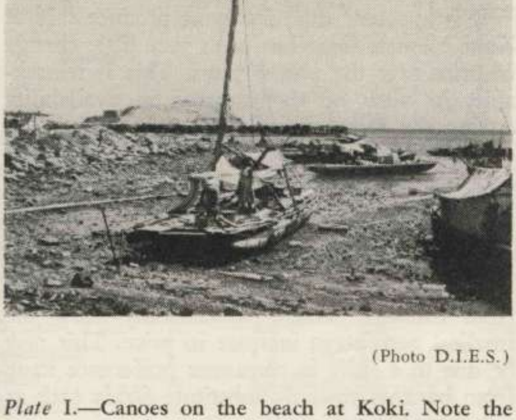
Area	Commodity (tons)											Q 1969-1970 / Q 1962-1963
	Bananas	Betel Nut	Pepper Stick	Sweet Potatoes	Coconuts	Taro	Oranges	Pineapples	Yams	Pumpkins	TOTALS	
1. Rigo												
1962-1963	226	85	36	30	12	15	1	11	5	2	423	2.4
1969-1970	459	63	29	50	137	69	0	63	72	76	1,018	
2. Kairuku												
1962-1963	162	114	14	1	17	15	12	7	4	7	354	3.4
1969-1970	140	680	110	14	155	22	6	54	27	....	1,214	
3. Gulf												
1962-1963	1	9	1	0	0	1	....	....	....	....	12	3.6
1969-1970	2	35	3	14	0	2	....	....	....	....	43	
4. Abau												
1962-1963	1	9	2	1	0	1	....	....	....	....	14	7.5
1969-1970	13	31	8	13	3	34	....	1	1	1	105	
5. Brown River, Vanapa												
1969-1970	79	4	11	62	4	19	....	3	16	17	215	
6. Sogeri												
1969-1970	16	1	2	41	0	18	....	6	1	12	97	
7. Other Port Moresby and Unclassified												
1969-1970	19	3	8	10	22	1	....	....	4	4	71	
8. Total Port Moresby (5+6+7)												
1962-1963	167	14	26	34	21	36	2	5	7	2	314	
1969-1970	114	8	21	113	26	38	0	9	21	33	383	
9. TOTAL												
1962-1963	558	231	79	66	50	68	15	23	16	11	1,117	2.5
1969-1970	728	817	171	191	321	165	6	127	121	110	2,764	
10. Q 1969-1970 / Q 1962-1963	1.3	3.5	2.2	2.9	6.4	2.4	0.4	5.5	7.6	10.0	2.5	

Note.—The 1969-1970 quantities may be overstated, particularly for betel nut, peppers and coconuts from Kairuku.
Source: 1962-1963 Unpublished survey—G. Spinks, Department of Agriculture, Stock and Fisheries 1969-1970 Survey A.

The quantity of goods available from the Port Moresby Subdistrict increased by only 20 per cent. This relatively small increase may be due to many villagers in the area engaging in wage employment in Port Moresby rather than subsistence farming. Moreover, most of the area was already provided with road access to Koki when the 1962-1963 survey was made, and consequently there has not been the same percentage increase in the period as a result of improved communications as in the outlying areas.

There is evidence of regional specialization whereby the different areas supply the commodities for which they are suited by their location in relation to the Market, and the mode and cost of transporting goods to Market. For instance, the quantity available of relatively low weight, high unit value products such as betel nut and pepper stick has increased from the Kairuku, Gulf and Abau Subdistricts, which lack road access to Koki Market, but is less from the Port Moresby and Rigo Subdistricts. On the other hand, the quantity available of a comparatively low value bulky crop such as bananas has increased from Rigo but is less from the Kairuku Subdistrict.

The changes may be attributed in part to transport costs which can be as high as 2.2 cents per lb for some sellers from the Kairuku Subdistrict using a combination of road and sea transport (Sherwin, unpublished,[6] pp. 23-26) or 6 cents per lb by air.[7] Transport costs from Rigo, on the other hand, are much lower, and are usually less than 1 cent per lb (Yeats, unpublished, p.15).[8]



(Photo D.I.E.S.)

