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COVER ILLUSTRATION by Kumar & Kaumana: A scelionid parasitoid wasp ovipositing in pentatomid pest eggs.

FOREWORD

Due to financial and staffing constraints the PNG Journal of Agriculture, Forestry and Fisheries is appearing after a lapse of two years. The present issue is however, a bold attempt to break away from the past. The entire production of the journal has, for the first time, been carried out in Papua New Guinea. The staff of the DAL Publications Unit, some though still learning, have acquitted themselves commendably in this venture. While we have tried for the better, we seek your understanding for any shortcomings as ideal often conflicts with the best.

A number of people have helped us in this undertaking. Mr Philip Pondiku and Mr Sam Lahis have had the vision and faith in our capabilities to entrust us the job of revitalising the journal. Mr Hilarion Eral and Mr Joseph Kaptigau have continued to encourage us in various ways. Dr Arnold Ningiga tried hard and arranged the much needed initial funding to kick-start the journal.

Ms Betty Aiga carried out the typing; Mr Jackson Kaumana assisted with design and layout while Mr Rupa Raraimo handled the production schedules. We were most fortunate in receiving generous assistance from a number of reviewers. We would especially wish to thank the following colleagues for the time and expertise they have willingly given to the journal:

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The responsibility for published opinions, and facts presented, however, rests entirely with the author(s) of each contribution.

HOHOLA, 1993 **R. KUMAR**

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CONTENTS

BANANA PRODUCTION BY KUBO PEOPLE OF THE INTERIOR LOWLANDS OF PAPUA NEW GUINEA

Peter D. Dwyer[1] and Monica Minnegal[2]

ABSTRACT

A 15 month study of subsistence agriculture was undertaken at the small Kubo community of Gwaimasi, on the Strickland River, NNW of Nomad, Western Province, Papua New Guinea. Bananas and flour from sago palms were the primary carbohydrate foods of the people. The former were grown at small gardens cut into 15-20 year old secondary forest on river- or stream-side levee banks. Planting density was 1382 plants/hectare. Preparatory work (clearing, collection and transport of suckers, planting and felling trees) occupied 850-900 person-hours/hectare. The gardens were not fenced and 42 percent of the work was in collection and transport of suckers. Males did somewhat more work than females. Bananas were available for eating between 8 and 20 months after planting and the yield was 1313 bunches/hectare (4494 kg edible/hectare). At Gwaimasi village, with a monthly average of 25 residents through a 14 month period, banana production was sufficient to provide at least 50 percent of people's energy needs. Production was variable in time with people shifting between virtual independence of, and full dependence on, bananas. There is no evidence that these shifts were seasonally determined.

Key words: Subsistence agriculture; bananas; tropical lowlands; Kubo; Papua New Guinea

INTRODUCTION

Among the cultivated plant species of Papua New Guinea, McArthur (1972) ranked bananas fourth, after sweet potato, taro and yams, in terms of annual production. Walters (1963; in King *et al.* 1989) considered that the area under bananas was second only to sweet potato and that, nationally, the crop yielded 1 kg/person per day. In the lowlands, bananas are recognised as a primary carbohydrate food in areas where annual rainfall is 1000-2500 mm and a pronounced dry season occurs (Lea 1972; McArthur 1972); they can be also important where annual rainfall is 4000-8000 mm (M. Bourke personal communication).

There have been few studies of the ecology of banana subsistence within Papua New Guinea. The most detailed recent work concerns the Amele (Madang Province) and Vanapa River-Kabadi (Central Province) areas though, in both these cases, banana production was tied to local market economies (King *et al.* 1989).

In the interior lowlands of the Western Province bananas have been reported as the major carbohydrate food of Betamuni, Gebusi and Samo people (Knauft 1985; Beek 1987; Shaw 1990). In this paper we describe the ecology of banana production by Kubo people whose territory lies to the north and northwest of these three groups (Dwyer *et al.* in press). In 1986-87, Kubo subsistence practices were not influenced by market economies. We report areas under cultivation, planting regimes, work associated with banana gardening and yield

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patterns and estimate that bananas provided at least half the energy needs of the people.

ENVIRONMENT AND SUBSISTENCE

The Kubo village of Gwaimasi was on the west bank of the Strickland River, 48 km NNW from the District Headquarters at Nomad, Western Province, at an altitude of about 80 m (lat. 5°54'S, 142°6'E). We lived at Gwaimasi from August 1986 to November 1987 and had visited the area in late January 1986. The village was established in February 1986. Thirtyone individuals were classed as residents during all or part of the 450 days we lived at Gwaimasi, with from 24 to 26 residents in any month. Thirteen males older than 14 years accounted for 4782 person-days of residency, 10 females older than 12 years for 3688 person-days, four children between three and 11 years (two males and two females) for 1800 person-days and four nursing infants (three males and one female) for 934 person-days. With nursing infants excluded these values are equivalent to 22.8 full-time residents (i.e. 10270/450) of whom 18.8 are classed as people who worked in gardens.

To satisfy subsistence needs the people used an area of about 50 km^2. This area included forested foothills to the north and east, extensive backswamps to the south and west and levee banks either side of the Strickland River and along major streams. Rainfall was high with 6580 mm recorded from September 1986 to October 1987 and monthly totals varying from 306 to 776 mm (Table 1). Lower rainfall and, particularly, longer runs of days without rain may be usual from September to November though year to year variation is probably high. Monthly mean minimum temperatures varied from 22.6 to 24.0°C and monthly mean maxima from 29.0 to 33.1°C (Table 1). The decline in mean maxima from February to July corresponded to increasing spells of day-long cloud cover and drizzling rain.

Carbohydrate staples were bananas and sago flour, the latter from both wild and planted palms *(Metroxylon sagu)*. Primary protein foods were wild pigs, cassowaries and many fish though other animals, including insect larvae reared in felled sago palms, were also important (Dwyer and Minnegal 1991). Some domestic pigs were kept

Table 1. **Rainfall and temperature records from Gwaimasi village (lat.5°54'S, 142°6'E), Western Province, September 1986 to October 1987.**

	Months													
	S	O	N	D	J	F	M	A	M	J	J	A	S	O
Rainfall														
mm	343	329	343	371	776	523	707	635	346	512	306	437	586	366
Temperature (°C)														
min	23.3	23.7	23.4	23.2	23.5	23.2	23.7	23.6	23.7	23.7	22.6	22.9	23.5	24.0
max	33.1	33.0	32.7	33.1	32.1	32.6	32.3	32.1	31.5	30.1	29.0	29.4	31.1	33.0

(maximum population = 13) but these were usually killed and eaten on special occasions only.

Gardens were made on levee banks, usually near the river, sometimes adjoining major streams and, occasionally (one of 39 gardens), on minor rises within the backswamps. Bananas were the dominant crop in larger gardens where they were usually interspersed, at varying densities, with taro *(Colocasia esculenta)*, highland pitpit *(Setaria palmifolia)*, aibika *(Abelmoschus manihot)*, occasional pineapples *(Ananas comosus)* and new plantings of *Pandanus conoideus*, *Terminalia* and *Artocarpus altilis* (breadfruit). Saplings of *tulip (Gnetum gnemon)* were often left to supply leaves. Most sugar cane, lowland pitpit *(Saccharum edule)* and cassava were planted near the perimeter of banana gardens. In some parts of the gardens, tubers (taro, yams and sweet potato) and a mix of greens, beans and corn were concentrated and there were other small gardens where these crops predominated and bananas were few. Kubo people named 40 varieties of banana plants, all of which appeared to be diploids and some of which were very recent introductions. The collective name for bananas was *e*.

TECHNIQUES

The areas of all gardens that yielded bananas during the time we lived at Gwainasi, and of all gardens made in this period, were measured using compass and tape. Perimeter zones, from 5-20 m wide, where trees were felled but crops were not planted, were excluded. Mapping was done, where possible, about one month after trees were felled; this facilitated movement around the garden. Nine of the gardens were planted and felled before August 1986; we saw two of these in January 1986 soon after they had been felled and estimated planting times at the others. Gardens are identified consecutively from Garden 1 planted in about January 1985 to Garden 39 planted in November 1987. Garden 9 comprised the area under crops at the village itself; this area altered in size and precise location through time as different families and individuals harvested or planted crops.

Gardens were classed as banana or tuber gardens on the basis of predominant crops. (Two very small non-banana gardens included tubers but were, in fact, dominated by lowland pitpit.) Banana plants were counted at seven plots, amounting to 1.97 ha, within three banana gardens. These counts were made three to four months after planting. Thus, estimates of planting density ignore very early losses but attempts to count bananas soon after planting led to serious underestimation. The numbers of primary (or initial) plants per 100 m^2 were 5.54 (0.23 ha), 12.21 (0.25 ha), 13.18 (0.32 ha), 14.32 (0.74 ha), 15.86 (0.14 ha), 19.26 (0.25 ha) and 28.29 (0.04 ha) with an overall mean of 13.82 plants/100 m^2. The total of 2723 banana plants in these samples included 120 with multiple stems, increasing the total number of stems to 2858. The value of 13.82 plants/100m^2 was used to estimate the numbers of banana plants at other banana gardens; we are satisfied that the extreme values of density were exceptional. At tuber gardens all banana plants were counted.

Productivity data were obtained from eight gardens that were selected to represent different times of planting. At Garden 10 all 35 banana plants were monitored at each census. At other gardens, depending on size, details were recorded from between one and three 30 m transects. All banana plants within 2 m of the transect were included. We recorded diameter of primary stems 50 cm above ground, presence or absence of suckers and the condition of the plant (non-productive, flowering, early or late set, medium or advanced fruit, harvested, or lost through death or collapse). The stem of harvested plants was routinely cut and withered and rotted quite rapidly. At advanced gardens where weeds were well developed, plants that had been harvested months before were detected only on the basis of developing suckers; in a few cases

we may have misinterpreted collapsed plants as being harvested.

We estimated labour input in two ways; as hours and as days per unit area. The former included rest periods and travel time on land but excluded travel time on water unless this entailed transport of banana suckers. Movement by dugout canoes to garden sites on the east bank of the Strickland River usually required that the canoe was first bailed and, when travelling upstream, necessitated an arduous haul along the bank against the current. Although the times recorded were all related to gardening they will overestimate actual hours of physical effort. Estimates of effort expressed as days/unit area take six or more hours (travel, work and rest included) as a full day, 4-6 hours as 0.75 days, 2-4 hours as 0.5 days and less than two hours as 0.25 days. Thus, these estimates index times when no other major activity could be undertaken and, in the Kubo context, may index effort more usefully than estimates of actual hours worked. In both sorts of estimates contributions from children less than 11 years old were ignored although very young children were encouraged to acquire skills, older children were expected to assist and young married females (perhaps 12 years of age) worked as adults did.

Table 2 records the distribution of hands of bananas/bunch and of fingers/hand from 58 bunches. Fortyseven of the bunches were sampled at gardens where we obtained productivity data. The criteria for selection were that the plant carrying the bunch was included within a transect, that the fruit were judged to be medium or advanced relative to expected harvesting time, and that the top of the bunch could be reached by hand; this last was usually accomplished by climbing logs that were strewn through the garden. Terminal hands without viable fingers (n = 18 bunches) or with a maximum of two viable fingers (n = 5 bunches) were excluded. The data show much variation in bunch characteristics. The average number of edible fingers/bunch was 49.6 (s = ± 22.3) for the 47 bunches sampled during standard productivity censuses; this value is used in later calculations.

Table 2. **The composition of banana bunches.**

Hands per bunch	Number of bunches	Fingers per hand	
		$\bar{x}$	±s
1	2	10.00	-
2	2	6.50	4.95
3	4	8.42	1.77
4	20	9.28	1.47
5	18	10.62	2.92
6	8	12.11	2.18
7	4	11.71	3.33

Table 3. **Weight (per finger) and proportion edible of 11 varieties of bananas.**

Variety	Type[a]	Sample[b]	Stem[c]	n	Total weight g	±s	Edible weight g	±s	Prop. edible	±s
ma	CS	A	P	18	42.1	18.3	29.8	13.4	0.71	0.03
		B	P	4	52.3	3.6	34.0	2.7	0.65	0.02
oiya	S	A	P	8	49.2	3.2	41.4	2.2	0.84	0.01
		B	P	12	54.4	3.7	45.5	2.7	0.84	0.02
		C	A	4	62.3	4.7	51.5	4.4	0.83	0.02
tisa	CS	A	P	14	48.3	12.3	34.4	7.8	0.72	0.04
		B	P	9	55.8	13.5	39.3	9.6	0.70	0.04
		mixed	P	15	74.2	24.9	53.7	19.7	0.71	0.06
mugua	CS	A	P	4	77.3	6.9	61.3	5.6	0.79	0.02
sosoi	CS	A	P	35	76.1	16.0	57.0	13.4	0.75	0.04
		B	P	8	92.1	7.4	69.9	4.6	0.76	0.04
		C	A	5	139.0	12.6	106.0	7.0	0.77	0.06
		C	P	6	139.8	13.5	104.3	10.0	0.75	0.05
gisio	CS	A	P	6	93.7	28.2	67.0	22.6	0.71	0.03
maiabu	CS	A	P	29	108.5	10.5	77.1	8.1	0.71	0.04
yimo e	CS	A	P	6	122.3	12.3	67.0	7.2	0.55	0.06
kogwai e	CS	A	P	8	127.9	10.3	80.9	7.0	0.63	0.01
tuguwa	CS	A	P	4	194.8	12.9	121.3	7.3	0.62	0.02
		mixed	P	15	195.5	38.7	137.1	27.9	0.69	0.03
		mixed	A	11	200.0	25.8	145.1	21.8	0.72	0.04
		B	P	10	227.4	18.7	154.6	10.9	0.68	0.02
saviti gwage	S	early	P	6	224.2	22.4	153.9	11.0	0.69	0.02
		late	P	5	200.2	16.2	149.3	11.4	0.75	0.01

a. C = cooking banana; S = sweet banana.

b. A, B and C denote seperate bunches, 'mixed' refers to a sample taken from more than one bunch and 'early' and 'late refer to samples taken from the same bunch at different stages of ripening.

c. P = stem of finger present; A = stem of finger absent.

Banana fingers were seldom badly damaged. Of 2362 potentially viable fingers on the 47 bunches referred to above only six were diseased and another 25 had been eaten by rats; our estimates of production accept this level of loss (0.01%). One exceptional case of damage is not included in the estimates of production. At two adjoining plots of Garden 16, 25 percent of potentially viable fingers (n = 425) from 11 bunches had been lost to disease or rats with most of the damage being to four bunches. The record was obtained late in the seventh month after planting. People said that the losses occurred because the garden had not been weeded. We did not see and were never told of damage caused by fruit bats *(Pteropus* and *Dobsonia* species) and presume this reflects the fact that most bananas were harvested for cooking while green and starchy rather than sugary. Fruit bats are recognised as major pests of bananas in other parts of Papua New Guinea and, in some areas, traps are made (e.g. Beek 1987) or ripening bunches are covered to reduce damage (Dwyer, personal observations; King *et al.* 1989).

Major differences in the energy content of bananas have been reported in the literature. King *et al.* (1989) obtained values of 137-180 kcal/100 g edible weight from 10 banana varieties from Madang Province, Papua New Guinea (overall mean 152 kcal/100 g edible). They compared their estimates with eight literature reports that varied from 87 to 128 kcal/100 g edible. An important component of this variation, though not noted by these workers, arises from changes during ripening. Osmotic effects cause water to move from the skin and stem of a banana finger into the pith (von Loesecke 1950). Von Loesecke reported that the edible proportion could increase from 0.62 to 0.74 during 26 days of cool storage from time of harvesting. In parallel with this increase the energy content, when standardized against weight, will decrease. King *et al.* (1989) purchased bananas at local markets and prepared fingers for analysis by peeling with a sharp knife. The bananas were unlikely to have been ripe. Combining von Loesecke's data with that of King *et al.* suggests that a banana finger that increased from 0.62 to 0.74 in edible proportion would drop from 152 to 127 kcal/100 g edible portion.

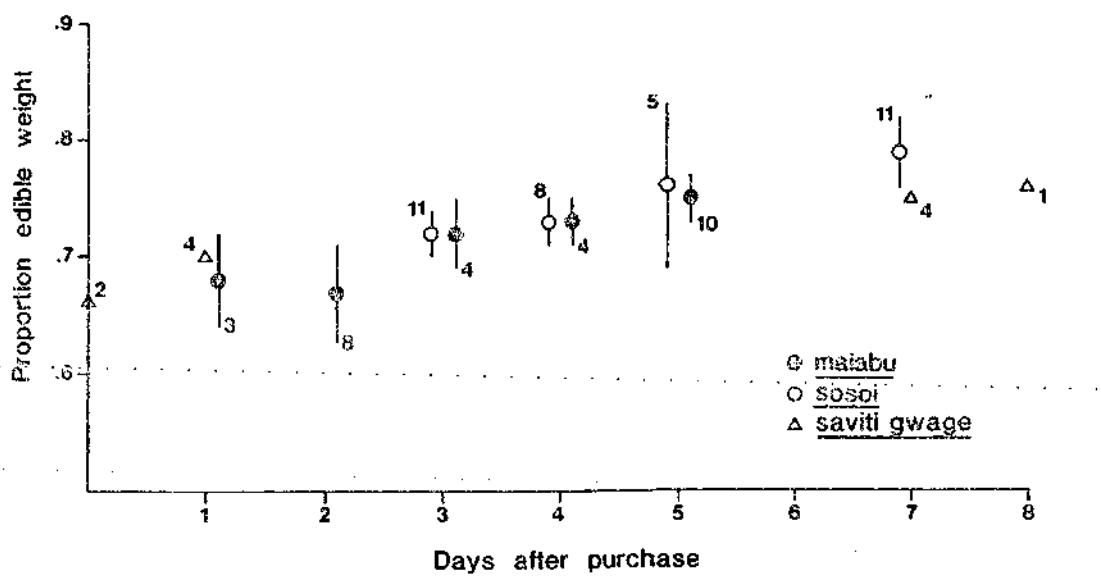

Figure 1. **Changes in the ratio of edible weight to total weight during ripening for fingers of three varieties of bananas.**

Table 3 summarizes data concerning total weight, edible weight and edible proportion of 244 fingers from 11 different Kubo varieties of bananas. These data were obtained from bananas that we purchased to eat. There is much variation in both weight and edible proportion. Edible proportions varied from 0.55 for the variety *yimo e* to 0.84 for the thin-skinned, sweet variety *oiya*. Data from two hands of the one bunch of *saviti gwage* (only one plant at Gwaimasi) and from single bunches of each of the varieties *sosoi* and *maiabu* showed substantial increases in edible proportion through time (Figure 1). Because we favoured ripe bananas and tended to be sold ripening fruit it is necessary to adjust for our behaviour before assigning energy ratings to bananas.

Based on the moisture-laden weight of 75.9 g edible/banana finger (Table 3) we use the range of 100-125 kcal/100 g edible for bananas at the time we ate them. The lower value is probably conservative, the upper value matches our reading of the estimate of King *et al.* (1989). Kubo people ate most bananas after cooking them when the fruit were not ripe and, therefore, before much starch was converted to sugars (cf. von Loesecke 1950). Figure 1 suggests a 10 per cent increment in edible proportion of a banana after five or six days in our larder. Using this value the average weight of a banana as eaten by Kubo would have approximated 69 g and the equivalent range of energy values would be 110-137.5 kcal/100 g edible. Von Loesecke (1950) reported values for total carbohydrate in the edible portion of five banana varieties between 21.51 and 33.02 percent. The highest value was from plantain and is equivalent to a minimum energy value of 130 kcal/100 g.

AREA AND NUMBER OF BANANAS PLANTED

Areas planted in crops are shown in Table 4 for each month from January 1986 to November 1987. Banana and tuber gardens are separated and estimates of the numbers of bananas planted are provided. We left Gwaimasi on November 18, 1987. The values for this month are from one garden where clearing but not planting was completed. Because preliminary clearing is time consuming, it is unlikely that more bananas were planted at new gardens in November.

In 23 months 6.98 ha were planted, 4.87 ha as banana gardens and 2.11 ha as tuber gardens. This is equivalent to 0.16 ha per full-time resident per year, 0.11 ha as banana gardens and 0.05 ha as tuber gardens (nursing infants excluded from the tally of residents). For banana gardens differences between years appear pronounced (0.14 ha and 0.08 ha per resident/year in 1986 and 1987 respectively, though the value from 1987 is based on records from only 11 months).

The 411 banana plants scattered through, or clustered within, tuber gardens would have occupied 0.30 ha if planted at conventional densities. Thus, the total commitment to bananas across 23 months was 7204 plants occupying an equivalent of 5.17 ha (316 plants and 0.23 ha per resident). Sixty percent of the bananas were planted in 1986. The pooled data from 1986 and 1987 reveal that 85 percent of bananas were planted in the months December to March and August.

The mean sizes of garden plots held by individuals or families, and of sets of contiguous plots that were made more or less synchronously, are given in Table 5. Average sizes were greater for banana than for tuber gardens; 2.86 times greater where comparison is based on plots and 4.44 times greater where comparison is based on entire gardens.

WORK AT BANANA GARDENS

The sequence of tasks at banana gardens was *(a)* initial clearing of undergrowth and small saplings, *(b)* collection of suckers from older gardens and their transport to the new site, *(c)* planting, *(d)* tree

Table 4. **Gardens areas (ha) and numbers of bananas planted from January 1986 to November 1987.**

Month	1986				1987			
	Banana garden		Tuber gardens		Banana gardens		Tuber gardens	
	ha	bananas	ha	bananas	ha	bananas	ha	bananas
Jan.	0.74	1021	-	-	-	-	0.05	2
Feb.	0.52[a]	722	-	-	0.62	992	-	-
Mar.	-	-	0.30[b]	34	0.51	736	0.07	26
Apr.	-	-	0.10[b]	17	-	-	0.29	181
May	-	-	-	-	-	-	0.29	52
June	-	-	0.21	35	-	-	0.09	50
July	-	-	-	-	0.18	242	0.10	-
Aug.	0.83	1253	0.08	-	0.28	387	0.02	-
Sept.	-	-	-	-	-	-	0.18	6
Oct.	0.19	263	0.19	6	-	-	-	-
Nov.	-	-	-	-	0.16	221	-	-
Dec.	0.84	956	0.14	2	no data	no data	no data	no data
Totals	3.12	4215	1.02	94	1.75	2578	1.09	317

a. Data from February 1986 exclude 0.30 ha and 419 bananas planted by a family that did not take up residence at Gwaimasi.

b. These areas were the first garden plots established at the village itself. Between August and October 1986 an additional 0.13 ha was planted but no bananas were included. Between November 1986 and November 1987 another 0.06 ha was cleared and planted and about one-third of the area that had been used earlier was replanted; again, no bananas were included. Areas used after mid-1988 are not included in the table; they are equivalent to approximately 0.30 ha of non-banana garden.

Table 5. **The sizes of gardens.**

	Banana gardens	Tuber gardens
Plots held by nuclear families and independent individuals:		
sample	23	16[a]
mean area (ha ±s)	0.20 ± 0.12	0.07 ± 0.05
range (ha)	0.03 - 0.52	0.01 - 0.21
Contiguous plots (pooled areas):		
sample	13	20
mean area (ha ±s)	0.40 ± 0.32	0.09 ± 0.06
range (ha)	0.07 - 1.13	0.01 - 0.21

a. **There were several cases where individual plots within tuber gardens were not identified; thus, sample size here is lower than for the pooled areas from contiguous plots.**

felling, *(e)* weeding and *(f)* harvesting and transport of the crop. Fences were not usually made at banana gardens; the only exceptions were two gardens that included yams and were contiguous with a tuber plot. Only once were banana plants damaged by pigs; this occurred when a domestic sow destroyed 20 of 25 bananas planted near a small house in the forest.

Estimates of labour input for all tasks except fencing and harvesting are summarized in Table 6. Both sets of values - hours and days per hectare - show that much effort was required in garden preparation. From 850 to 900 person-hours or, as opportunity costs, 110 to 120 person-days were occupied in clearing, obtaining and transporting suckers, planting and felling one hectare of garden. These values are equivalent to 120-130 hours or 15.5-17.0 days per worker allocated to the preparation of banana gardens in 12 months (based on 5.17 ha in 23 months and an equivalent of 19 full-time workers).

Clearing and planting occupied about one third of the time allocated to preparation of banana gardens; collection and transport of suckers and felling of trees occupied about two thirds. Clearing entailed fairly thorough removal of undergrowth and slashing of saplings. Most of the work was with machetes and, during this phase, some trees were felled, especially at the garden perimeter beyond the zone of planting. Sucker collection and transport was the most arduous preparatory task. Suckers were dug from gardens that had been planted a minimum of 10 months earlier (usually 12 or more months earlier) where weeds and regrowth might be tall and dense. They were prepared by paring the corm and cutting across the stem to leave a portion 8-12 cm in diameter and 20-30 cm long. Average weight was near one kilogram. A few suckers with intact leaves were nearly always included among those that were planted. Suckers were carried by foot or by canoe to the cleared garden site. Distances varied from a few hundred metres to more than 4 km with most suckers for larger gardens carried more than 1 km. Distances travelled to service one set of contiguous plots where 1727 bananas were planted summed to 89 km by foot unladen, 63 km by foot laden and 28 km by canoe. Use of canoes either on the river or by haulage in streams greatly reduced the work. Very

Table 6. **Labour inputs at banana gardens.**

Task	Sample no. of plots	ha.	Days/ha[a]	Sample no. of plots	ha.	Hours/ha[a]
Clearing	1	0.17	23.5	1	0.17	155.9
Suckers	3	1.47	40.6-41.7	2	0.34	374.0
Planting	3	0.45	18.3	3	0.45	106.6
Tree felling	6	1.05	34.5-35.5	6	1.05	229.9-238.2
All preparatory tasks[b]	3	1.47	110.8-119.0	1	0.17	851.9-902.9
Weeding	1	0.31	56.5	1	0.31	401.6

a. **A range of values is indicated for some estimates.**

b. **Data from these plots do not separate labour inputs as clearing, transporting suckers, planting and tree felling.**

often the suckers were obtained from other people's gardens.

Planting of banana suckers was relatively quick. There was no soil preparation. A digging stick, made on the site, was used to make and widen a hole in the ground and the sucker was thrust inside. Trees were usually felled immediately the bananas had been planted. Steel axes were used and larger, buttressed, trees were usually felled from flimsy frames that placed the axeman above the level of the buttresses. Because banana gardens were made in advanced second growth forest many trees were relatively large and the work was difficult. The 35.0 person-days (234.1 person-hours) needed to fell 1 ha of banana garden contrasts with an estimate of 21.3 person-days (124.7 person-hours; sample 0.20 ha) needed to fell 1 ha of tuber garden; the latter gardens were made in younger regrowth.

Ideally, portions of banana gardens where taro had been planted relatively densely were thoroughly weeded in about the fourth month after planting and areas where taro were absent or few were weeded in the sixth or seventh month after planting. Delays beyond these times seriously reduced taro yields and promoted the chance of damage by rats to fruiting bananas. Again, ideally, weeding of taro and bananas was maintained until about the twelfth month after planting by which time the taro harvest was effectively over and banana productivity was at a peak. A garden might be older than one year before much weeding - in fact, slash clearing - was done in fringe areas where sugar and lowland pitpit were concentrated. At Gwaimasi few people adhered to these ideals. Most people did weed taro in the fourth month after planting but many did little subsequent weeding; the cost to them was probably reduced yields in the later phase of the harvest period, after about 8 months. Some people did little or no weeding among banana plants, or delayed the task until the ninth month when the harvest was underway. Often they merely slashed back higher weeds to improve access and did not maintain the

work. Again, the cost would be in the later phase of the harvest period, after about 15 months from planting.

The magnitude of differences among garden owners in their enthusiasm for weeding, combined with the intermittent nature of the work, meant we obtained few quantitative records. Details are available from a 0.31 ha garden that was very thoroughly weeded in the fifth month after planting (Table 6). The effort entailed was both considerable and exceptional. The work was done on behalf of a married couple who had been absent for one month awaiting the birth of their child and, with most village residents contributing to the task, the occasion was as much social as it was necessary. At Gwaimasi, few people made this sort of commitment and we doubt that the average for all weeding would match the value recorded from the one episode shown in Table 6.

One other maintenance activity was performed, with varying consistency, by banana gardeners. This was removal of the bell (or male bud) from the bunch after all bananas had set. (This act may increase final bunch weight; Johns and Stevenson 1979). The task was accomplished easily when people were weeding or harvesting and, hence, opportunity costs were probably negligible. Groups that weeded their bananas most thoroughly were also most likely to cut the bell from the bunch, doing so when the fruit were well established. The frequency with which the bell was cut was highest in the ninth month after planting (>50% of bunches with medium or advanced fruit) and was low after the twelfth month (<10% of bunches with medium or advanced fruit). Kubo do not eat the bell of banana bunches though, elsewhere in Papua New Guinea, it is sometimes cooked and eaten (cf. Womersley 1972; May 1984). Trashing was not done and propping stems was uncommon. Suckers were not thinned except as required for establishing new gardens. Because suckers were often obtained from gardens that had been planted about one year earlier, and from plants that had not yet produced, there was probably an incidental gain in weight to bunches carried by these mother plants (e.g. Heenan 1973).

We lack specific data concerning harvesting. A one hectare banana garden yields 1313 bunches of bananas (see below). At Gwaimasi most bunches were carried from the garden to the village for consumption either intact or, less often, as separated hands. Average bunch weight was about 5.5 kg and average round-trip distance was about 1.20 km. A minimum estimate, based on three bunches per load and 3 km per hour, would be 180 person-hours to harvest 1 ha but actual cost would have been higher because relatively few loads included three bunches.

Males and females contributed in different ways to gardening tasks and, additionally, assistance with work at other people's gardens was common. Table 7 summarizes relevant data; these are from nine different sets of contiguous banana garden plots. On a per-person basis the estimates in this table, and in Table 8, slightly overstate the contribution of males because males comprised 56 percent of the available work force (4782 of 8470 person-days). An individual is classed as an 'owner' for work done at any plot within a contiguous set where he or she held a plot. Thus, the data overstate the contributions of true owners. In one exceptional case, true owners contributed only 1.5 person-days to the preparatory tasks at a 0.14 ha plot which, in total, required about 16 person-days effort. Note also that the ratio of visitors to residents at Gwaimasi (excluding absences by residents beyond the local subsistence area) was approximately 0.23:1.

Males did all tree felling in banana gardens and contributed more than females to the collection and, especially, transport of suckers; they did somewhat less clearing and much less planting and weeding than females. Assistance was most common with the labour-intensive tasks of transporting suckers

Table 7. **Gender roles and assistance at banana gardens.**

	Garden task				
	clearing	suckers	planting	felling	weeding
Sample: no. of person days	24.25	62.75	32.25	51.75	41.75
proportion by males	0.46	0.62	0.29	1.00	0.33
proportion by 'owners'	0.81	0.59	0.74	0.45	0.57
proportion by assistants:					
residents	0.19	0.41	0.26	0.47	0.40
visitors	-	-	-	0.08	0.03

and felling trees. Indeed, owners contributed less than assistants to felling trees and, with this task, visitors as well as residents were likely to help. Assistance with felling trees was sometimes actively solicited, even between communities. Most assistance with clearing and planting was from females (0.95 and 0.88 of 4.5 and 8 days respectively) and, with sucker transport, from males (0.64 of 25.5 days). The pooled data of Table 7 mask variation between gardens. Less assistance was forthcoming at small gardens than at larger ones, and when bachelors initiated gardens that were not part of a contiguous set of plots they were likely to do nearly all clearing and planting themselves.

