Plant Path.

Vol. 34 No. 2

New Series

JULY – DEC. 1972

FIJI AGRICULTURAL JOURNAL

FIJI DEPARTMENT OF AGRICULTURE 50c

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Fiji Agricultural Journal

VOL. 34, No. 2

July - December, 1972.

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METRIC CONVERSION FACTORS

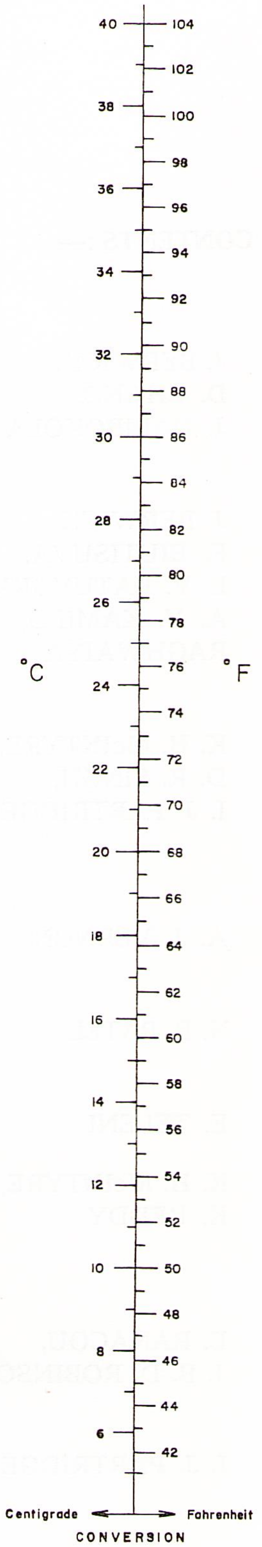
A	B	To convert A to B multiply by	To convert B to A multiply by
inches (in)	centimetres (cm)	2.54	0.394
feet (ft)	metres (m)	0.305	3.28
yards (yd)	metres	0.914	1.09
chains	metres	20.1	*
chains	kilometres (km)	0.0201	49.8
miles	kilometres	1.609	0.621
ounces (oz)	grams (g)	28.35	0.035
pounds (lb)	grams	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.



EXPERIMENTS BY FIJI SCHOOL OF AGRICULTURE

EDITORIAL

In this issue of the journal we welcome two papers giving the results of student projects in the Fiji School of Agriculture. Since 1954, when the school opened, part of the land on Koronivia Research Station has been used for school purposes and in 1970 a block of about 10 ha was formally allocated to the school. This area comprises most of the former 'Field 2' (see Fig. 1 of another paper* in this issue), thus including about a third of the well-drained, readily-cultivatable, land on the station, together with the poorer land lying between Field 2 and the main laboratory area. A separate small block of drained peat land has also been allocated.

The school land thus embraces a range of soil types, which are cropped to demonstrate the proper use of each, viz :

Rewa sandy clay loam
— vegetables, dry-land rice, etc.

Rewa and Navua clay loams
— root crops, etc.

Navua clay and Tokotoko clay
— pasture.

Peat
— vegetables, voivoi.

The heavy clays could also be well used for irrigated rice; but the students can learn about this crop from the research areas.

Labour for the school farm is provided almost exclusively by the students themselves, either in group work (particularly during vacations, when 20-30 may be working each day) or individually on their own projects. Each student has to complete a project during his third year, and although some may do livestock, engineering, or other work about half usually choose a crop project. Simple field experiments made ideal projects, as they involve field work (some labouring, some weighing and measuring), numerical office work, and food for thought. They also provide valuable examples for school lectures on field experimentation methods; and are, often, more useful as a demonstration of crop husbandary than would be simple non-experimental cropping, because they help to bring home to students the fact that we are still learning the answers to many questions. For example, we cannot teach them the proper spacing for dalo until we ourselves know; and a trial such as that reported elsewhere in this issue† helps them to realize that we do not, yet.

The school resources of land and labour limit these teaching-experiment projects to relatively small simple trials, which if planned in a vacuum, would contribute little to research knowledge. But by close cooperation between the present Crop Husbandry lecturer (Mr. J. Berwick, C.B.E.) and appropriate Research Officers the school projects are now being contrived to supplement research programmes (e.g. by giving extra replication, by filling a gap, etc.) Each of the papers in the issue from the School represents the drawing together by Mr. Berwick of the results of two or three related student projects (the students being named as co-authors) and each is a welcome contribution to research in Fiji.

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* Rice Research in Fiji, 1960-1970, part IV, long term trials.

Fiji agric. J. (1972), 34, 44-50.

YAM *(DIOSCOREA ALATA)* PLANTING RATE, STAKING, VARIETY AND PALATABILITY TRIALS.

by

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SUMMARY

In a factorial trial at Koronivia, yams with vines supported on a horizontal trellis yielded 30%, and vertically-staked yams 150%, more than unstaked yams. The yields of Jamani and Beka were respectively about double and treble those of two Taniela varieties (which suffered from anthracnose); plantings of setts weighing about 240 and 400 gm respectively yielded about treble and quadruple those of 125 gm setts. These effects were multiplicative. Beka, planted with large setts and vertically-staked, yielded 53 mt/ha (21.2 tons/ac).

In a palatability trial, these four varieties were compared with ten less-well-known varieties. *Taste* and *texture*, were distinguished, and found to be positively, but not highly correlated. Some of the lesser-known varieties were much preferred in either taste, texture, or both to Beka (in particular) and to the Tanielas and Jamani (to a lesser extent).

INTRODUCTION

Little has been written about yams in Fiji, and few studies made except some variety trials (8). Although popular, because they store well and are more nutritious than most tropical root crops (4), they are relatively little grown. The 1968 Census (2) found only 584 ac of yams as a sole crop, mostly in the dry zone (Ba 96, Bua 74, Macuata 61 ac) or on islands with comparatively low rainfall (Lau 77, Lomaiviti 33,). There were also 3,043 ac of intercropped yams. (c.f. the census finding of 8,629 ac pure, + 8,428 ac intercropped, cassava, and 3,064 + 8,507 ac of dalo). The mean yield of the yam plots harvested in the census was 6.5 tons per acre (16.5 mt/ha.)

Many species of yams are cultivated but two together account for the bulk of world production: *D. alata,* a native of S.E. Asia, but now spread throughout the tropics including Fiji and *D. rotundata,* native of, and still little grown outside, West Africa (3). Two other important species are *D. cayensis,* and *D. esculenta,* the latter of which is grown to a small extent in Fiji under the name *Kawai.* Generally these, and other species of *Dioscorea* are better liked, but less grown and more costly, than other roots, and in many countries (including Fiji) yam culture has declined in historic times, usually with cassava taking its place.

This decline seems to be largely because yam cultivation requires more labour than e.g. cassava and yields are generally much lower unless (a) a large amount of planting material is used, (b) the crop is staked and (c) the crop is weeded more often than other root crops need be.

The first is psychologically difficult for subsistence farmers, as the 'setts' planted are tubers, or pieces of tuber, which could otherwise be eaten, while the last two add to the cost and labour involved. The first two practices are traditional in most yam-

*Lecturer

†Student

growing countries but not all: e.g. in Barbados, where *D. alata* is the species most grown, it is customary not to stake. Moreover, although both these practices are well-supported by experimental evidence, this comes mostly from W. African work with *D. rotundata*: e.g. it has been shown (5) that yield per acre, as well as individual tuber size, increases with height of stake up to 12 ft. This work has recently been reviewed by Enyi (6). Coursey (3) mentions only two West Indian trials on staking (in both it gave a big yield increase), and no seed rate studies of *D. alata* in particular (although he mentions many studies of yams in general, all showing that a sett weight of more than 0.5 lb. [220 gm] is desirable).

As regards weeding *D. alata*, Brown (1) quotes a Trinidad writer as saying that there weeds do more damage among unstaked than among staked yams; while Ronanet in Guadaloupe (7) points out that controlling the weeds in unstaked yam culture is very important.

