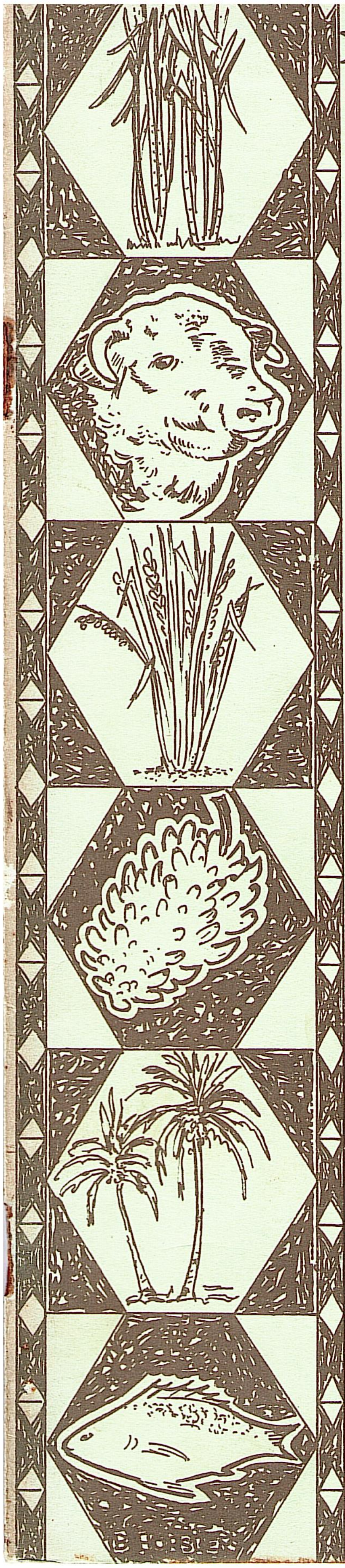

Vol. 35 No. 2
New Series
JULY — DEC. 1973

FIJI AGRICULTURAL JOURNAL

MINISTRY OF AGRICULTURE FISHERIES & FORESTS. 50c

Fiji Agricultural Journal

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Fiji Agricultural Journal

VOL. 35, No. 2

July - December, 1973.

CONTENTS :—

CORRIGENDA Vol. 35 No 1.

p 36 col. 2 line 12. For '1958' read '1952'.

p 46 Notes to Table 1. The first line of the 3rd note should read
(c) These are the antilogs of the (b) figures.

METRIC CONVERSION FACTORS

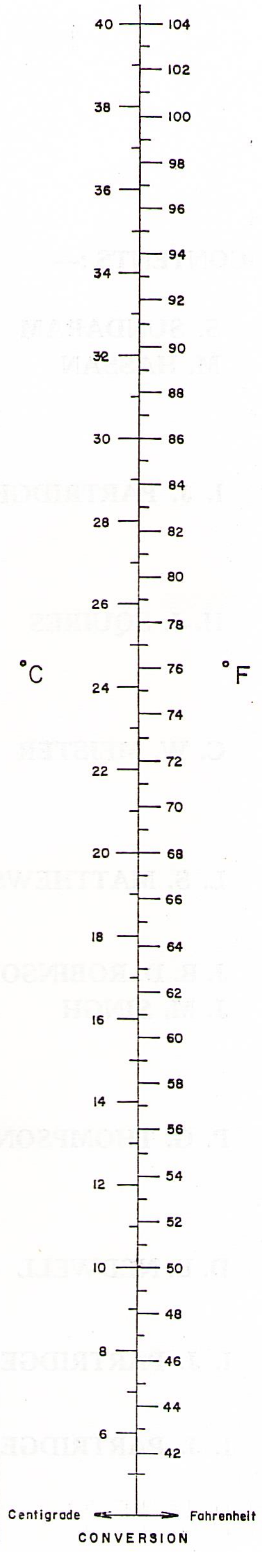
A	B	To convert A to B multiply by	To convert B to A multiply by
inches (in)	centimetres (cm)	2.54	0.394
feet (ft)	metres (m)	0.305	3.28
yards (yd)	metres	0.914	1.09
chains	metres	20.1	*
chains	kilometres (km)	0.0201	49.8
miles	kilometres	1.609	0.621
ounces (oz)	grams (g)	28.35	0.035
pounds (lb)	grams	454	*
pounds	kilograms (kg)	0.454	2.205
hundred-weights (cwt)	kilograms	50.8	*
tons	kilograms	1016	*
tons	metric tons (tonnes) (mt)	1.016	0.984
square in (sq in)	square cm (cm^2)	6.45	0.155
square ft (sq ft)	square metres (m^2)	0.0929	10.8
square yd (sq yd)	square metres	0.836	1.196
square chains	square metres	405	*
square chains	hectares (ha)	0.0405	24.7
acres (ac)	hectares	0.405	2.47
square miles	hectares	259	*
square miles	square km (km^2)	2.59	0.386
fluid ounces	millilitres (ml) †	28.4	*
pints	litres (1)	0.568	1.76
gallons	litres	4.55	0.22
cubic feet	cubic metres (m^3)	0.0283	35.3
cubic yards	cubic metres	0.765	1.31
lb/ac	kg/ha	1.12	0.89
cwt/ac	kg/ha	125.5	*
ton/ac	mt/ha	2.51	0.398
pint/ac	1/ha	1.40	0.712
gall/ac	1/ha	11.2	0.089

$$°C = 5\,(°F - 32)/9$$

$$°F = [9\,(°C)/5] + 32$$

* These factors will seldom be needed.

† For practical purposes 1 ml = 1 cubic centimetre.



Fiji agric. J. (1973) 35, 61-66

FURTHER NOTES ON THE WAIMARO COCOA PART 2 YIELD

by

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SUMMARY

During 1968-'72 individual plots at Waimaro, the first Amelonado cocoa planting in Fiji, yielded between 1,500 and 3,700 Kg/ha. Large variations in yield, and in loss to black-pod, within the small area of the trial (1.7ha) show that the growth of cocoa is highly sensitive to small variations in soil, and the incidence of black-pod to variations in microclimate. The average black-pod loss (25%) is so high as to make it doubtful whether cocoa should be planted in this rainfall zone.

INTRODUCTION

The planting of a 1.7 ha block of West African Amelonado cocoa at Waimaro in 1958 was an important landmark in the history of cocoa cultivation in Fiji. Before then (as reviewed by Vernon [9], with references) only Trinitario cocoa had been planted: a few hundred acres during 1880-1930, and rather more during 1956-1958 with seed derived from remnants of the earlier plantings. Extensive Trinitario plantings continued until 1965, and some has continued to be planted until recently; but since 1965 the Departmental policy has been to plant only Amelonado, using seed directly or indirectly from Waimaro.

Amelonado was imported as a result of policy decision to switch to Forastero cocoa (of which Amelonado is a variety) because of its greater disease resistance; but it was only later realized how crucial this is in Fiji. Most of the Trinitario plantings are now derelict, primarily because of the canker disease, to which Amelonado is relatively resistant (9, 1).

The present productive cocoa of Fiji, therefore, and several hundred acres not yet in bearing, is predominantly Amelonado. Little of this is over 8 years old, except the Waimaro block which is 15 years. The performance of this latter, therefore, is important as a guide to what may be expected generally from Amelonado as it matures. Vernon (10) reported the results of the pruning trial that was started in 1968; but said nothing about pre-1968 yields, the variation in yield with soil type, point-to-point variation in black-pod loss, and other topics now covered.

FURTHER BACKGROUND INFORMATION

Some details of the site, and history of the planting were given by Vernon (10) and the soils have been described by Kafoa and Tora (5). The following further details are relevant to points raised later (location particularly to the question of black-pod loss).

Location and Rainfall

The station lies on the north side of the King's road about 50 km (30 miles) north of Suva at the foot of the windward side of a ridge about 150 m (500ft) high. It is, therefore, a wet place. During 1970-1973 the annual average rainfall was 3,825 mm, compared to 3,525 mm at Suva in those years, and 3,100 mm long term average at Suva. The new rainfall maps by Matthews (6) show Waimaro just on the dry side of the 4m isohyet. By contrast, that part of the Wainibuku valley a little to the north-west where much of Fiji's present cocoa comes from is about the 3m isohyet, and those parts of Vanua Levu where most of the present crop is grown, and where most new planting is now being located, generally have about 2.5m annual rain.

Management

Seed of West African amelonado was introduced from Malaya in September 1958, and planted in bamboo pots. At 3-4 months old, the seedlings were transplanted into holes about 0.5m cube, filled with loose earth. At this stage the shade comprised a few large forest trees, mostly on the better drained part of the plateau and on the alluvial flats, plus artificial reed shade for individual plants. Harwood (3) reported that initial establishment was satisfactory; but with the removal of all the artificial shade at about 9 months of age, some cocoa seedlings (particularly those in the poorly drained plateau area) seemed to suffer from excessive drying of the soil. As a result, dadap cuttings were planted later when the cocoa was 1½-2 years old. These took well except in the poorly drained plateau area where growth continued to be unsatisfactory. In the hurricane of 1965 some cocoa was temporarily damaged by falling dadap trees and branches. From 1968 onwards shade was progressively thinned over the areas of better growth, and reduced to almost nothing by 1972. In the other areas, efforts were made to supply gaps and to increase shade; but progress was very slow. The hurricane of October, 1972 flattened almost all the cocoa trees but most have since recovered remarkably well.

Fertilizer has been applied somewhat generously throughout. In recent years the most costly item has been urea, applied at some 100-150 Kg/ha during Sept-Dec. in an attempt to speed vegetative recovery from the check that occurs each winter. The lack of any response to N, P, and K in a trial at Wainigata (11), however, suggests that this may have been largely unnecessary.

Yield Recording

From first bearing until 1968 all good pods were picked, but for the early years the only records that can be traced are the annual total number of such pods. For later years monthly totals were recorded but it is not clear whether the harvesting was once a month, or whether more frequent picks were summed by months. If the former, then black-pod loss must have been severe. (In a trial superimposed on the pruning trial in 1970, the black-pod loss on the monthly-picked plots was 45%, on the weekly-picked plots, 15%).

No records of losses from black-pod or rodents seem to have been made before 1968; indeed removal of black-pods as a disease-control measure seems to have been lax, because there were thousands of old black-pods in various stages of decomposition, on the trees in November, 1967 (Vernon, pers. comm.) From January 1968 all good, diseased, or damaged, pods have been picked and recorded at regular and frequent intervals (usually weekly or fortnightly). Except during periods of negligible yield (see below) the numbers of pods in the categories 'usable' 'black', 'rodent damaged', and 'otherwise damaged', have been recorded at each pick.

YIELDS

Weight of dry beans per pod

In West Africa the standard factor used in research reporting of Amelonado yields is 12 pods = 1 lb dry cocoa (i.e. 38 g/pod). This conversion was assumed for early reports of the Waimaro yields; but later (1970-1971) study of the bulk processing records of Naduruloulou fermentary showed that Amelonado cocoa (including Waimaro produce) gave 40-42 gm dry cocoa per pod, which figures were used for later reports (e.g. 11). In 1972 each pick of each plot at Waimaro was separately broken and weighed. The weight of wet beans per pod ranged from 119 gm (in July) to 96 gm (in November) averaging 110 g/pod, with negligible, non-significant variation between pruning treatments.

The dry bean/wet bean conversion factor of these samples, throughout the year averaged 39%, so this represents 43g dry cocoa/pod, i.e. a 13% increase on the standard West African figure. This is encouraging, as it presumably represents a bigger bean size, which is a favourable sales feature.

Annual Yields, Actual and Potential

The annual yield of usable pods since bearing began, converted to dry cocoa at 43 g/pod; has been:-

Year	Kg/ha	Year	Kg/ha
1962	120	1968	1,060
63	530	69	1,200
64	620	70	910
65	250	71	1,310
66	550	72	1,860
67	630	73	520

The big increase in 1968 was probably due largely to improved sanitation and more frequent harvesting, and the further big increase in 1972 to shade removal. The decreases in 1965 and 1973 were due to hurricanes, and that of 1970 to the excessive black-pod loss of some treatments in the superimposed 'frequency of picking trial' (9).

Vernon (10) presented the pruning treatment results for 1968-1972 in terms of *potential yield,* i.e. the total pod count converted at 43 g/pod. This is much greater throughout than the *actual yield,* given above, because of losses to rats (averaging 10% over the five years) and black-pod (averaging 25%). The rats were deliberately uncontrolled during most of 1968-72, to allow the studies of Williams (12) but have been controlled by poison baiting since May 1972. The differences between the actual yields of 1,860 and 520 kg/ha in 1972 and 1973 and the corresponding potentials of 2,740 and 772 Kg/ha have been due chiefly to black-pod loss; and this despite frequent picking, strict sanitation, and fortnightly fungicide spraying for several months each year.

Seasonal Distribution of Yield.

Williams (12), Fig. 1, shows this for 1969-73. In preparing this graph, weekly harvest figures were used when available, and estimated when not (e.g. by splitting fortnightly records into two parts). From these actual or estimated weekly figures, four-week running means were calculated to smooth out erratic week to week variation (Vernon, pers. comm.) In studying the graph, note that the vertical scale is logarithmic, so that small apparent variations during the main crop period represent a range of 500-3,000 pods/ha, while bigger apparent variations in slack times represent a 10-500 pods/ha range.

Three features are consistent over all years:

1. A sharp rise in weekly rate from practically zero in early March to an annual peak in early May.

2. Following this peak a gradual decline to November, interrupted by a more or less well marked second peak in October.

3. A period of practically zero yield during December-January.

The May peak weekly rate appears in the graphs as about 2,500 pods/ha; but this is in 4-week running mean terms. Actual peak week picks were sometimes 5,000 pods/ha (an important point if peak labour demand of a plantation is at issue). The periods of almost zero yield appear in the graphs not to be well determined, as in most years the whole of this period is represented by dotted lines (= no recording). But although experimental plot recording ceased in these periods, station records of usable pods were kept, from which it is known that in many weeks in summer not 10 pods are picked.

This seasonal distribution of Amelonado yield is markedly different from that of Trinitario cocoa. The latter also gives practically no yield during Jan-Feb; but then continues to yield at a very low level until about August, from when until December it gives almost all its annual yield.

RELATION BETWEEN BLACK-POD AND TOPOGRAPHY

The topography of the station was described by Kafoa and Tora (5) and Vernon (10) gave a diagram of plot locations, now repeated as Fig 1 on next page.

It has always been apparent that the incidence of black-pod was greatest in the low-lying Block 1: and least on the plateau, chiefly in blocks 4, 6, and 7 where the cocoa itself was poorly grown and low yielding. Thus, if plots 3D, 5A and 5D, which are transitional in location between the plateau and the valley, are distinguished as a fourth group, the area falls into the following sections, in each of which

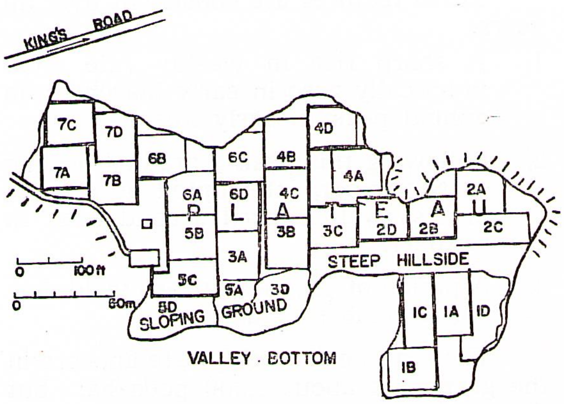

Figure 1.

the average black-pod loss during 1971 and 1972 was as follows:

1.	Low lying area (block 1)	44%
2.	Transitional area*	28%
3a.	Well grown plateau area	22%
3b.	Poorer grown plateau area +	18%

*Plots 3D, 5A, and 5D
+ Block 4, 6 and 7

The distinction between categories 1, 2 and 3 is clear cut, and of great practical significance, as discussed below. That between 3a and 3b is less clear cut. As pointed out by Vernon (8) in a discussion of black-pod variation at a station in Ghana, two of the main factors affecting the disease themselves interact. First, areas of low yield tend to have little black-pod because as total yield rises so, for any given percentage infection early in the season, there is a greater number of black-pods hence a greater density of spores throughout the area, hence a greater risk of any one pod becoming infected (Hasselo and Price [4] call this the 'Thorold effect', and give references to the relevant work of C.A. Thorold and others). Secondly the incidence of the disease tends to be greater in shaded than unshaded areas (8). But shade itself tends to depress yield. Thus these factors to some extent cancel out. At Waimaro, however, in some parts of blocks 4 and 6 (where the soil is unfavourable: see next section) there is little top shade, a thin cocoa canopy, and low yield; which combination of factors results in some plots having as little as 10% loss.