The values of Table 7 and the estimates of labour input in Table 6 are combined in Table 8 to arrive at approximations of the total work done by males and females, owners and assistants. Males did more work than females in the preparatory phases of gardening but females contributed much more to weeding. Assistance at gardens amounted to a minimum of 40 percent of all work though little of this was with clearing or planting. One bachelor ratio-

Table 8. **Labour inputs at banana gardens (days/ha) by males and females, and by 'owners' and assistants.**

Task	Totaldays/ha	Males	Females	'Owners'	Assistants
Clearing	23.5	10.8	12.7	19.0	4.5
Suckers	41.1	25.5	15.6	24.2	16.9
Planting	18.3	5.3	13.0	13.5	4.8
Tree felling	35.0	35.0	-	15.8	19.2
Weeding	56.5	18.6	37.9	32.2	24.3
Totals	174.4	95.2	79.2	104.7	69.7

nalized the amount of weeding done by women by asserting that "women who have pigs should keep watch over gardens".

Most harvesting was done by owners or their appointed agents and the work was shared by males and females. Females contributed more than males to day to day harvesting needs but, if a large harvest was due, then males did most of the work.

Because females living near the Strickland River did not paddle canoes, all work at gardens east of the river required some male participation. It is probable that males contributed more to all tasks at

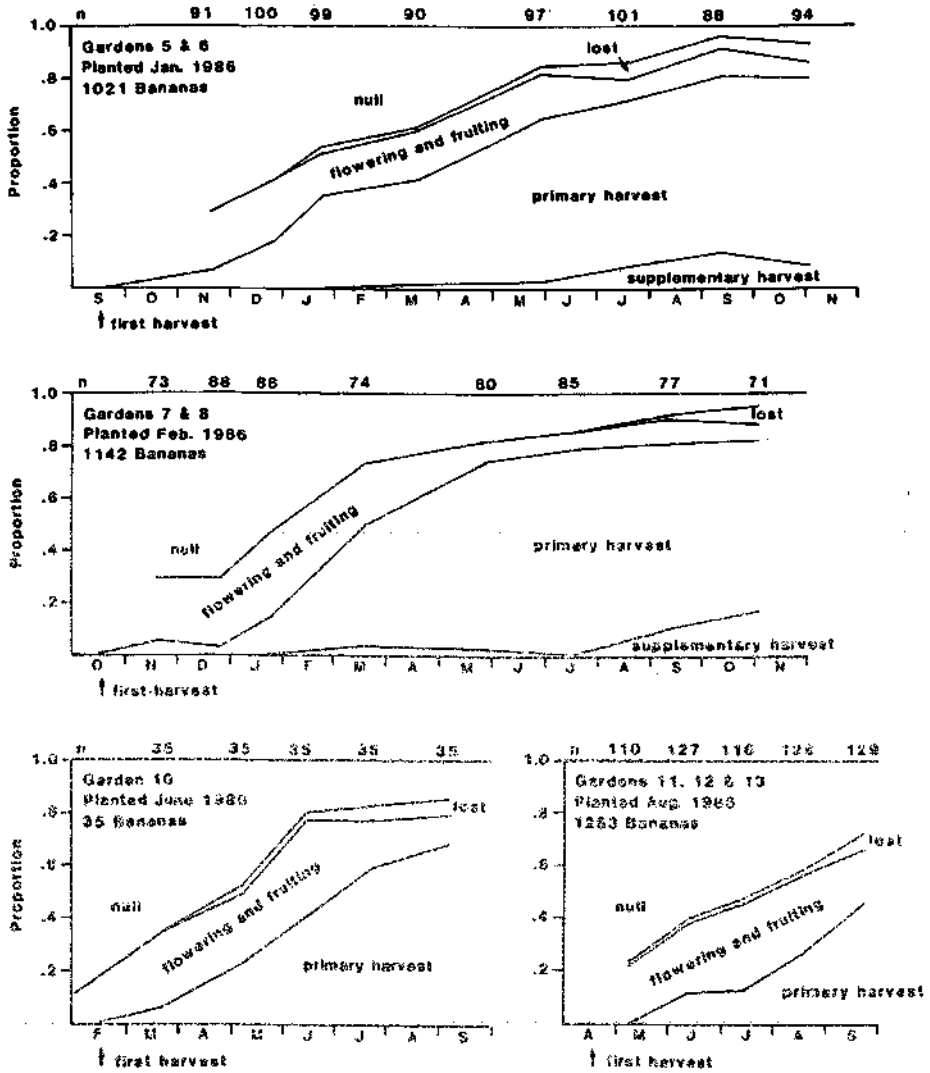

Figure 2. **Yield patterns of bananas from eight gardens. For each garden, or set of gardens, the figure records the month of planting, the number of bananas planted, sample sizes and the proportions of plants in these samples that were non-productive (i.e. null), collapsed or dead (i.e. lost), bore flowers or carried fruit (i.e. flowering and fruiting) or had been harvested. The 'supplementary harvest' is additional to the primary harvest and derived from multiple-stemmed plants and daughter suckers.**

these gardens than was the case for gardens west of the river. (Values in Tables 7 and 8 are biased by estimates from west-side gardens). East-side family gardens had not produced bananas by the time we left Gwaimasi but, unless the families concerned relocated to the east, the burden of harvesting would have fallen almost entirely to males. Larger banana harvests from west-bank gardens were often made by men using canoes.

YIELDS

Yield data from eight gardens are summarized on *Figure 2*. Data from gardens planted in the same month are pooled and, for each garden or set of gardens, the plots of Figure 2 commence in the eighth month after planting. It was in the latter half of this month that the first harvest of bananas could be expected. This was not confirmed at any of the gardens depicted on Figure 2 but was confirmed at two other gardens.

The depicted patterns are similar. About 5 percent of plants were lost because they died or were blown down. Flowering was underway as early as six and a half months after planting, and from the ninth to fourteenth months, between 20 and 30 percent of bananas were either flowering or carrying fruit. Thereafter, this proportion dropped rapidly to about 5 percent. Banana production was well underway by the eleventh month post-planting and continued at a high rate until the fifteenth month. After this time the rate of production from primary suckers was greatly reduced but a brief supplementary harvest, from multiple-stemmed and secondary suckers, commenced. (In the case of multiple-stemmed plants 'supplementary harvest' refers to second and subsequent bunches from the one set of stems.) After nineteen months the yield was effectively over. By the close of this month, 82 percent of initial plantings had produced a bunch of bananas and the supplementary harvest amounted to 13 percent of the number of suckers that had been planted. The average density of banana plants was equivalent to 1382 plants per hectare. Thus, the expected yield of bananas is 1133 bunches from primary suckers and an additional 180 bunches as supplementary harvest. This is equivalent to more than 7500 kg bunch weight or 4494 kg edible weight (at time of harvest) per hectare.

Little harvesting occurred at banana gardens beyond the twentieth month after planting. By this time the garden was difficult to traverse, walking tracks that once passed through it had been rerouted around it, and the banana plants were overgrown by a tangle of weeds, vines and regrowth and were often withered and dying. But we think that if maintenance had been sustained the yield would have persisted longer. People abandoned banana gardens because access became difficult and this happened because they ceased maintaining the gardens. At several very advanced gardens we saw bunches of ripening and of rotting fruit. Sometimes when people visited these sites for other purposes - to harvest lowland pitpit, obtain banana suckers, tend groves of fruit pandanus or fish nearby - they would eat bananas. Often they discarded most of the bunch because quality was poor and they did not carry these bananas to the village. Run-down gardens were fit for an occasional snack but were not visited with the expectation of a useful harvest.

For cases where data from two or three gardens were pooled in *Figure 2*, chi square comparisons within sample periods revealed differences in yield profiles in only one case; the harvested proportions recorded in samples from Gardens 7 and 8 were significantly different in January 1987. Further, there were no significant differences in yield profiles between gardens or sets of gardens of the same age since planting. Nor was there any difference between a yield profile obtained by pooling data from gardens planted in January and February (Gardens 5-8) with a profile from gardens planted in August (Gardens 11-13). In 1986-87 these times represented climatically distinct periods; they fol-

lowed and preceded the months when rainfall was lowest.

Figure 3 combines data from all eight censused gardens to construct an ideal yield profile. The curve shows the cumulative yield from time of planting. Data after the twelfth month from planting have been bracketed as two-month blocks to smooth sample differences between Gardens 5 and 6 on the one hand and Gardens 7 and 8 on the other. The figure was used to construct a yield profile from all gardens (pooled) and it is this that is the basis of analyses of availability and consumption of bananas in the following sections.

AVAILABILITY OF BANANAS

Estimates of the numbers of bunches of bananas produced each month from January 1986 to December 1988 are given in *Figure 4*. These estimates are from all gardens made in the vicinity of Gwaimasi between January 1985 and November 1987. They are based on the ideal yield profile of Figure 3 with adjustments made for cases where bananas were known to be planted either early or late in a particular month. Gardens 1 to 4 were planted in 1985 and estimates of the numbers of bananas planted are approximations only.

The longhouse at Gwaimasi was built during February and March 1986. Before this time the residential base of the people who eventually lived at Gwaimasi was Sesanabi, 8 km northwest of Gwaimasi, and well outside the area used once Gwaimasi was established. By March or April 1986 Gwaimasi residents had effectively abandoned gardens associated with Sesanabi. From this time, until late 1986, when gardens planted in January and February 1986 were productive, the people were dependent upon sago starch. In December

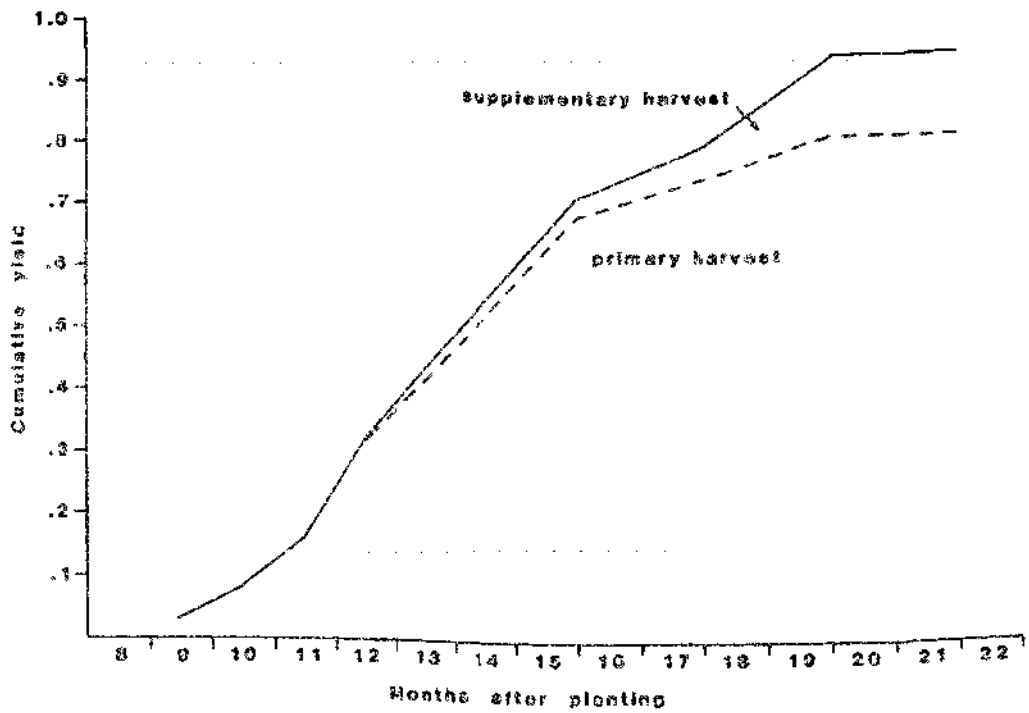

Figure 3. **An idealized yield profile for bananas. Yield is represented as a proportion of the number of bananas planted. The 'supplementary harvest' is derived from multiple-stemmed plants and daughter suckers.**

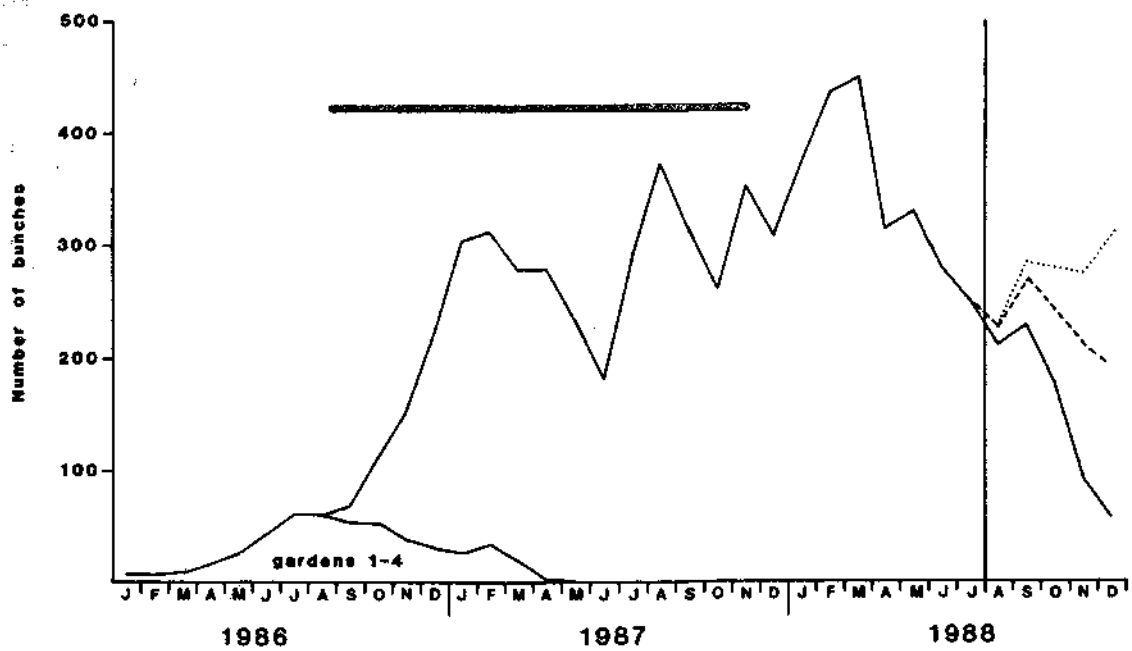

Figure 4. **Total production of bananas (bunches/month) at Gwaimasi from January 1986 to July 1988. Estimates from Gardens 1-4 are less reliable than those from gardens that were planted later. The study period is represented by a bar. Outcomes of planting (a) 1000 bananas in December 1987 (dashed line) and (b) 1000 bananas in each of December 1987 and January 1988 (dotted line) are indicated.**

1986 local gardens yielded 220 bunches of bananas and, thereafter, until July 1988, the yield fell below this level in only one month (June 1987). From mid-1986 until early 1988 the month to month yield oscillated but trended consistently upward to peak at an expected 450 bunches in March 1988. Thereafter, production from gardens we measured would fall dramatically. Until July 1988 (with an expected yield of 250 bunches) this fall could not be reversed but, if large scale planting occurred in December 1987, after we departed, further decline could have been avoided (i.e. gardens planted in December 1987 would produce bananas from August 1988). The figure records outcomes of planting (a) 1000 bananas in December 1987 and (b) 1000 bananas in both December 1987 and January 1988. Clearly, to maintain banana production at the 1987 level would have required much effort in the months immediately following our departure. Through the 29 months from March 1986 to July 1988 average production was 231 bunches per month (s = ±131 bunches) with a range from 8.5 to 450 bunches per month.

CONSUMPTION OF BANANAS

We did not directly investigate the consumption of bananas. The following analysis assumes that (a) Figure 4 represents month to month availability of banana bunches, (b) all harvested bananas were eaten and (c) sharing resulted in an even distribution of available bananas among actual consumers.

Table 9. **Monthly availability of bananas, September 1986 to October 1987.**

Month	Consumer-days (C)[a]			Bunches of bananas (B)			kcal/C[c]
	residents	visitors	total	total	adjusted[b]	B/C	
1986							
Sept.	616.2	67.1[d]	683.3	67.1	61.9	0.09	339-424
Oct.	584.4	173.8	758.2	110.8	103.2	0.14	527-659
Nov.	621.4	144.6	766.1	151.6	137.4	0.18	678-847
Dec.	545.8	71.7	617.5	219.8	191.6	0.31	1167-1459
1987							
Jan.	532.4	294.9	827.3	303.5	284.5	0.34	1280-1600
Feb.	492.4	23.6	516.0	312.8	288.5	0.56	2108-2635
Mar.	538.4	113.3	651.7	278.3	261.2	0.40	1506-1882
Apr.	542.6	88.4	631.0	279.6	265.3	0.42	1581-1976
May	532.8	132.7	665.5	235.1	218.4	0.33	1242-1553
June	474.2	221.1	695.3	182.1	165.6	0.24	904-1129
July	498.0	145.3	643.3	292.0	267.9	0.42	1581-1976
Aug.	601.0	131.2	732.2	370.3	339.2	0.46	1732-2165
Sept.	567.2	98.0	665.2	311.0	284.0	0.43	1619-2023
Oct.	580.8	71.8	652.6	261.6	240.4	0.37	1393-1741
	7727.6	1777.6	9505.2	3384.2	3109.1	0.33	1242-1553

a. Residency values for children under the age of approximately 12 years were weighted (see text).

b. Adjustments have been made for bananas eaten by domestic pigs and the authors.

c. Estimates of energy are based on mean values of 49.6 fingers per bunch of bananas and 75.9 g edible per ripe (moisture-laden) finger and a range from 100 to 125 kcal/100 g edible (see 'Techniques').

d. Minimum estimate.

In broad terms these assumptions fit our impressions. The number of actual consumers on any day was taken as all individuals (residents and visitors) who slept that night at Gwaimasi village or within the subsistence zone associated with Gwaimasi. Residency values for children were weighted such that one 2-4 year old was taken as 0.5 units, one 6-8 year old was taken as 0.7 units and two 9-11 year olds were each taken as 0.8 units. Nursing infants were excluded. (Comparable adjustments were made for visitors who were less than about 12 years old.)

Month to month estimates of banana bunches per consumer day and of calorific returns per consumer-day are summarized in Table 9 for the months September 1986 to October 1987. Through this period the mean return per day was equivalent to 0.33 bunches per adult consumer. A conservative estimate of the mean calorific return is 1242 kcal/day to each adult consumer but the value of 1553 kcal/day may be more realistic. Recommended daily intakes for males of Kubo stature (assuming a moderate activity regime) are of the order of 2500 kcal/day. At Gwaimasi, adult females, taken collectively, were either pregnant or lactating during 54 percent of their aggregated months of residency and, hence, average daily requirements for females may have approached those for males. Thus, even the conservative estimate of calorific returns from bananas suggests that from September 1986 to October 1987 people could have derived half their energy needs from bananas. Monthly variability in the availability of bananas to consumers was high with a range from 0.09 to 0.56 bunches per consumer-day. Thus, at a minimum, this food supplied from as little as 14 to as much as 85 percent of energy needs a month.

Between September 1986 and October 1987 the mean monthly total of consumer-days was 678.9; despite high mobility variance was not extreme (s = ± 75.8). Using this average value for March to August 1986 (before our arrival) and November 1987 to July 1988 (after our departure) gives mean values, respectively, of 0.05 and 0.51 bunches/consumer-day. If 678.9 consumers need 224 bunches (678.9 x 0.33) to meet half their energy needs, then from March to August 1986 bananas were of minor importance in the diet of Gwaimasi people (2-14% of monthly energy needs) and from November 1987 to July 1988 they were of major importance (56-100% of monthly energy needs; see Fig. 4). Pooling values for all 29 months (March 1986 to July 1988) and, again, using 678.9 consumer-days per month where data are missing, gives an overall mean of 0.33 bunches/consumer-day. All these values are, of course, crude approximations to what was possible. But they reveal that the people at Gwaimasi had the capacity to move back and forth between virtual independence of, and full dependence on, bananas as their primary carbohydrate source.

DISCUSSION

Kubo agriculture was non-intensive. Small gardens were cut into secondary forest that, in the case of banana gardens, had been fallowed for not less than 15 years. Different varieties of bananas and, usually, a mix of other crops were interplanted.

Bananas commenced yielding in the eighth month after planting and were most productive from 12 to 15 months. Planting densities averaged 1382 plants/hectare and the expected yield was 1313 bunches or 4494 kg edible (about 7500 kg as bunch weight) per hectare. All was available from eight to 20 months after planting and we estimated that from September 1986 to October 1987 bananas provided at least 50 percent of the energy requirements of the people. They contributed more to diet at Gwaimasi than they did in the seasonally dry environments at Kaiapit (Morobe Province, 30% by weight; Langley 1950) and Oriomo Plateau (Western Province, seasonal maximum 26% of energy; Ohtsuka 1983). At Gwaimasi people shifted between virtual independence of, and full dependence

on, bananas but this variation in yield was not seasonal. In 1986-87, at Gwaimasi, most bananas were planted at intervals of roughly six months (Table 4). At nearby communities we knew of relatively large banana gardens that were planted in December-January, between late May and mid-July and in August. Shaw (1990) reported that among Samo, who live immediately south of Kubo, most bananas were planted from June to August. Though these records are few that suggest that in this region of Papua New Guinea the period from September to November may be least suited to planting bananas.

Relative to residents of Gwaimasi, people of the Amele area (Madang Province) ate about one third the quantity of bananas. King *et al.* (1989) estimated that in this area banana yields were about 5573 kg (bunch weight)/hectare. In South America the Bari (Columbian-Venezuelan border) produced about 4260 kg (bunch weight)/hectare per year (Beckerman 1983). These estimates were based on planting densities of 1030 and 770 bananas/hectare, respectively, and, thus, relative to planting density, match the Gwaimasi estimate. Compared to the wide range of values reported from Papua New Guinean sweet potato gardens these estimates of banana production are on the low side (Rappaport 1968; Waddell 1972; Hide 1981; Sillitoe 1983; Hide *et al.* 1984; Bourke 1985).

At Gwaimasi the work required to prepare a banana garden - clearing, sucker collection and transport, planting and felling trees - was 850-900 person-hours or 110-120 person-days per hectare. These gardens were not fenced and so this commitment appears high. For example, Clarke's (1971) estimate of the labour in preparatory tasks at the fenced tuber gardens of Bomagai-Angoiang Maring (Madang Province) was approximately 625 person-hours/hectare. Given that this value excluded travel and rest times it is probably similar to the Gwaimasi estimate. In the Bomagai-Angoiang case planting (36%) and fencing (34%) were the most demanding tasks; at Gwaimasi banana gardens the collection and transport of suckers occupied 42 percent of preparatory person-hours. Chagnon (1983) was also impressed by the work entailed in transporting banana (=plantain) suckers when Yanomamo (Venezuelan-Brazilian border) established new gardens at a distance.

Total commitment for all work at Gwaimasi banana gardens may have exceeded 185 person-days (or 1400 person-hours) per hectare. Using these values return for effort from banana gardening was 24.3 kg edible/person-day or 3.2 kg edible (3520-4400 kcal)/person-hour. Allowing that our estimates of hours worked included periods of rest, energetic efficiency may be in the range of 10-15:1, near the mode of the range of values reported from a variety of subsistence agricultural systems (e.g. Ellen 1982).

At Gwaimasi, banana gardens were virtually abandoned 20 months after planting. By this time weeds and early regrowth were well developed and remaining banana plants were in poor condition. Thus, the people obtained a single, staggered harvest and then shifted attention to another garden site. This behaviour has not been described among subsistence people who depend upon bananas as a staple food though it may be a correlate of growing bananas in regions of high, year-round rainfall. It is more usual that some weeding is maintained, that suckers are thinned and that daughter plants are promoted *in situ* or replanted within the same garden. In the Markham Valley of Papua New Guinea banana gardens, planted with dry-adapted triploid varieties, may continue producing for more than 10 years (King *et al.* 1989). Among the Yanomamo, Hames (1983) reported that plantain gardens were maintained until a third harvest after which the yield dropped. There was a small increment in yield from the first to the third harvest that resulted from a "near-doubling of plants" after each harvest combined with a substantial decrease in the size of bunches from suckers that had been sepa-

rated from the mother plant. Hames' report implied that Yanomamo banana gardens exhibited discrete harvest periods. Chagnon (1983), however, wrote that "there is no peak harvest period, for plantains, if planted in the proper fashion, are ripening all year long". Oriomo Papuans (Western Province) also continued to harvest bananas from gardens that had been planted three or four years earlier (Ohtsuka 1983).

When the life of a banana garden can be extended, felling of trees and transport of suckers are needed less often and, presumably, efficiency may be increased. The abandonment of gardens by tropical agriculturalists is commonly discussed in terms of costs arising from increased growth of weeds, decreased soil nutrients, or both (e.g. Chagnon 1983; Hames 1983). In North Queensland (Australia), where rainfall is high but seasonal, commercial banana growers plant on alluvial flats and maintain the gardens for only three to five years (Cull 1987; E. Gall, personal communication). This contrasts with the 10-15 year life of commercial banana gardens in southeastern Queensland. The relatively brief lifespan of the northern gardens is, in large part, a consequence of reduced productivity in response to increased infestations of root and corm nematodes (E. Gall, personal communication). Depletion rates for both nitrogen and potassium are also high. The long fallow period accepted as necessary by Kubo implies that restoration of soil nutrients was needed before a site could be reused. It may be that the combination of high temperatures and very high rainfall characteristic of the region promoted both parasite load and excessive weed growth as it exacerbated nutrient loss. More detailed research is needed to enlarge understanding of both the successes of, and limits to, banana production in this region of year-round high rainfall.

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EFFECTS OF APPLICATIONS OF MULCH AND POTASSIUM ON *CAPSICUM ANNUUM*

D.E. Gollifer[1]

ABSTRACT

*Applications of organic mulch and potassium resulted in increases in yield of chilli fruit (*Capsicum annuum*), of up to 170% and 113% respectively. The effect of mulch was to supply potassium to the plant, and when mulch was applied at 40 t/ha it was equivalent to supplying 210 kg/ha of K. Mortality of plants in the plots which received no mulch or potassium was high. A crop of 2500 kg/ha of dry chilli fruit (10,000 kg/ha fresh) removed approximately 62 kg/ha of K from the soil. The total dry matter per plant was considerably smaller in the plants which received no mulch or potassium. Plastic mulch enhanced plant growth probably because of the reduced competition by weeds for available K. Differences in the pH and moisture content of the soil between treatments were not considered important.*

Key words: Chillies, calcareous soils, mulch, fertilizers, potassium.

INTRODUCTION

Chillies (*Capsicum annuum* L. var. *annuum*) were introduced to the Solomon Islands from Ceylon and India for trial and evaluation as a potential cash crop for local growers (Gollifer 1973). The investigations on cultivar type and fertiliser requirements were carried out at Dala research Station on Malaita Island which lies between 8° and 10° S and 160° and 162° E. The climate is wet tropical, mean maximum temperatures seldom exceed 31°C. The average relative humidity is approximately 80 percent throughout the year, and mean annual rainfall is over 3000 mm for most areas and is well distributed. The soils of the research station are known as the Dala Series, they overlie calcareous material and are low in exchangeable potassium (Ballantyne 1961; Wall & Hansell 1973). Ballantyne (1961) described the soils as all being of fine texture, between a silty-clay-loam and a clay and show no signs of restricted drainage. The percentage of nitrogen is high (0.60 - 0.92 percent) in the undisturbed top soil which is associated with the high organic matter content of this layer. Total phosphorus ranged from 0.36 to 0.80 percent, but availability may, however, be low due to formation of complex iron and aluminium compounds. Total potassium ranged from 0.71 to 1.27 meqiv. per 100 g. The exchangeable potassium was very low, and excluding the top 5 cm ranged from 0.15 to 0.04 mequiv. per 100 g dry soil. The potassium deficiency may well be accentuated by the high exchangeable calcium and/or magnesium status of the soil which gave a ratio of exchangeable calcium to exchangeable potassium of generally wider than 50:1.

Gollifer (1972) reported yield responses in chillies due to applications of potassium of up to 70% over those of the non-fertilised plants. The aggregate yields of fresh fruit were 12,535 and 7,139 kg/ha for the fertilised and control plots respectively by 42 weeks from planting. Furthermore 30% of the plants that received no potassium died due to

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infection of the stem base by the fungus *Sclerotium rolfsii* Sacc., whilst only 4% of the fertilised plants were affected.

A mulch treatment superimposed on a chilli cultivar trial resulted in significant yield increases 47% over those of the non-treated plants. Aggregate yields of fresh fruit over a harvest period of 24 weeks were 5,597 and 3,801 kg/ha for the mulched and non-mulched plants respectively. Additionally by 42 weeks from planting, 50% of the non-treated plants and 11% of the mulched plants were dead. Mortality in this case was not due to infection by *S. rolfsii* as this was controlled by applications of PCNB (Penta chloro nitro benzene).

As the mulch treatment was so beneficial, it was decided that further investigations should be made to determine the role played by mulch on the soils of the Dala Land System. Also as it is difficult to convince subsistence agriculturalists to use fertilizers on their crops it was thought that they would more readily accept the use of mulch as it was a practice formerly used in the Solomon Islands for cultivation of taro (*Colocasia esculenta*) (L.) Schott. mulch being known as *tatavo*. This paper describes two experiments in which mulch and potassium were applied to chillies.

MATERIALS AND METHODS

The aims of the two experiments were to investigate the effects of applications of mulch and potassium (as muriate of potash) on the yield of the Indian chilli cultivar "B16 A-1" grown as a rainfed crop at Dala Research Station, Malaita Island. Seedlings were transplanted into the field when 9 weeks old at a spacing of 0.6 x 1.2 m. In both experiments the potassium was applied in two dressings, one at transplanting and the other 12 weeks later at a total rate of 180 kg/ha of elemental K. PCNB was applied to all plants 11 days after transplanting at a rate of 9.9 kg in 3595 litres of water per hectare. Fruit were harvested at weekly intervals commencing at 9 weeks after transplanting and this was continued for 32 weeks (Experiment 1) or 17 weeks (Experiment 2). Fresh weight yields of fruit and mortality of plants were recorded. The harvestable plot size was thirty and fifteen guarded plants for Experiments 1 & 2 respectively.

Experiment 1

Field planting took place during September 1969. The experimental design was a 2^2 factorial arranged as a randomized block with four replicates. The potassium was applied as outlined above at 0 and 180 kg/ha of elemental K, and the mulch at 0 and 30 t/ha in two dressings at transplanting and 12 weeks later. The mulch consisted of cocoa pods, grass and sweet potato vines which had been mechanically chopped and then composted for 2-3 weeks before application.

Soil samples were taken from the surface and at depths of 10 and 20 cm for determination of the pH (H_2O). The first sampling was done before the treatments were applied and the sample size was sixteen. A further sampling was made immediately prior to the second application of fertiliser and mulch, and the sample size was ten per plot or forty per treatment. Samples of oven-dried mulch were forwarded to Unilevers Plantation Group of London for chemical analysis.

Experiment 2

Field planting took place during July 1970. The experimental design was a split plot with five replicates. The main plot treatments were: (a) organic mulch of similar composition as in Experiment 1, applied in one application at 40 t/ha at 7 days after transplanting; (b) plastic mulch positioned at 7 days after transplanting; (c) bare soil. The sub plot treatments were: (a) potassium; (b) no potassium. The plastic mulch consisted of 0.9 m wide strips of yellow plastic sheeting laid down between the rows of chilli plants leaving 0.3 m gaps in which the plants grew.

Fifteen plants were selected randomly per plot for growth analysis studies and the remaining fifteen were used to provide yield data of fresh fruit. Growth analysis measurements including plant heights, were made at monthly intervals starting at 8 weeks after sowing through to 32 weeks. The sample size was two plants per plot or ten per treatment. The dry matter contents of component plant parts were determined after oven drying at 100°C for 24 h.