In Fiji *D. alata* is usually grown with only a low trellis of sticks, and our departmental Field Manual says that a sett size of about 4 oz (115 gm) is 'preferred'. This seems to be a statement of current practice rather than a recommendation, but, insofar as it might be taken as the latter, it is extremely questionable, in view of the weight of general evidence that larger setts are better. Weed control is usually poor.

Thus there appeared to us to be scope for a field experiment on these factors which would be likely to give useful results, possibly leading to improvements in Fiji practice while providing a useful school exercise in field experiment methods. An experiment varying stake and sett-size while keeping weed competition constant, seemed most likely to give big treatment effects.

It is common knowledge that yams vary in their eating qualities. Doku (5) found that *D. rotundata*, varieties differed greatly in yield and taste; yield ranged from 1.5 — 4.5 tons/ac (3.8—11.2 mt/ha), and the two best varieties in respect of taste yielded only 1.5 and 2.5 tons/ac. In Fiji with *D. alata*, it has been pointed out (8) that no critical palatability studies have yet been made. Varietal palatability trials were therefore made by the school during the year. The School is particularly well able to undertake such trials as the students, a representative group from all the races and provinces of Fiji, are ever-ready to sample extra food and able intelligently to assess its quality.

CULTURAL AND VARIETAL TRIAL

Design and Treatments

This was a split-plot multi-factorial trial with three blocks of nine whole plots to accommodate all combinations of three sett-sizes and three staking treatments, with each whole plot split into four sub-plots for varieties. The sett-size treatments were small, medium and large with details as follows :—

		Small	Medium	Large
Sett wt.	oz	3-6	7-10	12-16
	gm	86-170	200-285	340-460
Wt. planted	Tons/ac	0.8	1.6	3.0
	Mt/ha	2.0	4.0	7.5
Cost/ac	$F	80	160	300
Cost/ha	$F	200	400	750

The staking treatments were (a) none, (b) horizontal stakes of bamboo supported about 20 in. above the ridges, and (c) vertical stakes, cut from scrub, about 1.2 in. (30mm) diameter and 6 ft (2m) long, one per plant. The cost of these stakes depends on local availability, and transport. The cost at Koronivia for purchase and erection was $40/ac for the horizontal stakes and $120/ac for the vertical.

The varieties were those available from our Departmental warehouse, at Suva Wharf, that deals with quarantine and general import and export of agricultural commodities. These include yams coming from the outer islands for sale in Suva, of which four varieties, all from Kadavu, were available at the time, viz: Taniela Balavu, Taniela Leka, Beka and Jamani. The Tanielas are popular, medium-sized, white-fleshed varieties; Taniela Leka has a rounder tuber which makes it suitable for packing for export; Beka, as sold commercially, is a mixture of two types (A.

Hazelman, personal communication); (a) large, rough-skinned, much-branched. with white flesh, too large to be a good eating variety but likely to win prizes at agricultural shows, and (b) a smaller, smooth-skinned rounder type but still 'winged' (*beka* = Fijian for bat), with white flesh and more popular than (a). Jamani is another popular white-fleshed variety with a longer tuber.

The small sett treatment is about what has been said to be 'preferred' in Fiji. The medium and large are about the lower and upper ends of the range usually recommended for *D. alata* and *D. rotundata*, although sometimes in conjunction with somewhat wider spacing, as recommendations seldom go to more than about 2 tons/ac. The horizontal staking is a formalized version of customary Fijian practice. The vertical stakes are shorter than those customary in some other countries, where stakes over 12 ft are sometimes used.

The trial site was in 3 ft ridges, on which the yams were 2 ft apart. Ten ridges by 16 ft constituted a gross whole plot. There were no guard rows between the sub-plots, which were two ridges (6 ft) by 6 plants (12 ft), i.e. 1/613 ac (1/1515 ha) containing 12 plants. This might be considered unduly small but it must be remembered that the trial was intended primarily as a school exercise, to be done within the school's limitations of land and labour, rather than as a self-contained research project.

Management

The site (known as FSA field A2, a refenced part of the old KRS field 2d) was on Rewa sandy clay loam (9) and had previously been under pasture, largely of Koronivia grass *(Brachiaria humidicola)*. It was ploughed twice, harrowed and ridged at 3 ft and planted in early September, 1971. The whole area was given a pre-planting dressing of 224 lb/ac (250 kg/ha) each of superphosphate and potassium sulphate; and later 168 lb/ac (188 kg/ha) urea was applied in October and again in November. The trial was sprayed with atrazine after planting pre-emergence of the yam shoots, and hand-weeded twice; later there was severe competition from weeds, in which Koronivia grass was dominant. The trial was harvested at the end of April, 1972.

Results

Symptoms of anthracrose leaf-spotting disease caused by *Colletotrichum pestis* were soon seen on the Taniela varieties and by harvest they were suffering severely. Their yields averaged only about 3 tons/ac. Jamani and Beka were little affected by the anthracnose and grew well, particularly when staked. The former yielded 6.5 tons/ac on average of all sett-size and staking treatments and the latter 9.5 tons/ac. There were big effects of sett-size and staking, and big interactions between all the factors. Table 1a shows the main effects and 2-way tables in metric tonnes/hectare.

As discussed in the Appendix a simple analysis of variance of these figures is of dubious validity, because the effects are so large that assumptions of homogeneity and additivity of error are suspect. Logarithmic transformation allows a valid analysis in which, as shown in Table 1b, and the Appendix, the main effects are very highly significant but all the interactions negligible and non-significant: i.e. the apparent interactions in the original data take the form of a multiplication of effects.

The sett-size and staking effects are best considered omitting the varieties which suffered severely from disease, i.e. on average of the Jamani and Beka yields only, which were:

	Small setts	Medium setts	Large setts
	Yield in tons/acre		
No stakes	2.0	5.5	8.0
Horizontal stakes	2.7	7.9	9.8
Vertical stakes	5.8	13.2	17.1

The Jamani yields are about 20% lower than these averages throughout, and the Beka about 20% higher, with a yield of 21.2 tons/ac (53.2 mt/ha) with large setts and vertical stakes. Although based on only three sub-plots with a total of 36 plants, this yield accords so well the general trends of effects throughout the experiment, which appear highly significant and free from interaction in the logarithmic analysis, that it must be considered as well established (see Appendix for an estimate of its Standard Error).

TABLE I

2-FACTOR TABLES OF YIELDS OF FIELD TRIAL

	(a) Mean yields, mt/ha				(b) Logarithmic means of yield in mt/ha with S.Es. derived from analysis of variance of logarithms of plot yields.				
	Staking				Staking				
	None	Horiz.	Vert.		None	Horiz.	Verti.		
Taniela Balavu	4.0	7.0	12.5		0.44	0.91	1.08		
Taniela Leka	4.3	7.0	12.5		0.53	0.94	1.06		
Jamani	10.5	15.1	23.6		0.81	1.28	1.41		
Beka	15.6	19.1	35.1		1.03	1.41	1.53		
	Sett-size				Sett Size				
	Small	Medium	Large	Varietal Mean	Small	Medium	Large	Varietal Mean	
Taniela Balavu	3.0	8.3	12.1	7.8	0.58	0.79	1.06	0.81	
Taniela Leka	3.3	9.0	11.3	7.8	0.60	0.84	1.07	0.84	
Jamani	6.4	18.6	24.2	16.4	0.98	1.16	1.37	1.17	±0.018
Beka	11.0	25.9	34.2	23.7	1.16	1.26	1.56	1.32	
	Sett-size			Stake Mean	Sett-size			Stake Mean	
No Stakes	3.3	9.3	13.0	8.5	0.49	0.67	0.95	0.70	
Horiz. Stakes	4.8	13.3	17.8	12.0	0.94	1.10	1.37	1.14	±0.021
Vert. Stakes	9.5	23.8	30.3	21.2	1.07	1.27	1.48	1.27	
Sett Size Mean	5.8	15.6	23.8		0.83	1.01	1.26	±0.021	

Discussion

The varietal result is in accord with those of past trials (see Table 5 of [8]) insofar as Beka proved the highest yielder. Jamani, however, had previously done badly in wet zone trials, although bearing about the same relation to Beka on average of all past trials as in the present one. Some Taniela varieties had previously been noted to fail in wet zone trials because of anthracnoce, but not Taniela Balavu which had previously done fairly well in the wet zone. Some confusion of variety indentification may account for this.