Plate I.—Canoes on the beach at Koki. Note the canoe dwellings in the background

(Photo D.I.E.S.)

Plate II.—Sellers at Koki Market

However, the evidence is not consistent or conclusive, as increased quantities of coconuts and yams, both bulky commodities, were offered for sale by Kairuku villagers.

Means of Transport

Sellers were asked how they travelled to the Market. Their replies are summarized in *Table* 4.

Koki probably became a market place because it was a canoe anchorage where fishermen sold their catch from canoes on the beach. However, when the surveys were made, only 11 per cent of all sellers arrived at Koki by canoe, and canoes were a significant form of transport only for sellers from Marshall Lagoon/Abau and Kairuku (76 and 29 per cent respectively).

Note.—Fish sellers (many of whom arrive by canoes) were not included in the Series A surveys as fish were the subject of a survey being carried out by the Department of Agriculture, Stock and Fisheries at the same time.

Table 4.—Means of transport

Area	Boat		Canoe		Truck		Other and No Answer	
	No.	Per Cent	No.	Per Cent	No.	Per Cent	No.	Per Cent
Kairuku	166	54	89	29	38	12	17	5
Rigo	1	....	5	1	347	95	12	3
Gulf	34	87	3	8	....	....	2	5
Sogeri	....	....	....	....	66	92	6	8
Marshall Lagoon/Abau	6	18	25	76	....	....	2	6
Brown River/Vanapa	....	....	....	....	90	94	6	6
Moresby coastal	....	....	1	2	53	95	2	4
Other (including unclassified	....	....	....	....	33	33	68*	67
TOTAL	207	19	123	11	627	59	115	11

*Includes urban residents arriving on foot or by bus.

Nearly 60 per cent of sellers travelled to the Market by truck. Even from areas where canoes are available such as parts of the Rigo Subdistrict and the Moresby coastal villages, the great majority (95 per cent in both cases) arrived by truck.

The majority of sellers from the Gulf (87 per cent) and from Kairuku (54 per cent) travelled by coastal trading vessels.

WEEKLY PATTERN OF TRADING

Except during the period before Christmas, trading at the Market is usually slack from Monday to Thursday of each week. Only after 3.30 p.m., when the fishermen bring in their day's catch, and urban workers call in to buy food on their way home from work, is there much activity.

Fridays and Saturdays are the busiest times at the Market. Many sellers travel to Koki on Friday mornings and stay until Sunday afternoons or Monday mornings.

The number of sellers counted each day during the Series B surveys is shown graphically in *Figure* 2.

It is noteworthy that the number of sellers recorded was greater on the Administration pay-day (marked P) than on the "off" Friday during each survey.

The market is most crowded on Sunday mornings when many indigenes call at the Market after attending services at one of the churches in the area. These visits are largely for social reasons such as seeing their friends and relatives. Whilst at the market, the visitors often make a small purchase such as betel nut, a small bunch of peanuts or oranges.

PRICES

Table 5 shows average prices and the quantity available per fortnight during 1962-1963 (Spink's survey) and during each of the three surveys of Series A.

Table 6 is based on the data in *Tables* 3 and 5. The data in column 2 are a simple average of the prices recorded during the three surveys of Series A (*Table* 5) and the information in column 4 is derived from item 10 of *Table* 3.

Relative price and quantity changes are shown graphically in *Figure* 3.

It is apparent that, for most produce sold at Koki Market, there has been very little change in price over the past 7 years. This is remarkable, in view of the increase in availability during the same period. The total population of Port Moresby, which represents potential demand, has grown from an estimated 31,108 in December, 1962 to an estimated 54,675 in December, 1969.[9] This is an increase of 76 per cent which is less than the increase in the availability of all the items of *Table* 5, apart from bananas, which paradoxically show the smallest percentage increase in price. This may be due to a shift in consumer preference away from bananas towards substitute foods such as rice, bread and biscuits.