Soil temperatures at 7.5 cm depth were determined at 1200 and 1500 h for 120 days with soil thermometers. One thermometer was used for each main plot treatment. Three soil auger samples taken from the 0.15 cm layer were removed per sub plot at weekly intervals on four occasions, and the soil moisture was determined gravimetrically after oven drying at 100°C for 24 h. On collection the samples were sealed in tins until the initial weights had been recorded.

Oven dried samples of leaves and fruit taken from each sub-plot when the plants were 20 weeks old were sent to the Land Resources Division, Tolworth, England for chemical analyses. Soil extracts and plant root samples were forwarded to Rothamsted Experimental Station, England to determine if pathogenic plant nematodes were present. The soil extracts were made using the method described in Peachey (1969).

RESULTS

The yields of fresh fruit are shown in Tables 1 and 3, and mortality of plants in Tables 2 and 4 for Experiments 1 and 2 respectively. The potassium and mulch treatments were both significantly different and had a positive effect on the yield of fruit in Experiments 1 and 2. In the case of plant mortality, the mulch effect was significantly different in Experiment 1, whilst both the mulch and potassium effects were significantly different in Experiment 2, resulting in less plant mortalities. The interaction effect (Table 2) is explained by the fact that applications of potassium resulted in a reduction of mortality in the unmulched plots, but a slight increase in the mulched plots.

Table 1. **Yield of fresh chilli fruit (kg/ha) for the 32 week harvest period (Experiment 1).**

Mulch (t/ha)	Potassium (kg/ha) 0	180	Mean
0	2735	12959	7847
30	14560	16228	15394
Mean	8648	14594	

	s.e.d(0.05)	Sign. effect
K x mulch	+/- 2092.0	*
Mulch	+/- 2087.1	***
K	+/- 2087.1	**
C.V. = 25.4%	S.E. +/- 1476.1	

Table 2. **Mortality (% of chilli plants which died) by 40 weeks (Experiment 1).**

Mulch (t/ha)	Potassium (kg/ha) 0	180	Mean
0	48.0	25.0	36.5
30	8.0	11.0	9.5
Mean	28.0	18.0	

	s.e.d(0.05)	Sign. effect
K x mulch	+/- 7.51	*
Mulch	+/- 7.49	***
K		n.s.
C.V. = 44.0%	S.E. +/- 5.7	

Table 3. **Yield of fresh chilli fruit (kg/ha) for the 17 week harvest period (Experiment 2).**

Mulch	Potassium (kg/ha)		Mean
	0	180	
Organic	12879	15910	14395
Plastic	3195	11374	7285
Bare soil	1160	9502	5331
Mean	5745	12262	

	s.e.d(0.05)	Sign. effect
Kx mulch	+/- 1139.1[1]	**
Mulch	+/- 1148.0	***
K	+/- 1132.7	***

Main plots: S.E. +- 814.0; C.V. = 10.1%

Sub plots: S.E. +/- 446.9; C.V. = 20.0%

[1](approximate for all comparisons)

Table 4. **Mortality (% of chilli plants which died) by 32 weeks (Experiment 2).**

Mulch	Potassium (kg/ha)		Mean
	0	180	
Organic	5.4	5.4	5.4
Plastic	50.8	25.4	38.1
Bare soil	38.0	14.8	25.3
Mean	30.7	15.1	

	s.e.d (0.05)	Sign. effect
Mulch	+/- 9.14	**
K	+/- 7.71	**

Main plots: S.E. +/- 6.5; C.V. = 32.1%

Sub plots: S.E. +/- 3.2; C.V. = 53.0%

Growth analysis

The dry matter of the plant components and plant heights are shown in Table 5 with effect from week 20. The measurements recorded prior to week 20 and all standard errors were excluded for reasons of clarity, as they were not considered to be sufficiently important to present. At each determination, the plant components were larger for the plants which received organic mulch and potassium, and by 28 weeks the dry weights of fruit from these treatments were almost three times as large as those from the other plants. The dry matter of plants generally reached a maximum at 28 weeks and thereafter declined in most treatments, whilst plant height was still increasing at 32 weeks. The plastic mulch had a favourable effect on plant growth as plants from this treatment were larger than those grown in bare soil probably due to reduced competition by weeds.

Nematodes

No plant pathogenic nematodes were found in the soil nor in the roots of chilli plants.

Soil values

The pretreatment soil pH values recorded at 12 weeks, just prior to the second applications of mulch and potassium, and of soil temperatures recorded at 7.5 cm depth are presented in *Table 6.* There was a small positive effect of mulch on the pH which decreased linearly with depth. Temperatures were higher under the plastic sheeting and bare soil than under the organic mulch (Table 6). There was little difference in the soil moisture values among the treatments and gravimetric determinations were discontinued after four samplings.

The concentrations of potassium in oven dry leaf and fruit material, and for leaf magnesium are shown in *Table 7.* The levels of leaf and fruit potassium were significantly higher in the plants

Table 5. **Changes in dry matter of plant components (g/plant) and plant height (cm) over time (Experiment 2).**

Age	Mulch			Potassium		Mulch			Potassium	
(weeks)	O	P	N	-K	+K	O	P	N	-K	+K
	Leaves					**Stems**				
20	41.7	27.6	16.3	23.1	33.9	44.7	36.0	18.5	29.3	36.8
24	70.2	31.4	19.6	27.0	53.8	87.1	52.8	24.6	40.5	69.1
28	91.4	36.3	26.6	27.6	76.3	132.6	55.3	40.1	49.1	102.9
32	66.8	35.9	25.2	26.6	58.6	118.6	71.8	46.9	58.1	100.0
	Roots					**Fruits**				
20	10.1	9.9	6.7	8.2	9.5	60.4	54.9	21.5	34.5	56.6
24	16.0	15.1	7.4	9.6	16.0	139.8	96.5	51.6	70.8	121.2
28	26.9	15.0	11.4	13.3	24.2	149.7	55.7	60.1	47.0	131.1
32	21.1	15.6	11.4	13.0	19.0	101.5	54.7	44.4	40.9	92.8
	Total dry matter					**Height**				
20	156.9	128.4	63.0	95.1	136.8	77.5	68.1	59.9	65.3	71.6
24	313.1	195.8	103.2	147.9	260.1	79.8	69.9	55.6	63.8	72.9
28	400.6	162.3	138.2	135.0	332.5	94.2	70.4	72.1	71.4	86.6
32	308.0	178.0	127.9	138.6	270.4	101.1	81.5	76.2	76.0	96.5

Table 6. **Soil pH values and temperatures at 7.5 cm depth (Experiment 2).**

	pH			Temperature (°C)	
	Surface	10 cm	20 cm	1200	1500
Pretreatment	6.00	5.60	5.10	-	-
No mulch	6.04	5.99	5.48	30.2	32.1
Organic mulch	6.40	6.26	5.70	28.1	29.8
Plastic mulch	-	-	-	32.5	35.3
Mulch effect	+ 0.36	+ 0.27	+ 0.22	-	-

	pH	
	s.e.d(0.05)	Sign. effect
mulch	0.22	*
soil depth	0.04	***

Main plots C.V. = 1.8%

Sub plots C.V. = 3.6

Table 7. **Mean percentages of potassium in oven-dry material of chilli plants (Experiment 2).**

	Leaf K (%)			Fruit K (%)			Leaf Mg (%)		
	-K	+K	Mean	-K	+K	Mean	-K	+K	Mean
Organic	4.61	4.70	4.66	3.01	3.31	3.16	0.98	0.88	0.93
Plastic	0.64	2.43	1.54	1.64	2.69	2.17	1.61	1.19	1.40
Nil	0.90	2.93	1.92	1.82	2.66	2.24	1.24	1.06	1.15
Mean	2.05	3.35	_	2.15	2.89	_	1.28	1.04	_
	s.e.d (0.05)	Sign. effects:							
Mulch	0.33	***		0.25	***		0.15	**	
K	0.35	***		0.28	***		0.14	**	
Mulch x K	0.33	**			n.s.			n.s.	
Main plots:	s.e. +/- 0.237			+/- 0.174			+/-0.100		
Sub plots:	s.e. +/- 0.139			+/- 0.113			+/-0.053		

which received applications of organic mulch or of potassium, particularly the leaf values. The values of leaf magnesium were significantly higher for plants which received no applications of organic mulch or potassium.

Analysis of mulch

Chemical analysis of the dried ground mulch showed that it contained 1.00% N; 0.23% P and 2.15% K which at the rate of 30 t/ha of mulch (25% dry matter) was approximately equivalent to 75 kg N, 18 kg P and 158 kg K per ha.

DISCUSSION

Applications of organic mulch and potassium resulted in increases in yield of chilli fruit of 96% and 69% respectively in Experiment 1, and of 170% and 113% respectively in Experiment 2. The different maximum productivities over time between the two experiments was partly due to the differential mortalities (11.0% compared to 5.4%) for the organic mulch/K combination in Experiments 1 and 2 respectively. The weights of plant components, of total dry matter and of plant height were much reduced in the plants which received no mulch or potassium (Table 5).

As the applications of mulch in Experiments 1 & 2 were equivalent to 158 and 210 kg/ha of elemental K respectively, it appears that the mulch effect was mainly a potassium effect, especially as K is so easily leached out of dead vegetation. The mulch plus potassium treatment produced the largest yields in both experiments and this was probably due to the increased input of potassium resulting from this treatment combination.

Applications of organic mulch and potassium reduced the percentage of plant deaths by 27% and 10% respectively in Experiment 1 and by 26% and 16% in Experiment 2 (Table 2 & 4). As the plants commenced to bear, potassium would be transferred to the fruit and as reserves of soil K were limiting, potassium deficiency probably accounted for mortality. *Sclerotium rolfsii* did not cause execessive plant mortality as infection was controlled by applications of PCNB. Analysis of plant tissues indicated that a crop of dry chillies (2500 kg/ha) removed approximately 62.5 kg/ha of K from the soil. The highest fruit yields recorded (16,288 kg/ha of fresh fruit, Experiment 1) would have extracted approximately 130 kg/ha of K from the soil, and as the treatment combination of organic mulch plus K would have contributed in excess of 340 kg/ha of K, it is likely that in addition to higher uptake of K in the leaf tissue of plants from high K treatments (Table 7), there was also considerable leaching of soluble K from the root zone. This is due to the nature of the soils of the Dala Series, and the high well distributed annual rainfall experienced on Malaita. The significant negative yield interaction between K and organic mulch (Table 1) provides strong evidence that the effect of mulch was to provide K to the crop.

The levels of potassium in the leaves and fruit were much higher in the plants which received applications of organic mulch or potassium (Table 7). Leaf potassium values ranged from 0.64 to 4.70%, and fruit potassium levels from 1.64 to 3.31%. The higher values of leaf magnesium in plants which received no applications of mulch or potassium (Table 7) was probably due to the antagonistic effect of K on Mg uptake (Mengel & Kirkby 1987). Additionally the improved growth caused by alleviation of K deficiency would be expected to result in further depression of leaf Mg concentrations due to growth dilution. Leaf magnesium levels ranged from 0.88 to 1.61%. There were however no significant differences in the fruit magnesium levels, nor between the levels of other elements analysed in the leaf and fruit tissue between treatments. The mulch was fairly rich in K as the cocoa pods and sweet potato vines were taken from fertilised plantings and all plant material contains a component of K. Mulch made from plant material collected from non-fertilised areas, always has a beneficial effect on tree crops and ornamentals on soils of the Dala Series.

It was considered important to determine whether pathogenic plant nematodes were present in the soil and root tissue, as mulch has been known to have a nematicidal effect in bananas (E. Edmunds, pers. comm. 1969). No pathogenic nematodes were found however, in the samples of roots and soil taken from and in association with moribund plants.

The plastic mulch (Experiment 2) resulted in increased yields of fruit (Table 3) and an enhanced plant growth (Table 5), compared to plants grown in bare soil. There were no significant differences in the soil moisture values between treatments. The soil temperatures recorded under the plastic mulch (Table 6) were higher than those of the other two treatments, and this may have affected plant growth and mortality of plants (Table 4). The plastic mulch eliminated weed growth, and thus more soil potassium was available for the chilli plants in this treatment as compared to the bare soil treatment. Weeds were however also suppressed to some extent by the organic mulch.

In Experiment 1, there was a small positive effect of mulch on the soil pH which decreased linearly with depth (Table 6). It is doubtful if such slight changes in pH would have any effect on nutrient availability or uptake. It may however indicate that on the mulched plots, relatively less cations were being leached down the profile or that more were being made available from the mulch. The decrease in pH with soil depth indicates that nutrients are being recycled by the vegetation (Ballantyne 1961).

Further work will be required to determine if the

costs of application of potassium and mulch to enhance yields of chillies in the Solomon Islands are economic, based on current costs and prices. Alternatively, would the mulch be better used on an alternative crop. The local farmers have knowledge of the improved plant performance which results from the use of mulch on soils of the Dala Series

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WOOD BREAK-DOWN IN MANGROVE ECOSYSTEMS: A REVIEW

S.M. Cragg[1,2]

ABSTRACT

This paper reviews information from a wide range of sources which relates to the process of wood break-down in mangrove ecosystems. A high proportion of the standing biomass in mangrove forests consists of wood with a life-span and residence-time as litter much greater than that for leaves. Mangroves are subject to attack by terrestrial and marine organisms, but are protected by chemical and physical mechanisms. The marine organisms which exploit mangrove wood include ascomycete fungi, teredinid molluscs, isopod crustaceans and possibly bacteria. The input of wood litter in a mature mangrove forest is constant though locally patchy. In a forest which is colonising a bare substrate, wood litter input slowly increases from zero. In a managed forest, pulses of wood litter input occur with each thinning but the bulk of wood biomass is removed from the ecosystem. Teredinids process wood on the forest floor, converting it into products which can be transported by currents. Nitrogen-fixing cellulolytic bacteria live symbiotically in teredinids. Some of the nutrients and energy derived from wood are carried offshore by currents and through food-webs.

Key words: biomass, forest, litter, teredinids, food-web.

INTRODUCTION

Significant flows of energy and matter occur between mangrove forests and adjacent ecosystems as a result of water movements, particularly tides, and of food-webs. The magnitude and direction of these flows is a matter of controversy and few efforts have been made to measure them directly. There is probably much variation among mangrove ecosystems with respect to the characteristics of these flows, a better understanding of which is a key to improved management practice in mangrove areas. Attempts to understand the dynamics of energy and matter flows in mangrove ecosystems have tended to focus on that proportion of net productivity channelled into "litter", namely the material readily gathered in collectors placed 1 - 2 metres above the substratum. In successional or managed forests, this is likely to be the main organic matter input to the ecosystem. In mature forests, however, the input of woody material is probably very important. This paper assesses the likely significance of such longer-lived and refractory tissues in the dynamics of mangrove ecosystems and considers the means by which they are broken down.

WOOD PRODUCTION

To assess the significance of wood in mangrove ecosystems, it is necessary to have estimates of the proportion of biomass represented by woody tissues, and an index of the rate at which matter passes through this biomass compartment. This rate is a function of the proportion of total production

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channelled into woody tissue, the life-span of tree organs formed of woody tissue (roots, branches, trunks) and the rate of turn-over of dead woody tissues.

Woody Biomass

Woody tissues form a high proportion of total biomass in mangrove forests. Suzuki and Tagawa (1983) found that in a low-canopied mixed stand of *Rhizophora mucronata* and *Bruguiera gymnorhiza* located near Okinawa, leaves formed only 6% of the total above-ground biomass. Woody tissues presumably formed the bulk of the remainder. Christensen (1978) estimated that in a taller 15-year-old stand of *Rhizophora apiculata* in Thailand, leaves constituted less than 5% of above-ground biomass and reproductive parts less than 0.2%, the remaining 95% being woody tissue (trunks 47%, branches 10%, prop roots 38%). Golley *et al.* (1975) found that leaves from a mature stand of *Rhizophora brevistyla* in Panama constituted less than 1.3% of the total above-ground biomass. Woody tissues were categorized into prop-roots (42%) and stems (57%). The indication from the above measurements is that the proportion of woody tissue within the total biomass increases with increasing tree size. This is supported by measurements of biomass partitioning in *Rhizophora mangle* in a forest in Puerto Rico given by Cintron and Schaeffer-Novelli (1984). They found that as trunk diameter increases from 1.1 cm to 15.4 cm the proportion of biomass consisting of leaves and that consisting of branches decrease (from about 16% to 4%, and from 23% to 13% respectively), but the proportions of biomass in trunks and prop-roots increase (from about 55% to 63%, and from about 7% to 20% respectively). Thus, in mature mangrove forests the proportion of biomass in woody tissue is likely to be even higher than it is in successional or managed forests.

Measures of partitioning of production into trunks and prop-roots have been obtained from an even-aged, managed mangrove forest (Gong *et al.* 1984), but it should be borne in mind that in such forests growth rates are probably much greater than in a "steady-state" mature mangrove forest. I know of no published data on growth rates in unmanaged mangrove forests, though records of permanent plots established at the time of the studies reported by Watson (1928) have been kept regularly up to the present day: the evaluation of this data remains to be undertaken (Ong, J.E., pers, comm.).

Life-spans of Biomass Partitions

The partitions of mangrove biomass (i.e. the proportions of biomass represented by leaves, branches, trunks, prop roots and subterranean roots) have strikingly different life-spans and rates of break-down after death. The life-span is the period during which the biomass is available to herbivores. Christensen (1978) reports a mean leaf life-span of 0.7 years in a managed mangrove forest in Thailand. No direct measurements of branch life-spans have been made, but since few twigs grow into large branches, twigs probably have a relatively short life-span, perhaps one to two years and, like leaves, are shed throughout the life of the tree. Branch-shedding must also be a regular occurrence during the life of the tree, particularly in the case of species such as members of the Rhizophoraceae, which are self-pruning (i.e. lower branches naturally drop off in approximately the order in which they appeared). Branch life-spans would depend on species. However, it is likely that most branches fall within fifteen years of first appearing. As the tree becomes senescent, branch-fall may increase in a sporadic fashion up to and after death.

The life-span of the trunk is generally that of the tree; unfortunately reliable data on life-spans of mangrove trees are not available. In Papua New Guinea, specimens of *Rhizophora* or *Bruguiera* exceeding 30 m in height and 50 cm in diameter are quite common in sites where conditions favour

mangrove growth (Percival and Womersley 1975; Floyd 1977). Such trees frequently show signs of senescence. In comparison with the size of mangroves in managed forests which have grown under conditions conducive to rapid growth for up to 30 years, it is likely that these mature or over-mature mangrove trees are over seventy and may even exceed one hundred years in age (Ong, J.E., pers, comm.).

Root life-spans are also likely to be at least partially a function of diameter. It is unlikely that fine hair-roots are long-lived. Thus, as they appear to represent a substantial but difficult-to-quantify proportion of biomass (Golley *et al.* 1975) it is likely that they represent a significant proportion of primary production. Prop-roots like branches, though longer-lived, are probably shed throughout the life of a mangrove tree. Observations at Bootless Inlet near Motupore Island, Papua New Guinea Island, Papua New Guinea indicated that a proportion of prop-roots in a healthy forest get damaged or infected so that they eventually become detached form the tree (Cragg and Swift unpub.).

There are extensive data available on litter-fall rates which give a good indication of the rate of turnover of leaves, twigs and reproductive parts (see for example Duke *et al.* 1981; Gong 1984). However, litter-traps do not collect longer branches efficiently and they are unable to catch falling trunks. Furthermore they are situated above the height of prop-roots so they do not measure turnover of this very significant biomass partition.

Litter Break-Down Rates

Studies of leaf-litter decomposition are reviewed by Polunin (1986). Root-litter break-down has been investigated by Van der Valk and Attiwill (1984), but the break-down of woody tissues has received little attention until the study of Robertson and Daniel (1989). Certain mangrove management practices rely on the biodegradation of branches and roots left behind after harvesting. Casual observation suggests that the break-down rate for main stems may be quite slow. For example, in late 1974 a road was built to the Kaut timber concession in New Ireland, Papua New Guinea which traversed an area of mature mangrove forest. The trees felled during road construction were left in an area subjected to daily tides unimpeded by the road. Observations in late 1985 showed that though the tree stems were extensively decayed by basidiomycetes, they were still intact. By measuring standing stocks of dead wood and rates of break-down of logs of known ages of up to 15 years old, Robertson and Daniel (1989) estimated that the rate of flux for wood detritus was 4 g $C.m^{-2}.y^{-1}$ in a young mangrove forest and 44g $C.m^{-2}.y^{-1}$ in a mature mangrove forest in tropical Australia. More such systematic measurements of wood break-down rates in a range of mangrove environments are required before the significance of energy flow through the biomass compartments represented by woody tissues can be properly understood.

ECOLOGICAL CONSEQUENCES OF WOODY TISSUE CHARACTERISTICS

Owing to the limitations on the distribution of wood-consuming organisms imposed by tidal inundation, the spatial distribution of woody tissues is of ecological significance (Rimmer *et al.* 1983). This is particularly so in the genus *Rhizophora* with its elaborate root architecture, which has been analysed by Sato (1978). The tree consists of a range of aerial, intertidal and subterranean niches for wood-dependent organisms. Furthermore the spatial distribution of tissues within a given limb may also affect susceptibility to bio-degradation. Young *Rhizophora* prop-roots consist of spongy tissues within which is embedded a cylinder of woody tissue (Gill and Tomlinson 1971). Teredinid borers are restricted to the woody tissue while the crustacean *Sphaeroma* frequently occurs in the spongy tissue (unpub. obs.). *Rhizophora* responds to animal or fungal damage to its prop-roots by branching in the

damaged area (Kohlmeyer 1969; Ribi 1981, 1982). The differentation of woody tissues into bark, sapwood and heartwood is also of ecological significance. The bark of certain mangroves contains high levels of polyphenolics: up to 40% of the dry weight in *Rhizophora mucronata* bark consists of polyphenolics (Hills 1985). Tannin levels can be sufficient for commercial exploitation (Percival and Womersley 1975). The sapwood of many trees contains starch, which can be exploited by certain beetle larvae. The sapwoods of the mangrove genera *Avicennia, Exceocaria* and *Sonneratia* are rated as susceptible to the starch-dependent beetles of the family Lyctidae, while those of *Bruguiera, Rhizophora* and *Xylocarpus* are rated non-susceptible (Eddowes 1978).

Wood consists principally of three classes of organic chemicals:- celluloses, hemicelluloses and lignins. Few organisms apart from white rot basidiomycete fungi are capable of breaking down the lignins, whereas the celluloses and hemicelluloses can be broken down to simple sugars by organisms possessing the requisite combination of enzymes. Though energy-rich, these molecules are relatively refractory and only certain groups of organisms are capable of utilising them.

Some organisms can attack live trees. These organisms include a range of marine animals and basidiomycete fungi, and beetles and termites which occur also in dry land forests. The isopod crustacean *Sphaeroma* (Rehm and Humm 1973; Simberloff *et al.* 1978; Ribi 1981, 1982), the pholad bivalve *Martesia* (Dharmaraj and Nair 1981) and the teredinid bivalve *Bactronophorus* (Roonwal 1954) have all been reported to be capable of burrowing into live trees. *Sphaeroma* and *Bactronophorus* also occur in live mangroves in Papua New Guinea (unpub. obs.). Attack by marine animals may be sufficiently severe to affect the survival of the trees attacked (Roonwal 1954; Rehm and Humm 1973). However, if attack on live mangroves were as severe as that on dead mangrove wood in the intertidal zone, the mangrove forest could not exist, because most trees would be felled by borer activity before they reached maturity.

Whereas animals respond to disease and injury by healing, trees compartmentalise damaged portions, isolating them from sound wood (Shigo 1985). Apparently mangrove trees have some form of defence against marine borers, which is lost after death. The water soluble polyphenolics found in high concentrations in the bark may provide this defence. It is likely that they continue to be secreted and leached into the water while the tree is alive, but secretion ceases at death. Mangroves such as *Xylocarpus, Rhizophora, Sonneratia* and *Bruguiera* have heartwood rated as durable or moderately durable, that is to say they have some natural resistance to basidiomycete and termite degradation owing to extractives in the heartwood. *Excoecaria* and *Avicennia* have non-durable heartwood (Eddowes 1978). No clear data are available regarding the ecological influence of these variations in natural durability. The degree of durability may affect not only the ability of the tree to withstand disease and insect attack, but also the rate of breakdown and decay once the tree falls to the forest floor. Ritchie (1968) found that the heartwood of *Rhizophora mangle* is naturally resistant to marine fungi.

WOOD-DEPENDENT BIOTA

The wood-dependent biota of mangrove forests can be categorized into terrestrial and marine groups. The domains of activity of these groups have a boundary at about the high-tide mark, with some overlap. The terrestrial biota closely resembles that of adjacent non-tidal forests, with basidiomycete fungi, adult and larval beetles, subterranean and drywood termites predominating. The ecology of these organisms and their importance in wood breakdown is well documented (see Swift *et al.* 1979) but no detailed studies specifically relating to their role in mangrove ecosystems have

been carried out. It is noteworthy that subterranean termites are active in areas subjected to regular tidal inundation. They build their earth runways extending from the forest floor up into the tree in the usual fashion (Cragg 1983) despite the tides.

Kohlmeyer (1969) reviewed the limited records of distribution of fungi in mangrove forests. Above the high-tide line, wood is colonised by basidiomycetes whereas in the intertidal zone, ascomycetes and deuteromycetes occur. This distribution pattern has also been observed in Papua New Guinea (Cragg and Swift, unpub.). Further information regarding the distribution of fungi in mangrove forests is provided by Hughes (1975). Leightley (1980) investigated the wood-decaying capacity of marine fungi occurring in mangrove forests.

The significance of bacteria in wood break-down should not be overlooked. Buckley and Triska (1978) found that nitrogen-fixing bacteria participate in wood decomposition in freshwater streams in the United States of America. No comparable study has been conducted on mangrove wood, but bacteria have been found forming tunnels in wood from marine pilings in Papua New Guinea. This bacterial activity may prepare the wood for colonisation by marine wood-borers (Cragg and Nilsson, unpub. obs).

Rather more is known about the ecology of marine wood-borers than of other wood-degrading organisms found in mangroves. This is perhaps a reflection of the economic significance of the damage caused by these organisms to man-made structures. The isopod *Limnoria* is a major pest in maritime pilings, but is not particularly important in mangrove areas. In addition to occuring at port sites around Papua New Guinea, it has been observed colonising *Sonneratia* pneumatophores in a small stand of mangroves at Motupore Island near Port Moresby, Papua New Guinea. However, extensive collection in major mangrove areas in the country have failed to locate any *Limnoria*. It appears that in Papua New Guinea *Limnoria* favours sites with marine salinities (Cragg and Aruga 1987). A variety of other isopods are found inhabiting burrows in mangrove wood. Whether these animals simply excavate their burrows, or consume the wood excavated remains to be established (Bowman 1977; Jones *et al.* 1983).

The most significant wood inhabiting isopod in mangrove forests is *Sphaeroma*. This animal is mainly found in prop roots of *Rhizophora*, but it also burrows into detached dead wood and can tolerate extremely low salinities (Cragg and Aruga 1987). It burrows at right angles to the surface of the wood and there is still doubt as to whether it digests the wood removed (John 1968). The most detailed account of the ecology of this animal is provided by Estavez and Simon (1975). There has been considerable unresolved debate as to whether the burrowing activity of this animal is beneficial for (encouraging extra branching, increasing stability) or detrimental to (causing structural weakening), the mangrove trees in Florida (Rehm and Humm 1973; Simberloff *et al.* 1978; Ribi 1981, 1982).

Little is known about the feeding of the species of *Sphaeroma* which inhabit mangroves. Rotramel (1975) described how a non-mangrove species, *Sphaeroma quoyanum*, uses feather-like hairs on its walking legs as a filtering net. Cragg and Icely (1982) found that *S. terebrans* has similar hairs, but that *S. triste* does not. Both these species occur in mangroves in the vicinity of Port Moresby. These authors were unable to identify gut contents, but found that most animals examined had empty guts, suggesting that feeding is intermittent. John (1968) reports that an extract from the hepatopancreas of *S. terebrans* is capable of converting chemically-prepared cellulose into glucose, but cellulose in wood is less liable to enzyme conversion than artificial cellulose substrates (Dean 1976).

In terms of their importance in breaking down dead wood, teredinids are by far the most significant

marine wood-borers in mangrove swamps. These highly modified bivalves with worm-like bodies excavate cylindrical burrows which may extend into the centre of large tree stems, but generally run parallel to the axis of the branch stem or root. There are nearly forty species of teredinids in Papua New Guinea (Rayner 1983). These vary considerably in their salinity-tolerance range. Some species are commonly associated with mangrove ecosystems and two species *(Bactronophorus thoracites* and *Dicyathifer manni)* are virtually restricted to mangrove wood (Rayner 1983). Cragg and Aruga (1987) found that the teredinid fauna of the mangroves of the Gulf of Papua is very distinct from that in wood washed offshore from this mangrove ecosystem.

Teredinids consume the wood they excavate and digest it. The mechanism of digestion has been studied in detail (Dean 1978; Morton 1978). Recent studies have shown that nitrogen fixing symbiotic bacteria are implicated in the digestion process (Waterbury *et al.* 1983). Teredinids are also able to filter-feed on phytoplankton (Pechenik *et al.* 1979). Differences in gut structure appear to reflect the relative importance of phytoplankton and wood in the diet of different shipworm species. The "mangrove specialist" *Bactronophorus* apparently emphasies filter-feeding (Turner 1966). It is generally assumed that teredinids filter phytoplankton. However, other particulate food sources may be available to teredinids in mangrove ecosystems including bacteria inhabiting clay particle flocs which tend to form in tropical estuarine areas (Paerl and Kellar 1980) or particulate organic matter.

Wood-boring members of the Pholadidae also burrow into woody litter in mangrove forests. They have been observed in this niche in, for example, the mangrove forests of eastern India (Turner and Santhakumaran 1989), of the Gulf of Papua (Cragg and Aruga 1987) and of Singapore (Cragg and Murphy, unpub.). These bivalves are rarely as important as teredinids in the breakdown of mangrove wood.

LIFE, DEATH AND BREAK-DOWN OF MANGROVE TREES

The Fate of the Individual Tree

During its life, a tree is subject to herbivory which includes not only the consumption of live leaves, but also other plant tissues including live wood. Live tree tissue is also catabolized by certain fungi. It is likely that only a small proportion of the woody biomass is utilised in this fashion, the majority entering decomposer-dominated food-webs. Regular twig and branch-fall will enter the pool of material available to the decomposer community on the forest floor. With senescence and death, fungal and borer activity increases sharply, tree limbs are shed at an accelerated rate, and eventually the main stem falls. Further break-down occurs on the forest floor.

Teredinids are the principal agents of wood break-down on the forest floor. They riddle fallen wood until over 50% of the original volume (Cragg and Swift unpub.) has been consumed and metabolised. This vastly increases the surface area available for fungal and bacterial degradation and mechanically weakens the wood, eventually leading to its fragmentation into smaller pieces.

The end result of the activities of the marine decomposer community is the conversion of a large and (particularly in the case of a main stem) relatively immobile structure into a range of products which can be readily transported by water currents. These products include particulate and dissolved organic matter, the planktonic larvae of teredinids, and teredinid faeces.

Wood Break-down in Different Forest Types

In a mature mangrove forest unaffected by human activity, if a sufficiently large areas is taken into consideration, a steady state with respect to wood input and breakdown is likely to exist. The distribution of wood detritus is very patchy, with high

concentrations where a large tree has recently fallen. In a recently established forest there is initially no wood litter input at all. As the colonising trees grow older, wood litter builds up due to branch-fall and eventually stem-fall. The situation in a managed forest is that there are pulses of branch and root wood input after thinning and final felling, but main stems are removed from the ecosystem.