Of more practical significance is the increase in loss in the transitional area, and the prohibitive loss in Block 1. This area is only some 20 m horizontally and 8 m vertically from Block 2; but evidently there is some crucial difference in micro-climate between the two areas. Possible operative factors are the occasional presence of standing water in the plots; the continual presence of running water nearby, and shelter from the wind.

YIELD IN RELATION TO SOIL

From the soil map of Kafoa and Tora (5), the plots were classified as either lying across a soil boundary, or fully on one of the four soil types, and the 1972 potential yields of the latter averaged as follows:-

	Kg/ha
Alluvial soils (i.e. Block 1)	3,610
Terrace soils:	
Koronivia sandy clay loam (K.S.C.L.)	3,280
K.S.C.L., impeded drainage phase	2,120
" , moderately steep phase	2,740.

Potential yield rather than actual yield has been taken, as the object of this study is to consider the suitability of the soil, *per se*. In actual yield, the alluvial soils, were lower yielding than the terrace soils, because of the much greater black-pod loss in Block 1 (see above). The 1972 yields have been used because in earlier years there was more variation due to varying shade (largely removed by 1972) and in 1973 due to hurricane damage.

The three terrace soils show a gradation in yield from 2.1 mt/ha for the impeded phase to 3.3 mt/ha for the well-drained phase. This gradation is related to the extent of rooting, as mentioned by Kafoa and Tora (5), which in turn is presumably related to what Hardy (2) defined as "root room": the volume of soil having suitable characteristics for the development and functioning of the root system of plants. Root room is much reduced in the impeded phase by the clay pan, and consequent lack of aeration due to poor internal drainage. There is almost no root growth below about 12 cm in this phase. The poor initial establishment of both shade trees and cocoa, and subsequent low yield of cocoa, was no doubt due to these factors. The poor growth of cocoa may also have been to some extent due to the poor growth of the shade trees, and hence increased weed competition. The condition of much of the cocoa on the impeded drainage area improved markedly during 1969-1972 with regular paraquat spraying.

The high yield on the alluvial soils, greater even than on the best terrace soil, is surprising in view of the almost complete waterlogging of these soils, as indicated by the gleying. The root room would seem to be very small. To some extent the true potential may have been overestimated by the conversion of *all* the pods harvested, at 43 g/pod, because some of the black-pods are not fullsized. (Cherelles, i.e. fruit less than about 75 mm long, are not counted; but black-pods may be anything between this and fullsized.) To some extent, therefore, the trees may be able to produce some extra fruit in compensation for those lost. But even making some allowance for this possibility, the yield on these gley soils is remarkable.

However, the extent of water-saturation in the surface layers of these soils is uncertain, as discussed by Kafoa and Tora. Moreover, the profile of the Serea sandy clay loam, which accounts for most of the area, is freely draining; and according to Purseglove (7) cocoa tolerates waterlogged soil, provided there is constant movement of this water.

DISCUSSION

The overall mean yields, particularly the potential yield, the year before the hurricane are encouraging; and the potential yield of the better soils (i.e. over 3,000 Kg/ha) extremely encouraging. By contrast, in world cocoa cultivation 1,200 Kg/ha is considered a good yield (the economics of plantation development are usually calculated on this expectancy) and 2,200 Kg/ha is rarely exceeded, even on research stations. Moreover even the observed 'potential' yield may not represent the absolute potential cocoa production of these soils. The spacing, except in Block 1, is rather wider than we now recommend and as shade removal was only completed during 1972, the full benefits would not then have been reflected in yields.

At Wainigata, on alluvial soils rather better drained that those of block 1, and with slightly closer spacing a nine-year-old block of Amelonado was yielding well over 2,000 Kg/ha in 1972 despite much damage caused during de-shading. Some small-holders in the Wainibuka valley were getting actual yields of 1,000-1,500 Kg/ha from six-year-old amelonado in 1972.

But enthusiasm must be tempered with caution. The growth of cocoa on the areas of less favourable soil at Waimaro was so poor that it eventually achieved a reasonable yield only as a result of efforts of replanting, draining, shade-planting, manuring, and paraquat spraying that would be uneconomic in farm practice. Any farm plantings made on such unfavourable soil would have to be abandoned. But, as so clearly seen at Waimaro, patches of such soil can occur next to patches of excellent soil, with no topographical clue to the variation. Only extremely detailed soil surveying prior to planting would reveal the situation; and even such detailed surveying will be of limited use until the requirements of cocoa are better known than at present.

More disturbing still is the black-pod loss situation, particularly in Block 1. Until the microclimatic situation is clarified, we do not know but that the 45% loss in this part of the station may be more typical of this rainfall zone than the 20% loss on the plateau. Moreover, this was with rigorous sanitation and fungicide spraying. In ordinary farm practice, without spraying, losses may be practically 100%; and spraying may not be economic.

As mentioned earlier, cocoa planting is not now recommended in areas as wet as this; and some recent new planting is in much drier areas, in Macuata province. But the chief difference between the wet and dry zones of Fiji is in winter rain; and the bulk of the Amelonado crop is 'at risk' during January-April (i.e. before the peak harvest of May: see earlier notes on timing of crop). Thus this switch to drier areas will not necessarily make as much difference to black-pod loss as might be thought. Further understanding of the microclimatic situation is needed to allow optimum siting for black-pod avoidance.

CONCLUSION

Amelonado cocoa in Fiji is likely, in general, to give excellent yields by world standards. But loss to black-pod disease is likely to be serious everywhere, and prohibitive in the wet zone.

ACKNOWLEDGEMENT

This work was done under the supervision of Mr. A. J. Vernon who contributed particular help to the passages concerned with the incidence of black-pod.

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PHOSPHATE RESPONSES BY A PASTURE LEGUME ON A NIGRESCENT HILL SOIL IN S.W. VITI LEVU.

by

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SUMMARY

Siratro on a nigrescent hill soil showed a very strong response to phosphorous and to sulphur in the first two years of growth. An application of 900 kg/ha (800 lb/acre) of single superphosphate increased the total herbage dry matter production fourfold in the first year. Low levels of P (0.116-0.15%) and N (1.50-2.44%) were recorded in legume leaf samples at the end of the first year. Siratro failed to establish satisfactorily without superphosphate.

INTRODUCTION

Large areas of the dry and intermediate zones of Viti Levu consist of moderate to steep sloping land suitable only for grazing. The soil types are predominantly nigrescent clays derived from parent material of high base status and their associated steepland phases. Typically these show six inches of dark grey friable clay with a strongly developed fine nutty and granular structure containing many distinct fine grey species of weathered rock and passing sharply into shattered and weathered tuff (6). They are moderately acid with high contents of exchangeable calcium and magnesium and moderate to high potash, acid soluble phosphate is very low to negligible, and they are thought to be highly phosphate fixing (6). Recent analysis of the nigrescent hill soil 'Koromavu stony clay' of the Sigatoka Research Station (Chandra, pers. comm.) showed this to have low potassium content also:

pH (Ca Cl_2)	5.10	
Total P	238	ppm
Available P*	8	ppm
Available Ca	9.50	m.e.%
Available Mg	6.51	m.e.%
Available K†	0.25	m.e.%

*0.05 normal sulphuric acid extraction.

†2.5% acetic acid extraction.

Trials on a similar (Kabisi clay) soil type at Sigatoka by P. Thompson (unpublished: but see Rhodes [5] for a partial report) had shown that the fresh weight of cut herbage over two years was increased by superphosphate, at 375 Kg/ha/year, as follows (in mt/ha):

	No P.	With P.
Trial on unimproved pasture	9.3	14.9
Trial on Pangola/Nadi Blue grass	43.1	64.4

This suggested that legumes on such soils would respond well to P, hence the trial now described was planned with four rates of P, the highest more than twice that used in the grass trials.

METHOD

The experiment was begun in 1969, on a moderately steep slope of Koromavu stony clay soil on Sigatoka Research Station, having as main treatments four rates of P, viz O, 47, 94 and 188 Kg. P_2O_5/ha. Three replications of these four treatments were randomized and the 1/40 ha. plots then split to compare single and double superphosphate. The actual rates of application of the former were 225, 450, and 900 Kg/ha; and of the latter half as much, for the P_1, P_2, P_3 treatments respectively. In the second year the treatments were reapplied at half rates.

The slopes were originally covered with a dense mat of Nadi blue grass (*Dicanthium caricosum*) that had been closely grazed by goats. It was disc harrowed lightly to form a fine seedbed and to reduce competition from the grass. Superphosphate was broadcast by hand and inoculated, pelleted siratro (*Phaseolus atro-*

purpureus) was then broadcast at 3.4 kg/ha on 18.12.69. Guinea grass seed was also broadcast (3.4 kg/ha) but it did not germinate.

The Siratro was mowed by Allen Scythe when growth reached 20 to 30 cm high. A 90 cm. guard row was cut around each 360 x 540 cm plot, the fresh material of each split-plot cut and weighed, and samples taken for dry matter determination. The herbage was originally all legume, but a gradual invasion of Nadi blue grass meant that later harvests consisted of grass and legume, especially at low rates of P.

In December, 1970 Siratro samples from the first five fully expanded leaves and stem were taken for N and P analysis.

RESULTS

The trial was harvested three times in 1970 (9 April, 27 July, and 20 December) and twice in 1971 (12 March and 11 November). Table 1 shows the treatment main effects (the interaction was non-significant) on annual total dry matter yields of herbage and Table 2 the N and P percentages of siratro leaf, bulked from all replicates, on 4.12.70.

DISCUSSION

Effect of rates of P

There was an enormous, almost linear, response to P in 1970 with a four-fold difference between P_0 and P_3. In 1971 the P_0 yield was a little lower, and the responses to successive rates of P only about half those of 1970.

The high phosphorous response is not unexpected. Chemical analysis of the nigrescent soils show them to have very low to negligeable levels of available P. Legumes generally respond well to phosphorus, but siratro has been shown by Andrew and Robins (4) to be particularly responsive. Andrew (2) also calculated critical percentages of P in foliar tissue from pot trials with field verification. The P levels from samples in this trial were all considerably below the critical level of 0.24%. However, field leaf samples are frequently lower than this critical level and this can be aggravated by the age of plant and with dry weather prior to sampling (Andrew, pers. comm.)

The N% figures are all considerably lower than those recorded by Andrew and Robins (4) who found levels of N varying from 2.90 to 4.01 for siratro, as P applications rose from 2 to 12 cwt. superphosphate per acre. The N values do, however, increase with increasing applications of P. Low figures could reflect the time of sampling but other field samples are frequently low. Failure to nodulate effectively due to other nutrient defficiencies should be investigated as the effect of the low crude protein levels. (10 to 15% CP) of the siratro considerably reduces its value as a protein rich feed.

Effect of forms of P: suspected sulphur effect

The main effect of "forms of P" was also highly significant in each year, and more consistant between years that of rates of P. The greater yield with single superphosphate is presumably due to the sulphur content of the latter (about 12% as opposed to about 1.5% S in double super).

TABLE 1

ANNUAL TOTAL DRY-MATTER YIELDS OF HERBAGE

	1970	1971
Main effect of rate of P	Yields, mt/ha.	
O Kg P_2 O_5/ha	5.2	4.4
47 "	9.3	6.1
94 "	14.5	6.8
188 "	20.2	9.6
S.E.	±1.3	±0.8
Main effect of form of P		
Double superphosphate	12.5	6.3
Single "	16.2	8.8
S.E.	±1.50	±0.58

TABLE 2

SIRATRO LEAF ANALYSIS (4.12.70)

Superphosphate kg/ha	Form	%P	%N
0		0.135	1.60
112	Double	0.116	1.50
225	Single	0.118	1.75
225	Double	0.140	1.81
450	Single	0.116	1.89
450	Double	0.144	2.16
900	Single	0.150	2.44

A sulphur response by legumes is not uncommon. Anderson and Spencer (1) showed that sulphur deficiencies markedly affected the growth of subteranean clover, and Andrew and others (3) showed a very strong sulphur response by *Phaseolus lathyroides* on black earth soils in S.E. Queensland. The shallow discing in the establishment year may have released sulphur which diminished the S response in that year compared to the second.

Interaction of "rates" and "forms" of P.

There was some suggestion, not statistically significant, of an interaction between 'rates' and 'forms' of P, with less difference between the double and single forms at the highest rate of P. As double super contains a little S (about 1.5% as an impurity) such an interaction is to be expected: a big enough application of double super would supply an appreciable amount of S, so there would be relatively little response to the extra S given by a P-equivalent dose of single super. But the observed interaction was not determined with sufficient precision for any conclusions to be drawn.

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Fiji agric. J. (1973) **35**, 71-74

SHELLFISH ON NEARSHORE FISHING GROUNDS AT WAILOALOA BEACH, NADI, 1973.

by

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SUMMARY

A survey to estimate the quantity of shellfish at Wailoaloa Beach, Nadi, Fiji, was done by metre grid and transect counts of live shells made by underwater swimmers. There were estimated to be 11,000 Kg of cockles (*Anadara* spp.) and 800 kg of surf clams (*Latona* spp.). In an average working period of about 1½ hours per tide, per day, fisherwomen were seen to have personal daily rates of about 2 Kg cockles and 1 Kg surf clams. It was estimated that the annual removal of cockles is about 3 tons and of surf clams 0.5 tons.

INTRODUCTION

At Wailoaloa Beach in Nadi Bay near Lautoka traditional fishing rights are retained by villagers, but business interests propose building a marina by extending a jetty from the shore to about 450 m, connecting it with a breakwater about 300 m long parallel to the beach, and dredging the seaward half of this partly enclosed area to a depth of about 4 m. Surveys of the shellfish beds before and after the construction work (expected to take three years) are required.

The shellfish present are bivalves, principally a cockle or ribbed ark shell (*Anadara* spp.) known locally as "kaikoso," and of secondary importance a small surf clam (*Latona* spp.) or "siqale." Two species of kaikoso were found singly, or scattered thinly in beds, in muddy sand just offshore in the sublittoral zone; the siqale in fine sand in the littoral zone. Both genera of these shellfish are common around Fiji wherever conditions are suitable. They are taken in subsistence fishing and may also be sold in urban markets or exchanged for agricultural produce in rural areas.

FIELD WORK

Survey methods

Part of Wailoaloa Beach which forms a low crescent of sandy shore about 50 m wide and 1000 m long, with a jetty at each end was surveyed. The jetties are about 200 m long and made of concrete rubble, stones and gravel. The foreshore was uncultivated land with high grass, bushes, and trees, and some mangroves about halfway along the beach where a small creek out-flows.