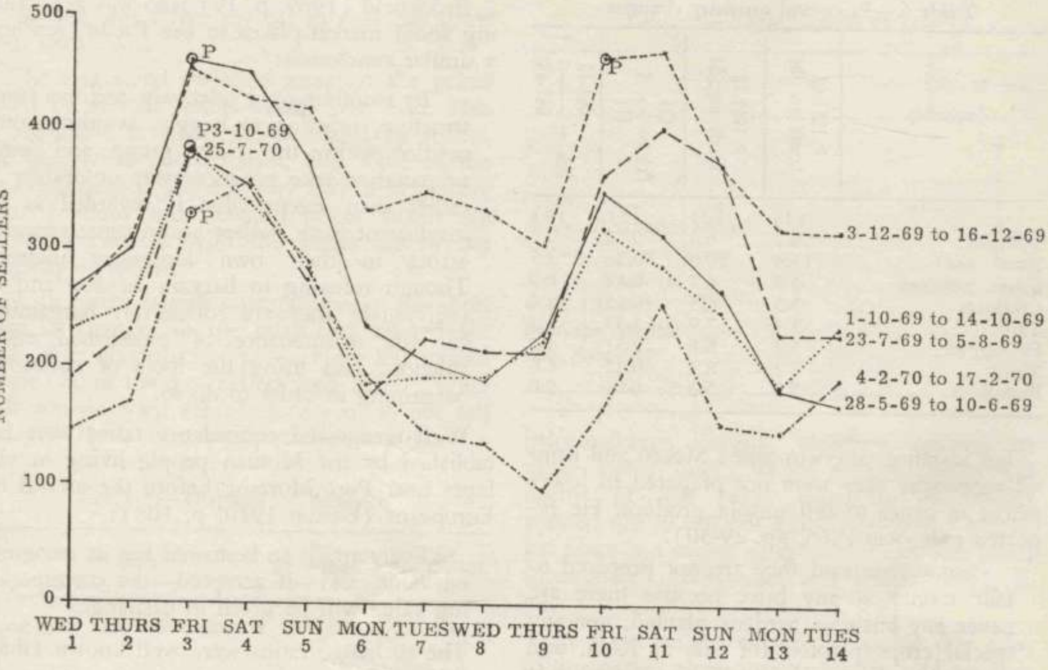


Figure 2.—Daily counts of sellers

Similarly, quite large seasonal variations in the quantities of commodities offered for sale were associated with small variations, if any, in prices (*Table* 5).

The explanation of the limited response of prices to large fluctuations in the quantities supplied is to be found in the notion of accepted or customary prices.

Table 5.—Price and quantity available of certain commodities

Commodity	1962-63		August, 1969		December, 1969		April, 1970	
	P(cents per lb)	Q(tons)	P(cents per lb)	Q(tons)	P(cents per lb)	Q(tons)	P(cents per lb)	Q(tons)
Bananas	6.2	21.5	5.9	4.2	6.0	36	7.1	7
Betel Nut	13.3	8.9	21.6	45	19.3	32	21.5	13
Manioc	4.1	0.1	4.1	1.4	4.5	0.9	5.6	1.0
Sweet Potatoes	5.9	2.6	6.6	6.4	6.3	10.0	7.2	7.2
Coconuts	5.5	1.9	7.6	8.3	5.6	28.6	5.8	4.4
Taro	3.4	2.6	8.6	8.0	6.6	7.9	8.6	1.6
Papaws	4.6	0.4	6.8	2.0	6.1	3.4	7.8	2.0
Pineapples	5.2	5.1	7.0	0.03	6.6	14.0	....	0
Yams	7.2	0.6	7.3	10.6	7.5	2.6	10.1	0.5
Pumpkins	5.0	0.4	5.0	5.7	5.2	0.5	5.7	6.1

Table 6.—Price and quantity changes

Commodity	P 1962-63 (cents per lb)	P 1969-70 (cents per lb)	Pch = (2)/(1) . 1	Qch = Q69-70/Q62-63 . 1
	(1)	(2)	(3)	(4)
Bananas	6.2	6.3	0.02	0.3
Betel nut	13.3	20.8	0.56	2.5
Sweet potatoes	5.9	6.7	0.14	1.9
Coconuts	5.5	6.3	0.15	5.4
Taro	3.4	7.9	1.33	1.4
Pineapples	5.2	6.8	0.31	4.5
Yams	7.2	8.3	0.15	6.6
Pumpkins	5.0	5.3	0.06	9.0

For instance, Sherwin asked Mekeo and Roro villagers why they were not prepared to lower prices in order to sell unsold produce. He reported (Sherwin 1965, pp. 29-30).