Sources and Output of Wood

The mangrove ecosystem receives a variety of inputs of wood. In Papua New Guinea, substantial quantities of wood are transported by rivers into mangrove swamps from the forests inland (Cragg 1983). This input will be particularly high in times of flood. The input of wood from the mangrove forest itself may be dramatically increased by natural disasters of the type detailed by Johns (1986) such as cyclones, lightning, tidal waves or erosion. A small input of drift-wood may occur in mangrove areas subject to strong tidal currents.

The wood input to mangrove ecosystems is either consumed by the decomposer community and converted into transportable products as already described, or is physically removed. Some wood may become buried due to the very dynamic deposition/erosion regime found in many mangrove areas. Any wood of a size, shape and density suitable for water transport may be exported due to the residual seaward component of the current regime.

NUTRIENT AND ENERGY FLUXES

Because of the paucity of experimental data it is only possible to discuss fluxes of nutrients and energy associated with wood break-down in very general terms.

The initial energy resource, the wood partition of the tree biomass, has been measured in a range of mangrove ecosystems (see for example Golley *et al.* 1975; Christensen 1978; Suzuki and Tagawa 1983; Cintron and Schaeffer-Novelli 1984). No estimates of the proportion of this biomass which is consumed before the tree dies are available. The standing stock of wood litter has been estimated from one site in Papua New Guinea (Cragg and Swift unpub.) and from sites in Australia (Robertson & Daniel 1989), but casual observations show that the stock varies considerably between different mangrove sites.

The flow of wood-derived energy through the mangrove related food-webs has not yet been mapped. Observations in a *Rhizophora*-dominated forest in Papua New Guinea suggest that at least 50% of wood litter biomass is converted by teredinids (Cragg & Swift unpub.). The products of this conversion would be teredinid tissue, planktonic larvae, excretory products and perhaps dissolved organic matter. Owing to the protection afforded by their burrows it is unlikely that teredinids are subject to severe predation. Thus, teredinid tissue will be mainly converted by the decomposer community *in situ*. Their larvae, on the other hand will be broadcast by water currents, as will excretory products and dissolved organic matter.

Wood which is carried out to sea becomes water logged and eventually sinks. Even if it sinks in deep water, it will become colonised by marine borers. Turner (1977) has described how wood "islands" in the deep-sea can support communities of animals in areas otherwise virtually devoid of animal life. Cragg and Aruga (1987) investigated wood collected by prawn trawlers operating some kilometres off-shore of the mangroves of the Gulf of Papua and found that this wood (some of which originated inland of the mangrove forest) supported a number of species of teredinids.

As a nutrient resource, wood litter tends to be less rich than leaf litter. Aksornkoae and Khemnark (1984) found that in the main stems of a number of mangrove species, the concentration of nitrogen

was generally one half to one quarter of that of leaves, and that of phosphorus approximately half that of leaves. During the wood break-down process, the nutrient status of the wood may change. Nitrogen fixation occurs due to the symbiotic bacteria of teredinids (Waterbury *et al.* 1983). Calcium is extracted from the seawater and deposited to line the burrows, or form the shells of the teredinids. Additional nitrogen and other nutrients are taken by filter-feeding teredinids from the seawater in the form of phytoplankton or other particulate food. Nitrogen is lost as a result of excretion. Nutrient translocation is also likely to occur as a result of the microbial break-down of wood.

AREAS FOR FUTURE INVESTIGATION

The role of wood break-down in mangrove ecosystems is important, but is very poorly understood. It is not yet possible to determine the relative importance of leaf and wood litter in mangrove ecosystems. Further estimates of wood litter standing stocks, wood export rates, wood break-down rates, and associated nutrient fluxes are needed. Food-webs associated with wood break-down also require detailed investigation. Attention should be given to the wide range of animals including fish, crabs, polychaetes and nemertines which utilize burrowed wood as shelter. The importance of wood is not just of academic interest. It is also of concern to those who manage mangrove forests, who need to be able to forecast the impact of the removal of the bulk of woody biomass on the rest of the ecosystem.

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ANALYSIS OF COPPER AND ITS STATUS IN CATTLE FROM MOROBE PROVINCE, PAPUA NEW GUINEA

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ABSTRACT

The copper status of cattle from 16 properties in the Morobe Province was investigated by the analysis of liver and serum for copper levels. It was found that fifteen properties had animals with copper concentrations in serum and liver samples which were below normal. The normal serum and liver copper concentration in cattle was 0.60 ppm and 100 ppm Dry Matter. Haemolysed serum samples were often found to give higher results than non-haemolysed serum samples. Samples stored for nine days at room temperature gave lower values than samples stored in the refrigerator or freezer. No significant differences were found between trichloroacetic acid (TCA) and glycerol procedures in sample preparation. Treatment of a test serum with the concentrations of 5, 8, 11, 15, 20 percent TCA, did not give any significant differences in copper concentration.

Key words: Cattle, Copper status, Serum, Liver, Atomic Absorption Spectrophotometer, haemolysis and storage conditions.

INTRODUCTION

Research has shown that copper plays an important role in the biochemistry of ruminants. Because copper is a constituent of many enzymes and other biological catalysts, it is described as one of the prime-movers of the "biochemical machine" (Frieden 1978). It plays a vital role in the processes of pigmentation of hair and wool, formation of blood and bone, reproduction and myelination of the spinal cord (Blood et al. 1979).

The level of copper in biological materials is well documented (Underwood 1971; Bull 1980). The concentration of copper in pasture and animal tissues varies with species and age. For animal tissues, copper levels are generally highest in liver, brain, kidney, heart and hair (Bull 1980).

Deficiencies of copper in animals have been well studied since the 1930s. In the United States of America, Holland and Australia ruminant diseases such as 'salt sick', 'echsucht' and enzootic ataxia' were investigated and shown to be caused by copper deficiency (Bull 1980; Grace 1983; Jones and Hunt 1983). In New Zealand, two cattle diseases, 'teart' and 'peat scours', were shown to be caused by the combination of very high molybdenum levels in pasture forages and depletion of copper in the body tissues (Bull 1980). The interrelationships between copper and molybdenum and with other elements has shown that the effects of the total diet must be considered on the metabolism of copper (Bull 1980; Suttle 1986 a).

Animals deficient in copper vary with respect to the extent of the deficiency. The degree of copper insufficiency may be categorised as either severe or marginal. Marginal insufficiency results in a reduction in tissue enzyme activities and copper concentrations but no impairment of biochemical processes within the tissues. Severe copper in-

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sufficiency results in significant impairment of biochemical processes and alterations in tissue structure. Clinical signs such as depigmentation of wool or hair, severe scouring, enzootic ataxia and bone fractures are likely to be displayed (Jones and Hunt 1983; Paynter 1987).

Several studies have been performed to determine the copper status of ruminants in Papua New Guinea (Glasgow 1966; Mayall 1973; Holmes 1981; Holmes *et al.* 1986). These studies concentrated on major ruminant grazing areas and usually involved copper supplementation for some of the animals. Previous field observations, together with biochemical analyses, indicate that deficiencies exist in a number of areas including the Markham Valley in Morobe Province (Mayall 1973).

Analysis of biological samples such as serum or plasma for copper levels are usually performed by Atomic Absorption Spectrophotometry (AAS). Various methods of sample preparation have been used to overcome some of the problems associated with this technique.

Viscosity of samples has been postulated as a major source of error in flame AAS methods (Weinstock and Uhlemann 1981). If the viscosity of standards and samples differ, then the aspiration rates and hence the absorbances differ (Makino and Takahara 1981). The viscosity effect in biological fluids is due mainly to proteins, particularly albumin (Carthrew and Dey 1985).

There are two ways to counteract the effect of viscosity. One is to increase the viscosity of the standards to match that of the serum or plasma samples. Glycerol can be used for this. Another is to reduce the effects of viscosity of the serum or plasma samples by adding trichloroacetic acid (TCA) to precipitate the proteins (Clark 1971; Osheim 1983). Various TCA concentrations have been used by different authors (Saunderman and Roszel 1967; Mayall 1973; Healy *et al.* 1978). Therefore, the effect of different TCA concentrations on the determination of copper in serum was studied.

Sample handling is an important factor in obtaining accurate results for trace elements in biological samples. There is a particular problem with the collection of blood samples from animals in the field, where refrigeration may not be available. Samples are sometimes left at ambient temperature for long periods of time or may be transported over rough roads which may lead to haemolysis.

Haemolysis and storage are important aspects of sample handling. Haemolysis will affect the results if the intra-cellular concentration of elements differs from the concentration in the serum or plasma. Such effects of tissue membrane leakage into plasma, are particularly seen where the intra to extra cellular concentration differences are in excess of 10 fold e.g. with potassium and magnesium or with spectrophotometric assays where haemoglobin may be absorbed directly. In the case of copper measured by AAS, where in normal bovines, plasma and read cell concentrations are similar, and interferences by haemoglobin per sera should be very low. The following experiments investigated how haemolysis and the storage regime affect copper concentration.

There were three aims in this study. The first was to assess the copper status of cattle from selected properties in the Morobe Province; the second was to compare different methods of sample preparation, including effects of contamination from tubes and different methods of deproteinising serum samples; and the third was to establish the effects of haemolysis and storage conditions on copper results.

MATERIALS AND METHODS

The following test tubes and blood or serum containers were used:

(a) Sterile blood container without anticoagulant, 10mL, disposable plastic tube.

(b) Serum container, 5mL, disposable plastic tube.

(c) Centrifuge plastic tube, 10mL.

(d) Round bottom glass tube, 10mL.

All glassware was thoroughly washed with detergent, rinsed with tap water, and rinsed well with distilled water. Excess water was removed and the glassware was soaked in 5 percent analytical reagent grade nitric acid, for 24 hours. Finally it was washed with tap water, rinsed three times with distilled water and dried in an oven.

The following eight solutions were prepared simultaneously using both Glycerol and TCA procedures:

1. 1 mL distilled H_2O + 1 mL 10 percent Glycerol+
2. 1 mL deionised H_2O + 1 mL 10 percent Glycerol*
3. 1 mL control serum+ + 1 mL distilled H_2O
4. 1 mL control serum* + 1 mL deionised H_2O
5. 1 mL distilled H_2O + 1 mL 8 percent TCA+
6. 1 mL deionised H_2O + 1 mL 8 percent TCA*
7. 1 mL control serum+ + 1 mL 8 percent TCA+
8. 1 mL control serum* + 1 mL 8 percent TCA*

\+ : prepared with distilled H_2O

* : prepared with deionised H_2O

All samples were prepared in duplicates.

After pipetting each of the eight solutions the contents in the test tubes were immediately mixed on a vortex mixer. The TCA prepared control serum samples were centrifuged to separate the supernatant from the protein precipitate. All the test tubes were left to stand for 10 minutes, then spun for 10 minutes and aspirated without disturbing the precipitated plug. The absorbances were measured and the copper concentrations calculated. Blanks containing TCA and Glycerol solutions were analysed with the samples in each run and no contamination was found.

Atomic Absorption Spectrophotometer and Standard Reference Materials

A Varian model A-1475 atomic absorption spectrophotometer and Varian Spectra AA-40 spectrophoto meter with air/acetylene flame were used at 324.8 nm. A range of settings of the AA-1475 including use of single beam (SB), single beam/background correction (SB/BC), double beam (DB) and DB/BC were investigated.

A standard reference material, Gilford QCS Normal (freeze-dried human serum), with an established concentration of 0.94 ± 0.15 ppm copper was used as a control to test the recovery of copper when comparing the Glycerol and TCA procedures. The National Bureau of Standards (NBS), Standard Reference Material SRM 909 human serum and a certified NBS Bovine Liver control SRM 1577a were included in the sample analysis.

Sample Collection

In 1985 and 1986 serum samples were collected from slaughtered animals at the abattoir and from live animals in the field by officers of the Department of Agriculture and Livestock and staff of the National Veterinary Laboratory (NVL). However the precise time of the year and methods of collection, storage and transportation are not known. Analyses were carried out by the staff at NVL after sera were separated.

Serum and liver samples were collected at the Lae Central Abattoir in 1987 from slaughtered cattle. Figure 1 shows the farms in the Morobe Province from which the slaughtered animals came.

Serum samples were collected at the abattoir in sterile blood containers without anticoagulant and transported to the laboratory in an esky cooled by

an ice pack. These samples were left on the bench for 30 - 60 minutes to allow the blood to clot. They were then centrifuged to obtain clear serum samples. If the serum samples could not be analysed immediately they were stored in a freezer at - 23°C until required for analysis.

Comparison of Methods

Glycerol and TCA procedures as defined by Ross (1984) and as used by Mayall (1973) were evaluated.

A stock copper solution of 1000 ppm cupric nitrate, Spectrosol, British Drug House (BDH), was used for copper standard. The working standard solutions of copper was made up to 100 mL with 10 percent glycerol to copper concentrations of 0.0, 0.25, 0.50, 1.00, 1.50, and 2.00 ppm. An intermediate copper solution of 20 ppm was made up with 8 percent TCA from the stock solution to prepare working standard copper solutions. The working standard copper solutions of 0.0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4 and 1.6 ppm were prepared with 8 percent TCA. These standards were used for standard curve.

In one experiment a range of TCA concentration of the samples from 5 - 20 percent were tested. The volume of TCA added to sera was kept constant at a ratio of 1:1.

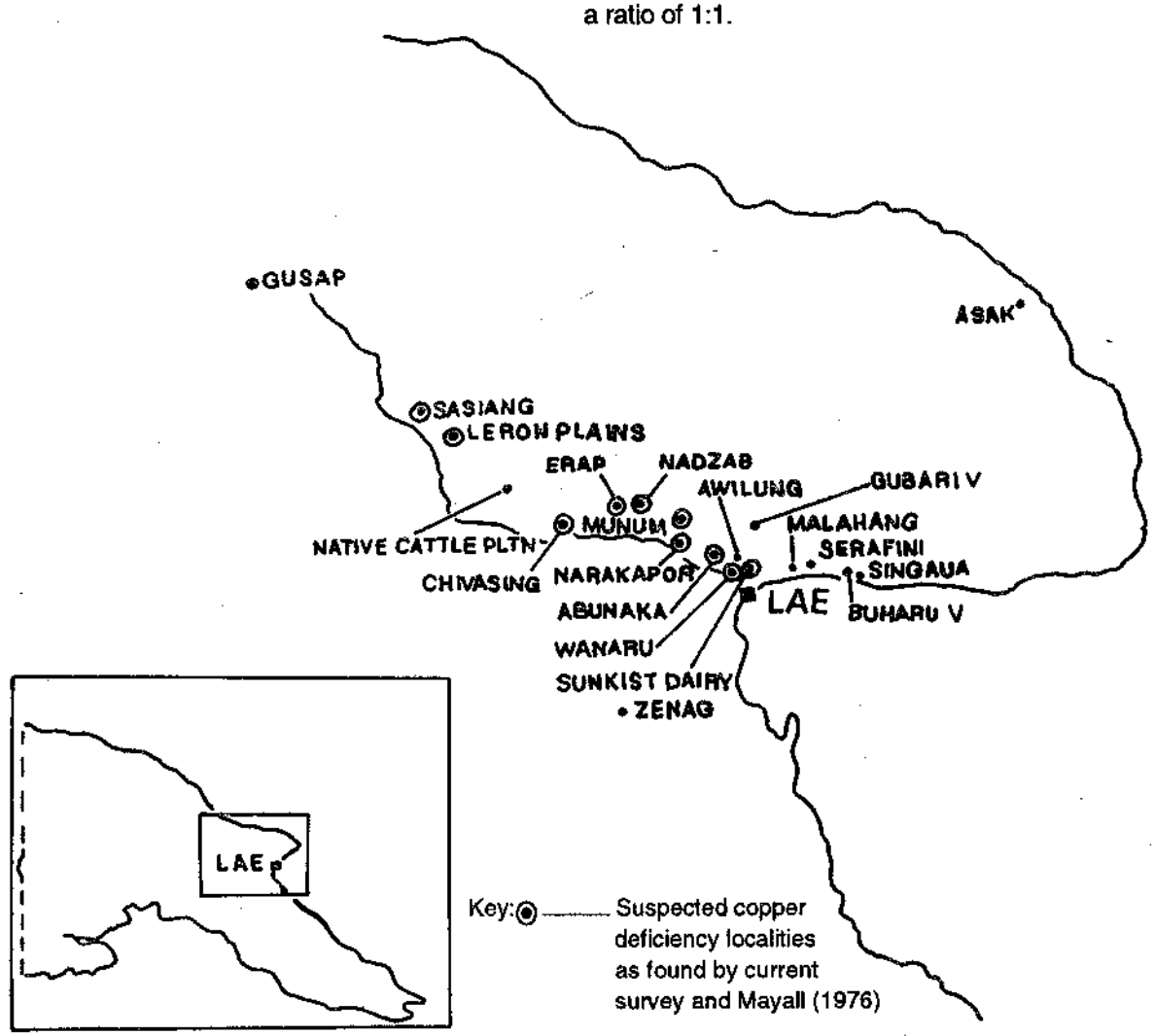

Figure 1. **Map showing locations in Morobe Province of beef and dairy cattle farms investigated for copper status.**

Haemolysis and Storage

The effects of haemolysis on the copper content prior to: (1) sera separation and (2) storage method of serum were studied under two types of conditions (non-haemolysed and haemolysed), three storage systems (freezer, refrigerator and ambient temperature) over five time periods (1,3,5,7,9 days post collection). Blood from one animal (A) was collected into 60 ten mL, tubes and centrifuged. Thirty tubes were allocated as clean non-haemolysed sera. One or two drops of concentrated red blood cells (RBC) (one of the tubes of centrifuged blood) was added with a pasteur pipette to each of the other 30 tubes and shaken vigorously to give haemolysed sera. Both non-haemolysed and haemolysed sera were stored in a freezer on the day of collection (Day 1). On day 1 twelve sera from both haemolysed and non-haemolysed serum groups were removed from the freezer and three of each groups were placed in each of the storage systems referred to above. This procedure was repeated on days 3, 5, 7, and 9. On day 10 all samples (60) were analysed for their copper content. Blood from a second animal (B) was analysed with Animal (A) at the same time and following the same procedure.

The liver samples were stored in a deep freezer until they were ready to be digested and analysed for their copper content.

Sample Analysis

One millilitre (mL) of 8 percent TCA was added to an equivalent amount of serum in a test tube and the contents were vortexed thoroughly to mix the TCA with the serum. The test tubes were allowed to stand for 10 minutes, then centrifuged for a further 10 minutes to separate the supernatant from protein precipitate and aspirated without disturbing the precipitated plug. National Bureau of Standards (NBS) Certified Standard Reference Material SRM 909, dried human serum, was included as an external serum standard.

Digestion of Liver Samples

Samples of thawed out liver weighing one to three grams were digested with 15 - 20 mL of a mixture of analytical grade nitric and perchloric acids (4 : 1). The digestions were carried out in 150 mL pyrex conical flasks. Anti-bumping granules were placed in the digestion flasks to prevent violent boiling. The temperature of the digestions was in the range of 120 - 200°C. A certified NBS Bovine liver control SRM 1577a was included as an external liver control. The digested samples were diluted into 50 ml volumetric flasks and analysed using the serum method. The results were determined on a dry matter (DM) basis.

Statistics

The data were analysed by one or four way analysis of variance (ANOVA) (Sokal and Rohlf 1981). The four treatments (SB, SB/BC, DB AND DB/BC) that have eight figures each were compared for their significant differences equally at one time by using four way analysis (Table 1). One way analysis was used between two tubes (CPT and RBGT), deionised and distilled waters, reagents (TCA and Glycerol) and different handling systems under various conditions for different periods (Table 1 and 2).

RESULTS

The results indicate that the washing procedure was adequate and no significant copper contamination detected from the tubes, reagents or the type of water used. In all cases the blank absorbances were in the range of 0.000 - 0.005 which were within the limits of the machine noise.

Different absorbance settings (SB, SB/BC, DB and DB/BC) at 324.8 nm of the AAS did not affect the accuracy or precision in copper analysis. Copper concentrations were all within the expected range 0.94 ± 0.15 ppm copper for the control serum. The AAS method was very suitable because of its

simplicity, accuracy and precision in determining copper at trace levels.

No significant differences in copper concentrations were found between the use of trichloroacetic acid or glycerol procedures. The mean of sixteen values for sera using TCA was 0.91 ppm and sixteen values for sera using glycerol was 0.89 ppm. the analysis of variance of these methods gave an experimental F ratios of 2.219 and 1.816 which are not significant because these F ratios were lower than the value of 4.35 obtained from the statistical tables. The TCA concentrations from 5 - 20 percent gave similar results for copper levels in a serum sample. The TCA procedure was used in subsequent analyses of serum and liver samples.

The mineral concentrations of control serum under different conditions are shown in Table 1. The analysis of variance was calculated assuming there were no interactions as the concentrations of the control serum were not affected by interference effects.

The four way analysis of variance (ANOVA) gave no significant differences at 5 percent F Critical

Table 1. **Comparison of copper concentrations in control serum obtained from Trichloroacetic acid and Glycerol procedures.**

			Copper concentration (ppm)			
Proceedures	Water type	Tubes	SB	SB/BC	DB	DB/BC
TCA	Deionised H_2O	CPT	0.80	0.94	0.94	0.90
		RBGT	0.92	0.94	0.98	0.98
	Distilled H_2O	CPT	0.94	0.90	0.94	0.84
		RBGT	0.92	0.86	0.94	0.86
Glycerol	Deionised H_2O	CPT	0.94	0.80	0.86	0.86
		RBGT	0.92	0.94	0.96	0.92
	Distilled H_2O	CPT	0.88	0.86	0.86	0.94
		RBGT	0.86	0.80	0.86	0.96

SB - Single Beam; BC - Background Correction; DB - Double Beam; CPT - Centrifuge Plastic Tube; RBGT - Round Bottom Glass Tube.

Points under various conditions.

Table 2 shows results of two sera analysed for two haemolysis types under three different storage systems. Samples stored at ambient temperature gave lower copper concentrations than those stored in the refrigerator or freezer. For Serum A, a mean copper concentration of 0.55 ppm was obtained for non-haemolysed and haemolysed samples stored in the refrigerator or freezer whereas a mean copper concentration of 0.51 ppm was obtained for samples stored at ambient temperature. In Serum B the concentration was 0.72 ppm and 0.66 ppm for the refrigerated or ambient temperature samples respectively. Although the change in copper concentration over time differed for the different storage systems no discernible trends were observed.

The results for the two types of sera with different handling systems under various conditions for dif-

Table 2. **The mean copper concentrations of two sera, both haemolysed, and non-haemolysed, stored under three diferent storage systems for one to nine days. Significant levels of ANOVA for this table are shown below.**

	Copper Concentration (ppm)											
	SERUM A						SERUM B					
Days (Periods)	Non-Haemolysed			Haemolysed			Non-Haemolysed			Haemolysed		
	Frz.	Ref.	A.T.	Frz	.Ref.	A.T.	Frz.	Ref.	A.T.	Frz.	Ref.	A.T.
1	0.53	0.54	0.50	0.55	0.55	0.49	0.69	0.74	0.57	0.69	0.69	0.65
3	0.51	0.53	0.49	0.54	0.56	0.51	0.75	0.69	0.65	0.73	0.73	0.66
5	0.54	0.58	0.52	0.55	0.56	0.52	0.72	0.71	0.71	0.69	0.71	0.64
7	0.55	0.53	0.51	0.55	0.53	0.53	0.71	0.64	0.67	0.77	0.71	0.66
9	0.55	0.55	0.51	0.53	0.53	0.49	0.68	0.73	0.65	0.72	0.71	0.69

Key: Frz.-Freezer Ref.-Refrigerator A.T.-Ambient Temperature

ANOVA

Between Serum A and Serum B - Significant at 0.1%
Between different storage systems - Significant at 0.1%
Period by storage system interactions - Significant at 0.1%
Period by Haemolysis interactions - Significant at 5.0%
Between different periods - Not Significant
Between two haemolysis types - Not Significant
Haemolysis by storage systems interactions - Not Significant

Table 3. **Copper status of cattle from different farms in the Morobe Province.***

Owner Cattle Farms	Sample Type	No. & Sex Type	Observed copper Range (ppm)	Mean ± SEM copper (ppm)
	serum	5 steers	0.70 - 1.10	0.98 ± 0.08
	liver		36.0 - 152.0	91.00 ± 20.97
		8 steers		
	serum	6 cows	0.70 - 1.20	0.86 ± 0.04
Chivasing#		5 steers		
	serum	8 cows	0.40 - 1.20	0.71 ± 0.06
	liver		17.00 - 246.0	121.5 ± 18.08
		8 steers		
	serum	4 cows	0.52 - 1.57	0.77 ± 0.08
	liver	1 heifer	43.00 - 212.00	108.4 ± 13.81
	serum	7 heifer	0.52 - 0.90	0.78 ± 0.05
Ex-Narakapor@	serum	6 cows	0.49 - 0.73	0.59 ± 0.04
Native Cattle@		1 bull		
Plantation	serum	6 cows	0.59 - 1.10	0.83 ± 0.07
Erap@	serum	18 -	0.71 - 1.74	1.06 ± 0.07
Leron@		7 -		
	serum	6 cows(D)	0.60 - 1.50	1.12 ± 0.12
Ex-Leron#	serum	12 cows	0.35 - 0.77	0.58 ± 0.04
	serum	6 weaners	0.40 - 1.00	0.73 ± 0.09
Sasiang@		4 weaners		
Cattle Range	serum	7 heifers	0.30 - 0.90	0.71 ± 0.05
	serum	7 heifers	0.52 - 0.90	0.78 ± 0.05
		4 weaners		
Markham@		6 cows(D)		
Farmers	serum	2 cows(W)	0.60 - 1.60	0.80 ± 0.08

(Contd.)

	serum	6 -	0.62	-	2.10	1.34 ± 0.27
Zenag@	serum	2 -	0.80	-	1.00	0.90 ± 0.10
Swiss@ Mission, Lae	serum	4 cows	0.94	-	1.73	1.26 ± 0.17
Ex-Munum#	serum	7 bulls	0.44	-	0.65	0.54 ± 0.03
Zimu Markis@	serum	4 heifers	0.52	-	0.79	0.65 ± 0.06
Yamaku Timas@	serum	1 bull 3 cows	0.52	-	0.75	0.58 ± 0.06

* - **These results were obtained by staff at NVL in 1985 and 1986**

@ - **Samples collected at Lae Central Abattoir**

\# - **Samples collected in the field,**

D - Dry and W - Wet

ferent periods and the ANOVA (assuming no serum interaction or no real order of interactions) are presented in Table 2.

The copper concentration for the control liver was 158 ± 10 ppm DM while the certified value was 158 ppm DM. The copper concentration in the control serum was analysed to be 1.10 ± 0.04 ppm whereas its certified value was 1.10 ± 0.10 ppm. The results from samples submitted to the National Veterinary Laboratory (NVL) in 1985 and 1986 are summarised in Table 3. Copper values for serum and liver samples (DM) in this project are presented in Table 4.

It was expected that the available serum copper concentration should correlate well with the liver copper concentration. However in correlating the copper values of liver and serum, no real relationship has been observed. A poor correlation existed between serum and liver copper (Figure 2).

DISCUSSION

The normal range of copper concentration in serum is 0.60 - 1.60 ppm (Campbell 1983; Grace 1983; Whitelaw 1985). Most of the mean serum values fell within this range (Table 3 and Table 4). However the mean values of serum copper in cattle from Abunaka, Narakapor, and Nadzab were below normal, indicating that there was probably a copper deficiency among cattle in these places (Fig 1). Field supplementation would be necessary to quantify the effects of this deficiency.

Although the mean correlation is within the normal range on many farms, there are some values below normal. This indicates that the copper status may be marginal in most of the existing farms mentioned in Table 3 and Table 4. It is recognised that animals with marginal copper deficiency grow more slowly and as a result reduce their apparent copper requirement. Because of this, these animals may still maintain "normal" serum/plasma values, but would

Table 4. **Copper llevels in serum and liver samples analysed rom individual beef cattle killed at Lae Abattoir.**

Owner/Farms	Sample Type	No/Sex or Type	Obseved Range copper (ppm)	Mean copper (ppm)
Chivasing	:serum	7 -	0.61 - 0.72	0.66
	:serum	9 steers	0.46 - 0.77	0.62
	liiver		55.6 - 397.5	166.6
Narakapor	:serum	10 -	0.32 - 0.62	0.47
Abunaka	serum	4 -	0.12 - 0.46	0.27
	serum	4 cows	0.38 - 0.53	0.41
	liiver		7.8 - 107.7	36.0
Native Cattle Plantation	serum	2 bulls	0.63 - 0.67	0.65
	serum	2 cows	0.65 - 0.79	0.72
	liiver		52.2 - 266.7	159.5
A & J Beline Nadzab	serum	10 -	0.38 - 0.68	0.58
	Liver		38.5 - 159	83.4
Boiyo Kaninga Gubari Village	serum	4 steers	0.62 - 1.02	0.89
	liver		132.6 - 265.9	205.5
	serum	2 cows	0.56 - 1.10	0.83
	liver		36.0 - 63.5	49.8
Yanamahu Buharu Village	serum	5 steers	0.74 - 1.12	0.94
	liver		63.2 - 159.4	95.1
	serum	1 cow	0.96	
	liver		105.7	
Livestock Development Corporation ERAP	serum	7 cows	0.42 - 1.05	0.71

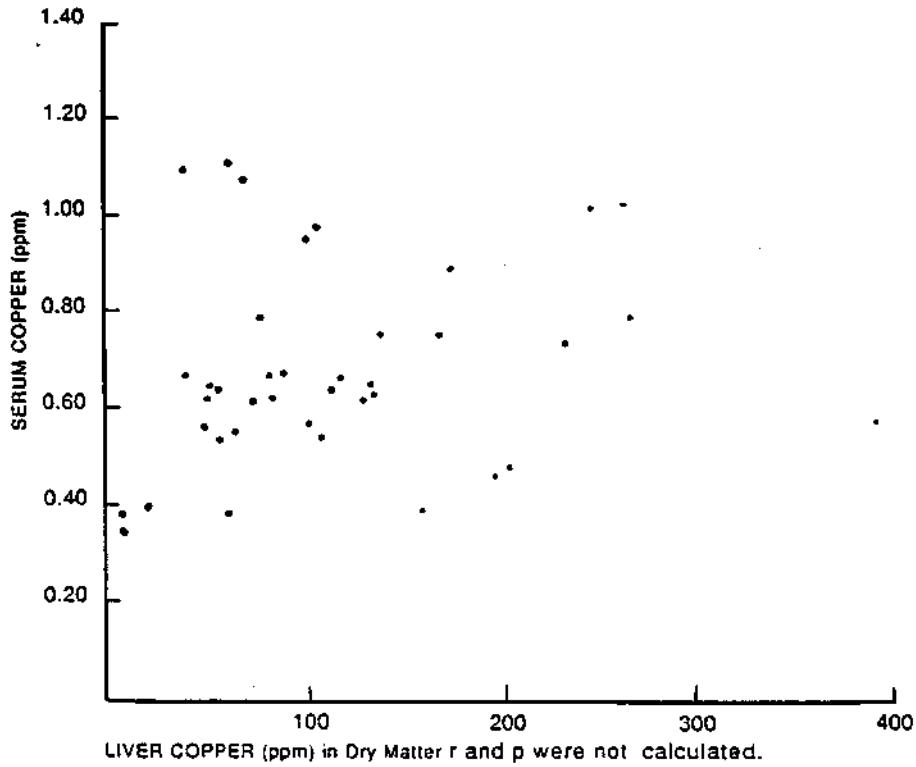

Figure 2. **Scatter diagram of Serum Copper concentration with Liver Copper concentration of individual Cattle from Morobe Province.**

respond to copper supplementation (Hill *et al*, 1962; Glasgow 1966; Mayall 1973; Reddy and Mahadevan 1976; Gallagher and Cottrill 1985; Langlands *et al.* 1986; Suttle 1986b). Although many of the animals slaughtered were in good condition and had no impairment, they were also mature adults. If the copper status was improved it might have been possible to slaughter at a younger age. Steers also have lower requirements for minerals than lactating or heavily pregnant cows. Lactating or pregnant cows are likely to have lower copper concentrations. However to confirm the lower copper concentrations in lactating cows a more detailed investigation of animals in the Morobe Province is necessary.