The sett-size and staking results accord well with those of research in other countries, so despite the little replication of this trial they can be accepted with considerable confidence. At face value they suggest that by staking and using larger setts, yam culture in Fiji can be much more profitable than hitherto supposed. The net yields (i.e. yield harvested minus weight of setts planted) of Beka with vertical stakes and (a) medium and (b) large setts, are (a) 13.7 and (b) 18.2 tons/ac, which at Nausori market 1971 average retail price is worth (a) $1,530 and (b) $2,050 per acre, or at the current Departmental buying price in outer islands (a) $920 and (b) $1,230 per acre. These are excellent returns by any standards, even after taking the $120 per acre cost of staking into account.

PALATABILITY TRIALS

Method

In one trial, tubers of the four varieties of the field trial were boiled and a portion given to each of ten students for assessment of taste, and of texture, on five-point scales. In the other trial, tubers of ten other varieties were obtained and boiled, in batches over a two-day period. Again each variety was sampled by ten students, with each student tasting three or four varieties on each occasion, but about thirty students altogether were involved in the tasting with a random allocation of varieties to students on each occasion (an incomplete block design, with 'student-occasions' as blocks, would have been theoretically better, but unduly complex for a student project). Thus over the two trials each of fourteen varieties was marked for taste and texture by ten students.

The tubers of Beka used in the tests were of type (b) mentioned above.

TABLE 2

RESULTS OF PALATABILITY TRIALS

	Marks out of 50 Taste	Texture
Rewamoni Mi	44	39
Kuro	41	47
Kaumaile	41	37
Niumadu	40	37
Vurai Dra	37	42
Vili Lekaleka	35	45
Uvi ni Vutuna	35	40
*Jamani	35	33
Teve	34	34
Kasokaso	32	34
*Taniela Leka	32	31
*Taniela Balavu	31	33
Rewamoni Gri	30	45
*Beka	29	33
Standard Errors	±1.8	+1.5

*Varieties in the field trial.

Results

Table 2 shows the total score of each variety. Strictly speaking combined analysis is complicated because among the four varieties of the first trial variation between students can be taken out (as 'block' variance) giving comparisons among these varieties a lower error than that applicable among the other varieties, or to comparisons between groups. The differences between errors, however, are probably trivial, so a simple analysis as if each variety had been tested by a random sample of ten students was made to get the errors shown in Table 2.

Discussion

All varieties were considered acceptable but some were better than others. With the exception of Jamani, the commercial varieties were in the lower part of the table for taste and were also low in texture. There is a low correlation between taste and texture ($r = 0.35$) indicating that the tasters are genuinely distinguishing between these two characters and not merely giving good scores on both counts to anything they liked, and that the two characters are independent. It seems that the varieties at the top of the table should command a higher price than the common commercial varieties.

ACKNOWLEDGEMENTS

We acknowledge with thanks the help received from members of other branches of the Department of Agriculture, in particular from P. Sivan and A. J. Vernon, of the Research Division, in planning and analysing these experiments and from A. L. Hazelman of the Quarantine Section who was of great assistance in obtaining planting material.

The appendix is written by A. J. Vernon.

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APPENDIX

The results of the field trial provide a remarkable example of experimental effects that are better described multiplicatively rather than additively. In biological population studies (e.g. insect counts in crop trials) a multiplicative situation is commonplace; but in crop yield studies, although there is often some suspicion of multiplicativity (and the knowledgeable agronomist should be aware of this) it is very rarely as well-marked as in this particular trial.

The orthodox analysis of variance of experimental results is based on an additive model. For example in a two-way table of 'blocks x treatments' a plot in a block whose mean yield is 3 units less than the overall mean yield, and having a treatment whose mean yield is 5 units more than the overall mean, will have a 'model' yield of 2 units more than the mean. The difference between this 'model' yield and the actual yield of the plot in question contributes to what is known as the error S.S. (sum of squares). Such a difference (known as a 'residual') can be calculated for each plot and the sum of squares of these residuals is in fact the error S.S. (more usually found by subtracting block and treatment S.Ss. from the total S.S.)

Similarly if the treatments have a factorial structure, say 3N x 3P, then any any one combination (say N_2P_1) has a 'model' yield which differs from the overall mean by the sum of the appropriate N and P main effects. E.g. if the effect (difference from overall mean) of N_2 is +6 units and the effect of P_1 is — 2 units the 'model' yield of N_2P_1 will be the general mean, plus (+6), plus (−2). In this case the sum of squares of the differences between the 'model yields' of all the NP combinations and the corresponding actual yields is known as the 'N x P interaction' S.S. Thus in this analysis the effect of any treatment is considered to be an absolute amount; and any departure from additivity of factors is known as *interaction* Most agronomists, when they first appreciate fully this implication of the analysis of variance, query why addition, and not multiplication, of effects should be assumed. One reasons, however, for generally using the additive mode. is that it is easier to discuss, and consider the economics of, additive effects. Thus a response to a certain dressing of fertilizer, insecticide, fungicide, etc., is better stated as an 'X kg/ha' increase in yield than as a 'Y%' increase because the former can be given a cash value which can be balanced against cost, while the latter can't. Another reason is that it has been found, by experience, that the additive 'residuals' in field experiments are usually approximately normally distributed; which is essential if the error variance given by the analysis of variance is to be used for significance testing.

Above all, *when effects are small it makes no practical difference which model is used.* For example suppose that of the four treatments (−), N, P, and NP, the yields of the first three were 100, 120, and 110. Adding effects, the "no interaction" NP yield would be 130; multiplying, it would be 132.* Thus an actual NP yield of 125 would be considered a negative interaction either way, and of 140 would be a positive interaction. A yield of 131 would be a positive interaction additively and a negative one by multiplication, but in practice would usually be entirely non-significant in either case.

It is, therefore, only when effects are large that one has to consider this point. Often when effects are very large there is a tendancy for multiplicative interaction. In particular if in one block, or

*Because the effect of N is to multiply by 1.2, that of P to multiply by 1.1, and together to multiply by (1.2 x 1.1) = 1.320.

at one level of one factor, yields are very low then there is likely to be little difference due to any other factor. *(Reductio ad abursdam,* if in a variety x fertilizer trial, one variety has failed to grow, then the response to fertilizer on that variety is bound to be nil). Not only may it then be better to *present* the results in multiplicative terms, but is often necessary to *analyse* in those terms, because the errors tend to be multiplicative also, thus invalidating significance tests based on an additive analysis of variance, because the residuals will not then be normally distributed.

Such analysis is quite simple: logarithms of all the yields are taken, thus transforming all multiplicative relationships into additive ones. For example, Table 1 shows the three 2-factor tables of the yam experiment, (a) in their normal form and (b) in their logarithm form. Every (a) table mean shows a very big interaction between the factors: e.g. in the bit-size x staking table, if small bits are used horizontal staking gives increase in yield of 1.5 mt/ha, and vertical staking one of 6.2; but with medium bits the corresponding figures are 4.0 and 14.6. In Table 1b however the figures are 0.45 and 0.58 with small bits and an almost-identical 0.43 and 0.60 with medium bits.