During 20-24 August 1973, three divers using SCUBA (Self-contained Underwater Breathing Apparatus) examined the bottom for shellfish over a wide track northward and towards the shore. The fishing methods of the villagers were also watched, while the divers estimated the extent of the cockle beds and made 47 grid, and 3 transect, counts. For the former, rod-iron frames, 1 m square, were cast at irregular, effectively random, intervals from a boat drifting over the beds. Divers located the frames from attached marker buoys, and searched inside for shells, reaching into the bottom to about 15cm. In the boat, any dead shells were

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discarded and the live counted. For the transect counts, a line marked in metres was stretched from low tide mark outward across the bed, and all live shells found about 15 cm on each side of the line were counted and differentiated into two species.

To determine surf-clam occurrence, 27 samples were taken at random from strips centred at 100 m intervals along the shore, each 3 m wide and extending across the intertidal zone. For each sample the sand from inside a 0.5 x 0.5 m frame was taken out to a depth of 15 cm, washed, and the live clams counted.

Observations on fishing

A group of fisherwomen waded out from the beach and felt with their toes for shells in the muddy sand. They did not submerge completely but picked up the shells with their toes, examined them and if they were alive put them in baskets. The women fish as far out as they can stand with their heads above water. This limits them to a depth of about 1.5 m. The outer edge of the cockle bed is about 2.5 m deep at a distance of about 60 m from the shore so that only part of the bed is fished.

The women fished for surf clams in the sand where the waves washed up the shore. Sand was sifted through their fingers and the clams separated out as the women knelt on the sand.

On the first day of fishing 18 women obtained 30 kg of cockles in 90 minutes while the tide was out. The following day 7 women caught 16.5 kg of cockles from parts of the beds somewhat farther north. There was some variation in time spent fishing, but it was estimated that the average catch was about 2 kg cockles per fisherwoman per day. One woman obtained 1 kg of surf clams in 90 minutes, the daily period of low tide.

Other species taken by the women were a medium-sized cockle, *Gafrarium* sp., and a very small mytilid or mussel. The quantities of these taken were small and therefore not considered in this report.

RESULTS OF SURVEY

The cockle beds

The beds of cockles consisted mostly of one species, tentatively identified as *Anadara subcrenata* (but see Glude, [1]), with another unidentified species scattered singly through the area, possibly less restricted in its range, totalling about 11% of the cockles taken in the transect counts (Table 1). Specimens of both species are deposited in the Marine Reference Collection at the University of the South Pacific.

The beds extended along the beach just off-shore from low water mark to about 65 m distant. A conservative estimate of their area was 1,000 m long by 60 m wide, i.e. 60,000 m^2. The cockles were not uniformly distributed but aggregated in groups of varying number, and there were some discontinuities of minor importance, as shown by the grid counts (Table 2). Number per m^2 ranged from 0 to 46 with an average of 7.2. At this rate the total number of cockles in the 60,000 m^2 would be 420,000, with a total weight or biomass of 10.5 metric tons (several counts and weighings showed an average of 40 cockles per Kg).

Surf Clams

The surf clams (*Latona* spp.: see Habe [2] for illustration of the genus) included at least two species. Specimens are deposited in the Marine Reference Collection of U.S.P. As the waves washed up the beach and receded, small depressions could be seen where some of the clams were partly uncovered and actively burrowing into the fine sand. They could be easily captured by hand when seen in this way, and many others were found down to a maximum depth of about 15 cm. A few were found near high water mark and a few near low water mark but most were concentrated about halfway between, south of where the small creek cut through the sand to the sea. The sands were coarser north of the creek and, as shown in Table 3 where the sample counts are totalled in two parts, the clam counts which averaged 71/m^2 south of the creek, averaged only 6.5/m^2 north of it. Average clam weight was 2.5 g.

TABLE 1.

TRANSACT COUNTS OF COCKLES

Distance along transect	Totals counted in three transects Species No. 1	Species No. 2
m		
0	2	0
0-5	27	0
6-10	16	0
11-15	0	1
16-20	20	3
21-25	11	1
26-30	9	4
31-35	12	4
36-40	21	1
41-45	16	0
46-50	7	0
51-55	1	2
56-60	3	0
61-65	4	0
66-70	0	1
71-75	0	0
76-80	0	0
81-85	0	0
86-90	0	0
91-95	0	1
96-100	0	0
101-110	0	1
111-120	0	0
121-130	0	0
Totals	149	19

TABLE 2.

SQUARE METRE GRID COUNTS OF COCKLES

No. of live cockles	Frequency	Sub-totals
0	7	0
1	8	8
2	7	14
3	3	9
4	3	12
5	2	10
6	2	12
7	3	21
8	2	16
9	1	9
10	1	10
13	1	13
19	1	19
20	1	20
22	1	22
25	1	25
29	1	29
33	1	33
46	1	46
Totals	47	338
Average		7.2

TABLE 3.

GRID COUNTS OF SURF CLAMS

	No. of live surf clams per sq. m.*	Frequency	Sub-totals
North of creek	0*	3	0
	4	4	16
	8	3	24
	12	1	12
	16	2	32
	Totals	13	84
	Average		6.5
South of creek	28	1	28
	32	1	32
	36	2	72
	44	2	88
	52	2	104
	60	1	60
	72	1	72
	80	1	80
	100	1	100
	124	1	124
	232	1	232
	Totals	14	992
	Average		70.8

A conservative estimate of areas of beach where the surf clams burrowed was about 400 m by 10 m or 4,000 m^2 on either side of the creek, hence (at the sample rates) 24,000 clams north and 284,000 south of the creek with a total weight for the beach of 0.8 metric tons.

Other species in the area

In the area of bottom outside the cockle beds and extending as far as examined (about 450 m from the shore) there were many openings to burrows which were probably used by crustaceans such as stomatopods or thalassinids. These are not fished at present, so little attempt was made to capture them or to estimate quantities (Bottom grabs would be needed to do this).

DISCUSSION AND CONCLUSIONS

Exploitable quantities of cockles

The fishing demonstrated that 15 women could take about 30 kg a day, and assuming that they fished twice a week (100 times a year), the yield from fishing would be about 3 tons annually. From the estimated total of 10.5 tons, this seems to be a safe note. Although some of the cockles were found attached to the substrate by a byssus, others were not, and it may be assumed that some could migrate the short distance to the exploited and therefore less-crowded parts of the beds. Also adults from the deeper inaccessible area would be producing larvae which would settle in the exploited area. As they grew to adult size they would provide replacements for the continued fishing.

Exploitable quantities of surf clams

As this small species of the Donacidae is apparently short-lived, grows quickly and most likely has a short reproductive cycle in the warm tropical environment, the biomass estimated in this instance might be replaced by an equal amount in six months if the habitat were cleared repeatedly by fishing (Hawkins, 1972 demonstrated rapid growth and short reproductive cycle in a similar species of the Donacidae fished on the Caribbean coast of Colombia, South America). It is conceivable, therefore, that a fishery could take more annually than the biomass estimated on one occasion.

One woman fishing demonstrated that 1 kg could be taken in a day. Although this was shown on one occasion only, it is likely that five women fishing twice a week for one year could take 500 kg from this beach.

Estimated value of the fishery for cockles and surf clams

At present prices for the cockles and surf clams about $1,750 could be realized from the sale of 3 tons of cockles and about $200 from the sale of 500 kg of surf clams.

ACKNOWLEDGEMENTS

We are grateful for the assistance of Mr. Eliki Vatuloka, Mr. Vatiliai Kuru and the villagers who carried on the fishing and lent us a small boat for the survey.

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Fiji agric. J. (1973) **35**, 75-78

DIFFERENTIAL REACTION OF CITRUS SPECIES TO DISEASES AND PESTS AT KORONIVIA

by

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SUMMARY

In a collection of seven citrus species and varieties growing at Koronivia, Emperor mandarin showed no anthracnose, Lisbon lemon and three mandarin varieties no canker and two orange varieties no scab. Vein corking, observed for the first time in Fiji, appeared on two mandarin varieties and bark cracking of unknown cause appeared on Lisbon lemon, Persian seedless lime and two orange varieties. Virus disease indexing showed that all trees had tristeza, and Lisbon lemon had exocortis.

INTRODUCTION

During 1966 seven citrus species and varieties were each budded into at least three citrus rootstocks; and in 1967 three trees of each stock-scion combination as listed in Appendix 1 were planted, practically randomly, in a valley near greenhouses at Koronivia Research Station.

After one year of pruning, manuring and insecticide spraying, the trees were neglected. Insects thrived and diseases developed so that by early 1972 all were badly damaged and many were dead. A recent study of the 57 surviving trees (6 or 9 of each variety as shown in Table 1) has disclosed marked differences between the scion species in susceptibility to some serious diseases.

IDENTIFICATION OF PATHOGENS

Fungi, bacteria and insects

All organisms mentioned in these categories are well known in Fiji. Diseases caused by fungi and bacteria have been described by Graham (3) and insect damage by Swain (7).

Anthracnose, scab and bacterial canker were responsible for most of the apparent damage. *Colletotrichum gleosporoides, Elsinoe fawcettii* or *Xanthomonas citri* were isolated from symptomatic leaves, pure cultures were obtained, and each was transmitted to susceptible citrus seedlings which then developed typical symptoms of anthracnose, scab or canker, respectively.

Melanose and greasy melanose fungi (*Diaporthe citri* and *Mycosphaerella horrii,* respectively) and lichens were ubiquitous but caused very little damage. The sooty mould fungus (*Capnodium citri*) was found subsisting on insect excretions on many leaves of mandarins and oranges and on the bark of Lisbon lemon and Persian lime trees. It was usually found associated with large infestations of white louse (*Unaspis citri*)

Aphids, ants and scale insects were noted on many trees. Aphids caused die back of many young shoots. High infestations of ants were found around the bases of several rootstocks showing bark splitting. White louse was consistently associated with bark cracking in the scion and with yellow patches on the leaves.

Viruses

Typical woody gall symptoms were observed on Rough lemon rootstocks and vein clearing occurred with stem pitting on Persian lime. These symptoms, previously described in Fiji by Graham (3), indicate the presence of vein enation virus in Rough lemon and tristeza virus in Persian lime.

Vein corking similar to that noted by Fraser on virus infected West Indian lime seedlings in Australia (2), but not previously recorded in Fiji was seen in many mature mandarin leaves. To test these trees and others for specific viruses, bud and bark tissue was taken from selected trees and inoculated into West Indian lime and Etrog citron indicator seedlings.

All citrus species tested produced the lime reaction specific for tristeza virus (8). Lime indicator seedlings inoculated with tissue from Lisbon lemon and Persian lime produced leaves with vein clearing and had stems with a few elongate pits. Similar seedlings inoculated with tissue from Washington navel orange and Ellendale Beauty mandarin developed more pronounced symptoms. Young leaves exhibited vein clearing over the entire blade. These leaves became chlorotic and cupped upwards. With maturation they curled downwards and produced corked veins. Stems were riddled with intense pitting. Tests are being conducted to determine if vein corking and intense pitting is caused by a virulent strain of tristeza or another virus acting alone or in concert with tristeza.

Exocortis was identified in Fiji for the first time by using the citron test (1). Within two months after *Etrog citron* Arizona 861 indicator plants were inoculated with tissue from six Lisbon lemon trees at Koronivia and from eight in other locations they displayed the exocortis positive reaction — leaf epinasty. Of the varieties tested at Koronivia, only Lisbon lemon had exocortis.

Bark cracking

Serious decline in health of Lisbon lemon trees in Fiji has appeared in recent years to be associated with bark cracking. In this study cracking was also found on many Persian limes and several orange trees. The bark cracked lengthwise above the graft union and sometimes up into the branches of the tree. The cause of this malady still remains unknown. Exocortis may influence the expression of bark cracking in Lisbon lemon for it is known to cause a type of bark cracking in other lemons (9). But exocortis cannot be the sole cause of bark cracking because these symptoms were seen on the exocortis free Persian limes. The rootstock might also influence the expression of disease symptoms. Bark cracking was most intense in scions propagated on Rough lemon.

There is circumstantial evidence that bark cracking is indirectly, if not directly caused by white louse. White louse was always found around the portion of a trunk or branch showing bark cracking. Moreover, trees in other locations that were sprayed to control white louse were free of bark cracking. But the insect might have been attracted to the cracked area after the break had occurred. Experiments have been started to study the cause effect relationship between white louse and bark cracking.

OCCURRENCE OF DISEASES

Methods

Individual trees in the variety trial were examined in January and July, 1973; the condition of each tree (Appendix 1) and the damage caused by selected diseases and insects (Table 2) were recorded. Damaged trees were rated on a three point system based on the percent of the affected part showing symptoms; 1 = less than 10%, 2 = 10% to 50%, 3 = over 50%. In the case of bark cracking these percentages refer to the affected length of trunk 0.1 to 0.5m. above the graft union. Rating of the other diseases were based on the percentage of the foliage showing symptoms.

Results and Discussion

All varieties except Emperor mandarin showed slight to moderate symptoms of anthracnose. Since this disease only develops in injured or senescent foliage of weakened trees (6), it can be assumed that affected trees were growing poorly.

Canker symptoms were never seen on twigs and branches of Washington navel and Local orange and these trees survived although a number of leaves and some fruit were severely infected. The scoring system failed to distinguish an important difference between the oranges

TABLE 1. SEVERITY OF SELECTED DISEASES IN COMMON CITRUS VARIETIES

Variety	No. of Trees Examined	Canker		Scab		Vein Corking		Bark cracking	
		Affected Trees	M.D.I.	Affected Trees	M.D.I.	Affected Trees	M.D.I.	Affected Trees	M.D.I.
Lisbon lemon	9	0	0	7	1.0	0	0	9	1.4
Persian seedless lime	9	4	1.0	4	1.0	0	0	7	1.1
Local mandarin	6	0	0	6	2.0	0	0	0	0
Ellendale Beauty mandarin	9	0	0	3	2.0	5	2.4	0	0
Emperor mandarin	6	0	0	2	3.0	3	2.7	0	0
Local orange	9	7	1.0	0	0	0	0	2	1.0
Washington navel orange	9	9	1.6	0	0	0	0	2	1.0

*M.D.I. = Mean disease index, the average disease rating based on percent of tree affected:
1 = less than 10%, 2 = 10 — 50%, 3= over 50%

and Persian lime. While the former were definitely susceptible to canker, on the limes only one or two lesions were found on less than 20 leaves (less than 0.5% of the leaves) on each tree. These observations suggest that Persian lime will remain partially resistant to canker in infested areas. The Lisbon lemons had so few levels (due to the other diseases mentioned here) that the zero score for the presence of canker symptoms on leaves is unreliable.

Scab symptoms appeared on young and old mandarin leaves but on only a few old leaves and some fruit of Lisbon lemon. Less than 1% of the old leaves of Persian limes had scab lesions. The Washington navel and Local oranges apparently resistant to scab under field conditions as none of these had symptoms.

Tristeza, an aphid transmitted virus disease, was found in all species tested and other surveys suggest that it is ubiquitous in all of Fiji's citrus. Exocortis virus was found only in Lisbon lemon. As it is transmitted by budding, and as all Fiji's lemons come from similar budwood sources, it is probable that every Lisbon lemon tree in Fiji is infected.