The mean copper concentrations of liver samples from cattle obtained from Abunaka, Nadzab and some smallholder cattle farmers at Buharu and Gubari villages are below the normal range (100 - 300 ppm DM) (Campbell 1983; Hill 1985). As with the serum results, some liver samples had very low copper concentrations of 7.8 - 63.5 ppm DM even though the mean concentrations were within the normal range.

Some authors (Campbell 1983; Grace 1983; Hall 1985; Paynter 1987) state that copper concentration in the liver is a better indicator of copper status than serum copper concentration because the former is the body's main reservoir of coper. Copper is drawn into the blood from this reervoir when it is required to maintain copper level. Therefore, the blood copper levels should not fall until the reservoir copper levels are exhausted. Field (1984); Suttle (1986 b) and Paynter (1987), indicated that there is

a relationship between plasma copper and liver copper in sheep, cattle and deer *(Axis porcinus)*, that normal plasma concentrations are maintained from the reservoir. However Hill *et al.* (1962) found no relationship between serum and liver values existed in cattle or buffalo. *Figure 2* indicates that in the 1985 - 87 survey there was no clear relationship between serum copper and liver copper, although animals from Abunaka had the lowest average serum and liver values. The data on the graph may agree with the trend observed by Paynter (1987) but there are many more outlying points and it would not be cautious to say that the data show this trend. This suggests that our understanding of copper metabolism is still incomplete.

The results obtained in 1985 - 87 in this study are consistent with those of Mayall (1973), although she recorded extremely low levels in animals from several cattle farms. Mayall's survey found that the Wanaru cattle in Markham Valley had copper concentration ranging from 0.04 - 0.12 ppm in serum, while Singaua Plantation, Bulolo and Sunkist Dairy cattle had low serum copper concentrations ranging from 0.17 - 0.40 ppm. Munum Plantation, Malahang and Seratini cattle had serum copper concentrations above 0.50 ppm. The liver copper concentrations in the cattle studied were found to be as low as 7.8 ppm DM which could suggests a primary copper deficiency as indicated in studies by Blood *et al.* (1979). The results of this study reconfirm that low serum and liver copper levels are occurring in the Morobe Province which indicates that production responses to copper supplementation may occur.

To more fully interpret the copper concentrations in cattle, factors such as growth and production rates, soil pH, cattle management systems, soil and pasture copper status need to be known. One very important factor is the molybdenum and sulphur status of the pasture (Hall 1985). These elements can cause a large reduction of copper availability for normal metabolic functions (Cunningham 1955; Hogan *et al.* 1971; Anon 1972; Smart *et al.* 1981; Paynter *et al.* 1982; Paynter 1984; Whitelaw 1985; Allen and Gawthorne 1987). It is unlikely that these elements are having an effect on the copper concentration because levels of molybdenum in soil and pasture in the Morobe Province are low (B. Kaupa, personal communication). Limited information is available on the copper status of soils in the Morobe Province and therefore further investigation is necessary to evaluate the cause of copper deficiency. No consideration was made on the seasonal effect of the copper status in this study.

The analysis indicates that the copper level was not affected by the different concentrations of trichloroacetic acid used to deproteinize the serum. Trichloroacetic acid at the concentration of 8 percent was probably sufficient to completely deprotenize the serum.

From the study of sample handling techniques it can be seen that non-haemolysed serum samples are required for copper analysis, as haemolysed serum samples gave slightly higher copper concentration readings. However there was no real trend of increased copper concentration being observed over time. The actual contribution of copper, to that already present in serum, from one or two drops of normal blood cells should be insignificant in AAS measurement. If serum and liver samples are not analysed immediately after collection, storage under freezing conditions is essential. Refrigeration, using ice packs, is necessary for transportation of samples, but care is required during transportation of whole blood to prevent haemolysis of red cells which may cause an increase in copper values of the serum.

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FERTILIZER TRIALS WITH TURMERIC (*CURCUMA DOMESTICA VAL.*) AT SANTA CRUZ, SOLOMON ISLANDS

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ABSTRACT

In four experiments with turmeric (Curcuma domestica Val.) at Santa Cruz, Solomon Islands (S.I.), potassium applications significally increased the yield of rhizomes in all trials. There was some indication that sulphate of ammonia, phosphorus and a proprietary mixture of trace elements may increase yields in the presence of potassium. Urea applied alone depressed yields.

Key words : Turmeric, fertilizers, potassium, Hydrandepts

INTRODUCTION

Santa Cruz is an Island situated at 10° 45'S and 116°E in the Solomon Islands. As part of the agricultural programme of diversification and development it was decided to introduce turmeric, *Curcuma domestica* Val., to Santa Cruz for trial and evaluation. The crop was chosen because the climatic conditions are favorable for growing turmeric (Purseglove 1973) and since the island is remote from a major port, a product with a relatively low bulk and high price is desirable. The boiled rhizomes are used in Santa Cruz as a cosmetic for adorning the body during traditional ceremonies. No local markets as such exist, and attempts are being made to establish export markets of the commodity. The boiled dried rhizomes of turmeric are a major constituent of curry powder.

The soils of Western Santa Cruz are ash-soils formed over limestone terraces and are classified as Hydrandepts (Wall and Hansell 1976). The addition of volcanic ash from Tinakula crater has resulted in a soil with chemical and physical properties deprived from the presence of allophane. The soils show no signs of impeded dainage, have a very high moisture content and low bulk density. If exposed to strong sun or if compaced they may dry out irreversibly resulting in destruction of the natural soil structure. The greater part of he profile is top soil which rests directly on weathered limestone.

The soils are influenced by the underlying limestone, and the exchangeable base are dominated by calcium. Levels of total phosphorus are high in the topsoil (0.38%) but available levels are moderate to low (9 ppm Olsen) and (25 ppm Bray). Total potassium is low in the upper topsoil (0.094%) and available levels extremely low (0.2meq %). In the lower topsoil there was only a trace of available potassium. Nitrogen levels in the topsoil were high (0.89%) and organic matter conter was unusually high (up to 16%) (Wall & Hansell 976).

MATERIALS AND METHODS

A 5.7 ha pilot project of turmeric was planted at Santa Cruzon farmers land during May 1972 using selected rhizomes of variety "Tuu vetolio" from Dala Research Station, Malaita, S. I., which had previously been commercially evaluated by the Tropical Products Institute, London(Gollifer 1973). Four fertilizer trials were superimposed on the block

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planting and the result are described in this paper.

Turmeric rhizomes approximately 25 g in weight of variety were planted during April and May 1972 at a spacing 0.6 x 0.6 m and at the depth of approximately 5 cm. In all experiments the plot size including guard rows were 0.0036 ha and the harvestable plots size was fifty plants (0.0018 ha). Fertilizers were applied 6 months after planting, and the crop was lifted with hand forks at 15 months, when senescence of the leaves was complete. All bulbous material was rejected and only the 'fingers' weighed.

Experiments 1 & 2

The design used was a 2^4 factorial with factors N, P, K and T arranged in blocks of eight plots each, with the NPKT interaction being completely confounded (Table 1) and randomized within the blocks. There were three replicates (Cochran & Cox 1966, plan 6.2).

Treatment :	N	Control (C)
	P	NP
	K	NK
	T	PK
	PK	NT
	NPT	PT
	NKT	KT
	PKT	NPTK

In Experiment 1 the nitrogen (N) was applied as sulphate of ammonia, N(a), and in Experiment 2 as urea, N(u).

Experiment 3

The design was a 3 x 2^2 factorial, with two forms of N, sulphate of ammonia (Na) and urea (Nu) in combination with P (triple super phosphate) and K (muriate of potash). The NPK interaction was confounded and the PK interaction partially confounded. There were three replicated with treatments randomized within the blocks. (Cochran & Cox 1966, plan 6.9).

Treatments :	K	C
	P	PK
	N(a)	N(a) K
	N(a) PK	N(a) K
	N(u)	N(u) K
	N(u) PK	N(u) P

Experiment 4

The design was a balanced incomplete block design with six replicates, type III (Cochran & Cox 1966, plan 11.16).

Treatments :	C	N(u)
	K1	N(u) K1
	K2	N(u) K2
	K3	N(u) K3
	K4	N(u) K4

Table 1. **Fertilizer treatment structure for Experiments 1 - 4.**

Symbol	Description	Experiment
C	Absence of fertilizer	1, 2, 3, 4
N(a)	56 kg of elemental N per ha as sulphate of ammonia	1, 3
N(u)	56 kg of elemental N per ha as urea	2, 3, 4
P	56 kg of elemental P per ha as triple superphosphate	1, 2, 3
K	56 kg of elemental K per ha as muriate of potash	1, 2, 3, 4
K2	112 kg of elemental K per ha as muriate of potash	4

(Contd....)

K3	168 kg of elemental K per ha as muriate of potash	4
K4	224 kg of elemental K per ha as muriate of potash	4
T	251 kg of "Ess-min-el" (*) per ha	1, 2

(*) A propriety compound manufactured by Amalgamated Chemical (NSW) Pty Ltd. containing Mg, Mn, Fe, Cu, B, Mo, Co, and S.

RESULTS AND DISCUSSION

The results for the four experiments are presented in Tables 2 - 5. Tables 2 and 3 provide a concise presentation of the main effects and two-factor interactions, the response to each factor being shown seperately for each level of every other factor. For instance the row labelled K contains mean response and the differential responses to potassium. The figure +22.36 for instance (response to potassium with trace elements absent) in Table 2, is the average response to potassium over all plots that did not receive trace elements. The Table enables a rapid appraisal to be made of the nature of the main effects and two-factor interactions.

In Experiment 1 (Table 2) there was a large, significant response in the yield of turmeric rhizomes resulting from applications of potassium. The interaction effects of NK, PK and PKT also produced significant increases in yield (Table 2). Similarly there was a significant response due to potassium in Experiment 2 (Table 3), and the interaction effect of KT also produced a significant increase in yield. Nitrogen in the form of sulphate of ammonia and in the presence of potassium resulted in an increase in yield (Table 2), but in the form of urea produced no yield increase when applied with potassium (Table 3).

Table 2. **Yield differences of fresh turmeric rhizomes (t/ha) - Experiment 1.**

	Response with							
Factor mean response	-T	+T	-N	+N	-P	+P	-K	+K
T +0.48	-	-	-1.38	+2.36	-1.00	+1.98	+0.88	+0.10
N(a)-3.92	-5.75	-2.06	-	-	-6.63	-1.21	-13.33	+5.47
P -2.56	-4.07	-1.08	-6.30	+0.15	-	-	-10.14	+5.47
K +21.96	+22.36	+22.19	+12.60	+32.23	+14.43	+4.39	-	-

Significant effects : K +21. 96 *; NaK***; PK**; PKT****
Significance levels : *(P=0.05); **(P=0.01); *(P=0.001)**
Control Yields 32.05t/ha
S.E. +/-2.75 for differental response; +/-1.96 for mean response.

Table 3. **Yield differences of fresh turmeric rhizomes (t/ha) - Experiment 2.**

		Response with							
Factor	mean response	-T	+T	-N	+N	-P	+P	-K	+K
T	-1.23	-	-	-0.98	-1.51	-4.42	+1.93	+5.52	+3.04
N(a)	-0.25	-0.03	-0.55	-	-	-2.81	+2.23	-0.13	-0.45
P	-0.73	-3.89	+2.46	-3.24	+1.81	-	-	-1.83	+0.40
K	+21.31	+17.07	+25.60	+21.49	+21.16	+20.21	+22.40	-	-

Significant effects: K +21.31*; KT***

Significance levels: *(P=0.05); *(P=0.001)**

Control yields 21.13 t/ha

S.E. +/-2.31 for differential response; +/-1.63 for mean response

Table 4. **Yields of fresh turmeric rhizomes (t/ha) - Experiment 3.**

	C	Na	Nu	Mean	C	P
	19.88	22.49	12.85	18.41	18.45	18.35
K	31.75	25.71	33.01	30.49	28.92	32.08
Mean	25.82	24.60	22.93		23.69	25.22
C	24.92	20.98	25.18	23.69		
P	28.71	28.21	20.71	25.22		

Significant effects K (P=0.001)**

As none of the interactions between the two factors were significantly different at P=0.05, a table exhibiting the three-way factor interactions has not been presented.
Control yields = 20.58t/ha

Table 5. **Yield of fresh turmeric rhizomes (t/ha) - Experiment 4.**

	C	N(u)	Mean
C	28.41	16.06	22.24
K	27.84	22.57	25.21
K2	29.19	33.51	31.35
K3	28.69	30.67	29.68
K4	32.68	36.57	34.63
Mean	29.36	27.88	28.62

S.E. of means +/- 2.89
S.E. of difference between two adjacent means = +/- 4.09
L.S.D (P=0.05)=2.83
The treatment means were significantly different at P=0.001
Control yields = 28.41 t/ha

In Experiment 3 (Table 4) the yield response due to potassium was highly significant but applications of nitrogen (as sulphate of ammonia/urea) and phosphorus had no effect (Table 4). In Experiment 4 (Table 5) the response to potassium was again significant. Nitrogen as urea when applied with high levels of potassium (224 kg/ha) produced a significantly larger yield than did low levels of potassium (56 kg/ha) with and without nitrogen, or the high level of potassium applied in the absence of nitrogen. Nitrogen applied alone as urea significantly depressed yields. The nitrogen/potassium interaction is however by no means clear, as there were positive NK interactions in Experiments 1 & 4 but not in Experiment 2 & 3.

Wall & Hansell (1976) have stated that phosphate may be immobilised by the volcanic ash soils at Santa Cruz, and as available soil levels are consequently low, this would explain the significant response to phosphate in the presence of potassium (Experiment 1) but not the non significant PK interactions (Experiments 2 & 3). They also suggested that part of the response of turmeric to applications of sulphate of ammonia (Table 2) could be due to the sulphur component of the fertilizer, as absorbed sulphate in weathered ash soils has low solubility. Wall & Hansell (1976) noted that the soils were low in iron and boron and that manganese applications may be beneficial to plant growth. Limiting levels of these elements may explain the response of turmeric to applications of trace elements in the presence of potassium (Tables 2 & 3).

Soils in the Solomon Islands formed over clacareous material are low in available potassium (Ballantyne 1961; Wall & Hansell 1973) and Gollifer (1972) has reported yield responses due to applications of potassium in annual crops grown on these soils. Further investigations are required to define the optimal dose of potassium for the soils of the area. However applications of fertilizer are unlikely to be used on cash crops unless an active outlet can be developed for the produce.

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AIBIKA (*Abelmoschus manihot*) GERMPLASM IN PAPUA NEW GUINEA

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ABSTRACT

Aibika, Abelmoschus manihot *(L.) Medikus, is a very important traditional leafy vegetable commonly grown throughout Papua New Guinea (PNG) and the Pacific Island Nations. Observations on the current germplasm collection at Laloki Agricultural Research Station (LARS) indicate a wide range of variations in its morphological and other characteristics. This suggests that PNG is an important centre of diversity for this species. A field germplasm of 112 accessions of Aibika is housed at LARS. Morphological description was conducted using the International Board of Plant Genetic Resources (IBPGR) descriptor list with some modifications. Documentation of the germplasm is discussed.*

Key words: Abelmoschus manihot, Germplasm, Accessions, Description, Documentation, Laloki.

INTRODUCTION

Aibika is commonly grown in the lowlands of Papua New Guinea (PNG), but can also be cultivated at higher altitudes, less than 2,000 m. In the Solomons, Fiji, Tonga, Vanuatu, Tuvalu, Kiribati and the Federated States of Micronesia, Aibika is locally known as Bele or Pele. Very few cultivars are grown in these Islands. The origin of Aibika is still uncertain (Siemonsma 1991), but the crop is thought to be native to South China (Mou 1991).

In a recent Food Crop Market Survey conducted by the Department of Agriculture and Livestock (DAL), sixteen main markets in major centres of PNG were covered. The quantity of Aibika offered for sale was 50.79 tonnes per month (DAL Agricultural Statistics, 1989). This is a yearly production of 609.48 tonnes worth 243,792 Kina. The Bureau of Statistics estimated an area of 809 hectares to be under Aibika production in 1961-62 (French and Bridle1978). Current figures of area under Aibika production are unavailable.

Fresh stem cuttings, 30-40 cm long are commonly used as planting materials but some cultivars have produced viable seeds. Aibika has been accepted as a nutritionally valuable green supplying vitamins and important minerals such as iron and calcium. It is said to be a much better quality food than many of the introduced vegetables (French and Bridle 1978; Westwood and Kesavan 1982; South Pacific Commission 1983). Studies suggest that 30% of the daily protein intake in PNG is supplied by green leafy vegetables which also contribute 4-12 percent of energy requirements (Westwood and Kesavan 1982).

The edible leaves and tips of Aibika are prepared using various methods of cooking common throughout PNG and the Pacific - boiled in coconut cream, steamed, fried, baked in earth ovens using hot stones (*Mumu or Umu*) and cooked in coconut cream using hot stones (*Aigir*).

This paper discusses the maintenance, description and documentation of the Aibika Germplasm at Laloki Agricultural Research Station.

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GERMPLASM COLLECTION

Need to Collect

Efforts have been made recently to conserve the genetic resources of the world's major food crops for future use in plant improvement programmes. Though Aibika is of less importance elsewhere, it is cultivated and consumed widely in PNG and the South Pacific. Other important centres of distribution are India, Africa, and parts of Asia (Borrsum and Van 1966; Rana and Thomas 1991)

The occurrence of a wide range of the cultivated and wild species in PNG supports the idea that PNG is a significant source of diversity (Kesavan 1986). An important contribution towards future utilization of this diversity therefore is to collect and conserve these materials. The Agricultural Research Stations have taken a leading role in conserving cultivated and genetically potential species of major traditional food crops.

Method of Collection

The methods of collecting vegetatively propagated crops are given in Hawkes (1980). Important points to note are:

1. All distinct varieties should be collected in each village or market visited. Duplicates can be identified later when collections are planted at the Agricultural Research Stations.

2. It has been suggested that collections should be made at intervals of 10-50 km. But this will vary greatly, depending on the population and frequency of villages.

3. At the time of collection full passport data for each crop should be recorded and materials labelled.

Maintenance of Collection

One hundred and twelve (112) accessions of Aibika in the collection at LARS were collected from various sources (Table 1).

Table 1. **Composition of Aibika Germplasm Collection at Laloki.**

Source (Province/Institute)	Number of Accessions
Keravat Research Station (ENB)	13
Bubia Research Station (MP)	15
Central Province	18
National Capital District	19
Oro Province	2
Morobe Province	23
Madang Province	7
East Sepik Province	11
Unknown	2
Total	112

Ten plants are maintained on un-replicated plots (10 m^2). Mature stem cuttings (30-40 cm) constitute planting materials which are planted at a spacing of 1 m x 1 m. This gives a population of 10,000 plants per hectare. The collection is replanted once every year.

DESCRIPTION AND DOCUMENTATION

The Aibika collection at LARS was started in 1983. Initial collections were from the Central Province and the National Capital District. During the past six years, materials were collected from various sources in the lowlands and maintained in the Agriculture Research Station at Laloki, with duplicate accessions at Bubia and Keravat.

Morphological character descriptions have been completed for the 112 accessions and documented using a computer data base (Table 2). Percentage distribution of leaf, stem, and flower characters are given in Table 3.

Table 2. **Description of Aibika Collection.**

Laloki Number	Province	Source	Local Name	* 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
L1	CP	Kolari	Laloki 1	2	8	2	6	1	5	3	1	2	4	6	1	1	2	1	0				
L2	CP	Kolari	Laloki 2	2	5	4	4	1	3	7	3	2	4	6	2	6	2	1	0				
L3	CP	Kolari	Laloki 3	5	10	2	5	4	7	3	2	2	4	6	2	1	2	1	0				
L4	CP	Kolari	Laloki 4	4	10	3	4	1	3	0	2	2	3	6	2	7	2	1	3	1	1	2	2
L5	CP	Kolari	Laloki 5	3	3	3	5	1	4	0	1	1	4	6	1	6	2	1	0				
L6	CP	Kolari	Laloki 6	5	10	4	4	4	7	0	2	2	3	6	2	6	2	1	3	1	1	2	1
L7	CP	Kairuku	Doura 1	4	10	4	2	6	4	0	4	2	3	6	1	7	2	1	2	1	1	1	2
L8	CP	Kairuku	Doura 2	5	10	2	5	3	6	0	2	2	4	6	2	2	1	1	0				
L9	CP	Kairuku	Doura 3	5	9	2	5	1	1	3	2	2	4	2	2	2	2	1	1	1	1	1	1
L10	CP	Kairuku	Doura 4	3	10	3	1	2	4	1	2	2	5	6	2	6	2	1	0				
L11	CP	Kairuku	Doura 5	5	4	4	1	4	7	1	2	2	2	4	2	4	2	1	0				
L12	CP	Kairuku	Doura 6	5	10	3	5	1	4	0	1	2	5	4	2	4	2	1	0				
L13	CP	Kairuku	Doura 7	2	3	3	5	4	4	0	2	2	5	6	1	6	2	1	3	1	2	1	2
L14	ENB	LAES	Keravat 1	4	8	3	1	1	1	2	2	2	5	1	1	6	2	1	0				
L15	N/R	N/R	Welman	5	10	3	5	1	7	0	1	1	5	1	3	6	2	2	2	1	1	3	1
L16	ENB	LAES	Keravat 3	5	8	3	1	1	1	0	2	2	3	6	1	4	2	1	2	3	1	1	2
L17	ENB	LAES	Keravat 4	4	8	5	1	1	1	1	2	2	3	6	2	4	2	1	0				
L18	ENB	LAES	Keravat 5	5	4	3	1	1	1	1	2	2	5	6	1	6	2	1	0				
L19	ENB	LAES	Keravat 6	5	8	2	1	1	1	3	2	2	5	6	2	6	2	1	0				
L20	ENB	LAES	Keravat 9	4	10	3	5	5	4	2	1	2	5	6	2	6	2	1	0				
L21	ENB	LAES	Keravat 10	3	8	3	1	1	1	3	4	2	5	6	1	8	2	1	0				
L22	ENB	LAES	Keravat 12	5	4	3	1	1	7	2	4	2	5	6	2	6	2	1	0				
L23	ENB	LAES	Keravat 16	1	9	4	3	1	1	1	5	2	5	4	1	6	2	1	0	1	2	1	2
L24	ENB	LAES	Keravat 17	5	1	2	1	1	1	2	3	2	2	4	1	4	2	1	0				
L25	ENB	LAES	Keravat 18	4	3	3	1	3	7	0	2	2	2	6	2	4	2	1	0				
L26	ENB	LAES	Keravat 19	4	9	5	5	1	1	0	1	1	4	6	1	1	2	1	0				
L27	ENB	LAES	Keravat 21	3	10	3	5	1	1	0	4	1	5	4	1	1	1	1	0				
L28	ENB	LAES	Keravat 22	4	10	3	1	1	1	3	4	2	3	4	1	4	2	1	3	3	3	2	1
L29	ENB	LAES	Keravat 23	4	8	5	1	1	1	1	4	2	3	6	2	6	2	1	0				
L30	NCD	Gordons	Nalpo	5	8	3	1	1	1	2	4	2	2	4	2	4	2	1	3	1	1	2	1
L31	NCD	UPNG	UH 1	4	9	5	5	1	1	3	1	1	5	6	1	1	2	1	0				
L32	NCD	UPNG	UH 2	4	10	2	1	1	5	0	2	2	3	6	1	6	2	1	0				
L33	NCD	UPNG	UH 3	5	3	3	4	2	4	0	4	2	3	4	2	4	2	1	0				
L34	NCD	UPNG	UH 4	2	3	3	4	1	2	0	4	2	5	6	1	4	2	1	3	1	1	1	2
L35	NCD	UPNG	UH 5	5	10	3	1	1	5	0	4	2	2	4	2	4	2	1	3	1	2	1	2
L36	NCD	UPNG	UH 6	3	10	3	5	4	7	0	3	2	5	6	1	2	1	1	0				
L37	N/R	N/R	N/R	5	6	2	1	1	5	1	2	1	5	8	2	7	2	1	0				
L38	NCD	UPNG	UH 17	4	10	3	4	5	4	0	2	2	3	6	2	4	2	1	0				
L39	NCD	UPNG	UH 21	3	8	3	5	4	3	0	1	1	5	6	2	1	2	1	0				
L40	NCD	UPNG	UH 31	4	10	5	4	1	1	0	1	1	5	1	2	6	2	1	0				
L41	NCD	UPNG	UH Dorumu	3	6	1	1	2	7	1	2	2	3	6	1	6	2	1	0				
L43	NCD	UPNG	UH 26	3	3	3	5	5	4	0	1	2	5	6	1	6	2	1	0				
L44	NCD	UPNG	UH 27	3	9	1	1	1	3	0	5	5	6	6	2	6	2	1	0				
L45	Oro	PAC	Algir	5	4	3	1	1	7	3	2	2	3	6	2	4	2	1	0				
L46	Oro	PAC	N/R	5	10	3	5	1	7	0	2	2	3	6	2	6	2	1	0				
L47	Morobe	N/R	Isaaakwa	3	10	3	2	1	3	0	2	1	5	6	2	6	2	1	0				
L48	Morobe	N/R	Natakalya	5	10	3	5	1	4	0	2	2	5	6	3	1	2	2	0				
L49	Morobe	N/R	Hackwongi	3	10	3	5	1	7	0	1	4	0	6	2	6	2	1	0				
L50	Morobe	N/R	Kanawera	4	8	5	6	4	2	2	1	1	5	6	1	6	2	1	0				
L51	Morobe	N/R	N/R	5	10	4	1	1	5	0	1	2	5	6	2	6	2	1	0				
L52	Morobe	Jipa	Hiendra	5	10	2	1	1	5	0	1	1	5	6	1	6	1	2	3	1	2	1	3
L54	Morobe	N/R	Hamiwa	4	10	2	6	1	7	0	2	2	5	6	2	6	2	2	0				
L55	Morobe	N/R	Ziandi	4	10	3	5	1	5	0	1	3	3	6	2	6	2	1	0				
L56	Morobe	Hengwa	Kwangapa	5	1	2	1	3	1	2	1	2	3	6	1	6	2	1	0				

* For definitions of descriptor codes see Table 4

Table 2. **cont'd....**

Laloki Number	Province	Source	Local Name	* 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
L57	Morobe	Hengwa	Jiandraka	5	10	3	5	3	4	0	2	2	2	4	3	4	2	2	0				
L58	Morobe	Damnga	Aiakua	4	10	3	5	1	4	0	2	1	5	6	2	6	2	1	0				
L59	Morobe	Koke	Hamawanga	4	3	3	4	1	6	0	2	3	3	6	2	6	2	1	0				
L60	Morobe	N/R	N/R	4	10	3	5	1	7	0	2	2	3	6	2	6	1	1	0				
L61	Morobe	Koke	Yambiawang	3	10	3	5	3	5	0	1	1	5	6	2	6	2	1	0				
L62	Morobe	Koke	Aponate	5	6	3	1	1	7	0	2	2	3	4	2	4	2	1	0				
L63	Morobe	Katopai	Howyauya	4	10	5	4	1	5	0	2	2	5	6	2	4	1	1	0				
L64	Morobe	Katopai	Maningya	4	10	3	5	1	5	0	1	2	5	6	2	1	2	2	0				
L65	Morobe	Watut	Wina	5	10	3	5	1	5	0	2	2	3	6	2	6	2	2	0				
L66	Morobe	Matatio	Yambia	5	10	3	5	1	5	0	1	2	5	6	2	6	1	2	0				
L67	Morobe	Matatio	Hiamtakaka	3	10	3	5	1	5	0	1	1	5	6	2	4	1	1	0				
L68	Morobe	Matatio	Hamawanga	4	7	6	5	5	4	1	3	1	3	6	1	7	2	1	0				
L69	Morobe	Matatio	Hopawa	5	0	3	1	1	1	2	2	1	3	6	1	6	1	1	0				
L70	Morobe	Matatio	Eakuwa	5	8	2	1	1	5	1	5	2	4	1	3	1	2	1	0				
L71	Madang	Zumim	N/R	5	8	3	5	3	5	0	5	2	5	6	2	6	1	1	3	1	2	2	1
L72	Madang	Zumim	N/R	5	0	3	1	3	5	2	1	2	5	6	3	6	2	1	0				
L73	Madang	Zumim	Iran	4	10	3	1	1	5	0	1	2	5	6	3	6	2	1	0				
L74	Madang	Zumim	Antiragen	4	10	4	3	1	1	7	2	1	5	6	2	6	1	1	0				
L75	Madang	Zumim	Iris	4	3	3	5	5	7	1	1	2	3	6	1	6	1	1	0				
L76	Madang	Zumim	Busibis	4	10	3	3	3	5	0	1	2	2	6	1	4	1	1	0				
L78	Madang	Zumim	Garia	5	9	3	1	1	1	1	2	2	3	6	1	6	2	1	0				
L79	NCD	Gordons	San-i-Ret	5	8	3	2	4	1	1	4	2	2	4	1	4	2	1	3	1	1	2	5
L80	NCD	Gordons	N/R	4	10	3	1	1	7	1	2	2	3	6	1	5	1	2	0				
L81	NCD	Gordons	N/R	3	8	3	2	4	1	1	1	1	3	6	1	6	2	1	3				
L82	NCD	Gordons	N/R	4	9	1	1	2	1	1	2	2	1	6	1	5	1	1	3	1	2	1	1
L83	NCD	Gordons	N/R	4	8	4	1	1	1	0	2	2	4	6	1	6	2	1	0				
L84	NCD	N/R	N/R	5	8	3	1	4	6	1	2	2	1	6	1	5	1	1	2	1	2	1	4
L85	ESP	Wosera	Sa-angna	5	10	3	5	5	7	0	2	2	5	3	3	3	2	2	3	1	2	2	2
L86	CP	Laloki	N/R	4	10	4	1	1	5	0	3	2	2	7	2	6	2	1					
L87	CP	Laloki	L9 Seedling	5	9	3	1	1	1	3	2	2	4	2	3	1	2	1					
L88	CP	Laloki	L34 Seedling	3	10	4	2	1	1	0	4	2	3	7	1	6	2	1					
L89	CP	Laloki	L15 Seedling	5	10	3	2	3	6	0	2	2	4	2	3	2	2	2					
L90	CP	Laloki	L23 Seedling	3	9	3	3	3	1	0	4	2	5	5	1	5	2	1					
L91	Morobe	Bubia		3	10	3	2	1	3	2	2	2	5	6	1	6	2	1					
L92	Morobe	Bubia		4	10	3	3	6	6	0	2	2	3	6	2	6	2	2					
L93	Morobe	Bubia		4	10	2	1	4	7	1	2	2	6	6	2	4	2	1					
L94	Morobe	Bubia		4	7	3	1	2	7	0	2	2	3	6	2	6	2	1					
L95	Morobe	Bubia		4	1	2	1	4	3	0	2	2	3	7	1	6	2	1					
L96	Morobe	Bubia		4	10	3	1	5	7	0	2	2	2	4	2	4	2	1					
L97	Morobe	Bubia		5	10	3	1	1	6	2	1	2	2	4	2	4	2	2					
L98	Morobe	Bubia		5	10	3	1	1	6	2	1	2	2	4	2	4	2	2					
L99	Morobe	Bubia		4	2	2	1	1	3	0	2	2	1	7	2	5	2	1					
L100	Morobe	Bubia		5	3	3	1	4	7	0	2	2	1	6	2	4	2	2					
L101	Morobe	Bubia		4	8	1	1	1	6	0	1	1	3	6	3	6	2	1					
L102	Morobe	Bubia		4	10	3	5	5	7	1	3	1	2	4	2	4	2	1					
L103	Morobe	Bubia		4	4	3	1	6	5	2	2	2	3	3	3	3	2	2					
L104	Morobe	Bubia		5	10	3	1	3	5	2	1	1	3	6	2	6	2	1					
L105	Morobe	Bubia		5	8	1	1	1	6	2	2	2	4	6	3	2	2	1					
L106	ESP	Wosera	SAM 09	5	9	3	1	1	1	0	1	2	4	1	2	1	2	1					
L107	ESP	Wosera	SAM 15	4	10	4	1	1	7	0	2	2	1	5	1	6	1	1					
L108	ESP	Wosera	SAM 22	4	4	5	5	1	7	0	2	2	4	1	2	1	1	2					
L109	ESP	Wosera	SAM 23	4	4	4	1	1	5	2	2	2	4	6	2	5	1	1					
L110	ESP	Wosera	WL 1	4	4	3	1	2	7	2	3	2	1	5	2	6	1	1					
L111	ESP	Wosera	WL 2	4	4	4	1	1	7	3	1	1	4	6	2	6	1	1					
L112	ESP	Wosera	WL 3	4	4	3	1	2	5	1	1	2	4	1	2	1	1	1					
L113	ESP	Wewak	Awai	3	3	3	1	1	7	3	1	2	4	6	2	1	1	1					
L114	ESP	Wosera	Nungwea	4	1	2	1	1	1	2	2	2	3	6	1	6	2	1					
L115	ESP	Wosera	SAM 21	5	4	3	1	1	5	2	2	2	4	6	2	6	2	1					