The individual-plot logarithms can be variance-analysed. For the yam trial, the analysis of variance of the plot yields in lb/plot, compares with that of the logarithms of these figures as follows (log variances x 10^3):

	d. of f.	Variances from raw data	Variances from log data
Blocks	2	142	80
Staking (S)	2	4248	3220
Bit-size (B)	2	3426	1680
S x B	4	232	4
Error (a)	16	24	16
Variety (v)	3	3461	1720
S x V	6	262	10
B x V	6	238	9
B x S x V	12	24	9
Error b	54	16	8

As seen also in the 2-way tables, the 2-factor interactions, which were highly significant in the raw data are entirely non-significant in the log. analysis. It must be understood, however, that the object of the log. analysis is not to conceal these interactions but to express them in their simplest form. In the original data three highly significant interactions, involving altogether 16 degrees of freedom, demand interpretation. The fact that the interactions vanish with log. transformation supplies an interpretation of all 16 d.f. in one phrase: *the effects of the factors multiply.*

It is suggestive of an improvement in normality of distribution of errors that whereas the whole-plot and sub-plot coefficients of variation were 24 and 19% respectively in the analysis of the raw data, the corresponding values in the log. analysis are 11 and 9%. The suspicion of non-normality and heterogeneity of error in the raw data is so strong as to invalidate any calculation of S.Es. for the main effects, as set out in the paper, or 2-way tables as in Table 1a. If it is desired to present treatment means in mt/ha complete with standard errors, this can be done by anti-logging the logarithmic means and their logarithm S.E. limits. For example, in log. terms the mean yield without staking (see Table 1b) is 0.70 (+0.021). Thus the upper S.E. limit is 0.721 and the lower is 0.679. The antilog of the mean is 5.00, and of the upper and lower limits is 5.25 and 4.78 respectively, ie. +0.25 and −0.22. For practical purposes this can be stated as 5.0 (+0.24). With a similar averaging of positive and negative errors the horizontal staking and vertical staking means become 13.8 (±0.65) and 18.6 (±0.85), mt/ha throughout. The figure given in the paper for the yield of the highest yielding treatment combination, ie. 21.2 tons/ac, has an S.E. of about ±2.3 tons/ac.

A. J. VERNON.

Fiji agric. J. (1972), 34, 51-56.

DALO (COLOCASIA ESCULENTA) FERTILIZER, VARIETY, WEED CONTROL, SPACING AND PALATABILITY TRIALS

by

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SUMMARY

In a variety x rate-of-nitrogen factorial trial the longer-maturing varieties (Tausala-ni-Samoa and Samoa) yielded an average of 13.9, and the shorter maturing (Kurokece, Vavai Dina, Vutikoto) 11.9 mt/ha, but the latter may have been depressed by premature harvest. There was a response of 2.8 mt/ha to heavier application, and no variety x N interaction. Palatability trials of the produce showed that N, particularly at the heavier rate (1200 kg/ha) tended adversely to affect both taste and texture, particularly when applied (as it was on the early maturing varieties) only 11 weeks before harvest.

In two other trials, (a) a plant population at least as dense as 27,000 plants/ha was confirmed to give greater yield than any wider spacing, with a suggestion than more plants per acre might be better still, although at 48,000 p/ha up to 30% of the produce might be unmarketably small; and (b) paraquat was confirmed to be an effective herbicide for dalo.

INTRODUCTION

The review article 'Taro *(Colocasia esculenta)* (6) summarises the literature on dalo, (as Taro is known in Fiji) up till 1969, including references to the First International Symposium on Tropical Root Crops held in Trinidad in 1967. Papers on this crop at the Second International Symposium (Hawaii, 1970) included a review of Fiji work by Sivan (8).

Some of the trials reviewed were at Lomaivuna, and others at Koronivia, on the levee-soil area, part of which is now occupied by the school farm. The results most relevant to our work were those of the three variety trials 1966-1968, at Koronivia. A fourth trial in this series, in 1969, has also been reported by Sivan (9). Four of the varieties that occurred were also compared in 1968-1972 in a rotation trial at Koronivia, by splitting the four dalo plots each year into four. That means that dalo yields for each year have been given in annual reports, as reviewed by Vernon (11), but the separate varietal yields are hitherto unpublished. Over the four years they averaged:

	Mt/ha	
	Variety trials 1966-1969	Rotation trial 1968-1972
Qawe-ni-Urau	15.1	8.6
Kurokece	14.1	7.4
Vavai-dina	13.4	7.3
Tausala-ni-Samoa	9.2	6.0
S.E.	±1.5	±0.5

The SEs in each case are derived from years x trials interaction (Vernon, private communication). It seems to be well established that under these conditions Tausala-ni-Samoa is at least 1 mt/ha lower yielding than the much-cultivated Kurokece and Vavai Dina, and less well-established that the comparatively rare Qawe-ni-Urau is higher yielding. Three other varieties were present in three of the four variety trials: Mumu, which gave a little less than Vavai-Dina: and Samoa and Vutikoto which gave about the same as Tausala-ni-Samoa.

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The work reviewed by Sivan (8) also established that at Koronivia, the best time for planting dalo is between September and November, and confirmed the well-known fact that the larger the planting material, whether it be tops or suckers, the higher the yield (3).

At the time when the School's Planting Programme for 1971/72 was being considered, two further papers on spacing (10) and weed control (4) were in preparation and have now been published.

One constant feature in these trials in Fiji has been low yield. The review article (6) gives the following yields in various parts of the world.

	Metric tons/hectare
Hawaii lowland	37 — 75
India	34
Philippines	25
Hawaii upland	15 — 25
Fiji	8 — 15
Malaysia	9 — 10
West Africa	4 — 9
Trinidad	5

There is clearly room for considerable improvement in Fiji.

It appeared to us therefore that the School's resources could be best concentrated on one large trial to see if heavy dressings of nitrogen could increase yields of some commercial varieties without decreasing their palatability, with smaller trials on weed control and spacing.

VARIETY AND FERTILIZER TRIAL

Design and Treatments

There were six randomised blocks, with five whole plots for five varieties, two short-term, (Kurokece and Vavai Dina) one medium-term, (Vutikoto) and two long-term, Tausala-ni-Samoa and Samoa. The whole plots were split into three for levels of nitrogen: none, 400 and 1200 kg/ha. The planting distance was, as then usual at Koronivia, 90 x 60 cm. The subplots were (6.3 x 3.0) m, 35 plants including a guard-row, leaving a net plot of (4.5 x 1.8) m or 8.1 m^2, containing 15 plants.

Management

The site, F.S.A. Field D1, a refenced part of K.R.S. Field 2i, on Rewa clay-loam (7), had previously been under unfertilised cassava. It was ploughed and harrowed in early August, well in Blocks IV, V, and VI, but because of weather conditions badly in Blocks I, II and III. The whole area had a preplanting dressing at 250 kg/ha each of superphosphate and potassium sulphate. It was planted as suckers became available between 13 August and 6 September. Weeds were controlled in the first few months by horse-hoeing and rotavating, and later by hand. Urea was applied to the N_1 plots in two dressings on

TABLE I **RESULTS OF VARIETY X NITROGEN TRIAL**

Maturation period	Variety	Area yield Corms mt/ha	Individual plant yield Corms g	Individual plant yield Tops g	Individual plant yield Total g	Suckers Number
Short	Kurokece	12.7	710	510	1220	6.2
	Vavai Dina	11.7	650	570	1220	4.0
Medium	Vutikoto	11.3	630	100	730	4.7
Long	Tausala-ni-Samoa	14.3	800	130	930	4.8
	Samoa	13.1	730	160	890	1.4
		±1.3				
Rate of urea	none	10.6	590	250	840	3.4
	400 Kg/ha	13.4	750	300	1050	4.5
	1200 Kg/ha	13.8	770	340	1110	4.9
		±0.40				

19 October and 25 November, and to the N_2 plots in three dressings, 19 October, 25 November and 16 February. The trial was alongside the main road and 16 plants were stolen in early April. Harvesting of the early varieties started on 3 May, before they were fully ripe, to forestall further thefts; harvesting of the long-term varieties was completed on 10 July.

Results

The yields were recorded as corm-weight whereas the previous yields given in this paper have been of dalo as marketed, ie the corms with about 40 cm of leaf-base attached which weigh about 25% more than the tubers alone. Table 1 gives the main effects of variety and nitrogen on yield per hectare; the interactions were all non-significant.