Without healthy controls it is impossible to ascertain the effects of these viruses on tree growth and vigour; but the response of indicator seedlings to inoculations suggest that the effects of viruses in Ellendale Beauty mandarin, Washington navel orange and Lisbon lemon may be severe. All mandarin trees in the field produced many branches that grew upright and curled young leaves pointed into the air. Several twigs and branches died prematurely. Every Lisbon lemon tree was either dying or completely dead. It may be indicative of the effects of viruses on yield that tristeza infected Washington navel oranges and exocortis infected Lisbon lemon at Seaqaqa Research Station (4) yielded less than half what is usual for those varieties in Australia (5).

RECOMMENDATION

These observations confirm the opinions of other Departmental workers in this field and support the current recommendation of Persian seedless lime as a preferred citrus variety for use in Fiji.

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APPENDIX 1. CONDITION OF CITRUS VARIETIES ON SEVERAL ROOTSTOCKS

Scion	Rootstock				
Variety	Rough lemon	Trifoliate	Mandarin	Sweet orange	Sour orange
Lisbon lemon	defoliated; dead branches.	—	defoliated; dead branches.	dead	partially defioliated; dead branches
Persian seedless lime	satisfactory; large trees.	satisfactory small trees.	dead	broken above graft union.	—
Local mandarin	dead. (incompatible)	dead (incompatible)	upright spindly growth	upright spindly growth.	—
Ellendale Beauty mandarin	excessive branching; fair.	stunted and spindly growth.	excessive branching; sparse growth.	—	—
Emperor mandarin	excessive branching; fair	stunted and spindly growth.	—	—	—
Local orange	satisfactory large trees.	stunted	open canopy dead branches	—	—
Washington navel orange	excessive branching; fair.	dead	excessive branching; poor.	excessive branching; fair.	—

Fiji agric. J. (1973) **35**, 79-84

FIJI RAINFALL MAPS

by

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SUMMARY

Maps of the average annual rainfall and of monthly rainfall isomers for Fiji have been prepared. The methods of data processing and map preparation are described, reliability of the maps discussed, and comparisons made with previous rainfall maps. Suggestions are made for the improvement of rainfall recording and future maps.

INTRODUCTION

Since 1958 the standard rainfall maps used by agriculturalists in Fiji have been those of Wright and Twyford (5), later re-published by Twyford and Wright (4), which are believed to have been based on rainfall averages to the end of 1955. At that time there were very few meteorological stations in the interior of either main island, or on the smaller islands, so the rainfall over much of the terriority had to be estimated from vegetation. Later maps by Harris (2), not widely circulated, were based on data to the end of 1960 by which time many more stations had been established, but had not been operating for long enough to give reliable averages. It is only recently, with the publication of averages to the end of 1970 (3) that data has been to hand of sufficient reliability to allow isohyets to be drawn across Viti Levu and Vanua Levu with some confidence.

A series of maps (7 sheets in all) has been prepared showing annual isohyets at 1m intervals, plus 1.75 m, superimposed on the standard 1:250,000 maps of Fiji. Blueprints of these are available from the Research Officer (Land use), Koronivia Research Station, Nausori. Attached to this paper are slightly simplified, scaled down, versions of the Viti Levu and Vanua Levu sheets.

A parallel series of maps, blueprints similarly available, has been prepared showing monthly isomers on 1:500,000 scale. On these the average monthly rainfall is expressed as a percentage of the annual rainfall, and isomers are drawn at intervals of 1% plus that for 1.5%.

This paper describes the techniques used in preparing these maps.

DATA SOURCES

Besides the averages to the end of 1970 (3), earlier issues of these averages (to 1965, and to 1960) were consulted as necessary, together with the Annual Meteorological Summary (1946-1969 inclusive) and monthly summaries of records of temperature and rainfall for Jan. 1970 to March 1972 inclusive, also published by the New Zealand Meteorological Service.

For a few stations for which no annual averages have yet been published, these figures were computed from whatever monthly records (usually short term, and often broken, records) were available. The direct averages of such figures would be unreliable; but it may be assumed that the total rainfall at nearby stations in any relatively short (possibly broken) period of time will be in proportion to their respective long term averages (LTA). Hence the LTA for a station from which only partial records are available (LTAs) can be estimated from (LTAp) for a nearby permanent (long-established) station, by the proportion of their respective rainfalls (Rs and Rp) during a sort period, thus :

$$LTAs = LTAp\ (Rs/Rp)$$

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The published averages were adjusted for a few gross errors, including

(a) errors in the station co-ordinates

(b) computational errors in the averages

(c) printing errors

but excluding a few small errors of little importance, e.g. errors of a mile or so in station locations.

CONSTRUCTION OF THE MAPS

Annual Average Maps

After converting the averages from inches to millimetres to conform to modern usage, the station averages were plotted on the maps. Where the period of observation was less than 20 years, the figures were bracketed. Isohyets were then drawn near the station values; but large areas were devoid of observation. The isohyets through these areas were estimated as follows :

Study of the data revealed, qualitatively that rainfall was influenced by :

(i) orographic effects due to the prevailing SE Trades, producing high rainfall on E and SE facing coasts and hill slopes, and relatively low rainfall on leeward coasts and hill slopes.

(ii) a marked correlation of rainfall with height above MSL.

The first effect is well-known, and needs no comment. The second is due largely to the fact that raindrops tend to evaporate as they fall from the cool upper levels of the atmosphere into warmer layers near sea level. Thus, although in certain valley locations rain may be observed to fall about as frequently as on the neighbouring hills, a greater quantity of rain will be recorded on the hills than in the valley.

To investigate the magnitude of these effects, cross-section diagrams were constructed : -

Viti Levu

(i) SE-NW through Naitonitoni and Tavua

(ii) W-E along the 17° 45' parallel (approx. Nadi-Lodoni)

Vanua Levu

(i) SE-NW through Lavena Point (Taveuni) and Labasa P.O.

(ii) WSW-ENE through Nabouwalu and Udu Point

Figs. 1 and 2 show respectively the cross-sections SE-NW over Viti Levu and over Taveuni and Vanua Levu. The abscissae are distances from the SE coasts in nautical miles, and the ordinates are heights above MSL in feet. The positions of stations lying near the line of cross-section were projected on to the centre line. Their annual averages are shown at the appropriate distance along the line, and at the appropriate height over MSL. The ground profile along the centre line is shown as a continuous line, and isohyets are shown as broken lines. The diagrams reveal : -

(a) a strong orographic effect on east and southeast coasts and hill slopes. This is greatest near Naitonitoni in Viti Levu, and on the SE side of Taveuni.

(b) a weak orographic effect on the NW and N sides of Viti Levu, which is ascribed to the incidence or rain-bearing winds from these directions during the summer months.

(c) a rainshadow effect downwind of the orographic maxima, resulting in relatively low rainfall at a specified height above MSL in the central parts of Viti Levu and in those parts of Vanua Levu lying to NW of Taveuni.

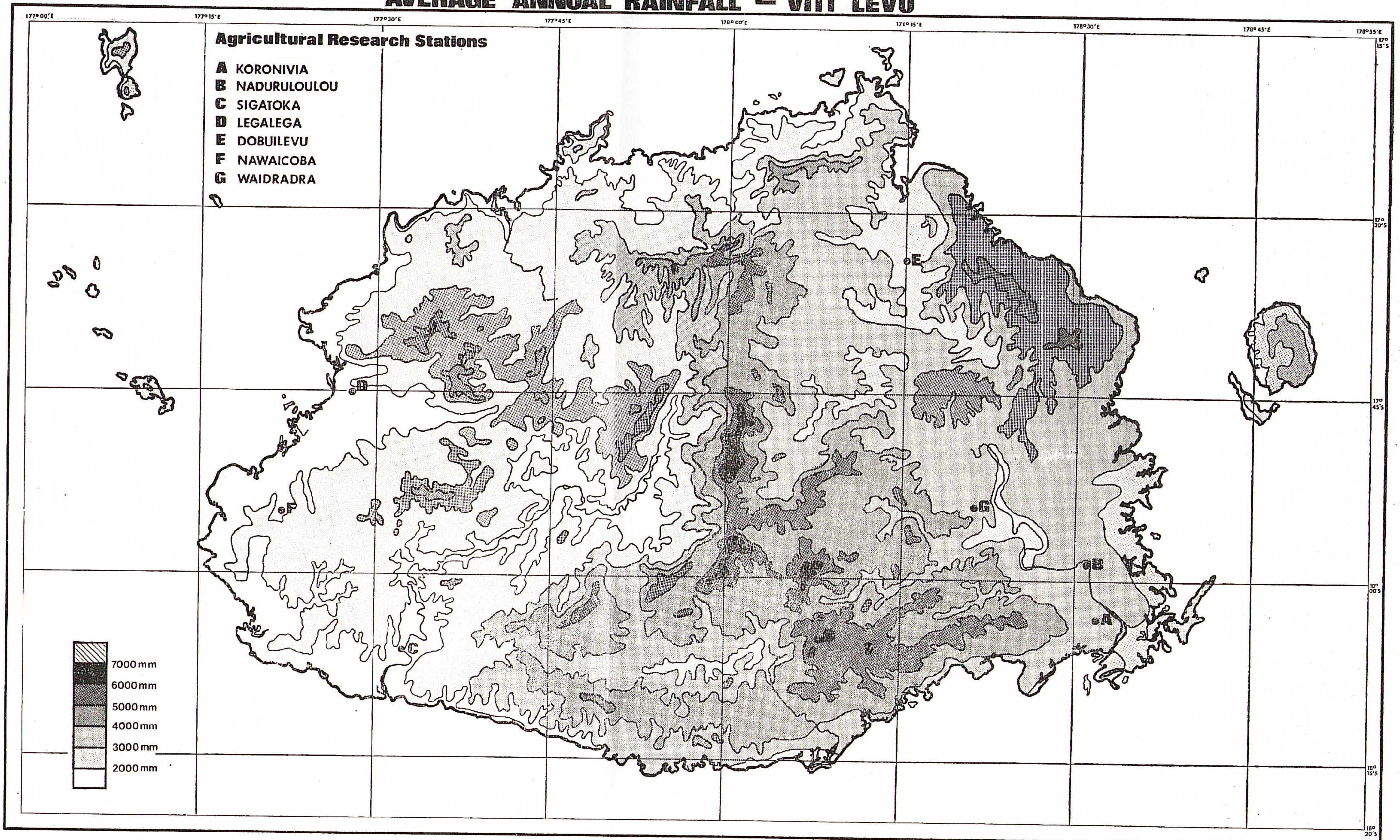
(d) a strong correlation between rainfall and height above MSL.

The diagrams were used to estimate the relationship between the isohyets and the contours in various parts of the country, thus enabling the completion of the isohyets in areas devoid of observations.

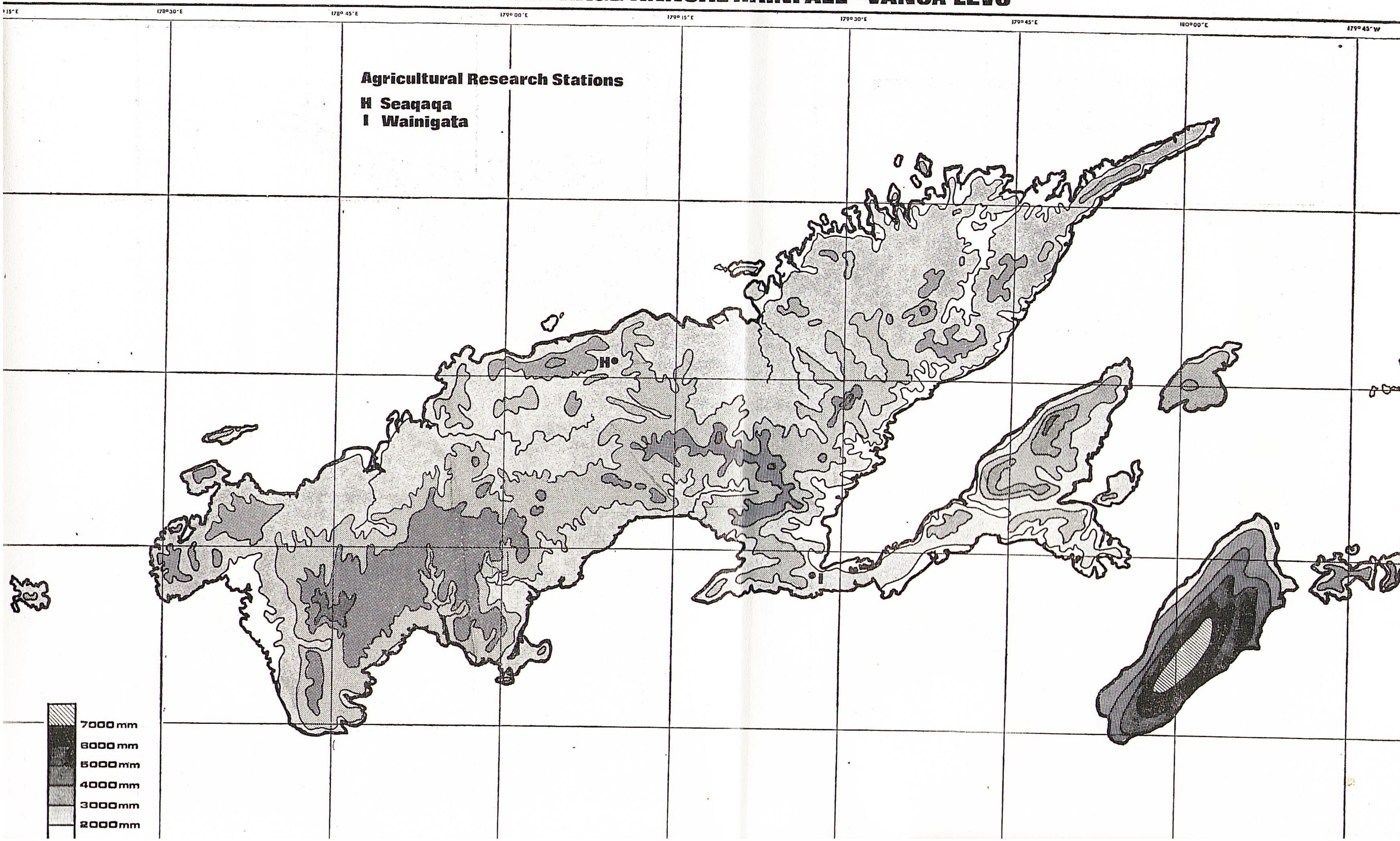
Monthly Isomeric Maps

It was found impracticable to construct monthly isohyetal maps, because of paucity of reliable monthly averages.