"Some men said they are not prepared to take money at any price because there are never any business gardens planted, nor any special crops planted for sale at Koki, and men and women take to Koki only what is surplus to their own needs. They are prepared to accept only customary prices because they rely on their gardens for food, not money; and since they have ample food, they don't eat their money. If their gardens were grown for business reasons only, they would be prepared to take variable prices.

"Probably a stronger reason why they don't vary prices is that they don't much wish to introduce price competition among themselves in the market and any consequent unpleasant forms of retaliation. By sustaining prices at a constant and reasonably high level, they consider they are better off all round."

Brookfield (1969, p. 19) who was generalizing about market-places in the Pacific, reached a similar conclusion:

"By maintaining a relatively uniform price structure, refusing to haggle, avoiding competition within the sellers' group, and being prepared to take produce away or destroy it rather than accept what is regarded as an insufficient price, sellers are in some measure acting in their own long-term interest. Though refusing to bargain *ad hoc* and as individuals, they are collectively bargaining for the maintenance of established equivalences, and using the tools of collective bargaining in order to do so."

Well recognized equivalency ratios were established by the Motuan people living in villages near Port Moresby before the arrival of Europeans (Barton 1910, p. 108):

"Every article so bestowed has its recognized value, and—if accepted—the corresponding value will be given in exchange."

The exchange ratios were well known (ibid, p. 115):

"One large 'toia' (armshell) buys one large 'gorugoru' (250-360 lb sago) or one 'asi' (dug-out canoe). One large 'uro' (clay pot) buys one 'turua' of sago (about 80 lb). Small 'uro' and 'keikei' (clay pots of different shapes) buy each a 'kokobara' (about 40 lb sago)."

Sellers at Koki continue the traditional practice of trading at established rates, and any attempt to haggle by buyers is indignantly resisted. The attitude of sellers is epitomized by the angry reply of one seller to a would-be bargainer:

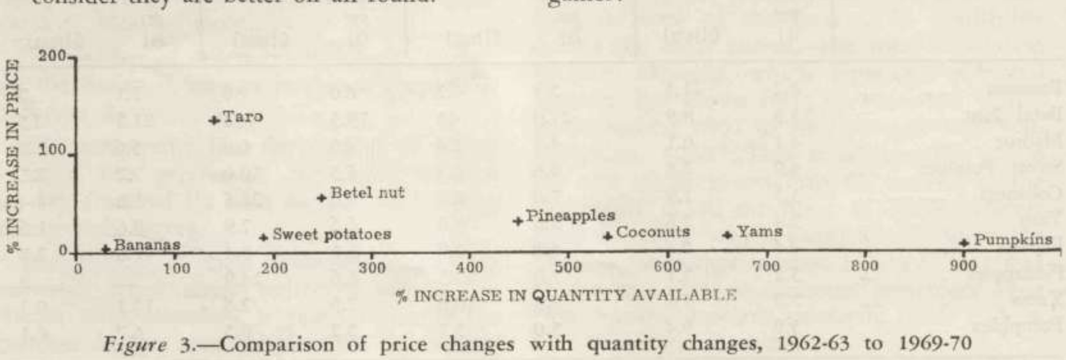


Figure 3.—Comparison of price changes with quantity changes, 1962-63 to 1969-70

"If you don't like my prices, you can grow your own food."

There is some variation amongst the prices asked by various sellers at any one time. This is inevitable as scales are not used by sellers, the quality of goods varies, and some of the less experienced are not very skilful at pricing their produce and demand prices which are quite inconsistent with the prices set by the majority of sellers.