Contrary to the results reviewed in the introduction, the long-term varieties yielded better than the short-term; but from the weight of tops (Table I) it is clear that the former were harvested prematurely, and it seems likely that had they been allowed to mature they would have been the higher yielding. The response to the first 400 kg urea/ha was significantly economic, but the lack of appreciable further response to the higher rate suggests that no increase in application over the lower rate would pay.

The importance of sucker-production, necessary for planting material for future crops, has been somewhat neglected in previous studies. As Table 1 shows, in this respect Kurokece is good and Samoa outstandingly bad.

PALATABILITY TRIAL

Method

The palatability of fresh corms, and of corms stored for seven days, was assessed using the method given for yams in another article in this journal (2). From a total of 68 students a random sample of 10 was asked to taste a boiled sample of each variety and to score it for taste, out of 10, and texture, out of 5.

Results

Whereas in the yam palatability trial *taste* and *texture* were to a considerable extent independent, in this trial the effect of variety, nitrogen and storage on the one were closely correlated with those of the other. The earlier maturing varieties were rated lower for both taste and texture than the late maturing, the mean scores being:

	Taste	Texture (x2)	Maturation
Kurokece	6.1	7.2	early
Vavai Dina	5.5	6.6	early
Vutikoto	7.3	6.4	medium
Tausala-ni-Samoa	7.3	7.1	late
Samoa	8.6	7.8	late
S.E.	±0.16	±0.22	

For both qualities the differences between the 'early' and 'late' maturing groups are highly significant and differences within groups are different at the 5% level or better. For both qualities, storage and nitrogen depressed score, and as Table II shows, in each case there was a significant interaction with varietal

TABLE II **RESULTS OF THE PALATABILITY TRIAL**

	Fresh	7 day	Mean S.E.	N_0	N_1	N_2	S.E.
Taste Scores							
Early Varieties	6.8	4.8	±0.16	7.5	5.7	4.8	±0.20
Late Varieties	8.0	7.6	±0.18	8.2	7.8	7.4	±0.16
Mean	7.5	6.5	±0.10	7.7	7.0	6.6	±0.12
Texture Scores (x2)							
Early Varieties	7.1	5.9	±0.22	7.1	6.5	6.0	±0.28
Late Varieties	7.6	7.2	±0.18	7.6	7.4	7.0	±0.24
Mean	7.4	6.7	±0.14	7.0	7.0	6.6	±0.18

'group', storage and nitrogen depressing the taste and texture scores of the early maturing more than the late maturing varieties. This is probably because the early varieties not only had the last nitrogen dressing closer to the time of harvesting than the late maturing but because they were also harvested less ripe.

The deleterious effects of storage and nitrogen appear slightly more pronounced in the *taste* than in the *texture* scores; but this is misleading, possibly because of the 5 point scoring for texture (compared with 10 point for taste), and possibly because the students allowed for a greater range of non-acceptibility in their concept of texture; samples scoring about 6.0 (3.0 x 2) for texture and perhaps a little less for taste were considered "unacceptable" in texture rather than taste. They were obviously "mushy", and unfit to be served at school meals. These studies were all of *boiled* dalo. When tubers from the "unacceptable" treatments were baked in a 'lovo' (a Fijian pit-oven), there were no complaints.

WEED CONTROL TRIAL

Design & Treatments

There were three randomised blocks with seven treatments. The dalo was planted on ridges 90 cm apart and 60 cm in the ridge. As the treatments were being applied primarily in the furrows, only a single (or shared) guard "row" was needed between plots. For herbicide application purposes each plot was three furrows wide (2.7 m), and for yield recording purposes two ridges (1.8 m) were taken and the ridges between plots discarded. The plot length was 6.0 m gross, 3.6 m net, giving a net plot area of 6.48 sq. m.

The treatments were

1. A hormone herbicide in the Phenoxy-acetic acid group, MCPA, 'Agroxone' at 2.25 kg a.i./ha.
2. A contract herbicide in the Quaternary Ammonium group, Paraquat, 'Grammozone', at 0.5 kg/ha.
3. A short-term residual herbicide in the Amide group, Propachlor, 'Ramrod', at 3.5 kg a.i./ha.
4. A long-term residual herbicide in the Triazine group, 'Atrazine', at 3.5 kg a.i./ha.
5. Hand-weeded and kept weed-free.
6. Hand-weeded twice, the customary treatment.
7. Unweeded.

Management

The site was in F.S.A. Field D1, previously K.R.S. Field 2 i, on Navua clay-loam (7) which had been fallowed for eight months, following a crop of cassava. At the end of August 1971 it was ploughed and in early September disc harrowed twice and ridged. It was planted with Vavai Dina on 10 and 14 September. The whole area received a dressing of 250 kg/ha each of superphosphate and potassium sulphate and later 400 kg/ha of urea in two dressings. Treatments 1, 3 and 4 were applied on 21 September, and Treatment 2 on 26 October. Hand-hoeing was done at the end of October and in early December. On 2 December Treatments 1, 2, 3 and 4 were all sprayed with Paraquat. Treatment 5 was maintained weed free. Observations were made on the crop and on the weeds in each plot. Harvesting was on 26 and 27 June.

Results

Observations on 6 October, and 5 days after spraying showed that MCPA, Propachlor and Atrazine had all caused some phytotoxicity, affecting 14, 25 and 28% of plants respectively. These three herbicides did not control the dominant weeds, paragrass, mimosa, *Muraina* and tar-weed, for long and it was necessary to spray later with Paraquat.

The yields, shown in Table III, averaged 5.5 mt/ha of corms, a poor yield but as much as could be expected on Navua clay-loam, following cassava. The yields fell into three groups, weed-free, hand-weeded twice, and sprayed twice with Paraquat, which averaged 7.4 mt/ha, MCPA, Propachlor and Atrazine which were significantly less effective, averaging 5.3 mt/ha, and no weeding at 1.3 mt/ha which could well have been omitted from the analysis of variance. Two conclusions may be drawn from this trial, firstly that in the

TABLE III

RESULTS OF THE WEED-CONTROL TRIAL

	Yield of corms mt/ha
Weed-free	7.8
Hand-weeded twice	7.0
Paraquat	7.3
MCPA	5.8
Propachlor	4.3
Atrazine	5.8
No weeding	1.3
S.E.	±0.88

wet zone on flat land, dalo may well be grown on ridges (from which mechanical lifting may be possible) and secondly that the use of paraquat as a satisfactory herbicide for dalo is confirmed.

SPACING TRIAL

Design, treatments and management

The trial consisted of three fan-shaped blocks, each with eight radii and nine arcs, the outermost radii and arcs being guard rows. The spacing increased logarithmically from arc to arc, from about (130 x 130) cm on the innermost to (400 x 400) cm on the outermost net arc, i.e. 47,000 to 5,300 plants/ha. This type of design will be explained more fully, with diagrams and bibliography, in a paper in the next issue of this journal (12).

The block were planted, each with a separate variety (viz. Kurokece, Vavai Dina, and Vavai Loa) adjacent to the before-mentioned variety x nitrogen trial, between 26 August and 10 September 1971. Superphosphate and potassium sulphate were each applied at 250 kg/ha before planting, and urea at 400 kg/ha on 19 September and 30 November. The trial was harvested on 18 May 1972.

Results

This trial was intended as a demonstration rather than to provide a reliable comparison of treatment mean yields. With only one replication per variety the experimental error is indeterminable but, with so few plants at each spacing, was *a priori* likely to be large.

In fact, however, the mean yields of the six closer spacings (Table IV) are in remarkably close agreement with the results of three recent well-replicated trials. The yields of these trials have previously been reported (10) as weight of produce as usually marketed, i.e. as corms with about 40 cm. of leaf-base attached. Sample weighings from the presents trials showed the ratio of corm to 'top' weights as marketed to be almost exactly 4: 1. Fig. 1 is a repeat of Fig 1 of (10), scaled down by 20%, with the new results added. The almost exact correspondence of the new points to the old (a) provides useful confirmation of the spacing/yield relationship (b) extends the basis of the evidence to include Vavai Loa (besides Kurokece, Vavai Dina, Qawe-ni-Urau and Tausala-ni-Samoa) and (c) provides a point for 47,800 plants/ha, well beyond the range of the previous results. The replication is so slight that little confidence can be placed in this, but the suggestion that yield continues to increase with increasing plant population, even to this very close spacing, is noteworthy.