AVERAGE ANNUAL RAINFALL — VITI LEVU



AVERAGE ANNUAL RAINFALL—VANUA LEVU



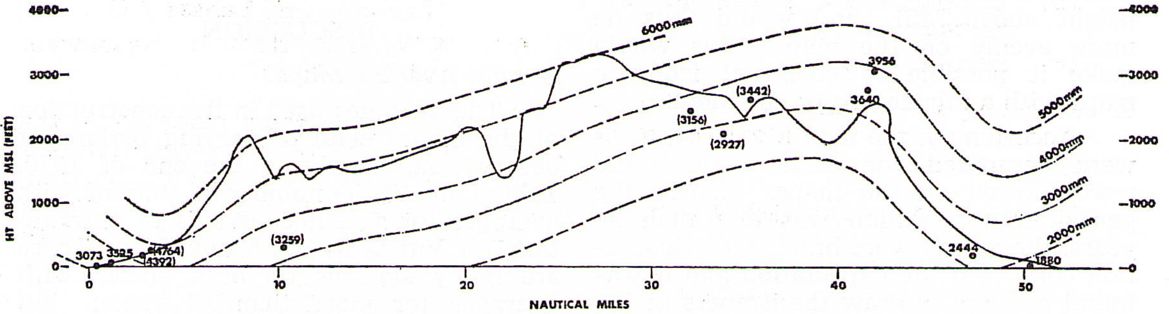


FIG 1 — CROSS-SECTION SE-NW THROUGH NAITONITONI AND TAVUA

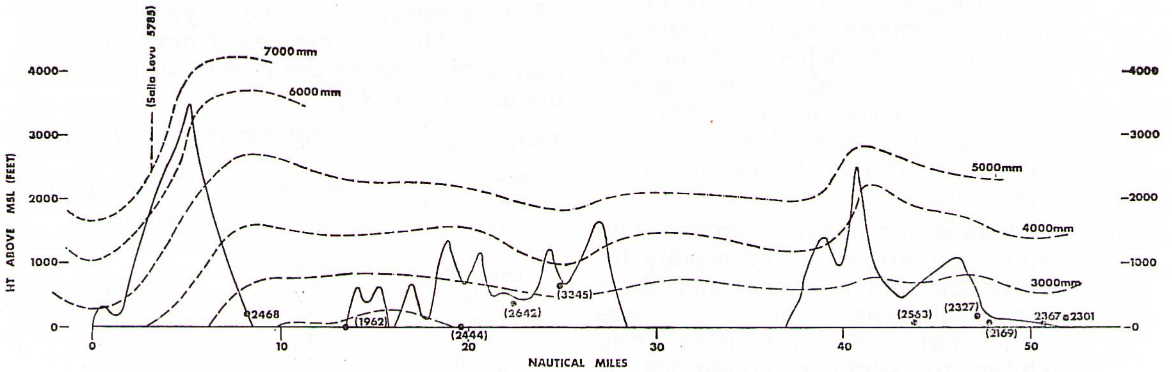


FIG 2 — CROSS-SECTION SE-NW THROUGH LAVENA PT AND LABASA P.O.

However, it was expected that if the monthly averages were expressed as percentages of the annual average for the station ,the resulting isomeric values would have little if any correlation with height above MSL, and would thus lie more evenly on the map. This would make it possible to construct isomeric maps with a fair degree of confidence.

Accordingly, the monthly percentages were computed for each station, and were plotted on the maps. Where the period of observation was less than 20 years, the values were bracketed. Inspection confirmed the expectation and it was found possible to draw the isomers at 1% intervals. That for 1.5% was also drawn where appropriate.

In drawing the isomers in areas devoid of observations, the following rules, derived by inspection of the available data, and from general meteorological principles, were followed:-

(i) in the summer months, the SE Trades are weak and inconstant, resulting in relatively low isomeric values on the SE sides of islands, whereas in these months, tropical cyclones give rise to short-lived but strong rainbearing winds affecting mainly the N and NW coasts of islands, where in consequence isomeric values are high.

(ii) in the winter months, the SE Trades are strong and consistent, resulting in high isomeric values on the SE sides of islands, whereas N or NW winds are virtually non-existent, apart from purely local sea breezes, resulting in very low isomeric values on coasts facing in these directions.

(iii) The transition between summer and winter conditions occurs rapidly towards the end of April, and there is no real transitional monthly isomeric map. The transition from winter to summer conditions is relatively slow, and the isomeric maps for November and December both show transitional characteristics, with fairly uniform isomeric values. On the December map for Viti Levu, it is noteworthy that the highest values occur in the central parts of the island.

DISCUSSION

Annual Average Maps

The averages used in the construction of the maps relate to varying periods of observation, mostly to the end of 1970. Table I shows the number of stations with averages for specified periods of observation, for Viti Levu and Vanua Levu. There are many stations on both sheets with averages for more than 20 years; but considerable weight had to be placed on shorter-term averages in drawing the isohyets, so it is estimated that the isohyets represent 15-20 year averages to the end of 1970.

The principal use of the maps is of course to estimate the average rainfall to be expected at a point, or over an area (using planimetric methods), during a future period of years. In doing so, it should be borne in mind that climate is not static, but is subject to random, cyclic and quasi-cyclic changes. Rainfall is one of the parameters thus affected, so some uncertainty is involved in estimating the mean rainfall during the coming N years on the assumption that this will be the same as in the past N years. A measure of this uncertainty is the Standard Error (SE) of the mean of the N years' rainfall totals. This is derived from the Unit Standard Error of the N rainfall totals, by dividing by $\sqrt{N}$.*

TABLE 1. PERIODS OF OBSERVATION

Period of Observation (yrs)	Viti Levu	Vanua Levu
	Number of stations	
under 6	13	9
6-10	7	7
11-15	11	19
16-20	14	9
21-30	16	5
31-40	16	2
41-50	6	2
51-60	3	3
over 60	7	4

* Strictly speaking, the SE of the mean is $\sigma/\sqrt{N}$, σ being the Standard Deviation of the whole population of rainfall totals, or o fa very long series, wh ich is not usually known. The method described is sufficientl accurate for our purpose.

TABLE 2 STANDARD ERRORS (PER CENT) FOR REPRESENTATIVE STATIONS

Station	Periods of Records (N yrs	Standard Errors (%) for specified periods				
		1 yr	Means of			
			10 yrs	15 yrs	20 yrs	N yrs
Laucala Bay	31	18.7	5.9	4.8	4.2	3.4
Suva Govt Ho.	84	21.2	6.7	5.5	4.8	2.3
Nadi Airport	31	27.0	8.5	7.0	6.0	4.9
Nadarivatu	56	36.7	11.6	9.5	8.2	4.9
Salialevu	44	22.6	7.2	5.8	5.1	3.4
Nabouwalu	54	22.6	7.2	5.8	5.1	3.1
Labasa P.O.	29	29.0	9.2	7.5	6.5	5.4
Vunikodi	26	19.8	6.3	5.1	4.4	3.9

If we consider the means of a large number of successive periods of N years' observations, about 68% of these means will lie between (A+SE) and (A+SE), and 95% between (A+2SE) and (A+2SE), where (A) is the actual very long term mean.

The foregoing discussion assumes that the distribution of annual rainfall totals is 'normal'. This is not quite true, as the distribution is somewhat skew, but the difference is negligible for our purpose.

Standard Errors for a number of representative stations have been computed, first for the N annual rainfall totals, then for means of 10, 15, 20 and N years. These are shown in Table 2 expressed as percentages of the annual average.

In the light of this Table, and considering that some of the errors of the means plotted on the maps were probably smoothed out in drawing the isohyets, it seems reasonable to conclude that the standard error of spot values derived from the isohyets is about ± 5% in the vicinity of long-term stations. The Standard Error of spot values in areas devoid of observations is difficult to determine, but is roughly estimated at ± 10%, i.e. double that near long-term stations.

It follows from the previous remarks that we should not be surprised to find that in the next 20 years or so, the average rainfall at a specified point may differe by 10 to 20% from the map value, either upwards or downwards, i.e. by ± 2SE.

Monthly Isomers

Monthly isomeric values (per cent of the annual average) may be derived for any place from the Monthly Isomeric maps. The 12 values should of course total 100%, but if not, small adjustments may have to be made. When the resulting percentages are applied to the annual average derived from the isohyetal map reasonable estimates of the monthly rainfall averages in millimetres are obtained. The isomeric vaules should be read off to 0.1%, although it should be remembered that no such accuracy can be calimed for the maps.

It is difficult to estimate the accuracy of the isomers, and this has not been attempted. However, monthly rainfall averages derived from them represent the best possible estimates at the present time. When reliable observational data become available, observed averages should be preferred.

Seasonal Average Maps

Seasonal average rainfall maps can be prepared by totalling the isomeric values at suitably spaced grid points for the months concerned, and applying these percentages to the annual average rainfall at the grid points, derived from the annua lisohyetal map.

A start will be made on this work soon and it is hoped that winter (May-Oct) and summer (Nov-April) maps will be published in Volume 36 of this journal.

COMPARISON OF THE PRESENT WITH PREVIOUS MAPS

A number of authorities have presented annual average rainfall maps of Fiji, e.g. Derrick (1) Wright and Twyford (5) and Harris (2), utilising, it is believed,

TABLE 3. NUMBER OF STATIONS AVAILABLE

Authority	Averages up to	Viti Levu	Vanua Levu
Derrick	1950	17	12
Wright & Twyford	1955	37	21
Harris	1960	58	32
Matthews	1970	93	60
—	1975	115*	75*

*Estimated

averages up to the end of 1950, 1955 and 1960 respectively.

The accuracy of these maps is vitiated by a paucity of data, and by an apparent neglect of the strong correlation between height above MSL and rainfall, discussed above. Table 3 shows the number of rainfall stations on Viti Levu and Vanua Levu, available for these studies. Numbers for 1975 are estimated.

The Table shows a steady increase in the number of stations available since 1950. This increase has enabled the construction of more and more accurate maps, especially those now presented. It has only recently become possible to form estimates of the quantitative relationship between rainfall and height above MSL in various parts of the country. There are now only just sufficient observations available in suitable locations for this purpose.

An important point which emerges from the present maps is that the valleys of the principal rivers (e.g. Sigatoka, Navua, Waidina and Wainibuka) appear to be much drier than was formerly believed. This conclusion is of obvious significance for hydrological, hydro-electric and agricultural schemes, among others.

SUGGESTIONS FOR FUTURE WORK

Following the usual practice, the Fiji rainfall averages will, it is expected, be up-dated to the end of 1975. By that time, as noted above, much additional data will be available, mostly as short-term records. These should be fully utilised, to obtain the maximum value from the data. It is suggested that the following techniques should be adopted.

1. 'Normals', i.e. averages for a specified period of years ended 1975, should be computed, instead of averages for varying periods. The period of the 'normals' should be as long as possible, not less than 20 years, but not so long that the number of normals is too much reduced.
2. Broken records, i.e. those with only occasional months missing, should be completed by estimating the missing values. This could best be done by constructing monthly isohyetal maps for each of the months of the 'normal' period, and extended as far back as possible. The resultant series of monthly maps would be extremely useful in carrying out detailed studies for various purposes.
3. Short-period records, or those for periods other than the 'normal', should be 'weighted' by reference to neighbouring stations having reliable 'normals'.
4. The co-ordinates of all stations, past and present, should be thoroughly checked, and their heights above MSL determined where this has not already been done.
5. All records should be critically examined in order to eliminate systematic errors, e.g. use of the wrong rain measure, failure to measure rainfall on holidays or weekend, errors of arithmetic, etc.

If these procedures are followed, the Fiji rainfall statistics will be greatly enhanced in value, and will enable more reliable rainfall maps to be prepared.

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EFFECTS AND ECONOMICS OF WEED CONTROL IN BANANAS

by

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SUMMARY

The application of one dalapon and eleven paraquat sprays to mixed weed growth in bananas controlled all weeds except *Merremia peltata* much more effectively than hand slashing. Weed control did not increase the plant or first-ratoon-crop yields over the unweeded treatment, but advanced the time of cropping, hence yields were greater over a 30-month period, with economic advantages.

INTRODUCTION

Weeds in commercial banana planting affect the crop adversely through competition for plant nutrients, for sunlight consequent upon the reduction in banana leaf area and for moisture during periods of drought, or where there is a pronounced dry season or seasons (1, 2, 3). It is general experience that the most serious competition occurs in the early life of the crop, particularly during the first three months (2, 3.). The effects of weed competition on the banana are retardation of growth and of bunch production; clean weeding has been shown to encourage early bearing (3).

The type of weed competition in the bananas has an important effect; in general grasses, particularly stoloniferous or rhizomatous species, are most serious whereas dicotyledonons weeds can be tolerated, except the climbing species (2).

Of importance in respect of the method used to control weed growth is the superficial nature of the banana root system, much of which is present in the upper fifteen centimetres of the soil (1). Hand or mechanical cultivation on that does more than gently scuffle or stir the immediate surface of the soil can have adverse consequences: directly by reducing the efficiency of the root system, and indirectly by predisposing the banana towards leaning or falling over altogether.

Most farmers in Fiji do little more than periodic removal of climbing weeds from the banana stool; a few slash all weeds at ground level every three months or so; and a small number of progressive growers now use contact herbicides at regular intervals (4). The experiment now described was undertaken to compare these practices.

METHODS

Layout and treatments

The trial was planted in May-July 1970 with small, clean, sword suckers of the Veimama variety of the sub-group Cavendish, at 3.4 x 1.8m spacing (11 x 6 ft.) on an alluvial soil at Waidradra Research Stations. A 12:12:18 fertilizer was applied at 350 kg/ha (315 lb/ac) every two months; and desuckering, bunchy-top virus roguing, fungicide spraying, and scab-moth control, followed standard practice throughout the duration of the trial.

During the rst three months after planting, all plots were carefully hand weeded every two weeks. Plots of 12 banana stools (3 rows of 4) with a common guard row between plots, were marked out and the following four treatments applied in randomized blocks with 5 replications.

1. No weeding, except hand pulling climbing weeds from banana plants.
2. Herbicidal treatment
3. Slashing weeds to ground with a cane-knife every 6 weeks.
4. As for (3) but every 12 weeks.

The herbicidal treatment consisted principally of spraying with paraquat of 0.2 kg a.i./1 (2 lb/gal) strength as and when necessary; but the first roes was supplemented by a single spray of dalapon (85% a.i.). A 'Rega' knapsack sprayer was used throughout at a volume of 525 1/ha (50 gal/ac), the paraquat concentration being 3 g/l (0.5 oz/gal) and the dalapon 6.24 g/l (1 oz/gal).

Additional treatment

Following an observation that M.S.M.A. controlled *Merremia peltata* (Waidamu creeper) better than did paraquat, two observational plots sprayed with M.S.M.A. were added to the trial.

Recording

All the treatments started bearing within 12 months. Each bunch was weighed, and then the fruit of export quality separated and weighed. (for export, single fingers, not less than 5½ ins long are packed in 56 lb cases). The trial was terminated prematurely by Hurricane 'Bebe' at the end of October 1972 i.e. 30 months from planting. During this time the plant crop was completed for all treatments while the ratoon crops had progressed as follow:

	1st ratoon	2 ratoon
No weeding	64% harvested	not started
Herbicide spray	100% "	28% harvested
6 weekly slashing	78% "	8% "
12 " "	82% "	7% "

RESULTS

Weed Species

About one year after the trial started the dominant weeds present in the treatments were as follows:

1. Unweeded treatment: *Paspelum conjugatum* (Sour grass); composites such as *Emelia sonchifolia, Mikania micrantha,* (Mile-a-Minute) and *Grassocephalum crepidioides; Lobelia zeylanica;* and *Merremia peltata,* (Waidamu Creeper). It was the aggressiveness of *M. micrantha* in particular that necessitated the hand pulling of smothering weed growth.
2. Paraquat treatment: *P. conjugatum* and a few composites.
3. Slashing at 6 weeks: Almost entirely *P. conjugatum*:
4. Slashing at 12 weeks: A more mixed weed composition similar to the unweeded treatment.

It was observed that paraquat exerted no effective and practical control at all on the vine *Merremia peltata,* producing only slight leaf scorch; but that M.S.M.A. herbicide gave a very effective control of this weed. Conversly, M.S.M.A. was observed to be less effective for the control of *Mikania micrantha.* Chemical weed control with paraquat was otherwise extremely effective.