With prices largely unresponsive in the short term to changes in the quantities offered for sale, large quantities of produce are left unsold at the end of the day. Sellers were asked "What will you do with the produce you do not sell today?" *Table* 7 summarizes their replies.

***Table* 7.—Disposal of produce**

Reply	Number	Percentage
Bring back and sell tomorrow	653	62
Eat oneself	270	26
Give away	63	6
No answer	52	5
Throw away	7	1
Sell elsewhere	3	....
TOTALS	1,048	100

Most sellers (62 per cent) said they would return on the following day to sell their produce. This is possible as Koki Market is open every day and most sellers stay for several days as is shown in *Table* 8, which sets out the modal length of stay at Koki of sellers from different areas. In addition, 298 or 26 per cent of respondents stated that they would stay at Koki for an indefinite period until their produce was sold.

Most sellers are subsistence farmers who travel to Port Moresby for social as well as economic reasons. The opportunity cost, in terms of foregone income, of selling at Koki is negligible and they do not mind if several days are occupied in selling their produce.

Price determination at Koki shows many of the characteristics noted at similar markets in sub-Saharan Africa, where "supply and demand forces are operative, but are affected by a variety of social factors which impinge on

***Table* 8.—Modal length of stay**

Area	No. of Days
Kairuku	7
Rigo	2
Sogeri	1
Marshall Lagoon/Abau	7
Vanapa/Brown River	1
Urban residents	1
Gulf District	4
Moresby coastal	1
Not classified	1

price-making: kinship, clanship, religion or other status indicators of buyers, traditional norms of just price, eagerness of market women not to sell out quickly because the market place is a source of entertainment and social intercourse" (Bohannan and Dalton 1962, p. 8).

At Koki sellers who make single day trips to the market place, usually take unsold produce back to their villages. Most produce taken to the market is produced primarily for subsistence purposes and unsold produce can easily be consumed by producers.

Here then is a form of price maintenance which derives from pre-contact times, whereby sellers act as a group in order to maintain established prices. Prices show only small response to fluctuations in the quantity supplied and in the absence of price fluctuations, demand is determined exogenously. Supply is an endogenous variable in that it is equated with the quantity demanded at established prices by sellers who limit supplies, either by returning with the same produce on the following day or by withdrawing produce from the market and consuming it in their home villages.

MOTIVATION

Sellers were asked what they would do with the money they obtained from selling the goods. Their answers are summarized in *Table 9*.

All answers were recorded. Many respondents stated that they intended to use the money for several purposes, hence the number of replies exceeds the number of respondents, i.e., is greater than 100 per cent.

Table 9.—Stated use of money 1969-70

Use	Number	Percentage of Respondents	Classification of Use
Spend on food	546	53	Consumption
Spend on clothes	376	35	Consumption
Spend at store	179	17	Probably consumption
Pay tax	153	15	Transfer
Pay fares	139	13	Marketing expense
Pay school fees	107	10	Transfer
Put in bank	64	6	Investment
No answer	56	5	....
Build house	56	5	Investment
Give to Church	50	5	Transfer
Spend on business	40	4	Investment
Buy truck	26	2	Investment
Buy outboard motor	13	1	Investment
Other uses	15	1	Various

Most sellers were motivated by the need for cash for consumption items, and only 6 per cent stated that they would save all or part of the money they obtained. Even smaller percentages advised that they would spend cash on other investment projects.

It appears that the propensity to consume of Koki sellers is high, and that few sellers are motivated by the desire to save or invest.

In the 1962-1963 survey carried out for the Department of Agriculture, Stock and Fisheries by Spinks, sellers were asked their reasons for selling. Unfortunately the data were classified on a different basis from that used during the 1969-1970 series, but an attempt has been made to compare the results of the two surveys. In *Table* 10 the percentages of *Table* 9 have been classified and modified so as to be comparable with Spink's percentages.

There has been a very marked decline in the percentage of sellers who require money in order to pay taxes. The decline is partly due to the relatively small percentage of sellers who were selling in order to pay taxes during the December, 1969, survey. This was by far the busiest period when over 45 per cent of the total sample in the 1969-1970 series was taken.