As in the previous trials there was a suggestion of a spacing x variety interaction, which merits further study. In practice, however, the relative merits of very close spacing for different varieties is likely to depend more on varietal differences in production of suckers (a critical factor in continuous high-population culture) rather than slight varietal differences in the form of the yield/spacing curve.

This Department recently published an advisory leaflet in which it was recommended that dalo for market should be at least 10 in (25.4 cm) in circumference

TABLE IV

RESULTS OF THE SPACING TRIAL

Number of Plants per hectare	Yield of Corms mt./ha.	Individual Corm g	Plants Top g	Number of per plant.
5,300	5.9	1110	620	10.8
6,700	6.6	980	490	7.8
8,800	7.4	850	420	7.6
12,000	9.0	750	460	5.7
17,200	10.8	630	390	4.6
26,900	16.4	610	310	3.9
47,800	21.0	440	270	2.4

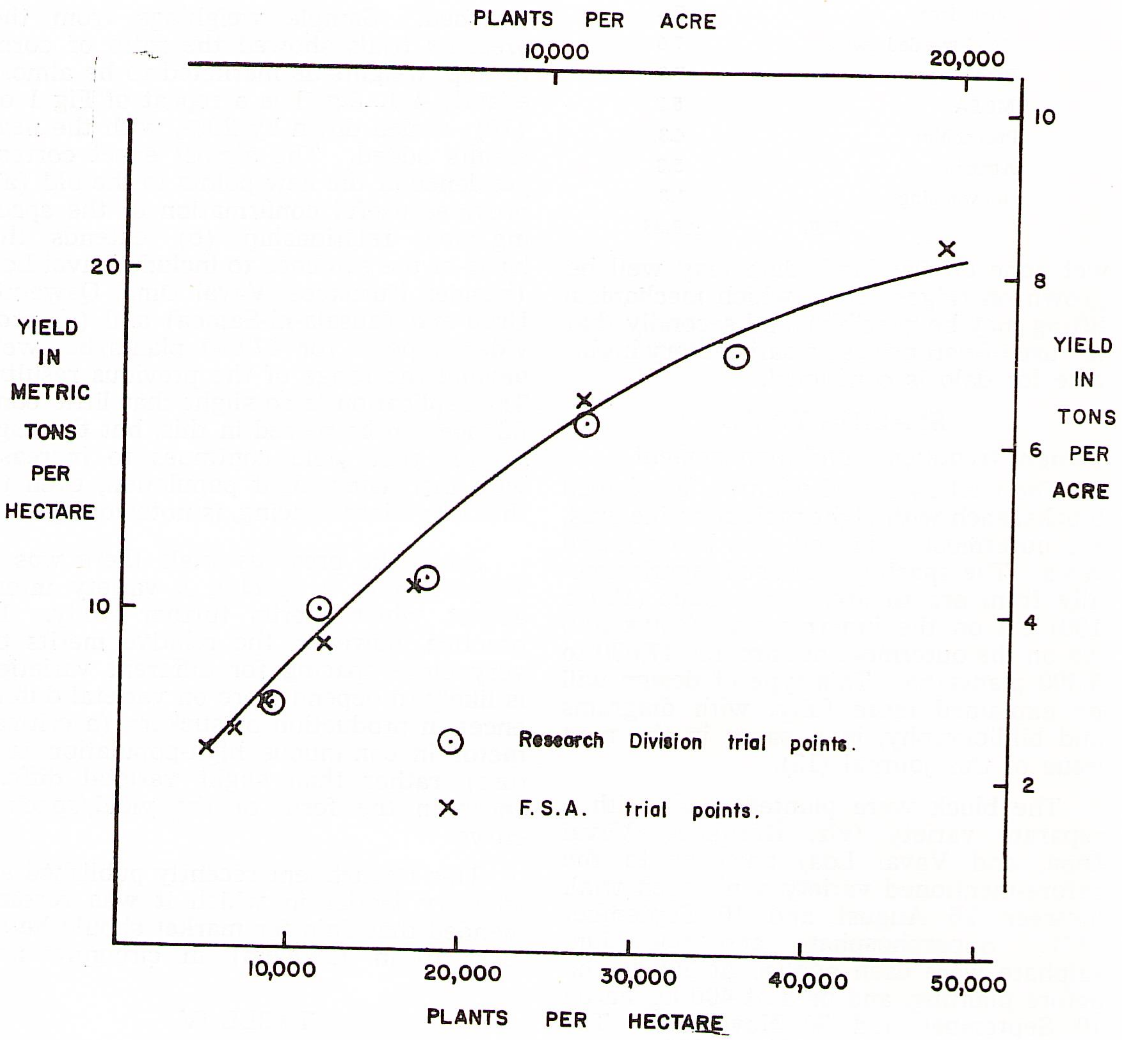

Figure 1. Mean yields of the Research Division and F.S.A. spacing trials.

The average weight of corms of this circumference in the spacing trial produce was 350g. Of the produce of the 47,800 p/ha plots, 29% were lighter than this, and of the 26,900 p/ha plots 10% were lighter. Presumably these fractions of such crops at these spacings could be marketed, if at all, only at a sub-standard price.

ACKNOWLEDGMENTS

We acknowledge with thanks the help received from other branches of the Department of Agriculture, in particular from P. Sivan and A. J. Vernon of the Research Division in planning and analysing these experiments. We would especially like to thank Filimoni Raigiso, joint author with B. E. V. Parham of a paper on Dalo in Fiji written in 1939 (5), who spent much of his time just before his retirement in collecting planting material for the trials.

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Fiji agric. J. (1972), **34**, 58–60

THE EFFECTS OF DRENCHING AND SUPPLEMENTARY FEEDING ON THE GROWTH RATES OF BEEF WEANERS DURING THE DRY SEASON

by

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SUMMARY

In a trial on typical hill pasture at Sigatoka, 20 regularly drenched beef weaners grew at a mean rate of 0.14 kg/day during the 30 weeks after weaning, in the dry season, while 10 similar undrenched animals had light, occasionally moderate, intestinal parasitic infestations and grew at a rate of 0.07 kg/day. A molasses/urea lick, available to ten of the drenched weaners throughout the period, was little used and with no significant effect.

The economic return from drenching at monthly intervals or feeding molasses/urea to weaners on hill land in the Sigatoka area is doubtful with such low weight gains, which were probably due mainly to poor quality feed.

INTRODUCTION

Beef cattle in Fiji, particularly young weaners, tend to loose condition during the May - October dry season, although this loss is less severe than in some other tropical beef-producing areas. It has been suspected from the appearance of such cattle that this weight loss is due not only to deficiencies in pasture quality and quantity, resulting from the low rainfall, but also to the presence of internal parasites.

No study seems to have been made in Fiji, however, of the effects of dry season supplementary feeding, or of drenching on the growth rates of young beef cattle, before that now described.

EXPERIMENT PARTICULARS

Location

The trial began on 13 April, 1970 on three contiguous, apparently uniform paddocks of 15 ha (36 acres) each, in an area of fairly steep hilly country at Sigatoka Research Station. The main vegetation was Nadi blue grass *(Dicanthium caricosum)*, wire grass *(Sporobolus spp)* and reeds *(Miscanthus japonicus)*, all typical of unimproved pasture in this locality.

Fifteen Santa Gertrudis and fifteen Brahman calves, were weaned at about six months of age, and five of each breed were allocated to each of the following treatments :—

Code	Treatment	Sex numbers
(−)	No drenching; no S.F.*	7 heifers, 3 bulls
D	Drenching monthly, no S.F.	7 heifers, 3 bulls
DS	Drenching monthly, given S.F.	6 heifers, 4 bulls

*S.F. = supplementary feed, described below.