Yield

The total yields of the four treatments were : -

	Export Cases/Ac.	Quality mt/ha	Rejects mt/ha
No weeding	697	44	16
Herbicide spray	994	62	16
6 weekly slash	761	48	22
12 " "	851	53	22

These figures were not statistically analysed, as it was considered more instructive to analyse (a) the bunch weights of the plant and first ratoon crops as set out in Table 1 together with the few data from the second ratoon, and (b) the median arrival dates of the plant and first ratoon crops, which were

	plant crop *	first ratoon †
No weeding	124	169
Herbicide spray	0	14
6 weekly slash	56	87
12 " "	39	51
Standard	± 16	± 20

* days from 1 June 1971
† days from 1 April 1972

As in the total yield figures the 12-weekly slashing treatment appears, anomolously, better than 6 weekly slashing; but here it can be seen from the Standard Errors that this apparent superiority is of no statistical significance.

Costings

The costs of all operations that varied between treatments are showing Table 2. Labour was costed at 42c per hour.

TABLE 1 BUNCH WEIGHTS IN KG.

		No weeding	Paraquat treatment	6-weekly slashing	12-weekly slashing	S.E.D. ±
Plant Crop	Mean weight of bunch	23.8	20.9	22.1	22.0	1.5
	Mean weight of exportable fruit per bunch	16.9	13.3	14.6	14.7	2.2
1st Root Crop	Mean weight of bunch	24.8	29.4	26.5	28.1	2.3
	Mean weight of exportable fruit per bunch	18.9	21.1	18.6	20.8	2.2
2nd Root Crop	Mean weight of bunch	—	29.8	26.6	30.3	—
	Mean weight of exportable fruit per bunch	—	21.8	16.7	25.4	—

It must be emphasized that these costings are based on a total of only 60 stools per treatment, or 24 in the case of the M.S.M.A. Labour rate determinations from such small areas tend to be unreliable.

DISCUSSION

Weed Control

The treatments in this trial were applied from the time that the banana plants had been in the field for three months. During this important establishment period effective weed control was attained with hand labour. This period of work was not costed, being common to all the treatments.

The weed population and species remained the same after stablisation as described in the results section, but growth was not as heavy after the first year because of the banana shade effect. The sour grass in particular had a weak, etiolated appearance. The regrowth of sour grass after slashing was rapid. The 12 week interval between slashing gave poor control whereas the 6 week interval gave quite good control and regrowth stablished into almost one hundred percent sour grass.

Paraquat at the rate used in this trial does not control Waidamu Creeper and the effect was to scorch it slightly and to check growth for a few days only; but it does control the other major weed, mile-a-minute, extremely effectively. Whilst M.S.M.A. controls Waidamu Creeper totally it is less effective for the control of mile-a-minute. Use of M.S.M.A. which is cheaper than paraquat at the rates used in this trial, with the occasional substitution of the latter, might be the most effective approach. Sour grass is most effectively killed by a dalapon spray followed 3 weeks later by a spray over the regrowth plus any residual growth.

Yield

Clearly the beneficial effect of weed control is primarily to hasten cropping. As shown in Table 1, the least weedy treatment (i.e. the herbicide spray) generally had no bigger bunches than the other treatments: indeed, for the plant crop it had the smallest bunches (20.9 kg) and the unweeded plots the largest (23.8). This difference (2.9 ± 1.49) is of some statistical significance ($p = 0.10$) but reversed in the first ratoon.

But there is no doubting the significance of the greater yield given by improved weed control in any period of time (e.g. in the 30 months of this trial) because this follows from the highly significant hastening of cropping. The difficulty is how to express the yields for the purpose of economic calculation. Suppose one treatment has become about three months advanced on another. The forer will appear much higher yielding than the latter at the date when the harvesting of, say, the first ratoon is nearing completion of the former but just beginning on the latter; whereas three months later the yield difference will appear slight.

Economics

For the reason just given, economic analysis of any trial of this nature is difficult, and no exact analysis is worthwhile

TABLE 2. COST OF WEED CONTROL TREATMENTS $F PER ACRE

	Vine-pulling only	Paraquat	6-weekly slashing	12-weekly slashing	M.S.M.A. *
No. of occasions	11	12 †	20	10	12 †
Man-days labour	6	13-5	85	16	13.5
	$	$	$	$	$
Labour cost at 42c/hr	22	51	320	231	51
Cost of chemicals	—	96	—	—	43
Total cost	22	147	320	231	94

* Two plots only.

† Including one dalapon spray.

on trial so arbitrarily concluded as this. The costs and returns up to the date of the hurricane, however, show some treatment differences so great as to certainly meaningful.

From the figures given earlier for overall yields the returns (with rejects sold at 1c/lb, and exports at $1.56 a case) of treatments 2, 3, and 4, in excess of the returns for the 'no weeding treatment', together with the corresponding costs (from Table 2) are:

	Costs in excess of 'no weeding'	Returns in excess of no weeding
Paraquat	$133	$297
6-weekly-slashing	$298	$153
12-weekly slashing	$210	$297

From this is seems certain that the paraquat is the best of the treatments. The 6-weekly slashing seems not worthwhile; but evidently the returns of this and the 12-weekly slashing treatment are subject to sufficient experimental error for there to be some doubt as whether or not either of these hand treatments is worth doing. There can be no doubt that it is profitable to use paraquat.

Relation to circumstances

It must be emphasised that in this trial a good standard of disease control was achieved by regular fungicide spraying. In the absence of such spraying the economics are likely to be appreciably less favourable.

CONCLUSION

Paraquat can be confidently recommended to banana growers who also practice regular fungicide spraying. M.S.M.A. offers hope of giving better control of weeds, particular Waidamu creeper, at lower cost, and hence merits further study. A combination of paraquat (which controls mile-a-minute better than M.S. M.A.) and M.S.M.A. might be better than either alone.

ACKNOWLEDGMENT

This trial was planned and initiated by Mr. P. Hoskin whilst he was Research Officer (Banana) in consultation with Mr. N. P. Patel, Department of Agriculture, Fiji. Mr. C. R. Baines, Statistics Section, Long Ashton Research Station, kindly handled the statistical analysis.

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CATTLE IN FIJI. PART 1, HISTORY OF BEEF

by

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SUMMARY

Cattle were introduced to Fiji about 1835. The population grew to about 5,000 head in 1880, and 50,000 in 1918, when 5,000 were being slaughtered annually. A large scale ranching and cannery development, 1922-1932 failed during the slump, when production generally declined. During the war it rose again, to a peak of 8,000 slaughterings a year, almost complete self sufficiency; but by 1966 there had been little increase in production and 23% of consumption was imported. Since then, however, a big rise in consumption has been more than met by increased production, now 15,000 carcasses a year.

Until recently only about 10% of production has been from beef farming *per se* the bulk being a by-product of cattle kept for milk or draught purposes; but since 1964 there have been two important developments: the keeping of substantial herds under coconuts on many Cakaudrove coconut plantations; and the encouragement by the Department of specialist beef-farming on medium-sized leaseholds created by mataqali sub-division.

Bos indicus cattle of the Brahman type were introduced in 1905 and of the Santa Gertrudis breed in 1954; and although only three small pure herds have been maintained, bulls have been widely distributed, so that many of the beef cattle in Fiji are now of part Brahman ancestry.

GENERAL HISTORY TO 1919

Introduction of Cattle to Fiji

Domestic livestock are not indigenous to Fiji. The first cattle in Fiji are believed (15) to have been a bull and two heifers landed in Rewa in the 1830's by a ship from Salem, Massachusetts. Nothing more is known about this introduction except the story that a Fijian standing on the river bank asked what these strange animals were called and was told, "That is a bull and that is a cow." This the Fijian translated as "bulumakau" and this word was adopted immediately as the name for cattle and is also used to describe beef.

Twenty years later Smythe (11) described the cattle situation in 1858 as, "perhaps a dozen head belonging to missions." Credit for the first serious attempt at cattle breeding goes to Dr. Brower (later the American Vice Consul in Fiji) who had an estate on Wakaya Island. Swanston (12) reports that in 1859 Dr. Brower brought several cows and and a bull to Fiji in the brig "Ocean." Thirty-five head of cattle were imported in 1867 (10), and in (1870) horse and cattle imports were valued at £4,200.

Developments, 1870 *to* 1919

Some planters drifted into cattle raising, particularly in the Rewa and Navua areas, after the failure of cotton prices in 1870. At this time there was a lack of sugar mills to process any cane that was planted and the whole economy of the country was at a low ebb. Beef production gradually increased and meat was beginning to be supplied to Levuka.

In 1879 *The Fiji Times* (21.6.79) noted: "Circumstances have changed from the date when meat had to be supplied by the Colonies, [i.e. Australia and New Zealand] and beef at 1 shilling per pound was considered cheap in comparison to the treat it afforded. Importers of stock have found their undertakings succeed almost beyond expectation and hundreds of cattle fit for the butcher are now found on the rich pastures of the Colony."

This report was probably optimistic as the estimated cattle population of Fiji in 1880 was only 5,000 head (1). Stock continued to be imported during the 1880's but there are no references to the type of cattle in the Colony or even any suggestion of breeds which should be introduced. Farmers were evidently starting to take a pride in their stock and *The Fiji Times* of 1879 commented on "the grand exhibition of prime beef held on Boxing Day at the establishment of Mr. Page".

Cattle were well distributed through the group by this time and herds were established at Tailevu, Suva, Navua and Nadi on Viti Levu, while Bua, Fawn Harbour and possibly other areas in Vanua Levu and Taveuni were known to have herds in 1881. The cattle population had increased to 22,366 head by the end of 1904 and there is mention of specific breeds for the first time. Some 3,000 Herefords were being run by Mr. Tarte of Taveuni and Shorthorns and Holsteins were kept at Nausori.

In 1918 the cattle population was reported at 51,266 head, although there was some doubt as to the accuracy of the figures. There are no statistics of slaughterings before 1939, when the registration of slaughter-houses was enforced; but statistics of hide exports are available from the 19th Century, as shown in Table 1 for 1915-1939. As discussed later, there is reason to think that these figures more accurately represent total killings than do slaughter-house returns. During the war these hide exports increased, to reach a temporary peak of 6,470 in 1920. This is not inconsistent with the 1918 population report.

Beef and Dairying

The next paper in this series will deal with the history of dairying since 1910. Before then there can have been little. The herd at Suva in 1880 no doubt supplied milk to that town, as probably did the Holsteins at Nausori in 1904. But it is clear from their locations (and from the breed, as regards Tarte's herd) that the other herds mentioned above must have been kept for beef.

BEEF PRODUCTION, 1920-1965

The inter-war years: The Tova Ranch

The first Veterinary Officer (W. Rainey) was appointed to the Department of Agriculture in 1919 and it is possible to obtain a good picture of the beef industry at the time. Prices for beef averaged 25 shillings per cwt. dressed weight, which Rainey (7) regarded as too low a price to encourage stock keeping since only the butchers were able to make a profit.

From his experience with Zebu cattle during previous service in India Rainey (8) recommended that the most suitable crossbreds for Fiji would be Zebu x Hereford and Zebu x Angus. In spite of a generally unfavourable market for beef cattle, the census of 1921 showed 80,000 head. Mr. J. J. Barker apparently had confidence in the future. Besides running a 1400 acre property at Samabula with his own slaughter yards (7) he sought and obtained a lease of 100,000 acres of land at Ra, centred on the Tova freehold. This was by far the most ambitious cattle-raising enterprise attempted up to that time. Government required Barker to lodge a bond for £10.000, which would be released provided improvements to this value were completed within 7 years. Within the first 2 years, Barker had fenced 11,000 acres, spent £16,000 and was running a herd of grade Zebu cattle. He was therefore released from his bond.

The project, however, became too big for Barker to finance and the Fiji Development Company was set up with Mr. Henry Marks as Managing Director. This company ran the grazing property and also set up a cannery in 1928 to process corned beef and ox tongues. Government granted a 2-year protective tariff of 2 pence per pound on canned beef entering Fiji. In spite of this, the cannery ran into stiff competition from the New Zealand firms which had previously supplied the Fiji market. Furthermore the cannery had to overcome an understandable local prejudice which resulted from the supply of a number of tins of bad meat.

TABLE 1. HIDE EXPORTS

Date	No. of hides	Date	No. of hides
1915	4,010	1927	3,770
16	2,950	28	6,480
17	4,740	29	9,560
18	4,840	30	5,860
19	5,390	31	5,860
20	6,470	31	4,210
21	4,690	32	3,470
22	4,620	33	3,860
23	3,860	34	4,550
24	3,340	35	4,510
25	3,360	36	4,530
26	3,770	37	5,430
		39	4,510

Some of these problems were overcome and in 1930 the Fiji Development Company asked Government to extend the tariff protection for a further period. It appears from the Company's submissions at this time that the ranching enterprise was being allowed to run down and there were only 10 bulls, 2,468 cows, 250 steers and 450 calves on the property in March 1930. The cannery was kept going by the purchase of cattle from Indian farmers. Over an 8-month period (August 1929-March 1930), 847 head were purchased at 16 shillings and 6 pence per 100 pounds dressed weight. A gross profit of £10,136 was declared in 1929 but the world depression in 1930, which was intensified in Fiji by a hurricane, cut trade drastically as the following shows :

Imports of Canned Beefs.

Jan. - Sept. 1929 — 529,126 lbs.
Jan. - Sept. 1930 — 278,668 lbs.

Up to September 1930 local production of canned beef was only 85,000 pounds, of which 16,028 pounds was exported to Tonga and Samoa. The Fiji Development Company advised Government in September that it would be closing down. It appears likely that Government would not have extended tariff protection beyond December 1930 even if the Company had continued, as it felt that the Company had not made an earnest endeavour to establish the grazing and canning industry at Tova.

In October 1932, J. P. Bayly and Company asked Government for a protective duty on canned meats ,with the intention of reviving the Tova enterprise, but this came to nothing.

Inter-war year : Other Developments

In the 1920's the two properties that are now by far the largest cattle stations in Fiji — Yaqara in Ra, and the Fiji Pastoral Company at Navua — came into their present ownership. The latter started ranch operations in 1922 on land mostly acquired when the Vancouver Sugar Co. ceased operations in 1922. Yaqara was bought by the Colonial Sugar Refining Co. in 1926, to provide meat for its employees, from a Mr. Thompson who was running a mixed herd of Shorthorns are Zebus. Hereford bulls and a few cows were imported, and the station developed to provide meat for company employees. In the same district at that time the Burness family had Shorthorns on the Cabori estate and Aberden Angus were established on Bureibai.

The hide export figures (Table 1) reflect world trade booms and slumps, with a depression in the early '20s, a boom in the late '20s, and then a prolonged depression in the '30s with some improvement late in the decade.

The very big export figure for 1929 was partially due to the before-mentioned run-down of Tova at that time. There are also some hints in contemporary Departmental reports that some coconut plantations had increased their stock in excess of economic outlets for beef, and possibly they were slaughtering for the sake of the hides.

During the depression years most of the big herds described by earlier writers (eg. Tarte's 3,000 Herefords) were drastically run-down. The coconut plantations kept only subsistence stock.

Most of the Tailevu farms turned permanently to dairying, as did the Fiji Pastoral Company to a large extent, although continuing a beef herd a sustantial side line. Only Yaqara kept a large beef herd going, with about 3,000 head in 1936.