Table 3. **Distribution of Morphological characters in Aibika Germplasm at Laloki.**

Growth Habit	%	Leaf Shape	%	Leaf Segment Shape	%	Leaf Margin	%	Leaf Tip	%
Poor	2	Linear	3	Acicular	6	Entire	41	Acuminate	65
Sparse	5	Cordate	10	Linear	15	Serrate	5	Acute	5
Moderate	17	Hastate	5	Lanceolate	63	Dentate	4	Caudate	10
Good	35	Sagittate	1	Oblanceolate	7	Crenate	12	Aristate	11
Luxuriant	41	Deltoid	3	Elliptical	9	Sinuate	38	Cuspidate	8
		Orbiculate	1					Mucronate	1
		Pinnatisect	20						
		Pedate-digitate	9						
		Palmate	48						
Leaf Base	**%**	**Leaf Shape Variability**	**%**	**Leaf Lustre**	**%**	**Leaf Vein Colour**	**%**	**Petiole Colour**	**%**
Acuminate	28	0	58	Dull	23	Purple	3	Light green	6
Rounded	3	1	21	Shiny	77	Dark green	10	Dark green	1
Truncate	6	2	11			Red	32	Pink	1
Cordate	16	3	10			Red to green	10	Red	17
Hastate	23	4	0			Other colours	45	Purple	0
Sagittate	4	5	0					Green with splashes of pink/red/purple	75
Auriculate	19							Other colours	0
Petiole Length	**%**	**Stem Colour**	**%**	**Stem Pit**	**%**	**Stem Hairiness**	**%**	**Flowering Habit**	**%**
Short	40	Light green	11	Hollow	20	Glabrous	88	None	90
Intermediate	51	Dark green	4	Entire	80	Pubescent	12	Sparse	2
Long	9	Pink	1			Hispid	0	Profuse	2
		Red	23			Other	0	Few	6
		Purple	4						
		Green with splashes of pink/red/purple	52						
		Other colours	5						
Flower Colour	**%**	**Sepal Colour**	**%**	**Stigma Colour**	**%**	**Filament Colour**	**%**		
Sulfur-yellow with purple base	88	Green	50	Purple (clustered)	59	White	35		
White with purple base	12	Green with purple base	50	Purple (divided)	35	White with purple stripes	47		
Other colours	0	Other colours	0	Dark purple	6	Purple	6		
				Other colours	0	Purple with white stripes	6		
						Yellow	6		

The IBPGR descriptor list (Table 4) was modified and used to complete the descriptors following the priority list given below:

Table 4. **Basic descriptor list for Albika.**

DESCRIPTOR	CATEGORIES	IBPGR CODE
1. Growth Habit	1 - Poor 2 - Sparse 3 - Moderate 4 - Good 5 - Luxuriant	3.1.0
2. Leaf Shape	1 - Linear 2 - Lanceolate 3 - Cordate 4 - Hastate 5 - Sagittate 6 - Deltoid 7 - Orbiculate 8 - Pinnatisect 9 - Pedate-digitate 10 - Palmate	3.2.1
3. Leaf Segment Shape	1 - Acicular 2 - Linear 3 - Lanceolate 4 - Oblanceolate 5 - Elliptical	3.2.2
4. Leaf Margin	1 - Entire 2 - Serrate 3 - Dentate 4 - Crenate 5 - Sinuate	3.2.3
5. Leaf Tip	1 - Acuminate 2 - Acute 3 - Caudate 4 - Aristate 5 - Cuspidate 6 - Mucronate	3.2.4
6. Leaf Base	1 - Acuminate 2 - Rounded 3 - Truncate 4 - Cordate 5 - Hastate 6 - Sagittate 7 - Auriculate	3.2.5
7. Leaf Shape Variability	0,1,2,3,4 & 5	3.2.6
8. Leaf Colour	1 - Light green 2 - Dark green 3 - Light/dark green with purple or red spots on upper or lower leaf surface 4 - Other (specify)	3.2.7
9. Leaf Lustre	1 - Dull 2 - Shiny	3.2.8
10. Leaf Vein Colour	1 - Purple 2 - Dark green 3 - Red to green 4 - Green 5 - Other (specify)	3.2.9
11. Petiole Colour	1 - Light green 2 - Dark green 3 - Pink 4 - Red 5 - Purple	3.2.10

(Contd.)

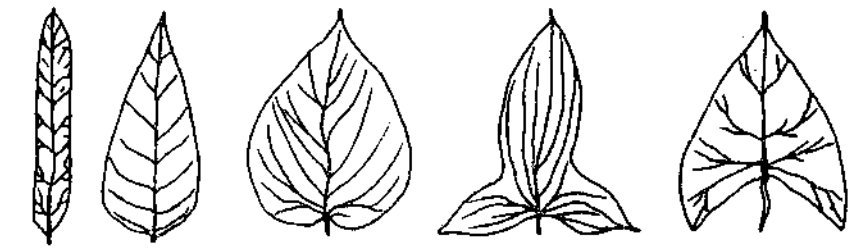
DESCRIPTOR	CATEGORIES	IBPGR CODE
	6 - Light/dark green with splashes of pink/red/purple 7 - Other (specify)	
12. Petiole Length	1 - Short (<20cm) 2 - Intermediate (21-30cm) 3 - Long (>30cm)	N/A
13. Stem Colour	1 - Light green 2 - Dark green 3 - Pink 4 - Red 5 - Purple 6 - Light/dark green with splashes of pink /red/purple 7 - Other (specify)	3.3.1
14. Stem Pit	1 - Entire 2 - Hollow	3.3.2
15. Stem Hairiness	1 - Glabrous (hairless) 2 - Puboscent (short soft Hairs) 3 - Hispid 4 - Other (specify)	3.3.3
16. Flowering Habit	0 - None 1 - Sparse (distributed) 2 - Profuse (plentiful) 3 - Few	N/A
17. Flower Colour	1 - Sulfur-yellow with purple base 2 - White with purple base 3 - Other (specify)	N/A
18. Sepal Colour	1 - Green 2 - Green with purple edge 3 - Other (specify)	N/A
19. Stigma Colour	1 - Purple (clustered) 2 - Purple (divided) 3 - Dark purple 4 - Other (specify)	N/A
20. Filament Colour	1 - White 2 - White with purple stripes 3 - Purple 4 - Purple with purple stripes 5 - Yellow 6 - Other (specify)	N/A

Abbreviations and Symbols used in Tables 1, 2, 3 & 4.

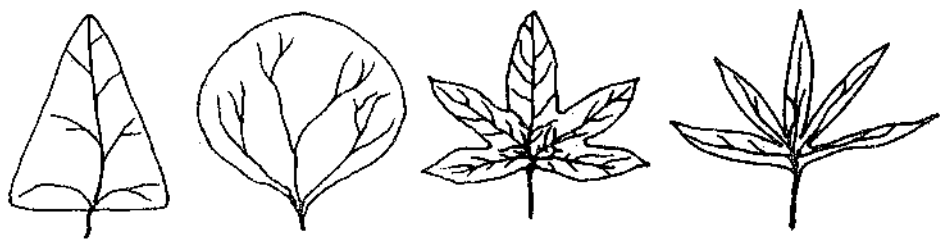
CP	=	Central Province
ENB	=	East New Britain
ESP	=	East Sepik Province
IBPGR	=	International Board of Plant Genetic Resources
L	=	Laloki
LAES	=	Lowlands Agricultural Experiment Station
LARS	=	Laloki Agricultural Research Station
MP	=	Morobe Province
NCD	=	National Capital District
N/A	=	Not Available
N/R	=	Not Recorded
PAC	=	Popondetta Agriculture College
PNG	=	Papua New Guinea
SAM	=	Saramandi
UH	=	University Number
UPNG	=	University of Papua New Guinea
WL	=	Wosera Local
%	=	Percentage

Figure 1: **Leaf Morphology (All diagrams adapted from Keesvan, 1980).**

Leaf shape *(3.2.1)*



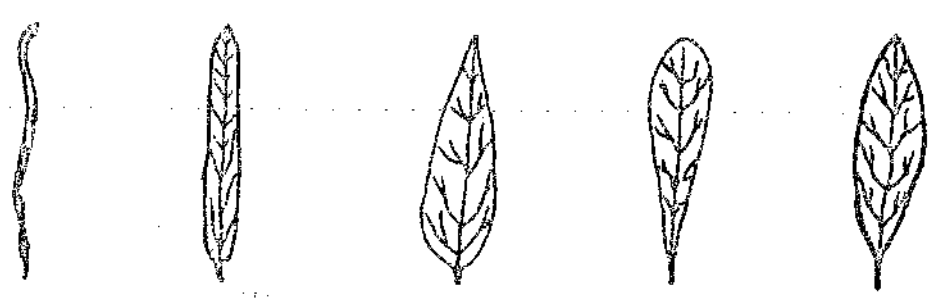
Linear lanceolate cordate hastate sagittate



deltoid orbiculate palmate pinnatisect

pedate - digitate

Leaf segment *(3.2.2)*



acicular linear lanceolate oblanceolate elliptical

(Cont'd.)

Leaf margin *(3.2.3)*

Leaf tip *(3.2.4)*

Leaf base *(3.2.5)*

First priority

Passport data: this includes province, source, local name, altitude, date and type of sample collected. Planting materials are usually in the form of stem cuttings but seeds may also be available at the time of collection.

Second priority

Morphological data: this includes characters and categories given in Tables 2, 3 & 4 and Figure 1.

Third priority

Evaluation data : this includes average yield in tonnes per hectare, number of marketable bundles per plant, consumer preference, days to first harvest, longevity, nutritive components and the assessment of common pests and diseases.

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THE USE OF CHLORPYRIFOS IN CONTROLLING WEEVIL BORER, *RHABDOSCELUS OBSCURUS* BOISD. (COLEOPTERA : CURCULIONIDAE) IN SUGARCANE SETTS

L. S. Kuniata[1] and G.R. Young[1, 2]

ABSTRACT

The weevil borer, Rhabdoscelus obscurus is a serious pest of sugarcane at Ramu Sugar estate, Papua New Guinea. A mode of infesting newly planted sugarcane crops is from the use of infested seedcane. Field trials were established in 1987-89 to select a suitable insecticide for treating infested seedcane. It was shown that chlorpyrifos was superior to dichlorvos, dieldrin and fenitrothion as a dip to disinfest setts. The LC50 and LC95 for chlorpyrifos were 0.03% a.i. and 1.50% a.i. and 4.60% a.i. against all weevil borer stages.

Key words: Weevil borer, sett dipping, chlorpyrifos, sugarcane.

INTRODUCTION

The larvae of weevil borer, *Rhabdoscelus obscurus* Boisd. (Coleoptera : Curculionidae) are a serious pest of sugarcane (hydrids of *Saccharum officinarum*) in village gardens in Papua New Guinea (PNG) (Szent-Ivany & Ardley 1962; Bourke 1968). Recently a commercial sugarcane industry was established in the upper reaches of the Ramu valley with the intention of producing sugar for PNG market and also export purposes (Eastwood 1990). Kuniata and Sweet (1991) pointed out that *R. obscurus* is currently rated as the second major stalk borer after *Sesamia grisescens* (Lepidoptera : Noctuidae) at Ramu Sugar Ltd (RSL) estate.

It has been shown that weevil borer starts entering a sugarcane crop at about four months after planting (Young & Kuniata, unpublished data). But in ratoon cane (regrowth after harvest), a high proportion of *R. obscurus* remain in the stubble after harvest and may emerge to infest the subsequent crop. Movement of weevil borer adults in the field is probably largely by flight rather than along the ground. Van Zwaluwenburg and Rosa (1940) observed that weevil adults were able to travel up to 500 m from point of release in the field. Seedcane infested with weevil borer can be transported to greater distances thus infesting newly established crops.

Possible control measures were discussed by Kuniata and Sweet (1991). They concluded that an integrated approach may be required to bring this pest to manageable levels. One approach is the use of planting material free of weevil borer life stages. Therefore, sett dipping trials were initiated to select suitable insecticides for this purpose.

MATERIALS AND METHODS

Field trials to screen various insecticides for controlling weevil borer in infested planting material were established between 1987-1989 at Ramu Sugar Ltd, Madang, Papua New Guinea.

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Trial 1 was a non-replicated trial established in February, 1987 to compare four insecticides (Table 1). One hundred 3-bud setts per treatment of sugarcan *var. Cadmus* showing weevil borer damage were dipped in the appropriate concentrations of each insecticide for 5 -10 seconds before being planted in furrows 30 cm deep. Plot sizes used were 1.5 m x 30 m. After five days these setts were recovered from the soil, carefully split-open and the number of live and dead weevil borer life stages and germinated sugarcane buds were counted.

Trial 2 was established in October 1987 using chlorpyrifos (LORSBAN 50 EC*) at concentrations of 0 (tap water only), 0.05, 0.10, 0.20, 0.40, and 0.80% a.i. Fifty two infested setts of var. Cadmus were dipped in each concentration. A randomised complete block design trial with 4 replicates was used. Plot sizes used were 4 rows x 5 m with 1.5 m and 1m separating replicates and treatment plots,

Table 1. **Mortalities of weevil borer and germination of sugar cane buds (%) in Trial 1.**

Treatments (% a.i.)	Mortalities of Weevil borer (%)			Germinated buds (%)
	Larvae	Pupae	Adults	
Control (0)	1 (86)	14 (22)	0 (21)	47
Dichlorvos				
(NUVAN* 50EC)				
(0.10)	0 (55)	11 (19)	17 (30)	49
(0.50)	2 (55)	8 (12)	0 (19)	52
Dieldrin 15EC				
(0.05)	12 (58)	50 (8)	25 (44)	74
(0.10)	23 (71)	29 (7)	38 (24)	68
Fenitrothion				
(DICOFEN* 50EC)				
(0.10)	16 (50)	29 (7)	6 (31)	56
(0.50)	58 (26)	64 (11)	55 (31)	51
Chlorpyrifos				
(LORSBAN* 50EC)				
(0.10)	85 (34)	100 (3)	50 (22)	64
(0.40)	94 (35)	100 (5)	92 (36)	60

* Trade names.

Figures given in parenthesis indicate total number of insects found per 100 setts.

respectively. Methods of planting and assessment were similar to those described for Trial 1. The trial was repeated in 1988 and 1989 as Trials 3 & 4, respectively.

Trial 5 was established in March 1988 to compare the germination of weevil damage and undamaged setts (taken from first 5 internodes from base of sugarcane stalks) and test for any interactions with various concentrations of chlorpyrifos. Fifty infested setts were used for each concentration. A split-plot design was used where the damaged and undamaged setts were used as main plots while the concentrations of chlorpyrifos as sub-plots with 3 replicates. Planting and assessment procedures were similar to those described for Trial 1.

The observed mortalities were transformed using arcsine and used in analysis of variance. Average mortalities were corrected using Abbott's (1925) formula and used in probit analysis. Probit analysis regressions were used to determine the LC50 and LC95 of each insecticide against weevil borer in infested setts.

RESULTS

In Trial 1, weevil borer mortalities in chlorpyrifos - treated setts were higher than in untreated control setts or setts treated with the other insecticides (Table 1). Dieldrin gave the highest percentage of germinated buds but did not control weevil borer.

It was observed from Trial 2 (1987) and the two similar trials established in 1988 and 1989 that the larvae of weevil borer in infested setts were susceptible to all the rates of chlorpyrifos (Table 2). In 1987, differences between mortalities were highly significant ($p < 0.01$) for both larvae and pupae and significant ($p < 0.05$) for the adults. Highly significant ($p < 0.001$) differences were observed in larval mortalities in 1988 (Trial 3). These were significant ($p < 0.05$) for adults but not significant for the pupae. Similarly, Trial 4 in 1989 showed highly significant ($p < 0.001$) mortalities for larvae while these were not significant for pupae and adults.

Regression analysis between various concentrations of chlorpyrifos used and probits are summa-

Table 2. Mean mortalities of weevil borer (arcsine transformed).

Chlorpyrifos (% a.i.)	1987			1988			1989		
	Larvae	Pupae	Adults	Larvae	Pupae	Adults	Larvae	Pupae	Adults
0 (Control)	4c*	25b	0b	1e	6	6b	1c	10	8
0.05	44b	74a	70a	23d	15	20ab	42b	35	15
0.10	63ab	90a	68a	32cd	40	23ab	53ab	54	19
0.20	70a	90a	80a	43bc	27	32ab	65ab	41	19
0.40	63ab	90a	65a	52ab	22	21ab	67ab	81	22
0.80	70ab	90a	82a	64a	27	42a	73a	74	36

* **Means followed by same letter in each column are not significantly different by DMRT (p 0.05).**

Table 3. **Regression analysis between log. concentrations and probits for weevil borer mortalities from 3 replicated trials (Trials 2-4).**

	1987		1988		1989	
	Larvae	All stages	Larvae	All stages	Larvae	All stages
r	0.823ns	0.744ns	0.999***	0.995***	0.955*	0.960**
a	6.49	6.47	6.33	5.98	6.69	5.95
b	0.67	0.67	1.28	1.03	0.91	0.61
SE of b	0.256	0.349	0.034	0.057	0.164	0.103
LC50	0.01	0.07	0.09	0.11	0.01	0.03
LC95	1.66	1.80	1.75	4.34	0.91	13.68

LC50 and LC95 are given in % a.i.

n.s., not significant, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4. **Mean germination of sugarcane buds in Trials 2-4 (%).**

Treatments (% a.i.)	Mean germination (%)		
	1987	1988	1989
0 (Control)	36	23	22abc
0.05	43	24	24ab
0.10	36	18	25ab
0.20	33	18	27a
0.40	35	21	18bc
0.80	44	20	17c

Means having similar letters in each column are not significantly different by DMRT ($p = 0.05$).

rized in Table 3. Except for 1987 data, highly significant positive correlations were observed between concentrations and probits. Average larval LC50 and LC95 was 0.03% a.i. and 1.40% a.i., respectively. These were 0.03% a.i. and 4.62% a.i. for all the weevil borer life stages.

Average percentage of germinated sugarcane buds were very low and are summarized in Table 4. The various concentration of chlorpyrifos did not significantly affect mean germination in 1987 and 1988. However, in 1989 concentrations were higher than 0.20% a.i. significantly ($p < 0.05$) reduced mean germination.

Comparisons of weevil borer damaged and undamaged setts from Trial 5 showed highly significant ($p < 0.01$) differences in mean germination between these with various concentrations of chlorpyrifos (Figure 1). There was a 24% reduction in germination observed in weevil damaged setts compared to

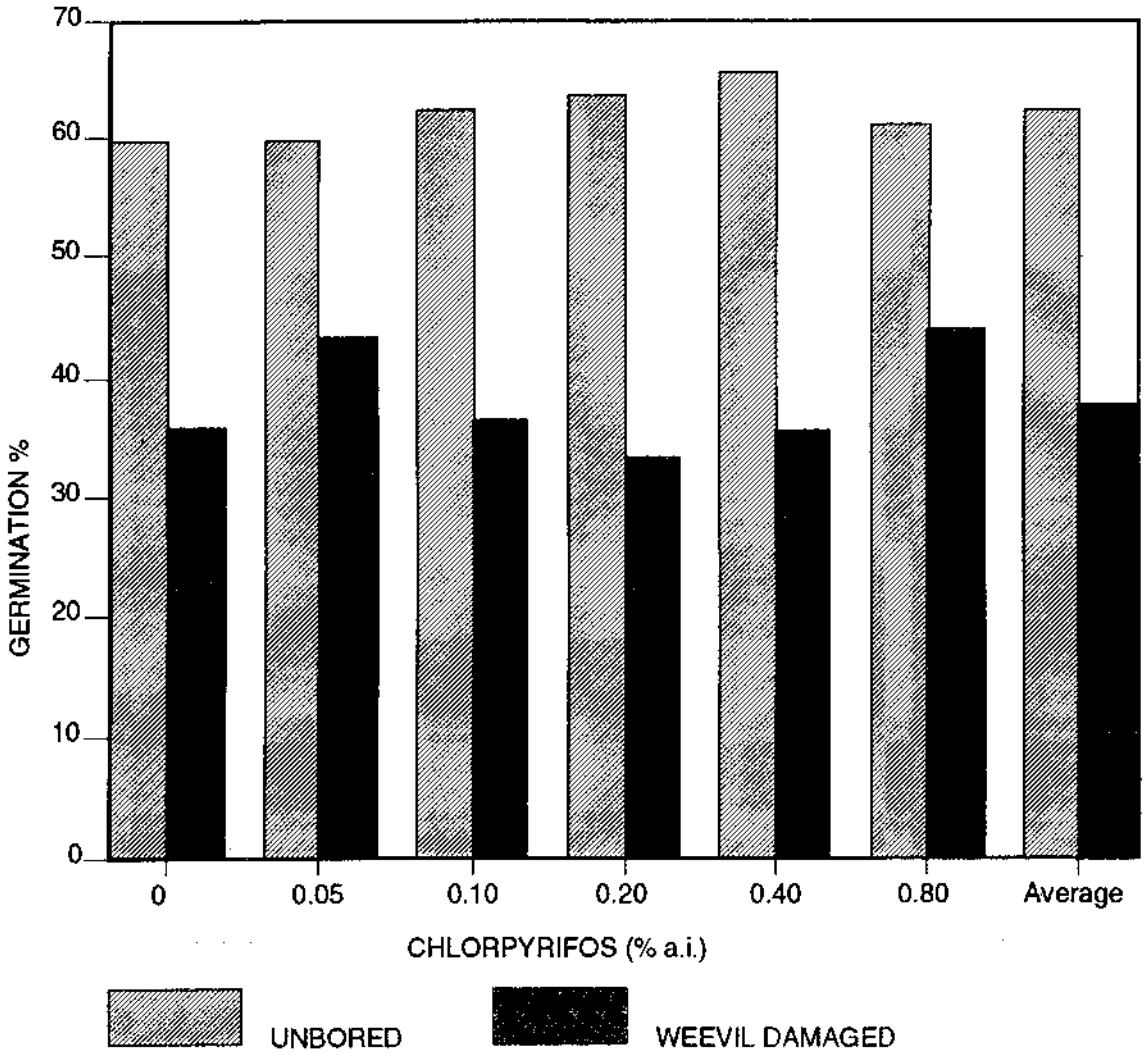

Figure 1. **Effects of chlorpyrifos on germination of weevil borer damaged and unbored sugarcane setts.**

undamaged ones. There were no significant interactions observed between types setts used and chlorpyrifos.

DISCUSSION

Emulsifiable concentrates of chlorpyrifos have largely been used as sprays against foliar feeding insects on other crops. These data indicated that chlorpyrifos can effectively control weevil borer infestations in sugarcane setts. Similar mortality trends observed in all these trials indicated that the larvae were most susceptible followed by pupae and adults. Larvae continue to move around and feed inside the setts for some time after treatment and therefore may become exposed to the insecticide. The pupal and adult mortalities were very variable. These stages do not feed and live inside tightly spun fibrous cocoons where they may be protected from the insecticide. The higher average mortalities observed in Trial 2 in 1987 were probably due to the additional effect from a severe drought experienced during the duration of the trial.

Generally, setts infested with weevil borer gave lower germination than unbored setts. Plant re-

serves in infested setts may have been used up by the larva of weevil borer with lesser amounts available for utilization by the growing buds and shoots. Dipping infested setts in chlorpyrifos did not improve germination and therefore infested setts should not be used wherever possible. A phytotoxic effect of chlorpyrifos on germination was not clear from these trials. However, a concentration of 0.20% a.i. has been suggested for use in dis-infesting sugarcane setts at planting.

Adults of weevil borer have been shown to travel more than 500 m from point of release in the field (Van Zwaluwenburg and Rosa, 1940). Infested seedcane can be transported to greater distances thus infesting newly established sugarcane crops. Sett dipping provides a means of minimizing weevil borer spread and reducing infestation in newly planted crops.

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PRESERVING CHICKEN EGGS INTERNAL QUALITY USING COCONUT OIL

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ABSTRACT

Chicken eggs were submerged for less than one minute in coconut oil and their rate of deterioration measured during 49 days period. These eggs were compared with eggs stored under room temperature (24-32° C) and cool room temperature (16-19° C). The eggs submerged in coconut oil had a slower rate of deterioration which resulted in maintaining a good internal quality for a longer period.

Key words: Eggs storage, Coconut oil, internal quality

INTRODUCTION

There are several methods of preservation of eggs. Some of them can be used at farm level without any costly equipment, whereas the others are commercial methods involving the use of specific equipment. In the former category there are various techniques - eggs can be preserved using limewater, padi ash and salt, salt solution, and other compounds. Oiling the shell of the egg has been documented as a method of preserving egg quality. Mineral oil (Heath and Owen 1978), paraffin oil (Heath 1977), linseed oil (Sabrani and Payne 1978), and vegetable oil (Imai 1981) have been used and shown to preserve eggs well. The reported work in this paper showed that the rate of decline in albumen quality decreased in oil-treated eggs and that the initial rapid phase of deterioration was greatly reduced. This study evaluated the possibility of using coconut oil as a coating medium for egg storage.

MATERIALS AND METHODS

Naturally clean eggs, between 46 and 52 g weight and collected within 3 hr after lay, were used in the experiment. A total of 240 eggs were randomly allocated into 3 groups of 80 eggs each and were treated as follows;

(1) Eggs were stored at room temperature (24-32°C),

(2) Eggs were submerged for less than one minute in coconut oil and stored at room temperature as in (1) and

(3) eggs were stored in a cool room (17-21°C).

At 7 day intervals, during the 49 day trial period, a batch of 10 eggs was randomly picked from the 3 groups, weighed and albumen height measured. This measure of albumen height was used as the criterion of interior egg quality in this study.

The characteristics of grades of egg described by Bundy *et al.* (1975) were used in grading the eggs. There are four grades of eggs; "AA", "A", "B" and "C" quality. "AA" quality being the highest grade and "C" quality the lowest. A good quality egg in terms of albumen quality is an egg in which the albumen holds together well and stands up high around the yolk. This quality is commonly measured in terms of "Haugh units" and is an expression relating egg weight to the height of the thick white. A Haugh meter was used to measure the thick white at about

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mid-point between the yolk and edge of the widest expanse of the thick white. Haugh units give a measure of albumen stability and the extent of deterioration of the egg contents during storage. Haugh unit scores less than 31 are classified as "C" quality, less than 60 as "B" quality, less than 72 as "A" quality and above 72 as "AA" quality.

RESULTS AND DISCUSSION

The results show clearly that coating egg shell with coconut oil subsequently stored at a room temperature is a better alternative to storage under cool condition (Fig. 1).

The Haugh Unit scores declined with time in all storage conditions with a more rapid and significant decline ($P< 0.05$) observed in eggs stored under room temperature during the first 7 days during which time the egg grade fell from "AA" to "C" quality. It took longer (28 d) for eggs stored under cool room condition to reach "C" quality. The eggs treated with coconut oil had slower declines in interior quality resulting in maintaining a "A" quality eggs after 14 d and "B" quality after 49 d. The effect of temperature on eggs quality is in accordance with the results of Card and Nesheim (1972) who reported a drop from "AA" to "C" quality with eggs held for 100 days at 3°C, 8 days at 23°C and 3 days at 37°C. The rate in quality decline after 7 d is also

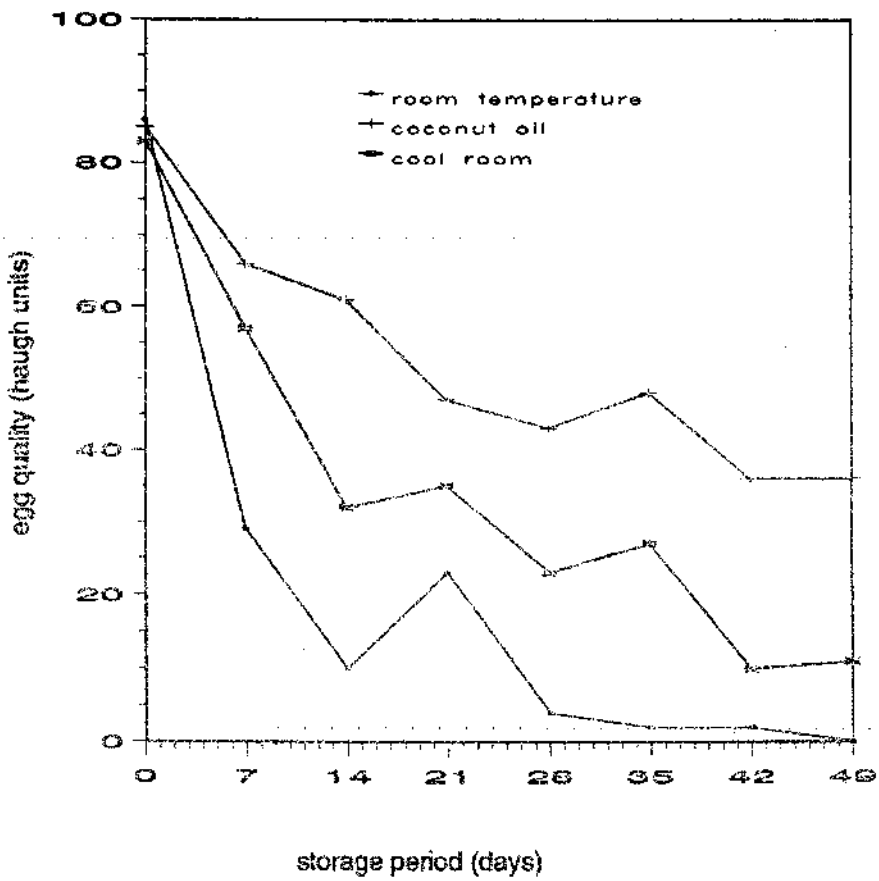

Figure 1. **Effect of storage conditions on egg quality.**

in line with the findings of Dawson and Hall (1954), who found a marked deterioration to have occurred within 3 days regardless of temperature.