The mean animal weight at the start was 145 kg (318 lb) and the animals were allocated to treatments, so that their total weights were practically identical. Each group of animals was then allocated to one of the three paddocks. In the D.S. paddock, roller drums, as suggested by Moore (2) were filled twice weekly with a molasses-water-urea mixture, and steamed bone flour was provided. The animals in D and D.S. treatments were drenched monthly with an anthelmintic (Nilverm).

The treatments were stopped on 10 November, when the bulls were separated onto improved pastures while the heifers remained together until 30 December.

Recording

The animals were weighed fortnightly after an 18 hour fast. Samples of faeces

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were collected monthly (dates in Table 3) from each animal, reaching the laboratory about four hours later. Eggs were counted and larvae differentiated by the methods described by Roberts and Sullivan (4) and Keith (1) respectively.

Rainfall

Rainfall totals for the dry season (April to November) at 988 mm (38.9 ins) were slightly above the average of 825 mm (33.2 in.). Table 1 shows monthly rain. The trial finished in early November at the start of heavy rain.

RESULTS

Feed taken

The D.S. animals started consuming the molasses only after about six weeks, and never showed more than a mild interest in it. Their consumption of supplementary food over the whole period averaged only 370 g (13 oz) molasses, 26 g (0.9 oz) urea and 17 g (0.6 oz) steamed bone flour per head per day.

Liveweights

Table 2 shows the liveweights at various dates. The D.S. animals grew faster than the D throughout but the final weight difference (14 kg) is not statistically significant when tested against between-animal, within-treatment, variance.

The difference between drenched and undrenched animals is more marked. The former grew at the rate of 0.14 kg/day (mean of D and DS treatments) over the trial period while the latter grew at 0.07 kg/day. By the previously mentioned test, the difference in final weight between drenched and not appears significant. This test, however, is inconclusive because of the lack of replication of paddocks. It shows that it is unlikely that the apparent difference is due to a chance selection of better animals for the D and DS treatments, but leaves open the possibility that the D and DS paddocks may have provided better grazing than the (—) paddock.

Worm egg counts

At weaning there was a general 'moderate' level of worm infestation by the criteria of Skerman and Hillard (4). This declined markedly during the next 8 weeks, especially in the D and DS treatments. Thereafter the levels of all the species remained negible in the D and DS treatments but in the undrenched animals, the *Bunostomum* infestation rose to a 'moderate' level, and that of *Cooperia, Hoemonchus,* and *Oesophagostomum* to the 'light' level.

These levels take into account not only egg numbers but also pathogencity: *Cooperia* species and *Oesophagostomum* are moderately benign, but others are more vigorous blood suckers.

TABLE 1

MONTHLY RAINFALL

Month	Rain, mm	Rain, ins
April	188	7.4
May	106	4.2
June	137	5.4
July	55	2.2
August	10	0.4
September	122	4.8
October	124	4.9
November	224	9.6
Total	988	38.9
Average	823	33.2

DISCUSSION

Feeding urea/molasses mixture appears to have little or no beneficial effect on weaner cattle in the dry season. This is not unexpected as its main value in other countries is as a drought relief ration to prevent weight loss. In Fiji in 1970, the pasture did not generally become so poor that such conditions prevailed.

Although no formal statistical significance can be attached to the apparent effect of drenching it is so large (an almost-doubling of the liveweight gains) as to command confidence. But the worm infestations were only moderate, and the overall weight gains still so low (only 0.14 kg/day, mean of two "drenched" treatments) that regular monthly drenching is unlikely to be economically useful. A material cost of $2.60 for Nilverm resulted in an increased meat value of $3.10. This does not take into account the cost of mustering and administering the drench.

It could be economical however to drench once at weaning and at greater intervals thereafter. Further work into the frequency of drenching would be useful. The value of drenching when good feed is available, eg. in the wet season or with improved species, is not known.

It seems then that weaner ill-thrift is is not primarily due to worm infestation and that urea/molasses mixture is unable to act as a suitable protein substitute. The ill-thrift is most likely due to a complex of factors in which nutrition is most important.

This suspicion was reinforced when another group of selected weaner bulls on siratro/guinea grass on fertile alluvial land gained ten times more weight than the undrenched group on the hill land.

A further trial to compare the benefits of a suitable supplementary feed and also of the inclusion of a legume in the pasture, with normal grazing is planned.

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TABLE 2

LIVEWEIGHTS AT 6-WEEK INTERVALS

	Dates (calendar, and weeks from start)				
	13/4	26/5	7/7	29/9	10/11
	0	6	12	24	30
	kg/animal				
Drenched with feed supplement	145	154	149	162	180
Drenched, no feed supplement	144	150	147	155	166
Undrenched, no feed supplement	145	149	140	148	159

TABLE 3

PARASITIC INFESTATION (eggs or larvae/gm of wet faeces)

	Date								
	30/4	27/5	25/6	23/7	19/8	16/9	16/10	9/11	20/12
Parasitic Genus	**Undrenched**								
Cooperia	683	362	234	146	111	59	27	186	28
Haemonchus	3	25	6	53	1	69	41	7	50
Bunostomum	—	24	1	22	—	3	25	8	—
Oesophagostomum	—	74	22	22	6	126	29	63	21
	Drenched.								
Cooperia	160	180	—	—	12	95	21	66	4
Haemonchus	—	—	—	—	2	45	17	2	14
Bunostomum	—	—	—	—	—	—	—	—	—
Oesophagostomum	—	47	167	—	1	1	—	1	4
	Drenched, with supplementary feed.								
Cooperia	—	367	42	—	96	87	34	81	18
Haemonchus	—	1	—	—	—	7	10	—	16
Bunostomum	—	—	1	—	—	1	—	—	—
Oesophagostomum	—	10	—	—	—	11	1	1	16

Fiji agric. J. (1972), 34, 61–70

RICE RESEARCH IN FIJI 1960-1970 PART IV, LONG TERM TRIALS

by

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SUMMARY

In a factorial fertilizer trial on continuous dryland rice, at Koronivia the N effect increased from 300 to 540 kg/ha, and the P effect from nothing to 210 kg/ha, during the first 13 years. In the absence of N there has been a response of 250 kg/ha to a K-Ca mixture, applied only during the last 5 years.

In several studies dryland rice yielded more (double in one trial) when grown in succession to grass leys than when grown in a rice-fallow rotation; and in another trial it yielded more when following roots or maize than when in rotation with fallow. In a drainage trial, wide cambered beds were best for rice, narrow beds best for sorghum.

These studies are of little relevance to rice culture in Fiji today: all except the drainage trial were on well-drained, fertile, soil, better used for more profitable crops than dryland rice.

INTRODUCTION

By 'long-term trials' is meant any field experiment in which one set of plots is studied for more than two years. All the long-term arable crop trials yet done in Fiji have included rice, and all have been at Koronivia Research Station, except one, which ran at Seaqaqa from 1966 to 1969, with rice as only a minor component, and with results already summarized adequately (15).

The formal long term trials at Koronivia began in 1953 with wetland and dryland rice 'exhaustion' (ie continuous cropping) trials. Both of these finished before the decade under review began; and a third trial, a revised form of the first, finished early in the decade and is conveniently considered now with its predecessor.

The wetland exhaustion trials (1953-1962)

The exact sites of these are now unknown but they were both on the Navua clay loam close by the Nausori-side boundary of the station (Fig 1). The land was puddled, rain fed, planted in rice each summer, and fallowed in winter.

The first trial comprised six whole plots accommodating three replications of the comparison of deep (tractor) with shallow (bullock) ploughing. Each whole plot was split into 8 sub-plots to accommodate a 2 N x 2 P x 2 L factorial, in which L represented the growing of a legume green manure in the winter as opposed to a winter fallow. The deep ploughing treatment proved impracticable, the legume did not grow well, there was no response to phosphorus, and a negative response to nitrogen. The last report on the trial (3) included annual yields of the whole trial period (1953-1958).

This was followed on an adjacent site by a conventional 2N x 2P x 2K factorial, concluded in 1962. Again the only significant effect was that nitrogen depressed yield, by about 450 kg/ha. The last report (10) gave annual yields of the five years.