Production since 1940

After Japan entered the war, the presence of the US army increased the demand for beef and there was a sharp rise in the number of cattle killed; to reach a peak of 8,050 in 1942. To stop the slaughter of breeding stock, restrictions were imposed in 1941 which prevented the slaughter of cows under 8 years of

TABLE 2. REGISTERED SLAUGHTERINGS

Year	Number	Year	Number	Mean carcass wt. in lb.	Year	Number	Mean carcass wt. in lb.
					1961	9,570	500
1939	4,290	1950*	4,460	457	62	9,820	480
40	4,315	51*	5,140	487	63	10,300	460
41*	1,052	52*	5,040	477	64	10,670	440
42*	8,051	53	7,030	515	65*	9,700	480
43*	5,240	54	7,840	525	66	9,590	500
44	4,329	55	8,501	511	67	10,960	510
45	6,373	56	8,420	483	68	13,500	500
46	7,745	57	8,380	499	69	16,200	490
47	9,364	58	8,760	510	70	17,100	470
48*	6,304	59	9,173	507	71	17,900	460
49*	5,285	60	9,010	522	72	14,800	460

* Restrictions in force

age and also the spaying of cows (16). The available stock from the total population of 84,344 head had been used up by the end of 1942 and slaughter figures declined to 4,330 in 1944; but rose sharply when slaughter restrictions were lifted at the end of the war.

Turbet (17) contrasted the long period of depressed pre-war prices, when beef cattle raising was unprofitable except as a side line, with the good prices and high demand of 1949. In 1947 the number of cattle passing through registered slaughter houses surpassed the peak figure of the war years (Table 2), and to protect breeding stock, restrictions on the number of cattle killed were again imposed in 1948 and were not lifted until 1953. There were also controls on the sale of meat between 1943 and 1949 which prevented the purchase of beef on at least one day of the week.

A comparison of the number of cattle killed in registered slaughter houses in the period 1940-49 (64,058) with the number of hides exported in the same period (79,206) suggests that the real number of cattle killed was at least 23 per cent higher than the figures quoted. Some estimates indicate that the true figures may well have been 50 per cent higher than the number of animals passing through registered slaughter houses since many cattle were killed on plantations and in villages and recording was impossible.

In an attempt to increase production to meet the new demand, a Beef Committee was appointed in April, 1948 to review the situation (6). This committee completed its work in June and made four main recommendations:

1. Tenure of land for cattle raising should be made more secure and rents should be lowered.
2. The fixing of Fijian land reserves should be completed.
3. Fencing materials should be made more readily available.
4. The Colonial Development Corporation (C.D.C.) should be invited to invest in the Development of Fijian owned land in Ra.

A representative of the C.D.C. arrived in Fiji in October 1948 to investigate the proposals and to look at the 60,000 acres in question. This area was that previously leased to J. J. Barker and centered on the old Tova cannery. Unfortunately the C.D.C.'s report on Ra was unfavourable, largely due to the low price of beef, and there were no other parties interested in large-scale investment in the post-war beef industry.

The industry was, unfortunately, unable to take full advantage of the improved market as the big cattle farmers of the previous period were gradually being replaced by others with less experience and capital and the hope that the Colonial Development Corporation would invest money had not been fulfilled. The spread of weeds and the disrepair of fences following the war also contributed to the difficulty of increasing beef production; thus, in 1950 meat imports were four times as high as they had been in 1938.

Turbet (17) recommended a grading system to encourage quality production and a sales yard to facilitate the marketing of cattle. A determined attempt was made to introduce two beef grades in

TABLE 3 BEEF CONSUMPTION IN TONS

Year	Home produced fresh meat	Imported fresh meat	Imported canned meat	Total	Percentage imported
1965	2,060	97	400	2,557	19
66	2,130	84	374	2,768	23
67	2,490	80	300	2,870	13
68	3,000	56	220	3,276	8
69	3,520	39	247	3,806	7
70	3,560	44	300	3,904	9
71	3,668	90	290	4,048	9
72	3,061	126	317	3,504	12

1951 but this was not generally adopted, due to resistance or indifference on the part of butchers.

The pattern from 1950 onwards was a slow increase in numbers killed, along with an increase in carcass weight, while restrictions were in force; followed by a much more rapid increase in the numbers killed when restrictions were lifted (Table 2).

The increase in consumption of local beef which followed the relaxing of butcher quotas in 1953 was thought to have been met more by the slaughter of working bullocks (which were being replaced by tractors) rather than by any real increase in beef production (3). The shortage of beef became so acute that slaughter restrictions were re-introduced in February 1965. Killing weights had declined as the number of cattle killed increased and the shortage was further intensified by the loss of cattle in the 1964 floods. However, over this period a number of factors were contributing to a real increase in beef production:

1. Measures were taken to combat the high calf mortality rate in dairy herds (estimated loss 50 per cent).
2. Government subsidies were introduced on weedicides and fencing wire.
2. A coconut subsidy also resulted in the improvement of pastures in coconut groves.
3. Improved advisory services and the increased control of tuberculosis were instigated.
4. Improved breeding stock and pasture grasses and legumes were introduced.
5. The Fijian reserves were demarked and agricultural credit was established.
6. A closer study of meat marketing problems was begun.
7. As an interim measure, Government started to trade in stock and this assisted the movement and marketing of beef cattle.
8. A concerted effort was made to establish Fijian owned beef farms.

RECENT DEVELOPMENTS

Production since 1965: sources of beef

As shown in Table 3 beef consumption rose by about 50% from 1965 to 1971, a sharper rise than in any previous 6-year period. This increase was more than met by increased local production, as the actual weight imported declined slightly, and the imported fraction of total production fell from 23 to 12%. This 12% is largely made up of luxury tinned meats and special quality fresh meat.

The big recent increase in production has been largely due to the return of specialised beef farming. From the slump years until about 1965, 25% of total production was a side product of dairy farming and almost all the remainder came from small holders and mataqali farmers keeping a few cattle as a side line, or as work-bullocks. But, as shown in Table 4, 10% now comes from cattle kept on coconut plantations and another 10% from specialist beef farms. This latter fraction is still largely from one big ranch (Yaqara) but now with a substantial component from medium sized (100-400 ac) leaseholds, created by mataqali subdivision, financed by Fiji Development Bank Loans, and supervised by Departmental staff on the pattern of a 'Verata Beef Scheme' started in 1962. Both the beef under coconuts and the Verata Scheme merit comment.

Beef Under Coconuts

As mentioned earlier, substantial herds were kept many years ago on some

TABLE 4. CATTLE SLAUGHTERINGS BY TYPE

Type of Farm	Number Slaughtered	% Beef Supplied
Arable	6,830	46.1
Dairy	3,000	20.3
Village	1,960	13.3
Beef/Coconuts	1,550	10.5
Specialist Beef		
1. Yaqara (900)		
11. New (560)	1,460	9.8
Total	14,800	100.0

large coconut plantations (e.g. Tarte's on Taveuni); but during the slump these declined. Most plantations kept cattle, but primarily to keep the undergrowth in check by grazing. Such beef as was produced was mostly consumed locally: little came through to the main markets.

This is still the situation on most plantations; but since about 1965 a combination of factors has induced several of the more progressive managers to develop quality beef production, for the Suva market and the hotel trade, to such a degree that an appreciable part of their plantation income now comes from beef.

The pre-requisite to this development was the improvement of communications. In 1966 the PWD built a landing-craft type of vessel, the Duiyabaki, which was used in part for shipping cattle to Suva direct from plantation water-fronts in Taveuni and Vanua Levu. With better transit conditions there was less loss of weight in transit than on the normal inter-island shipping. Other factors included a Departmental 'Commercial Undertakings' Scheme begun in 1966, for selling store cattle to farmers and providing a marketing service that gives Vanua Levu and Taveuni farmers a better price, relative to Suva, than before; and change of ownership on many large plantations bringing more progressive management.

The move to cattle received great impetus in 1971/72 from the very low copra price. On many plantations the copra income scarcely paid the basic costs of copra production, and what profit there was came only from the cattle. With copra prices now higher than ever before the relative importance of cattle has declined; but beef prices are also high, making cattle highly profitable, and as the keeping of cattle is complementary to copra production, the two can flourish together.

The pasture quality on most large plantations is very poor. Weeds flourish, guava and other shrubs sometimes choking all lower growth, and what little grass there is, is of poor quality. But on those plantations where cattle are taken seriously — about 30 out of some 130 large plantations — shrubs are generally cleared, and on some there has been some planting of pasture grass; mostly Batiki (*Ischaemum indicum*) and Nadi blue grass, (*Dichanthium caricosum*) with some Para grass (*Brachiaria mutica*) and, more recently, Koronivia grass. (*Brachiaria humidicola*). Few, however, have any legume pastures and little if any fertilizer is used, although research has shown the benefits of these.

The Verata Scheme ,and Later Developments

About 1960 a few Fijian farmers in Verata (a district 30 miles north of Suva) detached themselves from the community and attempted to farm for self-profit: a step unusual for Fijians at that time. None of them had proper land tenure or adequate capital, and their knowledge of animal and crop husbandry was slight; but they produced some surplus subsistence crops for local sale. In 1962 their interest in the possibility of cattle farming was noted by Veterinary Extension workers.

The land they were farming, and surrounding mataqali land, was in fact highly suitable for cattle, being open reed-covered country with occasional bush areas giving ample forage in spring and summer and some winter feed. A scheme was therefore devised of cattle-fattening for the Suva market. Yearling steers, strong enough to thrive on the rough grazing, would be bought from dairy farms in the area. Few skills would be needed, as all the farmers would have to do would be to fence and gradually develop improved grazing. The problems were (a) to increase each man's land from about 25 to about 150 acres, and regularize the tenure, and (b) capital, for stock purchase, etc.

The first was eventually solved by gaining the consent of land-owing mataqali to the subdivision of some 2,000 ac., but this involved allocation to selected mataqali members of six of the twelve 150ac. leaseholds (standard Native Land Trust Board 30-year grazing leases) thus created.

The second was solved partly by requiring each farmer to build his own house, and to sustain himself and his family by subsistence cropping for the first few years, (an exacting requirement, intended to discourage all but the keenest men) and partly by loans of $1,200 to $2,000 per farm to buy stock, fencing wire, and minor equipment. The latter came from the Agricultural and Industrial Loans Board, (now the Fiji Development Bank).

Each farmer established six 10-acre paddocks in the reeds, the store cattle were introduced, and the paddocks rotationally grazed. When the first was vacated, Batiki blue-grass was planted through the reeds and the paddock closed until this established; the intention being to progressively improve all the paddocks. But this was slow difficult work; and although some farmers were progressing well within 2-3 years, with a good income from sales to butchers, others lagged and it was necessary to re-formulate the original 6-year loans on a 12-year basis. After 10 years, four of the original farmers in the Scheme had paid off their first loans and were thriving, and most were well established and on schedule with repayments.

The success of this Verata Scheme prompted similar developments in other areas. In Central Division ,at the end of 1972, 35 beef farmers were being financed by the Development Bank, mostly in the Verata area but several in Waidina and elsewhere. Recently, progress has been more rapid in the drier areas with 83 such farms in Western and 9 in Northern Division. Because of the poorer grazing these farms have a lower stocking rate (1 beast to 4 or 5 acres) and are usually 300-500 acres. Two farmers in Western Division had repaid their loans by the end of 1972.

It had been the original intention that these drier area farms should keep, primarily, breeding herds of Brahman crossbreds, and supply store cattle to the fattening farms of the wetter areas; but many are now dual-purpose. The present availability, from these farms and elsewere in Fiji, of better stock than that originally obtained from the Tailevu dairy farms, has greatly helped the purely fattening farms of the wet zone.

All farms receiving loans from the Development bank are under close Departmental supervision, by specialist livestock extension workers, and the purchases and sales of stock are done through the Department's Commercial Undertakings section. There has been a tendency to manage the farms for the men, but the emphasis now is on educating them in farm management, book-keeping etc. Because of the very rapid recent expansion of this type of farming, the production figures for 1972 (Table 4) give an unrealistic picture of their present status. When all the existing farms of this type come into full production they should account for more than half the specialist beef production in Fiji.

BREED DEVELOPMENTS

Terminology

All the imports up to 1905 were of breeds of European origin, including Herefords, Aberdeen Angus, Shorthorns, etc, besides several dairy breeds. These may be classified as being of the species *Bos taurus*, by contrast with tropical cattle which are *B. indicus*, commonly known as Zebu. This teminology is questioned by some authorities (the species *B. primogenius* is considered by some as contributing to the ancestry of European beef breeds; and any species distinctions are dubious as these types are all fully cross-fertile); but it will serve the present purpose. Cross breeds between *B. taurus* and *B. indicus* are now generally recognized as being superior for tropical beef production than pure *B. taurus* breeds.

Brahman Cattle

B. indicus cattle were first introduced to Fiji when Mr. L. E. Brown imported three heifers and a bull of the Nellore breed direct from India. These were crossed with British breeds with such success that the Colonial Sugar Refining Co. commissioned him to import two bulls and two cows from India on their behalf. They arrived in 1918.

No other importations took place until 1933 when the C.S.R. Company located some Zebu cattle at Riverstone, New South Wales. These were the progeny of a cow brought from India by Lord Hopetown in 1900, and bulls from the Sydney Zoological Gardens. Over a period of time the C.S.R. Company purchased and sent to Fiji a total of eight Riverstone bulls.

The most important introduction of Zebu cattle took place in 1938 when 10 young bulls and 14 in-calf heifers were shipped out of Galveston, Texas on the "S.S. Rabual". All the animals were registered with the American Brahman Breeder's Association and were bred by Mr. J. D. Hudgins of Hungerford, Texas. When the animals arrived in Fiji they were distributed to the five existing sugar mills (Nausori, Lautoka, Rarawai, Penang and Labasa) to provide a source of Brahman blood for working bullocks which were used extensively by cane farmers.

No further importations of Brahman stock were made by the C.S.R. Company and the company decided to disband its herds in 1950. The policy of making Brahman bulls available for cross breeding with British breeds was most successful and Brahman progeny are to be seen throughout Fiji as working bullocks, in beef herds, and even in some dairy herds.

When the Brahman herd at the Nausori mill was sold, the Department of Agriculture bought nine cows and calves, and two bulls. The herds from the other mill centres pased into private hands and unfortunately, were not maintained as pure breds. The small nucleus herd was transferred to the Agricultural Station at Sigatoka where a stud herd was established to make top class breeding stock available to beef farmers in Fiji and the other South Pacific Islands.

In order to improve the quality of this herd, two Brahman bulls were again imported from J. D. Hudgins in March, 1958. These bulls produced some excellent progeny and, in order to maintain and continue the standard, a further two bulls and two in-calf heifers were imported from the same source in January, 1964 (13). In 1968 the Agriculture Department's herd consisted of about fifty breeding cows and heifers. The herd has been registered with the Australian Brahman Breeders Association since 1964.

Santa Gertrudis Cattle

Santa Gertrudis is a stabilized crossbreed (five-eighths Shorthorn and three-eighths Brahman) first developed in Texas and now widespread throughout the tropics. Breed registration is carefully controlled by an international association.

The first imports of this breed to Fiji were four bulls bought by the Fiji Government from the King Ranch in Australia. These bulls were among the first Santa Gertrudis cattle dropped in Australia and were the first exports from the Commonwealth. No Santa Gertrudis heifers were available in Australia at this time and the bulls were used on Hereford, Shorthorn, and grade Brahman cows at the Agricultural Station, Sigatoka and in two commercial herds.

After extensive enquiries in the U.S.A., it was possible to purchase ten pure-bred heifers in April, 1958 from the well known Armstrong Ranch in Texas. These cows were mated to one of the King Ranch (Australia) bulls and the first pure-bred calves were dropped in early 1960. Unfortunately, all the original Australian bulls were by the same sire and it soon became evident that it would be difficult to do justice to the breed without a wider range of blood lines.

The next importation was made by the Colonial Sugar Refining Company of Fiji which purchased a bull for Yaqara Estate from Australia in 1961. The following year, the Fiji Government also purchased a bull from the same source for use in the Sigatoka herd.