There are several suggested reasons for the decline in albumen quality with storage. Sabrani and Payne (1978) listed losses in carbon dioxide resulting in slight alkalinity causing the long mucin fibre to break, chemical reductions breaking the disulfide bonds of ovomucin producing depolymerised ovomucin and thinning of egg albumen because of a dissociation of hysozyme-ovomucin complex.

The important feature of oiling would be the slower rate of evaporation (Sabrani and Payne 1978). Oiling has been shown to slow the rate of quality decline as it seals the pores and thus prevents gas and water losses and entry of micro-organisms and odours. However, loss in egg weight was not significant, at the end of 49 d, eggs stored at room temperature were averaging weight losses of 3.5 g per egg compared with 1.6 g for oiled eggs and eggs stored under cool room. Weight lost under room temperature was expected as the condition was favourable for water and carbon dioxide loss to occur.

The reports of past work on oiling eggs for storage and the results of this work suggest the usefulness of coconut oil as a coating medium for egg storage.

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NUTRITIVE VALUE OF SWEET POTATO FORAGE (*IPOMOEA BATATAS* (*L.*) *LAM.*) AS A RUMINANT ANIMAL FEED

M. Moat[1,2] and G. McL. Dryden[1]

ABSTRACT

*Four varieties of sweet potato (*Ipomoea batatas*) (L.)* Lam.*) were tested for their forage production and nutritive value as a ruminant feed in subtropical Queensland. Forage was harvested 63, 104, 159 and 199 days after planting and assessed for yield and nutrient composition. Forage yields varied with age and variety. Red Abundance was the most productive variety, yielding 22 t dry matter (DM) per ha at 199 days. The DM contents of all varieties were initially low (79 to 119 g/kg) and increased (to 132 to 183 g/kg) with age, whereas the protein contents decreased with age from 146 to 103 g/kg DM. Neutral detergent fibre contents varied little from a mean of 467 g/kg DM, both between varieties or over the growing period. The mean DM digestibility coefficient of material obtained at 199 d was 0.76 and varied little between varieties. These forage production and nutrient content data suggest that sweet potato may provide a useful source of forage for ruminants.*

Key words: Sweet potato forage, nutritive value, ruminants.

INTRODUCTION

World production of sweet potato roots is some 130 million tonnes, obtained from approximately 9 million ha (FAO 1989). The crop is grown principally for its roots, but large amounts of vines and leaves are produced and these are usually left unutilised in the field. Some varieties can be sown 2 to 3 times each year, with annual yields of up to 125 t of fresh biomass of which forage accounts for approximately 64% (Pinchinat 1970). The total forage (vines plus leaves) contains 110 to 170 g/kg crude protein, and its digestibility is greater than 0.60 (Ffoulkes *et al.* 1978, Ruiz *et al.* 1980).

These data suggest that sweet potato could potentially be a useful ruminant feed in addition to its accepted use as a human foodstuff. The experiment reported here was designed to provide some information on the production and quality of sweet potato forage produced in a Queensland environment. This study examined the yield, digestibility and chemical composition of the forage from 4 varieties which are either currently grown in Queensland, or which have potential as root crops.

MATERIAL AND METHODS

Four varieties were tested, of which L0323, Rojo Blanco and NC3 were early-maturing and Red Abundance was a late-maturing variety. The performance of these varieties was assessed at each of 4 harvesting times, 63, 104, 159 and 199 d after planting on 11th December, 1990. The plants were grown in a field trial at The University of Queensland, Gatton College, Lawes (27° 33′ South, 150° 20′

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east, altitude 91 m) on a soil typical of the Black Earths of the Lawes soil series (Schafer *et al.* 1986). During the trial period from December 1990 to May 1991, 315 mm of rain was recorded at the Lawes meteorological station with 81% falling between December and February. The maximum temperatures were between 24 and 34°C and minimums between 9 and 20°C during this period.

A randomized complete block design was used, with 4 varieties and 4 harvesting times as treatment. Each block contained 16 plots each 3.4 m x 1 m. There were 4 plots for each variety for each harvesting time with 16 plants in each plot. Individual plants were planted 25 cm apart on ridges at 85 cm spacing. Adjacent plots were separated by 85 cm at the sides and 1 m at the ends.

Planting material consisted of 20 to 30 cm long cuttings with about 4 nodes, obtained from the apical portions of vines from mature plants. The cuttings were trimmed, leaving 1 or 2 young leaves, and then placed in 10 to 15 cm of water for 3 d to stimulate root growth before planting out in the field.

The crop was irrigated daily from the time of field planting to partial field establishment, a period of 3 weeks. Subsequently, irrigation was on a regular weekly basis. Regular hand weeding was carried out until the plants were well established, after which little weeding was required. No basal fertiliser was applied.

Forage (vines plus leaves) was sampled by harvesting the whole plot of 16 plants. The harvested material was chopped into approximately 5 to 10 cm lengths, weighed, mixed, and duplicate subsamples of 2 to 3 kg were dried at 60°C in a forced draught oven for 24 h for the estimation of DM content and DM presentation yield. The dried material was then bulked, ground through a 1 mm screen, mixed and sub-sampled for subsequent chemical analysis.

Analyses of the ground, air-dry forage were conducted for dry matter (ISO 1983), total ash (500°C for 4 h), total protein (by a semi-micro Kjeldahl technique using $CuSO_4$ catalyst), and neutral detergent fibre (NDF) as described by Goering and Van Soest 1970 and Moir 1971. Digestibility of the forage harvested at 199 d was determined by *in sacco* incubation using the procedure described by Dryden and Leng (1988). Samples of about 3 g of prepared air-dry sample (ground through a 1 mm screen and sieved to remove particles less than 0.45 mm) incubated in rumenfistulated wether sheep for 48 h. Each sample was incubated in each of 5 sheep, and between-run variation was accounted for by including a standard lucerne hay sample in each run.

Differences between means were examined by one-way analysis of variance, using the Minitab statistical package (Minitab 1989). Where significant differences were indicated, means were compared by the calculation of appropriate least significant differences.

RESULTS

The forage yield of all varieties increased linearly, both in DM (Fig. 1) and OM (Fig. 2) between 63 and 159 d, although different varieties grew at different rates. For each variety, DM yield at 199 d was not different from that at 159 d. Red Abundance was more prolific than the other varieties, yielding significantly more forage at 104, 159 and 199 d.

The DM content were low in the young forage (a pooled mean of 89 g/kg), but increased with age (Table 1). The DM content of each variety at the 199 d harvest was significantly higher than those of the earlier harvests. At 199 d, the earlier maturing varieties had significantly higher DM contents than Red Abundance. Organic matter contents increased with age, but there were no differences between varieties at the later harvests (Table 1). There was no effect of either variety or time on NDF contents, with individual values not differing significantly from

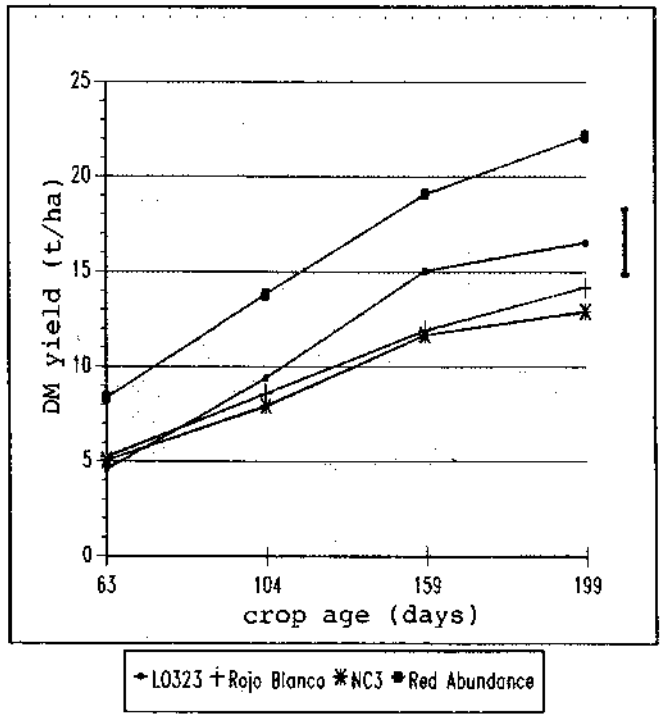

Figure 1. **Dry matter yields of sweet potatoe forage. Vertical bar, LSD p=0.05.**

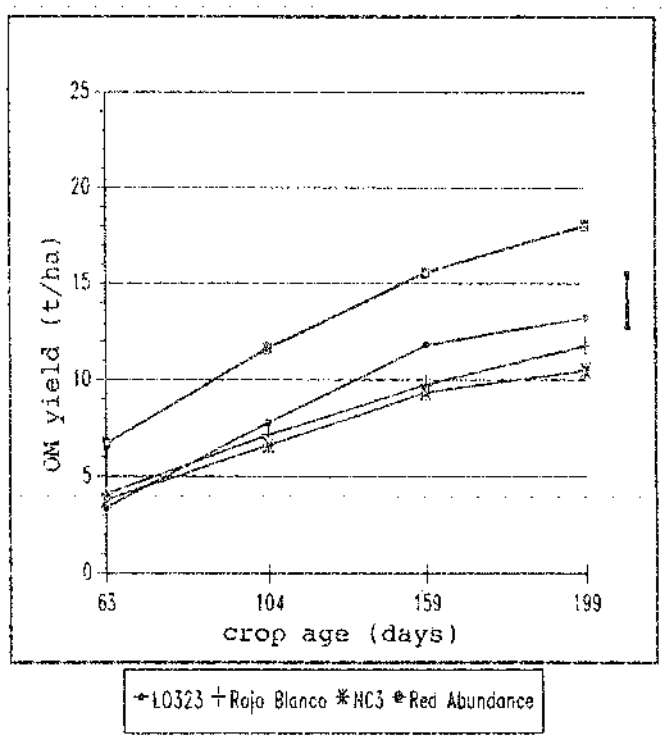

Figure 2. **Organic matter yield of sweet potatoe forage. Vertical bar, LSD p=0.05.**

the overall mean of 467 g/kg DM. Total protein varied from 77 to 151 g/kg DM over the 4 varieties and harvesting dates. Significantly lower protein contents were recorded in the final harvest than in the first harvest, except for Red Abundance (Fig. 3). There were no significant differences between varieties at the 63, 104 and 159 d harvests, but at the final harvest L0323 and Rojo Blanco had significantly less protein than Red Abundance.

The mean DM digestibility coefficient of the forage harvested at 199 d was 760 (SD, 41.4) g/kg. There was little variation between varieties.

DISCUSSION

The prevailing temperatures during the growing period were favourable for sweet potato growth, and a deficiency in rainfall was overcome by regular irrigation. Growing conditions were considered to allow the full expression of the production potential of these varieties.

Variations between sweet potato varieties have been reported by many researchers and the variation in forage production obtained in this experiment was expected. Red Abundance (the late-maturing variety) was the most productive variety, especially

Table 1. **Dry matter and organic matter contents of sweet potato forage.**

		Crop age (days)				
		63	104	159	199	mean
Dry matter contents (g/kg)	L0323	78.8	107.5	105.0	153.9	111.3[b]
	Rojo Blanco	96.7	118.7	111.8	183.2	127.6[b]
	NC3	82.5	116.7	114.0	162.7	118.9[b]
	Red Abundance	99.7	114.0	98.2	132.1	111.0[b]
	mean	89.4[c]	114.2[b]	107.3[c]	158.0[a]	
						mean
Organic matter contents (g/kg)	L0323	751.9	830.1	785.7	799.5	791.8[c]
	Rojo Blanco	780.3	835.6	818.5	831.0	816.4[a]
	NC3	749.7	835.6	800.9	812.4	799.7[b]
	Red Abundance	799.5	843.3	812.4	814.4	817.4[a]
	mean	770.4[d]	836.2[a]	804.4[c]	814.3[b]	

[abcd] **mean with same superscript do not differ significantly (P<0.05).**

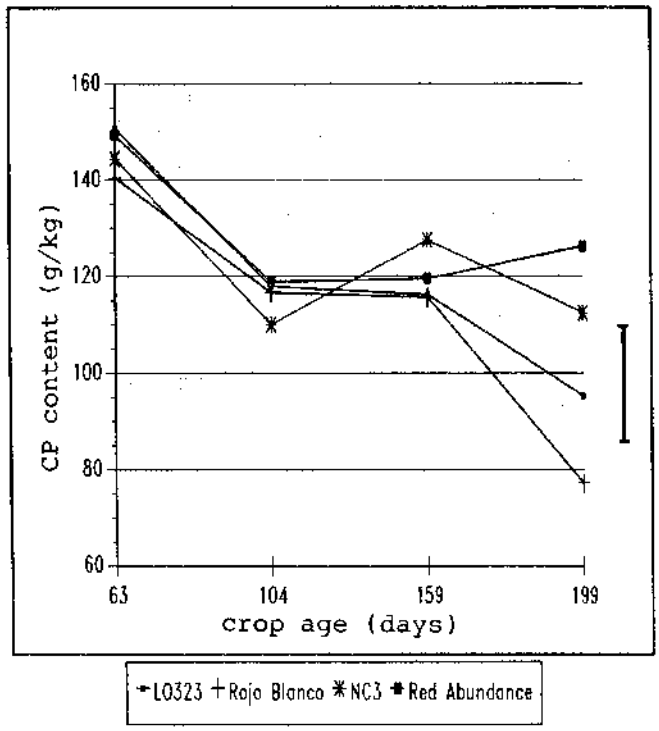

Figure 3. **Crude protein content of sweet potatoe forage. Verticle bar, LSD p=0.05.**

at the last 3 harvests, and at 199 d yielded 34, 56 and 72% more DM than that obtained from L0323, Rojo Blanco and NC3, respectively. The productivity of Red Abundance is illustrated by the observation that it yielded more at 63 d than Rojo and NC3 at 199 d, and as much at 104 d as L0323 at 199 d. Trends in organic matter yields were similar to those of DM. The forage yields obtained here were similar to those reported elsewhere (e.g. Huett 1976; Huett and O'Neil 1976; Rose 1979; Ruiz 1982; Villareal *et al.* 1982) over the same growth period. The data from this experiment indicate that a similar growth pattern occurred in all varieties, with a nearly linear increase in forage production from planting to about 159 d and a slower growth thereafter. The marketable root yield at 199 d was 106, 74, 93 and 68 t/ha for L0323, Rojo Blanco, NC3 and Red Abundance respectively. At 159 d, marketable root yield was 69, 55, 80 and 53 t/ha respectively and at this stage between 11.7 and 19.1 t of forage was produced. As there was no further significant increase in forage production after 159 d, there would be little advantage in delaying harvesting or grazing after that time.

The DM digestibilities suggest a metabolisable energy content of 10.5 MJ/kg DM at 199 d, estimated by the relationships given by MAFF (1984). It is suggested that this value may apply during the whole of the growth of the forage, as there was no significant change in total cell wall (NDF) content with age. The lack of variation in digestibility with crop age has been reported by Ruiz *et al.* (1980).

The protein contents determined in this study are in agreement with values reported elsewhere (NAS 1971; Gohl 1981; Ruiz 1982). Although the protein contents declined with age, the values at 159 d are still adequate for ruminant production. It is noteworthy, though, that the rate of decline from 159 to 199

d differed between species, and that Rojo Blanco forage contained least protein at 199 d. The decline in protein content indicates that harvest should not be delayed too long; under the conditions for this experiment, the optimum harvest date for L0323 and Rojo Blanco appears to be 159 d, but there was adequate protein in the forage of Red Abundance and NC3 at 199 d.

There may be some constraints to the performance of ruminants grazing sweet potato forage. The high water content of the immature forage (between 7.9 and 11.9%) may limit intake (Minson 1992), although the levels recorded at the later harvest should not impose any such constraint; and ingestion of intact vines may lead to rumen impaction (J. McCosker, personal communication). In addition, Ffoulkes *et al.* (1978) have suggested that sweet potato forage protein is less ruminally degradable than that of some other tropical forages, for instance banana and sugar cane. Nevertheless, the data presented here suggest that sweet potato forage is potentially a very useful ruminant feed, and this conclusion is consistent with the performance of beef cattle recorded by Ffoulkes *et al.* (1978) and Bracker *et al.* (1980). The consistent advantage in productivity and protein content observed in Red Abundance, suggests that late maturing varieties should be preferred for grazing.

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SOIL AND CULTIVATION IN THE PAPUA NEW GUINEA HIGHLANDS: 1. INDIGENOUS APPRAISAL OF THE VARIABLE AGRICULTURAL POTENTIAL OF SOILS

Paul Sillitoe[1]

ABSTRACT

The hypothesis that some Southern Highlanders of Papua New Guinea do not inspect the soil on potential garden sites before clearing for cultivation is examined. How Wola people assess the cultivation status of their soils is explored. It was found that properties central to their appraisal of soil are depth, strength, stoniness, 'grease' content and water state. Factors assisting the long term protection of Wola environment are briefly outlined.

Key words: Papua New Guinea, Southern Highlands Province, shifting cultivation, soils, ethnoscience, land use, appraisal.

INTRODUCTION

Soil is essential for plant growth, yet the Wola people of the Papua New Guinea highlands, who are highly skilful semi-shifting cultivators, contend that assessment of it does not feature in their selection of garden sites. Their apparently offhand attitude to soil on potential cultivation sites is unexpected. According to them, an inspection of the soil before clearing it of vegetation for cultivation is not among the considerations that constrain and influence their choice of site, which include issues like cultivation rights as stipulated by their kin-founded land tenure system, site aspect and ease of enclosure, location relative to house and other gardens, and so on.

It is possible to 'explain' away their apparently nonchalant attitude to soil on the grounds that its validity is difficult to assess. The people know their local regions so intimately that they have no need deliberately to look closely at the soil at any place before deciding to cultivate it. They already know its status on those territories where they have rights of access to garden land by virtue of living there, constantly walking over them in the course of their daily lives. But Wola insist that even if they found themselves in an entirely unknown part of their region (e.g. by virtue of affinal connections) they still would not closely inspect the soil before cultivating it.

Alternatively, we may try to account for their assertions by arguing that while they think that they do not look closely at the soil before establishing a garden, this is only their perception, and that they are unconscious of their assessment of their soil resources (e.g. walking around barefoot that they are tactually aware of texture and structure). Furthermore, we might suggest that the vegetation growing on a site may give an indication of the soil's worth, by its health and the prolificness of its growth, even the presence of certain species above others. But again the Wola deny that this is so, and casual field observations support their assertions (neither vegetational features seem to be associated with their soil assessments nor different soils).[1]

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ATTITUDE TOWARDS ENVIRONMENTAL ISSUES

The casual attitude that the Wola evince towards soil assessment reflects their off-hand attitude towards environmentalist issues. Unable to foresee soil agricultural potential, they acknowledge little control over or responsibility for their soil environment. The soil is there to be exploited, to the full, even if that exploitation is somewhat random and not finely judged. They push the soil to its fertility limits, until costs oblige them to relent.

The Wola follow their semi-shifting agricultural strategy and abandon some garden sites to natural vegetation and regeneration, not in their minds to protect the environment, but because crop yields decline beyond a tolerable point where the labour put into their cultivation is inadequately repaid. This is not to suggest that they invite environmental degradation, for example top soil erosion, if they can avoid it, although again not because of the environmental damage, but because of the wasted labour. No one likes to work to establish a new garden for example, to see their efforts swept away, although the steep slopes they are obliged to cultivate leave them vulnerable at certain times, and intense rainfall can result in serious erosion losses.

THE WOLA

Speakers of the Wola language occupy five valleys in the Southern Highlands of Papua New Guinea, from the Mendi river in the east to the Ak in the west. The region comprises many territories identified with bilaterally-constituted patrifilially-biased communities known as *sernonda*, subdivisions of which structure rights to, and tenure of, garden land. They live in small houses scattered along the sides of their valleys, in areas of extensive cane grass land; the watersheds between are heavily forested. Dotted across the landscape are their neat gardens. They practice a largely sedentary variation of shifting cultivation, featuring alternate cropping and fallow periods of variable duration, and subsist on a predominantly vegetable diet in which sweet potato is the staple (Sillitoe 1983).

They keep pig herds of considerable size. They hand these creatures, together with other items of wealth such as sea-shells and cosmetic oil, around to one another in interminable series of ceremonial exchanges, which mark all important social events. These transactions are central to the ordering of their fiercely egalitarian acephalous society (Sillitoe 1979). Their supernatural conceptions centre on beliefs in the ability of their ancestors' spirits to cause sickness and death, in various other forest spirit forces, and in other's powers of sorcery and 'poison'.

INDIGENOUS APPRAISAL: VARIABLE SOIL PROPERTIES

An analysis of soil and site data, presented in Part II of this series of papers, vindicates Wola assertions about having no need to inspect soil closely before cultivating it, not because they already know its status but because of the striking uniformity of the soil resources generally available to them (Wood 1987).[2] There is not a great deal to choose between the majority of soils of their region by readily observed properties (i.e. those not involving laboratory analysis). While the analysis distinguishes

[1] Any correlation that we might assume ought to exist between soil potential and vegetation would require a comparison of a detailed logging of plant development on different sites to prove, because according to the Wola it does not relate to any easily seen macrobotanical feature such as species type, which casual observations in the field confirm.

[2] The findings reported here reflect an emergent concern with others' perceptions of their soil environments, for while interest in ethnopedology is small in comparison to zoological and botanical ethnoscience, it has attracted some attention recently (see Ollier *et al.* 1971; Landsberg and Gillieson 1980; Dvorak 1988; Behrens 1989; Furbee 1989; Guillet 1989; Sillitoe 1991; Philips-Howard & Kidd 1991).

between grossly different soils (such as recent alluvial, gleyed and skeletal profiles), these only cover a small part of their region. The larger part of it comprises 'dark topsoil/clayey subsoil' soils (the humic brown soils, Rutherford & Haantjens 1965; Radcliffe 1986), which the analysis consistently groups together into stable clusters. When the horizons that comprise these soils are further divided into groups some very fine distinctions are necessary, which neither local people nor soil scientists would consider significant.

The Wola cultivate the majority of their crops on very similar soils (the notable exception is wet-soil-loving-taro), which cover by far-and-away the larger part of their country. In the light of this evidence their assertions no longer seem so remarkable, the soils of their region being, by and large, so alike that close inspection would be pointless. Nonetheless not all soils are the same when it comes to cultivation. The Wola do assess soils, if not before gardening, then certainly when they are under cultivation. In this event, how do they judge the worth of any soil, and why is this a post-cultivation process?

The Wola assess the agricultural potential of their soils according to a few properties which they take to be critical to their productivity. They relate to topsoil only, focussing understandably on the horizon in which crops largely root and grow. Nevertheless, while it is the status of the dark *pombray* topsoil that is critical in the appraisal of agricultural potential, the Wola recognise that the subsoil can influence the character of the topsoil, especially if the latter is thin and the former near the surface.

The properties central to the appraisal of a soil's productive status include its depth, strength, stoniness, *iyba* 'grease' content, and water state, as follows:

The depth ***of topsoil, which may be assessed as*** onduwp ***(lit: much) or*** genk ***(lit: little) or qualified versions of these words, is important as determining the amount available of the medium in which crops are recognised to grow well. Although there is really no lower limit to the thickness of topsoil acceptable in a garden, the thicker it is better, and if the subsoil shows through in places the site is likely to be abandoned.***

The strength ***of the soil and its assessment relates in part to concerns over its depth because the clayey subsoils are judged too strong for good crop growth. By strength the Wola are referring to the consistence and friability of the soil. They talk of soil as*** buriy ***(lit: strong) or*** tomiy ***(lit: weak) or as a qualified version of these terms, and assess it as a handling characteristic. If a soil is*** buriy ***strong its agricultural usefulness is low because they say roots and tubers have trouble penetrating it, the mechanical resistance to their growth results in stunted development and poor yields.***

The stoniness ***of a soil only becomes critical when it exceeds a certain percentage, hindering cultivation and acting to increase soil strength, impeding adequate root development. Some stones are judged beneficial to a soil. They act to warm it up according to the Wola, heating in the sun and retaining the absorbed heat longer than soil alone, so promoting the growth of crops which prefer a warm soil to a cold one. Stones also promote porosity, creating cavities and points of weakness in the soil which roots can exploit, and so off-set soil compaction. And some stones they say, especially*** araytol ***chert, promote the development of*** iyba ***'grease' (although silica minerals have no obvious nutritional value to plants).***

The iyba ***(lit: blood or sap) or*** hobor ***(lit: fat or grease) content of a soil derives from rotting plant matter. It is assessed by the soapy, silty feel that organic matter imparts to soil, the greasier the better. It dries out under cultiva-***

tion, little rotting plant material being returned to the soil, until the soil becomes exhausted iyba na wiy ***(lit:*** iyba- ***'grease' not resides) - it is interesting to note that a weak, sick person is also*** iyba na wiy, ***that is someone without blood. The growing crops take up the*** iyba ***until little remains. The only crop that can continue to yield on a considerably*** iyba ***depleted soil is the staple sweet potato. When the garden is abandoned, the rotting of vegetation deposited by the regrowth will replenish the*** iyba ***'grease' levels of the topsoil.***[3]

The water state ***of a soil, its*** iyba ***content, is critical for the healthy growth of crops. The majority require a moist aerobic soil; the staple sweet potato (*****Ipomoea batatas*****) cannot tolerate conditions too wet. The notable exception is taro (*****Colocasia esculenta*****) which thrives in a waterlogged soil. While distinguishing between waterlogged*** pa ***sites and others is straightforward, differentiating between moister and drier better drained soils is not easy. When under natural vegetation soils tend to be wetter, and the extent to which they will dry out and improve when cleared and exposed to the sun is difficult to assess.***

The element of chance features in all of these appraised properties, which relates to Wola assertions that they do not inspect soils before cultivating them. They may all be subject to change once a soil is under cultivation. The depth of topsoil is liable to diminish due to erosion, notably in newly planted gardens where the soil is exposed and scarcely protected by vegetation. The considerable slopes on which the majority of gardens are sited and the intensity of the region's rainfall exacerbate this problem. And loss of fine soil particles, leaving the larger stones behind, can increase stoniness beyond the point where it imparts beneficial qualities to the soil, hindering cultivation and crop growth. The soil's strength is thus likely to increase and diminish yield potential, especially if subsoil is exposed with erosion and subsequently mixed with the topsoil during cultivation.

It is not only the incorporation of clayey subsoil that increases *buriy* strength, some topsoils, when exposed to the sun for a considerable period of time in a garden, can become excessively dry and hard, which if they have a non-granular structure can render them unsuitable for further cultivation. The change in soil water content under cultivation is difficult to judge, but it usually falls. Until the sun has 'looked on' the soil, as the Wola put it, they cannot be sure of its water state under cultivation; it is possible that the soil might rapidly become too dry and strong. Furthermore the water state can be adversely affected during cultivation of a site. When establishing a garden for example, people are careful to keep off the site after prolonged heavy rain for fear of pudding it with their feet to a liquid mud state called *suw mondow;* for the same reason they take care clearing areas where there is *gaimb kolowmon*, a thick black layer of rotten water-filled cane grass (*Miscanthus floridulus*) stems, which trodden in will puddle and degrade the soil's structure and render it unsuitable for cultivation.

The organic matter related *iyba* content is certain to decline under cultivation - a fall in carbon content being long associated with fertility decline and site abandonment under shifting cultivation (Nye and Greenland 1960; Brams 1971; Zinke *et al.* 1973; Sanchez 1976). Again rate of depletion is not easy to estimate, although some locations are customarily recognised as more likely to retain respectable *iyba* levels than others (such as folds and down slope locations), but these may be too shaded and not see enough sun for optimum crop growth, sufficient to reduce water content, warm the soil, and give crops maximum exposure to the sun's energy.

[3] There is some parallel between this concept and the early notion of European science of 'juices of the earth' - Wild 1988: 2-5.

AGRICULTURAL POTENTIAL OF SOIL : DEVELOPMENTAL SOIL STATES

While the Wola have no series of appraisal class terms that they can apply to a soil before cultivation, to label its agricultural potential, they have a clear idea of what comprises a good, bad or indifferent agricultural soil. But using these criteria, they talk only in generalities, not specific predictions. A good topsoil for example, should extend to a fair depth, ideally with an abundant store of *iyba* organic matter, have a not too moist water content, and perhaps a modicum of stones. Structure features too in any soil assessment, the Wola having a keen sense of soil structure, referring to aggregates of any size as *suw ombo.*

A good soil has a loosely packed, non-coherent, porous crumb structure. A commonly heard phrase of such a granular soil is *dowhuwniy nonbiy* (lit: sweepings like), the Wola likening it to the crumbs of rubbish, grit and dirt periodically swept from houses. We can perhaps sense in part what they are looking for here in the computer cluster division of horizon 2 (that horizon which most often equates with their *pombray* topsoil class), as described in Part II of this series of papers. Notably the major distinction between loosely packed soils of low density, poor coherence and highly porous crumb structure, and more packed soils of higher density and coherence, and a less porous more aggregated blocky structure.

These criteria, by which the local people assess the agricultural potential of a soil, cut across their soil classification classes (Sillitoe 1991), although they may be used to qualify a class, by referring for example to *pombray buriy* 'strong topsoil' or *pombray iyba wiy* 'topsoil with *iyba* grease'. These criteria relate more to a series of soil states distinguished by the Wola than to soil classification. They serve to demonstrate further how appraisal for soil potential is largely a relative issue for them, closely associated with time and use. It is an ongoing rather than a predictive process, based on observed soil performance under cultivation, and occurs during and after land use rather than before it.