Table 10.—Comparison of stated use of money—1962-1963 and 1969-1970

Use	Percentage	
	1962-63(1)	1969-70(2)
Tax	39	14
Equipment(3)	8	7
Food and clothing	22	49
Education and social(4)	13	14
Savings	4	6
Loans and business(5)	5	4
Other(6)	2	1
No answer	7	5
TOTAL	100	100

(1) Where more than one use was given, the first was used in the Table.

(2) Percentages in this category are not precise.

(3) Includes housing, building materials, outboard motors, repairs, radios, shotguns.

(4) Church and club funds included. In the Port Moresby Subdistrict sales of small quantities of coconuts by school children were included in the 1962-1963 percentage.

(5) Repayment of loans, co-operative shares, trade stores and goods for trade stores.

(6) Includes feasts, sing-sings, bride prices, gifts, etc.

(Photo D.I.E.S.)

Plate III.—A seller from the Mekeo selling betel nut. Of the four people in the picture, only one is actually offering produce for sale

Moreover, from two groups of sellers which together made up over 10 per cent of the sample in the 1969-1970 series, only one respondent said he wanted money to pay taxes. These two groups were the highland labourers working at Sogeri, and urban residents who mostly sell powdered lime.

Changes in the timing of the surveys and in the numbers of sellers who are liable to pay taxes account for some of the decline. Nevertheless, it is apparent that although the need for money to pay taxes has grown in absolute terms, it is less significant as a proportion of total cash requirements. The desire for money to buy food and clothing became much more significant between 1962-1963 and 1969-1970. There is evidence of greater familiarity with and acceptance of non-traditional foods such as tinned fish and meat, and bread, sugar and rice, together with reduced dependence on subsistence foodstuffs and traditional clothing.

There was little change in the percentages of sellers motivated by the desire to save or to operate a business between 1962-1963 and 1969-1970.

Sellers were asked, "Are the goods bought especially grown for selling?" The answers to this question were most unsatisfactory in spite of the use of well-educated Motu speakers as interviewers, and it was apparent that many sellers were not able to give an unequivocal answer to the question. Most sellers planted their gardens for subsistence purposes and sold the surplus at the market place and consequently sold a heterogeneous assortment of produce, typical of the assortment of fruit and vegetables growing in a Papuan subsistence garden. Only the Kairuku villagers, who are subject to the constraint of high freight rates, and the Hula fishermen living near Port Moresby who are not subsistence farmers and who produce and sell in order to buy food, sold a comparatively narrow range of goods. Some sellers stated definitely that they were selling produce especially planted to sell at the market, but these were a minority.

Ward (1970, pp. 42-3) found a similar attitude to planting produce for sale amongst Rigo villagers:

"Field inquiries failed to show that any particular garden was planted primarily to sell its produce. Villagers appeared to be planting gardens a little larger than they might have done before the road (i.e., the Rigo road) was built, with the dual purpose of meeting the family's subsistence needs and of selling any surplus produce for cash in Port Moresby. Questions regarding the proportion of crops sold rather than consumed drew a wide range of replies. Some villagers estimated that they sold up to three-quarters of the bananas they produced, while other crops were grown largely for consumption at ceremonies and not sold at all. The only valid generalization seems to be that if there is a surplus which would otherwise waste, or if there is a felt need for cash, an effort will be made to market the produce."

Lack of commitment to the market economy is also shown in *Table* 11 wherein answers to the question "How often do you come to the market?" are summarized. Eighty-six per cent of sellers visit the market at irregular intervals. Only 10 per cent visit the market regularly.

***Table* 11.—Frequency of visits to Koki Market**

Frequency	No.	Percentage
Every day	47	5
Every week	55	5
Most weeks	76	7
Sometimes	817	79
No answer	45	4
TOTAL	1,040	100

INFLUENCE OF TRADITION

As well as relatively inflexible prices, trading at Koki Market exhibits other characteristics which survive from trading practices of prehistoric society. These include the practice of selling food in bundles rather than by weight, and the custom whereby sellers from a village or a tribe sit or squat in lines in a particular part of the market, as shown in the map (*Figure* 4).