Because of the embargo placed on the importation of Santa Gertrudis stock into Australia, the price of bulls became extremely high and by 1962 even average quality bulls were selling for more than £A1,000. There was still a shortage of unrelated blood lines in the Sigatoka herd and, to obtain the best value for money, a further nine in-calf heifers and two bulls, including the progeny of some outstanding bulls, were bought from leading Santa

Gertrudis breeders in the USA in January, 1964 (14).

When the Fiji Government purchased the assets of the C.S.R. Co. in 1973 the Yaqara Estate became the separate, Government owned, Yaqara Pastoral Co. The stud herd there, and at Sigatoka are member-herds of the Santa Gertrudis International Herd Association.
Breeders International Herd Association, and all registered animals are required to pass a quality check conducted by Association officers in addition to complying with pedigree regulations.

By 1968 the Sigatoka herd consisted of 110 breeding cows and heifers and since 1961 Government has sold bulls from this herd to commercial beef farmers at subsidised prices. This policy has had a marked effect on the beef industry and an ever increasing number of animals with Santa Gertrudis blood are passing through Fiji's slaughter houses.

The Performance of B. indicus breeds in Fiji

This has recently been reviewed by McIntyre (5) Pure Brahmans tend to have slighter higher, and Santa Gertrudis appreciably higher, growth rates than Herefords. But the Brahmans are lighter at birth, and all the *B. indicus* breeds are inferior in reproductive efficiency to Herefords. One great advantage of the *B. indicus* breeds in Australia, and other tropical countries, is resistance to ticks. This is of no advantage in Fiji because although there are some cattle ticks here there are no tick-borne diseases. Also the heat tolerance of *B. indicus* is not so important in Fiji as in many tropical countries, as temperatures in Fiji are never excessive and often low for the tropics. McIntyre suggested, therefore, that a cross-breed with Hereford might be better, for Fiji, than pure Santa Gertrudis.

ACKNOWLEDGEMENTS

The major part of this article is based on a paper presented to the Fiji Society in August 1968, and due to be published in the Transactions and Proceedings of that Society. I have to thank the Society's President, Mr. S. Tuinaceva, for permission to re-present this material here.

The Verata beef scheme owed its inception, early survival, and later extension to other areas largely to the efforts and enthusiams of Mr. D. Lornie, recently retired Assistant Director of Agriculture (Animal Health and Production), and I thank him for permission to base my notes on that subject on an unpublished memorandum of his.

The other notes on 'Recent Developments', including Tables 2 and 3, are based on a recent report of the Beef Commodity Committee of this Department, and I am grateful to Mr. A. J. Vernon for help with the assembling of the 1968 paper and the new material in its present form.

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TECHNICAL NOTES

ABATTOIR POLLUTION IN THE WAINIBUKU CREEK

Following a newspaper report (Fiji Times, 16th March 1973) that fish stocks in the Wainibuku creek between Suva and Nausori, had declined due to pollution, an investigation was made of the quality of the creek water near two of the major industrial concerns which are potential sources of pollution.

Three stations were investigated along the course of the creek:—

- Station 1 immediately below the Kings Road bridge:
- Station 2 below A.C.I. Harvey's factory but above Wahley's pig farm and abattoir:
- Station 3 about 50 metres below the outfall of Wahley's pig farm into the Wainibuku creek.

Water samples were taken from these stations and various measurements made to determine the condition of the creek water at these different points. Dissolved oxygen and Biochemical Oxygen Demand (B.O.D.) (1) were measured on two separate occasions while soluble nitrite, nitrate (6) and total ammonia (4) were measured on three separate occasions, with the results shown in Table 1. There was no appreciable change in the water chemistry between stations 1 and 2, but between stations 2 and 3 the quality of the water deteriorated rapidly. The increased B.O.D. at station 3 indicated that this was a result of organic pollution entering the creek.

The result of an organic pollutant with a high oxygen demand entering the creek would be ultimately to deoxygenate the creek water. The dissolved oxygen at station 3 was somewhat lower than at the other stations; but the deoxygenation effect is not immediate and a typical dissolved oxygen sag curve would be expected to develop downstream (2) as metabolism of the organic material resulted in progressive deoxygenation of the water. Accompanying the reduced oxygen concentrations at station 3 can be found other indications of the onset of anaerobic conditions in the creek. The ammonia concentration increased dramatically as did the NO_2/NO_3 ratio and both of these phenomena are particularly associated with the anaerobic bacterial metabolism of proteinaceous material such as sewage or slaughter-house effluent. The onset of anaerobic conditions in a stream is of great importance as not only do the low dissolved oxygen concentrations tend to restrict or kill animals, the higher animals in particular, but two common products of anaerobic bacterial metabolism, namely ammonia and sulphide, are both actively toxic (5).

The toxicity to fish of aqueous ammonia is due to the molecular ammonia (7), the ammonium ion being comparatively non-toxic. Both higher temperature and high pH increase the proportion of the total ammonia present in the undissociated form while low dissolved oxygen concentrations enhance the toxic effect (5). Although there are few data available on the toxic level of ammonia for tropical fish, the European rudd *(Scardinius erythrophthalmus)* has been shown to have a 7-day LC_{50} of 1 mg. NH_3-N/l and 95-day LC_{50} of 0.2 mg. NH_3-N/l (7). Again, for the Mosquito fish *(Cambusia affinis)* used to control mosquito larvae in treated sewage effluent ponds at sub-tropical conditions in South Africa, the ammonia concentration producing 50% mortality in 16

TABLE 1 Chemical analysis of water in Wainibuku Creek

	Sampling Date	Dissolved oxygen (mg. O_2/l)	B.O.D. (p.p.m.)	Total ammonia (micro-g atoms ammoniacal -N/l)	Nitrite (micro-g atoms NO_2-N/l)	Nitrate (micro-g atoms NO_3-N/l)	NO_2/NO_3
Station 1.	7. 5. 73	8.60	6.8	3.6	0.48	19.2	0.0264
	18. 5. 73	7.70	N.D.	3.6	0.38	16.7	0.0227
	18. 5. 73	N.D.	5.15	3.1	0.25	16.65	0.0150
	Mean	8.15	5.98	3.43	0.37	17.18	0.0213
Station 2.	7. 5. 73	7.96	6.23	1.82	0.48	25.4	0.0189
	18. 5. 73	8.76	N.D.	1.00	0.38	15.5	0.245
	28. 5. 73	N.D.	8.00	1.60	0.50	14.15	0.0350
	Mean	8.36	7.11	1.47	0.45	18.35	0.0261
Station 3.	7. 5. 73	6.80	34.0	71.0	9.60	13.9	0.6950
	18. 5. 73	5.76	N.D.	240.0	7.30	13.7	0.5330
	28. 5. 73	N.D.	25.6	91.0	3.78	2.61	1.4500
	Mean	6.28	29.8	134.0	6.89	10.40	0.8926

All stations, all dates, pH 8-2
*Not determined.

hours (1000 minutes) has been shown to be 1.1 mg. (NH_3/N/l.) The European Inland Fisheries Advisory Commission have suggested that the maximum concentration of free ammonia which can be tolerated by fish over a long period may be as little as 0.025 mg. NH_3-N/l (7, page 102). As higher temperature tends to decrease oxygen solubility, and hence enhance the ammonia toxic effect, the toxic levels for ammonia for tropical fish are probably equal to, if not lower than, these quoted values.

In the present case, at a water temperature of 25°C and pH 8.2 the mean total ammonia concentration at station 3 of 134 "micro-g" atoms ammoniacal-N/l corresponded to a molecular ammonia concentration of 0.188 mg. NH_3-N/l. This is substantially above the limit for ammonia recommended as a European standard, and similar to the 95 days LC_{50} for rudd. It seems likely, therefore, that the ammonia produced by bacterial deamination of the proteinaceous effluent from the pigfarm and abattoir is a reason for the decline of fish stocks in the upper reaches of the Wainibuku creek.

The influence of the effluent upon the lower tidal reaches of the creek was not investigated in the present work. There seems to be a case for the treatment of the effluent prior to discharge into the creek, possibly by means of an anaerobic digester similar to that in use near Sawani (3) followed by lagooning of the digester effluent to permit reaeration of the effluent before discharge to the creek.

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THE CONTROL OF INSECTS IN STORED MAIZE

In many tropical countries maize is a major crop, and the control of insects (chiefly weevils, *Sitophilus oryzae)* during its storage is a major problem, attracting much research especially in Kenya and Nigeria. In Fiji there has been less maize grown than required, so that farm storage has not been a problem. But in 1969, with regular demand by Crest Mills, and a better marketing organization there was an appreciable increase in production in the Sigatoka Valley; and further substantial increases are expected in the near future, following the release of varieties resistant to downy mildew, and hence suitable for growing in sugar producing areas.

Maize storage may, therefore, soon be a problem in Fiji. Until recently the Agriculture Department used fumigation with either methyl bromide or phosphine for maize storage on its own stations. This was found to be ineffective against weevils, at Sigatoka in 1969, so it was compared with malathion dusting which is now more generally recommended in other countries.

An open-ended barn at Sigatoka Research Station was cleared and fumigated with "Gammaxene 22" smoke. Four separate stacks were made, each of five 112lb (50Kg) sacks of newly harvested Tuxpeno maize from a nearby farm, and treated individually as follows:-

1. Fumigation with methyl bromide. The sacks were enclosed in a tarpaulin which was wrapped round several times and left in place for 24 hours after release of one cannister.
2. Fumigation with phosphine. One "Phostoxin" tablet was placed in the centre of each bag with a dowel, as recommended.
3. Admixing Malathion dust. Before bagging, 2% premium grade dust was mixed with the maize, at the rate of 1oz/cwt. (28 gm/50kg). Before stacking, a little dust was sprinkled over the surface of each bag.
4. No treatment.

Temperature, taken as indicative of insect activity, was recorded weekly at a depth of about 10 cm. As shown in Table 1, from week 4 to 11 there was a big rise in temperature in all the treatments except the Malathion, with no appreciable difference between the two fumigants and the "untreated." By the end of week eleven, insects could be heard feeding in all the stacks except that treated with Malathion, and the bag surfaces were covered with holes and frass. The bags treated with malathion had some holes, and dead weevils on the dusted surfaces.

TABLE 1 GRAIN TEMPERATURES

Weeks from start	TREATMENTS			
		Methyl bromide	Phos-toxin	None
	Temperature in degrees Fahrenheit			
0	84	83	83	83
4	79	80	85	80
8	79	90	90	93
12	81	81*	82*	94
16	81	93	93	93
20	96	90	87	91

* Following re-fumigation at week 11.

TABLE 2 GRAIN WEIGHT AND CONDITION

	Wt. of bags as after 11 weeks	% of initial wt. after 20 weeks	Wt. of 100 grains after 20 weeks	% grain damaged after 20 weeks
Malathion	101.3	97.0	36.1	43
Methyl bromide	95.7	86.7	28.5	92
Phostoxin	95.4	86.6	30.1	76
Untreated	95.6	84.7	27.5	82

The fumigation treatments were then repeated, causing a mass exodus of weevils from the "Phostoxin." After refumigation the temperatures of these treatments fell by 10°C (18°F) to that of the Malathion until week thirteen, but then rose again to the temperature of the untreated sacks. Between weeks 16 and 17 the temperature of the Malathion treated sacks also rose to that level. Bag weights, grain weights, and percentage grain damage were recorded as shown in Table 2.

It is evident that, starting with clean fresh maize, there is some weevil activity within four weeks, and thereafter a rapid build-up of infestation to reach a high level at 10 weeks. This rate of attack is apparently faster than that observed in West Africa by Le Conte and Bossom (5), but this may be because they took temperatures nearer the centre of the bag which takes longer to become infested.

Initial fumigation was not persistent, and fumigated bags became infested as quickly as untreated ones. The second fumigation was immediately and highly effective; but within three weeks re-infestation was as bad as before. This lack of persistence has also been noted in Kenya (2). Various ways of preventing reinfestation have been studied there and elsewhere (4, 1, 7) but without much success.

The rise in temperature after week 16 in the grain treated with Malathion parallels that of the untreated grain after week 4, suggesting that the Malathion had degraded by about week 12. Similar, or slightly longer, degradation periods have been found elsewhere (4, 1). A mixture of Malathion and Lindane is now being recommended in East Africa as being more persistent than Malathion alone.

Malathion is currently recommended by the Australian Wheat Board for treating grain for human consumption. It can, therefore, be presumed to be safe for use on maize in Fiji, and pending any new developments is to be recommended. But with the expected increase in maize production a more persistent protection should be sought. Ashman (private communication) has suggested fumigation by phostoxin in polythene bags which are then sealed and kept on rat-proof platforms. He also mentioned fenetrothion as the most promising of the newer insecticides.

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CHEMICAL CONTROL OF GUAVA

Guava *(Psidium guava)* is one of the most important weeds in range pasture in Fiji and is likely to become more widespread and serious as new areas are developed as beef farms. Mune and Parham (2) described methods of physical control, and of control by means of 2.4.5-T herbicide. But although 245-T will kill the aerial parts of the plant, sucker regrowth the following year requires further treatment.

A new herbicide, Dicamba (3, 6 dichloro 2-methoxy benzoic acid) admixed with 2.4-D or MCPA kills a wide range of broad-leaved weeds; and, mixed with 2.4.5-T, many shrubs like gorse. In trials in Hawaii 'good control' (very severe defoliation; death not apparent) of guava was achieved for 12 months by one spray of Dicamba alone (1).

In a trial started in November 1970 at the Sigatoka Research Station the following treatments were each applied to plots (5.5m x 3.6m) of heavy guava, approximately 2m in height.

(1) Untreated.
(2) 1 lb a.i. Dicamba + 2 lb a.i. 2.4-D per acre.
(3) 1 lb a.i. Dicamba + 4 lb a.i. 2.4-D per acre.
(4) 1 lb a.i. Dicamba + 2 lb a.i. 2.4.5-T per acre.
(5) 1 lb a.i. Dicamba + 4 lb a.i. 2.4.5-T per acre.
(6) 4 lb a.i. 2.4.5-T per acre.

The herbicide mixtures were applied as sprays, with a wetting agent added, thoroughly wetting the foliage.

Effectiveness was measured by visual assessment by three independent and unbiased scorers, after 1, 8 and 10 months after which an accidental fire burnt the whole area. After one month the assessment was simply one of percentage defoliation, expressed in Table 1, by deduction from 100% as percentage foliage not killed. Later assessment was complicated by re-growth and the 10 month figures given in Table 1 are of healthy foliage present, as a percentage of that of untreated guava. The scores for the untreated plots, not shown in Table 1, were a little less than 100% because a little foliage in these plots had been killed by drift spray.

The results show that although 2.4.5-T has the most rapid defoliation, after 10 months there has been sufficient regrowth to require further treatment. Dicamba with 2.4-D is slower acting but is much more effective after 10 months. Moreover, at these rates, Dicamba plus 2.4-D is cheaper that 2.4.5-T at the hitherto recommended rate. The standard Departmental recommendation for guava control therefore now becomes to spray with Dicamba at 1 lb a.i./ac mixed with 2.4-D amine at 2lb a.i./ac, and a wetting agent. For practical purposes the metric equivalents of these rates should be taken as 1 and 2 Kg/ha respectively.

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TABLE 1 ASSESSMENT OF FOLIAGE

Eye score of healthy foliage present as a percentage of foliage on untreated plants

Treatment	After 1 month	After 10 months
(2) Dicamba + 2.4-D	67	20
(3) " + " (H.R)*	50	32
(4) " + " 2.4.5-T	57	50
(5) " + " (H.R)*	37	47
(6) 2.4.5-T	27	75
S.E. of differences		±12

* at higher rate.

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