While the soil state classes they distinguish relate to soil assessment, they do so post-cultivation only. Indeed the soil state classes are not so much use assessment classes as a broad developmental sequence soils may follow under cultivation. They run as follows:

1) suw ka ***(lit: soil raw) is either soil under long standing natural vegetation or newly cleared soil that has not been cropped. It has a good*** iyba ***'grease' content but its final water state and strength are difficult to judge.***

2) suw hemem ***is the best soil state, and few soils achieve it. It occurs where a considerable depth of vegetation waste accumulates, notably at the foot of slopes and on small flat areas. It is often human-made as a result of the build up of decaying vegetation and topsoil along a fence line at the bottom of a slope. It rots down to produce a thick layer of soft, black,*** iyba-***'grease'-rich topsoil in which crops flourish. It is common, as a consequence, to see a variety of crops growing at the foot of the slope in an established garden adjacent to the fence where*** suw hemem ***accumulates, the remainder of the site given over almost exclusively to sweet potato.***

3) suw huwniy ***is a soil state achieved in some gardens following exposure to the sun. It is a good soil for sweet potato. It is not as soft as*** suw hemem, ***comprising coarser crumbs, and it is relatively deficient in*** iyba ***'grease'. But it is porous and*** tomiy ***weak, so tubers can penetrate and grow well in it. It only occurs following the break up of the topsoil, when women have heaped it up into mounds for sweet potato. And the more times it is cultivated the better the***

granular huwniy ***structure may become for sweet potato cultivation. If a soil develops into the*** huwniy ***state, the time that it remains cultivable is related to the depth of the topsoil. If it is considerable, and the garden slope gentle such that erosion losses are small when the soil is exposed under a newly planted crop, then it can remain in this state indefinitely and support a sweet potato garden for decades. A common strategy with these gardens is to work in a rotational manner around them, leaving an area to rest for a period under*** bol ***grass (Ischaemum polystachyum) to replenish its*** iyba ***'grease' levels, a practice called*** suw hombshor ***(lit: soil share-out i.e. share out its use, to conserve a modest organic matter content).***

4) suw taebowgiy ***is the worst soil state. The soil is*** buriy ***strong, hard and cloddy. Sweet potato tubers find it hard to penetrate and grow in, and weeds can compete effectively with the crop. It is deficient in*** iyba ***'grease'. Any tubers that grow are small and stringy, and may be so poor as to become what the Wola call*** hokay haeriy, ***that is bitter tasting with a flesh that turns an unpalatable grey colour when exposed (like a green apple turns brown when cut open). When a garden soil becomes*** taebowgiy ***it is time to abandon the plot. The time that soils take to reach this poor condition varies, from one or two years under cultivation onwards.***

5) suw pa ***is waterlogged soil. It is unsuitable for any crops other than wet-loving taro and skirt sedge (Eleocharis dulcis), although a range of other crops may be planted on any higher ground, notably around the base of trees whose transpiration demands have somewhat dried out the topsoil and bound it together (Sillitoe 1983). Waterlogged soil does not follow the above development sequence but remains*** pa. ***Nevertheless it quickly becomes tired under cultivation. Taro is a heavy user of*** iyba ***'grease' supplies and these soils are cropped once only and then allowed to regenerate their natural vegetation cover and*** iyba ***'grease' fertility.***

The foregoing gives further credence to Wola assertions about feeling no compunction to investigate soil before cultivating it. They can hardly assess the favourability or otherwise of any soil beforehand, if its character only becomes evident under cultivation. It is necessary to clear a site and allow the soil to dry out somewhat in the sun to appreciate better its potential. It also becomes more apparent following its break up and mounding, when the extent to which it may develop the favourable porous granular *huwniy* structure becomes clear. The extent to which its *iyba* 'grease' reserve might be conserved is also largely unknown, although certain localities are more favourable to this than others, such as down-slope and in folds where the best *hemem* soils are likely to form.

The locations where favourable soils are likely to develop are limited on any site. It would be pointless to assess an entire garden from one of these favoured locations alone, when they make up only a small part of its area. Similarly, assessment of topsoil depth, the criterion that might be thought readily determinable, is not feasible because it can vary greatly over short distances within a garden. There is little point in checking it in one or two places when it will probably differ everywhere else. The same applies to the assessment of stoniness. The gardeners themselves exploit these site micro-variations as they become apparent when they plant their crops, siting taro on particularly wet spots such as seepages, and a variety of crops such as greens, pulses and cucurbits along the bottom of slopes and in folds, where the topsoil is likely to be deeper and more *iyba* organic rich.

SOILS UNDER SHIFTING CULTIVATION AND LOCAL KNOWLEDGE

The soils of the Wola region not only display a considerable homogeneity overall, are similar in a

broad classificatory sense as the analysis presented in Part II demonstrates, but also, in the variations they do manifest, vary in a largely unpredictable and continuous manner, both in the way some of their properties respond to cultivation and spatially as distributed across garden landscapes. Where soils are generally so similar, and variations between them crucial to crop growth not readily perceived, even canny and experienced farmers find it hard to make reliably informed judgements about their possible potential. They cannot be at all sure about their behaviour. After all, some soils they maintain, progressively improve the longer they are under cultivation, and the only way to find out is to garden them. This is the exact reverse of the current image of soils under a shifting cultivation regime, as experiencing either a swift fertility decline, unmanageable weed infestation or some other rapid agriculturally deleterious change, which forces a change of site.

The shifting cultivation practices of these New Guinea highlanders appear to contradict the accepted wisdom of this agricultural regime. Regarding soil inspection for example, their disinclination to it when selecting a garden site contrasts with the behaviour of people elsewhere who study soil and vegetation, and even reportedly subject it to tests like tasting it (Conklin 1957: Gourou 1962: Allan 1967: Ruthenberg 1976: Allen 1982). The understanding that we have of tropical subsistence agriculture derives in considerable part from work in regions of old soils, like Africa and South America, and there is a tendency to generalise from it to the equatorial tropics as a whole, whereas we should not expect people living throughout this region of the world necessarily to follow similar practices.

The evidence suggests that we should not lump the subsistence cultivators of New Guinea, nor those elsewhere cultivating on relatively young soils (e.g. on other Pacific islands and parts of S.E. Asia), with shifting cultivators living on ancient land surfaces. The uniformity of the soils that occur in the Wola region, as demonstrated in Part II, which is central to understanding local pedological lore, can for example be attributed in part to their comparatively young age. Soils of the Inceptisol order show relatively little variation compared to older orders because they have not existed long enough to bear the imprint of local environmental variations and diverge. The geologically recent volcanic rejuvination of the region's soils has further contributed to their uniformity and youth (Pain and Blong 1979; Blong 1982; Wood 1987).

PROTECTION OF WOLA ENVIRONMENT

We have a long way to go before we understand the dynamics of these tropical agricultural systems. Clearly, those who have lived by them for generations can only help further our knowledge (Chambers 1983; Richards 1986). No matter how technically primitive people may appear, we should not allow this to fool us into thinking that their understanding of their environment is deficient in some regards, nor that their knowledge of the world as they experience it is somehow undeveloped and elementary, even inadequate. If this study has achieved nothing beyond demonstrating that a scientific survey and computer analysis cannot better local lore, so lending support to the tenets of sustainable agriculture now gaining ground, then it has been worthwhile. It is time that experts respected local knowledge and consulted it closely, before they try to improve on it. (Thomasson 1981; Chambers *et al.* 1989).

Nevertheless it would be erroneous to depict the Wola as innate conservationists, as culturally conditioned environmentalists who can be relied upon to use new technologies and innovations in a naturally sound way. They evidence little interest in environmentalism in their use of their soil resources, displaying no apparent cultural recognition of responsibility for the natural world nor act as if they have a duty to conserve it. It will look after itself

under the farming regime. If a soil develops favourable agricultural attributes under cultivation they are likely to crop it indefinitely, adopting cultivation strategies, like short term grass fallow and green composting, to extend its useful life (D'Souza & Bourke 1986). There is no notion here of protecting the natural environment from the potentially harmful effects of human activities, but of exploiting it to its maximum.

The Wola have abundant soil resources and can move to new sites as they exhaust old one; with abundant land available they are not exploiting their resources near to the margins given their current technology, when we might expect environmentalist-like concerns perhaps to become apparent. The abandoned sites in turn recover under natural vegetation. This is an inevitable natural process, not one dependent on human agency. It is their agricultural technology, coupled with a modest population density, rather than their cultural ideology, that protects the Wola environment in the long term.

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URBANIZATION AND THE URBAN POOR - VANUATU'S FOOD SECURITY CHALLENGE

Tim Foy[1]

ABSTRACT

Local staples in towns of Vanuatu are beyond the reach of the urban poor who rely on imported rice which provides cheap calories. Diversity in food options is lost and the urban poor's food security is dependent on the price of rice. National food policy, emphasizing self sufficiency, has led to the introduction of a tariff on rice. While successful in containing rural demand, the tariff has failed to reverse the high urban price differential between rice and local substitutes and urban consumption patterns have remained unaltered. The tarriff has however, raised the cost of food to the already vulnerable urban poor. It is argued that rapid urbanization will increase demand for imported foods unless consumption habits change. Tariffs will not achieve this. Emphasis must be placed on reducing the cost of local foods relative to rice by improving their production, distribution, marketing, and widening food options and providing incentive to change of habits.

Key words: Food policy; tariffs, rice imports; Vanuatu

INTRODUCTION

Vanuatu comprises an archipelago of over eighty widely dispersed islands stretching across 800 kilometers of the South West Pacific. Of the total land mass of 12,190 square kilometers, approximately 41% is regarded as cultivable land. At present, less than one third of the potential arable area is thought to be under cultivation, including that under commercial plantations and fallow. With a population estimated at just 142,944 in 1989, with abundant land resoruces and a favourable climate, Vanuatu has the potential to be physically food self sufficient. In contrast to many other developing countries, food security at either the household or the national level, should not appear an immediate problem. Urbanization is, however, rapidly changing the distribution of national population, and with it food consumption patterns, in a way that fundamentally alters the determinants of food security. In these circumstances physical self sufficiency at national level provides no automatic assurance of food security. This paper therefore discusses food policy issues applicable not only for Vanuatu but for the whole Melanesian region and attempts a contribution to the debate on food security, food import and traditional food production for long term stability of the developing countries.

VANUATU'S CHANGING POPULATION

Between the first national census in 1967 and the third and most recent in 1989, the number of ni-Vanuatu residents in Vanuatu's two urban areas - Port Vila (the national capital) and Luganville - increased at an astounding annual rate of 7.6%. Rural population over the same period rose annually by 3%, in itself a rapid rate of growth. The proportion of ni-Vanuatu urbanized has thus risen from 6% of the total population in 1967 to 17% in 1989. Almost all of this increase can be attributed to net immigration from rural areas. Table 1 shows

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Vanuatu's urban expansion. The urbanization radically alters the determinants of household food security (HFS), the household's ability to secure food in sufficient quantity and quality to maintain good health. The generally good access to self produced food, that characterizes rural Vanuatu with the occasional aberration of tropical cyclone, ceases when households settle in towns. HFS then becomes dependent upon securing access to purchased rather than self produced food; a command on food resources predicated on the maintenance of access to income to buy food which is affordably priced. Any disruption to income or unfavorable movement in food prices can potentially compromise HFS.

In Vanuatu today, the urban poor who represent the largest proportion of a rapidly growing urban population, are a particularly vulnerable group. If their food security is to be improved, it is essential that the reasons for this vulnerability are fully appreciated. Only then can interventions be appropriately designed and targeted and an accommodation of their needs brought to national level food policies. To date, food policy has emphasized national self sufficiency but little, if any, regard has been shown to food security needs at the household level. Measures implemented in support of this national objective have been detrimental to the food needs of the urban poor.

Table 1. **Vanuatu's changing population, 1967 - 1987.**

	1967		1979		1989	
Rural/urban	Number	%	Number	%	Number	%
Rural	70,216	90.0	95,467	85.8	116,650	81.6
Urban						
Luganville	2,564	3.3	5,183	4.7	6,983	4.9
Port Vila	5,208	6.7	10,601	9.5	19,311	13.5
Total	7,772	10.0	15,784	14.2	26,294	18.4
Vanuatu	77,988	100.0	111,251	100.0	142,944	100.0

Source: National Planning and Statistics Office, Port Vila.

There are unfortunately little data available on income and expenditure patterns in urban Vanuatu. The only survey conducted to date was done by the National Planning and Statistics Office in 1985. While this may be some time ago, the basic pattern of household expenditure and some indication of income levels can be derived from it. These data, combined with more recent information on food prices, allow a reasonable discussion on urbanization and the changing determinants of household food security in Vanuatu.

THE VULNERABILITY OF THE URBAN POOR

Four main factors influence the vulnerable food security status of the urban poor - two related to income and two to the pattern of household expenditure.

1. Low income

Income acts as the most fundamental constraint to the amount (and quality) of food any household can buy. The 1985 survey indicated that the average annual income of the poorest half of urban households was just 41% of the level enjoyed by the 39% of households defined as "middle income" household; 17% of the average annual income of the 11% belonging to the "high income" households (Table 2).

3. High share of income and expenditure on food

Although poor households spend less in absolute terms on food than wealthy households, that expenditure accounts for a significantly greater proportion of their total spending and income (Table 2). Any general increase in the price of food therefore hits the poor proportionately harder. A 10% increase in food prices, for example, would require a low income household to dedicate an additional 4% of its income in order to maintain the same level of consumption; two and a half times the level required by a high income household.

The degree to which price movements (or reductions in income) affect HFS, is also dependent on the household's ability to reallocate expenditure away from non-food items and towards food, if and when required. The higher allocation of a poor household's income to food, limits the flexibility for such substitution union is already difficult given that much non-food expenditure is on essentials such as housing.

Table 2. **Urban household income and expenditure on food, 1985.**

	Proportion of urban households (%)	Average annual household income (Vatu)	Average annual expenditure on food (Vatu)	Household income spent on food (%)	Household expenditure devoted to food (%)
Low income	50%	326,000	125,093	38.3	42.7
Medium income	39%	797,000	181,405	22.7	35.3
High income	11%	1,865,000	294,678	15.8	29.8

Source: National Planning and Statistics Office, Port Vila.

2. Variability of income

Any disruption to the flow of income to the household will impair access to food. There are several ways in which this can occur: unemployment, short time working or sickness. Low income employment tends to be more casual than higher paid jobs. Therefore breaks in employment and periods of underemployment are likely to be more common amongst the poor.

4. Limited diversity of food options

Examination of household expenditure patterns

reveals a high concentration of spending by the urban poor on a very narrow range of commodities. In 1985, five foods - rice, bread, locally produced starches, canned fish and canned meat accounted for almost half of expenditure on food by low income groups. Rice alone accounted for over 15% of that expenditure and provided an estimated 28% of daily adult calarie needs. By contrast, the same five items accounted for less than 10% of the average high income household's food expenditure (see Table 3).

Table 3. **Pattern of urban household expenditure, 1985.**

	Low Income	Medium Income	High Income
	% of all expenditure on food		
Rice	15.7	12.7	2.7
Bread	14.6	11.4	3.3
Local starches	7.2	5	1.9
Canned fish	5.1	3.5	0.6
Canned meat	6.3	5.8	1.4
Total	48.9	38.4	9.9

Source: **National Planning and Statistics Office, Port Vila.**

This pattern of expenditure is not unique in Vanuatu. It is a feature found elsewhere in the Pacific, and frequently attributed to consumer preference based on convenience and taste factors. These "non-price" advantages, while important to urban consumers, notably for working women, are however only part of the story. For those with low income, rice provides cheap energy relative to other available traditional foods excepting Manioc. In terms of calories obtained per unit of expenditure, rice represents good value for money (Table 4).

The high relative price of local foods not only skews consumption patterns towards imported items but it also limits food options open to urban consumers. This reduced diversity jeopardizes HFS as opportunities for substitution with other foods become limited by the high price of local staples. The price differential that exists is such, that rice will remain relatively cheaper even following a substantial increase in its price.

Understanding why traditional foods are so expensive in urban areas, not just in Vanuatu, but throughout Melanesia, has been the focus of much debate. In addition to the more obvious problems attributable to the bulkiness, perishability and high costs of transporting local staples, Melanesian food markets, as noted by Brookefield (1969), fail to conform to the basic tenets of neo-classical economic theory. They are frequently cited as being "inefficient", as evidenced by a lack of bargaining and the preference of vendors for taking unsold produce home rather than reducing prices to induce a sale. The result is a lack of accommodation between buyers, who go home unsatisfied, and producers who go less than fully rewarded. The market fails to "clear" in response to price signals - the key to the allocation of resources in the working of free and efficient markets.

Whether the emphasis of the explanation for high food prices lies with problems of infrastructure or results from the peculiarities of food markets, most observers would agree that it has little if anything to do with technical food production factors. Distribution and marketing aspects of the food system are far more improtant. Their effect has left the food security of poor urban households and therefore a significant and increasing proportion of Vanuatu's total population, largely dependent on the price of rice. Any increase in rice cost presents a threat to HFS. Furthermore, as rice is entirely imported, domestic prices are influenced by changes in world prices and exchange rates, so adding an international element to urban HFS.

Table 4. **Energy values of alternative foods, Port Vila 1980 - 1991.**

Year	Rice	Cooking Bananas	Yams	Sweet Potato	Taro	Manioc
			Kcals per constant 1980 vatu			
1980	61.3	35.6	19.3	33.9	36.1	76.1
1981	40.9	36.6	24.2	38.7	39.2	77.7
1982	57.1	45.1	24.8	42.8	36.0	77.9
1983	67.2	49.0	27.1	39.0	46.7	99.8
1984	70.2	41.2	25.9	37.1	42.4	87.7
1985	88.2	42.2	22.9	33.6	39.9	87.3
1986	84.2	43.3	26.4	38.7	51.7	89.1
1987	76.3	30.3	19.7	31.4	36.7	70.9
1988	72.1	27.1	19.0	32.1	29.4	64.9
1989	65.5	49.0	25.3	42.7	68.0	125.4
1990	72.3	57.6	30.7	37.6	69.6	129.5
1991	83.6	52.8	23.6	40.3	48.6	117.5
Average 1980-1991	69.90	42.48	24.07	37.33	45.36	91.98

Source: **Calculated from data supplied by the National Planning and Statistics Office, Port Vila.**

FOOD IMPORTS, FOOD POLICY AND HFS

For a country with such a rich agricultural potential and one physically capable of achieving self sufficiency, Vanuatu's food imports are remarkably high. Throughout the 1980s, annual average food imports amounted to a value equivalent to almost 20% of the value of total imports and 80% of the value of domestic exports. In three years during the 1980s, the value of food imports exceeded that of domestic exports (see Table 5).

Consumption of imported foods, despite the preceding discussion, is in fact neither a recent trend, nor a habit associated solely with urbanization. Malcolm (1951) showed that imported foods, notably rice, were already well established in both urban and rural diets more than forty years ago. More recent reviews of household expenditure patterns undertaken by the National Planning and Statistics Office in 1983 and 1984 indicate that rural, rather than urban consumption, has been the primary source of demand for imported foods. Estimated urban per capita consumption levels for imported items are generally higher than those in rural areas, but the predominance of rural ni-Vanuatu in the population (82% in 1989) means that the bulk of consumption has occurred in rural areas. To take the case of rice; in 1985, a year of particularly high imports, estimated rural consumption comprised more than 70% of total demand although per capita consumption was at 43 kg which was significantly less than the 78 kg estimated for urban areas.

This high level of food imports is viewed with great concern, primarily because of the foreign exchange

Table 5. **Vanuatu's food imports 1980 - 1990.**

Year	Food imports (millions of vatu)	Food imports as % of total imports (%)	Food imports as % of domestic exports (%)
1980	993	27.9	112.8
1981	1113	28.5	79.4
1982	1143	24.7	110.2
1983	1023	19.7	57.4
1984	1166	20.0	35.1
1985	1210	19.6	64.5
1986	1089	18.4	112.3
1987	1022	13.7	68.0
1988	1263	18.1	81.1
1989	1213	15.4	75.2
1990	1297	12.0	80.8
Average (1980-1990)	1139	19.8	79.7

Source: **National Planning and Statistics Office, Port Vila.**

costs. Increased self sufficiency, measured in terms of reduced imports, has consequently become the prime food policy objective, and figured prominently in Vanuatu's Second Development Plan. Amongst the strategies advocated in support of this objective, perhaps the most significant has been the imposition of a range of tariffs on imported foods in 1987. Table 6 highlights the rate of import duties which have been levied on a number of items important to the urban poor. In view of the vital dietary role of these foods such high rates of duty impose a serious burden on the urban poor and become a potential threat to HFS.

The degree to which a tariff will succeed in reducing the consumption of any good, depends upon the extent of the price rise it causes, and the price elasticity of demand for that good - the extent to which consumption responds to a change in price. Price elasticity of demand will vary between households with respect to the ease with which alternative goods can be substituted. In the case of food, this ease of substitution also determines the tariff's implications to HFS.

Table 6. **Prevailing rates of import duty on significant food items.**

	Rate of duty (%)
Rice	25
Flour	25
Canned fish	45

Note: **An additional 5% Service tax is levied on all items.**

Source: **Vanuatu Department of Customs.**

For rural households wth easy access to adequate home produced foods, substitution will be easy. Tariffs on items like rice and flour which are substitutes for home produced foods, can achieve the objective of dampening demand with no necessarily adverse impact on HFS in the rural areas.

The situation is very different in urban areas. The price elasticity for imported items, principally rice, is likely to be much lower, particularly given the limited range of food options available. substitution will be by necessity with another purchased food, and will only occur if the tariff succeeds in leaving imported items, principally rice, relatively more expensive. Given the extent of the present price advantage that rice offers, a very considerable increase in its price or tariff would be required to achieve this. The consequences for those on low and limited incomes of such a hike in basic food costs are self apparent.

In Vanuatu, tariffs have been set at a level below those required to reverse the existing structure of relative prices. Untaxed local foods remain relatively more expensive (see Table 2), so no inducement to substitution has been given. The tariffs have however required urban households to spend more to buy the same quantity of imported food. Those unable to meet this higher food bill are obliged to reallocate expenditure away from "less important" items (including presumably some foods), and towards obtaining basic calories.

If such a reallocation of expenditure cannot be made, and as discussed above the opportunity for the urban poor to do so is limited, reductions in food consumption may occur. Any suppression in urban demand for imported foods thus achieved, will not have been through the "substitution effect" initially intended, but rather by way of an "income effect". That is by reducing the physical amount of food the household is able to buy, in a manner analogous to that which would occur if income was itself reduced. The food security implication for households with limited incomes is once again all too readily apparent.

The dilemma for Vanuatu's policy makers, however, is that tariffs are an effective, and probably the only means of containing demand for imported foods: if the problems they present for the urban poor are pushed aside. To take the case of rice again, national per capita consumption appears to be significantly price sensitive, indicating that tariffs will dampen demand. This finding is consistent with the premise that the majority of rice, and with it most other imported foods are eaten in rural areas, where demand can be presumed to be relatively price elastic. This is illustrated by the regression equation presented below which expresses national per capita rice consumption between 1980 and 1990 and its price.

Annual per capita rice consumption (kg per year)
= 78.8 - 0.8 price per kg
(9.3) (5.1)

R2 = 0.75, F = 26.4; t values in parentheses.

As urbanization continues however, the proportion of imported foods eaten in urban areas will rise. Table 7 provides an indication of this for rice. Should urbanization continue at the pace seen in the last ten years, and per capita consumption in rural and urban areas remain at present estimated levels, total consumption will rise rapidly, and be increasingly led by urban demand, which will soon overtake rural consumption in terms of importance.

Table 7. **Possible future rice consumption in Vanuatu.**

Year	Total consumption	Urban consumption	Urban contribution to total
	(tonnes)	(tonnes)	(%)
1980	4132	1229	30
2000	8428	3996	47
2010	13541	8085	60
2020	23073	16357	71
2030	41358	33091	80

Assumptions:

1. The rural ni-Vanuatu population continues to increase at an annual rate of 2.1%, and the urban ni-Vanuatu population at 7.3% per annum. These were the rates recorded between the 1979 and the 1989 census.

2. Annual urban per capita consumption remains at the level of 78 kg per capita estimated by the 1985 Family Income and Expenditure Survey, and rural consumption remains at the estimated 1980 to 1990 average level of 30.4 kg.

3. Consumption of non ni-Vanuatu is omitted.

In these circumstances, not only will the adverse HFS impact of tariffs impinge on an ever greater number of households, but they will become progressively less efficacious in achieving their national objective. This will inevitably be the case unless realistic opportunities for substitution with local foods are available, or tariffs are set at levels sufficient to reverse the price ratio of local to imported staples for urban consumers, with absolutely no regard for equity, welfare or HFS.

Reviewing the food policy in Vanuatu reveals that it has been primarily directed at a national level objective - reducing food imports. HFS concerns of the urban poor have never figured in policy formulation. Similarly, no consideration has been given to assessing the impact of tariffs, the main thrust of that policy, on HFS, or to assessing their long run effectiveness in view of changing population distribution.

STRATEGIES FOR ENHANCING URBAN HFS

Continuing urbanization will require Vanuatu's policy makers to turn their attention towards meeting a growing HFS challenge. Four approaches can be identified, the mechanics and merits of each are discussed below.

1. Improving household purchasing power through transfer payments

Improving the incomes of poor urban households through the direct use of transfer (welfare) payments, either tied or untied to food, would clearly improve HFS. However, untied cash payments require extensive administration to avoid fraud, or leakage of benefit to those to whom it is not intended. Furthermore, as such direct income transfers do not reduce the price of food relative to the items, they do not necessarily encourage additional food consumption.

The use of food-tied income supplements, for example food stamps, would ensure both a greater targeting of benefits, and probably also achieve increased food consumption. However, in addition to the administrative requirements of such schemes and the incentive they give to urban migration - the fundamental cause of Vanuatu's food problems - more philosophically perhaps, they come close to institutionalizing poverty, food insecurity, and import dependency in a country in which this is surely not necessary. Simply improving incomes does nothing to address the expenditure side aspects of the HFS problem. Households will remain dependent on imported foods, and hence vulnerable to changes in their prices, unless supplementation of income is sufficiently responsive to protect them. It would seem that improving household purchasing power through welfare payments was not in the long term interest of national food policy.

2. Subsidizing food prices

Subsidization of specific food items, such as rice, would improve the HFS of the urban poor by reducing the cost of acquiring food. It would also provide a means of insulating households from rising food costs. However, it represents a symptomatic treatment rather than a cure of the basic problem that the limited diversity of food options in urban areas caused by the high relative price of traditional staples.

In practical terms, a subsidy would present the authorities with a new fiscal burden, almost certain to rise with increasing urbanization, and fluctuating with changes in international prices and exchange rates. Furthermore, the benefits provided would accrue to all consumers: rich and poor, rural and urban, not just the urban poor. General subsidies are not only an expensive way of assisting the poor, they are also inefficient.

3. Reducing dependency upon purchased foods

Urban HFS could be improved by reducing the household's dependency upon purchased foods.

Increasing home production represents the most direct approach to achieving this. Consumption of home produced food releases part of the income resource presently committed to food, and so improves the household's ability to reallocate expenditure towards food in the event of price rises. Income so released is also available for the purchase of "additional" food; although it may not be spent on this. The greatest benefit will be achieved if the household produces foods which account for the largest proportion of expenditure, i.e. starches.

A recently performed survey by the Vanuatu Department of Agriculture, reveals that the overwhelming majority of Port Vila's residents already practice this food security strategy. Of a representative sample of 6% of households, over 80% actively produce food. Food Production is very intensive and does concentrate on starches, particularly manioc and plantain, although a surprising range of crops, and even livestock, is produced.

Unfortunately, urban food production is not without its problems. Most households have no tenure rights to the land they utilize and so face possible eviction. Municipal authorities are in some instances unhappy about the presence of food gardens in urban areas. They are claimed to be unsightly, a health risk and to lack formal planning permission. Producers face problems of theft. While the intensive cropping systems practiced, frequently without any or adquate fallowing, deplete soil fertility. Crop yields are unlikely to be sustained should this practice continue. Nevertheless, urban food production is a logical household strategy to enhance food security which the Vanuatu Department of Agriculture has recognized and is supporting through the appointment of an agricultural extension officer specifically for urban areas.

4. Increasing diversity of food options

Widening food options in order to lower dependency on a narrow range of foods, means improving the availability of cheap local produce in markets by encouraging the production and marketing of food from the hinterland of urban areas. An increase in food production is not in itself sufficient but food must also be marketed at prices attractive to consumers.

In addition to any positive impact on urban HFS, improving the diversity of food options also makes a more constructive contribution towards achieving national food self sufficiency than the present reliance on tariffs. Clearly, the extent to which urban consumption of local food can be increased, depends upon the degree to which changes in consumer preference towards imported foods are determined by changes in relative prices alone, and how much by non-price factors such as taste and convenience. Whatever the case, it is clear that unless the price of local foods relative to imports can be reduced, and then by a process of levelling down rather than the levelling up which has been attempted to date, urban consumers will never be offered a choice in their consumption habits. In this case, Vanuatu's continued and growing dependency upon food imports will certainly be confirmed.

While intrinsically appealing, the approach is far from straight forward. The marketing and distribution problems leading to the existing pattern of high prices do not denote an environment immediately conducive to the development of a more commercially orientated food sector. However, recent reviews of market trends, such as those of Joughin (1988) suggest that a dynamic and developing level of commercial activity can, and has developed in Melanesia, with a positive impact on urban food prices.

Review of the four strategies above, suggests that the most viable approaches are those which in fact promote and improve the local production and marketing of foods. A greater compatibility car exist, and indeed will have to be encouraged, given the rapidly changing distribution of Vanuatu's popu-

lation, between meeting the needs of urban HFS and the national food objective of self sufficiency.

CONSLUSIONS

Rapid urbanization presents Vanuatu with a gamut of problems. Attention has, however, tended to focus on the challenge of providing adequate social infrastructure of housing, health, sanitation, water and education. Little, if any, regard has been given to the food needs of the urban poor, despite this being their most basic requirement. Policy makers have yet perhaps to appreciate the existence, no matter how paradoxical it may appear of food insecurity in a country so richly endowed with agricultural potential.

A number of conclusions can be drawn from this brief review. Firstly, urbanization has fundamentally changed the determinants of HFS for the increasing number of ni-Vanuatu who live in towns. Rural food security assured by good access to an abundant agricultural resource has, for urban ni-Vanuatu, been replaced with a dependency upon the ability to buy adequate food.

Secondly, the vulnerability of HFS in urban areas varies with respect to economic status. Poor households are clearly the most at risk. Their vulnerability, in part due to low and insecure incomes, is heightened by an acute dependency upon a very narrow range of mostly imported foods. Diversity in food options, a key element of food security, is absent in urban Vanuatu. This must be reestablished if urban HFS is to be enhanced.

Thirdly, food systems are not simply about food production. They are a more complex integration of production, distribution, marketing and consumption. In Vanuatu, it is an issue of marketing and distribution, rather than technical food production factors that thave determined the structure of relative food prices in favor of imported goods. In this context, the capability to achieve national food self sufficiency provides no guarantee of food security, either for the household, or ultimately given the pace of urbanization, for the nation. An appreciation of the multi-factorial and interrelated nature of food systems is central to the successful formulation of initiatives in the food sector.

Fourthly, policy makers need to carefully consider the possible impact at the household level of measures implemented in response to national food policy objectives. It should be recognized that a single policy measure such as tariff, is unlikely to have a common influence on all households. Its implications for food security will also vary according to socio-economic status i.e. urban/rural and rich/poor. Households are not all the same. Perhaps more fundamentally, it should be appreciated that policies implemented in support of national objectives can conflict with the needs of individual households.

There are no easy approaches to improving the situation of urban HFS in Vanuatu. The present extent of the problem, and its likely future development, will require policy makers to accord the matter serious consideration. They will certainly need to adopt a more analytical approach than has been the case up until now. Food policy analysis has been little in evidence, leading to the adoption of reactive policy measures which carry an inequitable burden for the most food vulnerable, and fail to address the fundamental causes for the malaise they seek to remedy. The key to improving policy lies in understanding the food system, from production to household consumption.

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6. Headings - In experimental papers the general order of headings is: Abstract, Introduction, Materials and Methods, Results, Discussion, Acknowledgements, References, Appendix. In descriptive, or other types of papers, as far as possible a similar format should be followed. No headings should be underlined.

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

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

Numbers under 11 should be spelt out unless qualifying a unit of measurement. If a number over 10 and a number under 11 appear in the same sentence, both are written as numerals. Do not begin a sentence with a numeral. Fractions should

be given as decimals or spelt out. All decimal numbers less than unity should have a zero before the decimal marker, e.g. 0.25. All units should be in the S.I. system.

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

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

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

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

10. Acknowledgements - The names, initials and place of work of those the author wishes to mention may be included. It is not necessary to mention everyone who has been marginally involved in the work.

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

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

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

BOWETT, C.M. and SMITH, L.N. (1950). Measurement of phosphorus. *Methods of Soil Analysis.* Ed. C.A. Lack. Department of Primary Industry, Port Moresby. 400 pp.

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

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

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

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

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

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

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

14. Recognised abbreviations in this journal are:

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

Levels of significance;

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

Either kg/ha or $kg.ha^{-1}$ is acceptable, but large combinations of units should be in the form $kg.ha^{-1}$ to avoid possible mathematical ambiguity.

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