At Koki the customary location in the market place of sellers from each area is consistent with the location of their home villages in relation to Port Moresby. Thus sellers from Rigo, Marshall Lagoon and Abau which are to the south-east of Port Moresby, occupy the eastern part of the Market, sellers from Kairuku and the Gulf which are to the north-west of Port Moresby occupy the western part, and sellers from Vanapa, Brown River, Sogeri and Efogi which are to the north-east, occupy the northern part. Even "foreigners", such as

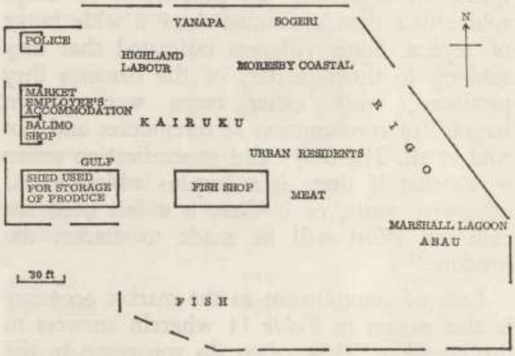


Figure 4.—Koki Market as at 30th September, 1970

labourers from the Highlands employed on the rubber plantations at Sogeri, usually sell in the northern part of the Market during their weekend visits.

AGENTS

No evidence of agents purchasing produce from village growers and selling at the market was found during the surveys. Some vendors act as agents by selling produce on behalf of friends or relatives in the village or by selling the remaining produce of a friend who has returned home rather than wait and sell all his produce himself. Some vendors, especially those from the Mekeo, which lacks regular road access to Port Moresby, sell on behalf of a village group and later return to the village to share the money with their fellow villagers. Some produce is sent to Koki by villagers and sold by a dependant who uses the money for his own maintenance. Sometimes money which is left over is sent to the supplier in the village, but respondents were vague about this and it appeared that suppliers often received no cash return for their produce.

As a rule producers prefer to market their own goods, and selling by agents is conducted in a casual, *ad hoc* way.

CONCLUSION

Trading practices at Koki Market show many characteristics which derive from pre-contact exchanges. The market belongs to a stage of development "in which market places exist and the market principle operates, but only peripherally; that is to say, the subsistence requirements of the members of the society are not acquired, to any appreciable extent, in the market place or through operations of the market principles. As in marketless societies, the test is a simple one: land and labour are not transacted by the market principle, and if the market—in either sense—were to disappear from such a society, inconvenience would result but no major hardship would necessarily follow because the basic necessities of life are acquired otherwise than by transactions in the market. Neither sellers nor producers depend on market sale for basic livelihood." (Bohannan and Dalton 1962, p. 2.)

Whilst the prices of goods sold at Koki are, to some extent, subject to the constraints of supply and demand, most sellers belong to a village society which meets the main criterion outlined by Bohannan and Dalton: viz., land and labour are not transacted by the market principle. Koki Market is peripheral to the market economy in this sense and also in that no major hardship would result if the market disappeared and it is paradoxical that such a market operates in a town where the market principle is dominant.

But the resolution of the paradox is simple: although the market-place is located in a modern town, most sellers live in villages outside the town and the majority, with some exceptions, are not farmers producing especially for sale. Koki Market is thus an enclave of subsistence society in a modern town. However, it is changing and will continue to change in the same way that similar markets in other countries have changed as rural communities replaced subsistence farming with cash cropping. The higher expectations of the younger generation leading to an increasing need for money and accompanied by the erosion of the system of reciprocal obligations, will accelerate the rate of change.

More farmers who produce especially for sale will emerge, together with middlemen to carry out marketing in place of producers. Both farmers and middlemen will be more dependent on the market due to the division of labour and resultant specialization, and their operations will be subject to the market principle. Concurrently, the factors of production—land and labour—will be allocated by price considerations to a much greater extent than at present. The pressure of economic necessity—of being compelled to earn a return in order to pay for the factors employed in producing the goods brought to the Market—will breach the solid front of collective bargaining and prices will react to fluctuations in supply and demand. The influence of tradition in the market will be greatly reduced.

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