The first dryland exhaustion trial (1953-1959)

This was a replica of the first wetland trial, but on the well drained soil of Field 3b (Fig 1). The deep ploughing gave

* On secondment from Rothamsted Experimental Station.

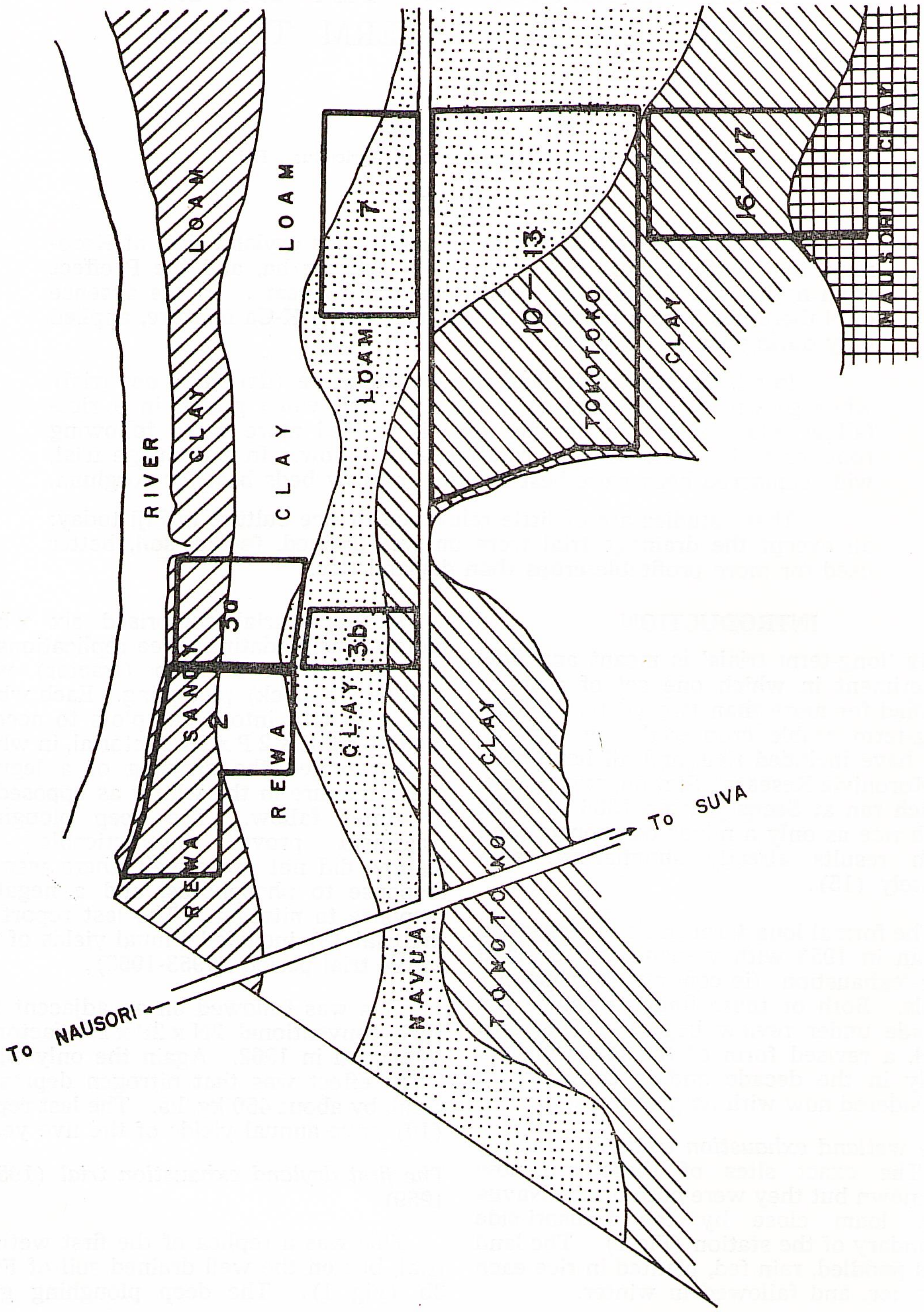

Figure 1. Location of trials at Koronivia Research Station.

much higher yields than the shallow for two years, but not thereafter. The contemporary reports offer no explanation for this. As in the wetland trial the legume grew poorly, and there was no response to this or the phosphorus treatment; but unlike the wetland trial there was a positive response (of about 200 kg/ha) to nitrogen. The last report (8) gave complete yield tables for all years.

Trials of the review period

Four other trials were begun before 1971, and are considered respectively in the next four sections of this paper:

(1) Revised dryland rice exhaustion trial (begun 1959)

(2) Grass/rice rotation trial (1958-1963)

(3) Arable rotation trial (1964-1972)

(4) Size of drainage bed trial (1963-1970)

The first of these is still continuing; for the sake of completeness all the results to date are given. Similarly the third, which finished in June 1972, is described in its entirety. In the second section is also described some related, informal, work at Koronivia during the decade.

There has been no double-cropping of rice in any of these trials, so every rice crop is a summer or 'main' crop, drilled in December and harvested about May. Each such crop is identified in annual reports etc. by the two years involved but in this paper by only the second of these two years e.g. 1968 for 1967/68. All yields are given as paddy.

REVISED DRYLAND EXHAUSTION TRIAL

This immediately followed the first in Field 3b and continued to alternate summer rice crops (the first was in 1960) with winter fallow. Three rice crops had been taken before the preceeding trial began, so the 22nd consecutive rice crop and the 13th crop of the trial was harvested in May 1972. In many of the annual reports since 1962, however, the duration of the trial is stated as if it had begun in 1954.

This misunderstanding seems to have arisen because the second trial followed the first with the same treatments except that the depth of ploughing factor, on whole plots in the first trial, was omitted, suggesting that the N, P, and L treatments continued unchanged on the same plots. Actually, because it was thought that these were too small (8), the trial was laid out again with 24 plots instead of 48, the new plots being three times as wide and two-thirds the length of the old (16, 18). Thus not only does the pre-1960 cropping make no contribution to the long-term results, but also the pre-1960 treatment application (particularly of persistent phosphate fertilizer to some plots and not others) may make a serious contribution to experimental error.

Changes in treatments and management

For two years the variety "New Guinea" was grown, since then BG 79 (75). The cowpea green manure seldom grew well and tended to depress yield so this treatment was discontinued after the 1966 crop. Instead, from 1968 onwards the L plots received a mixed dressing of potassium and calcium to each rice crop.

The forms and rates of N, P, K, and Ca, and the plot sizes, showing the various slight changes over the years including further slight changes proposed to bring all the quantities to round metric values in 1973 are appended. The Ca rate is much less than could have had any appreciable effect on soil acidity, this element having been included because nutritional deficiency was suspected. The change in 1969 from 18-inch to 9-inch inter-row spacing, was accompanied by a change from inter-row horse-hoeing to control weeds, to relying (perhaps unwisely : see below) on propanil herbicide.

Results

These have been given year by year in the annual reports, in some cases together with the yields of several previous years so that reference to (10), (5), and (6) gives the whole picture. As mentioned above, the pre-1966 legume treatment never had any noteworthy effect. Since then the lime-potash mixture has given a mean annual response of 250 (±56) kg/ha *in the absence of N*, but *no response* (actually a non-significant negative effect) *in the presence of N*. This negative interaction has tended to increase over the five years and it is difficult to find a plausible explanation, in terms of either the K or the Ca component of the mixture.

As the lime-potash has been applied for only five years, the chief long term interest is in the trends of the (—), N, P, and NP treatments. Fig 1 shows these, in terms of the average of the first three years (shown for 1960), of the first four years (1961), the first five years (1962) the five years beginning in 1961 (1963), and so on to end with the averages of the last four, (1971) and last three (1972) years.

Before taking these averages, the 1960 and 1961 yields were adjusted by addition of 390 kg/ha (350 lb/ac) that being the amount by which BG 79 (75), as grown in all later years, outyielded New Guinea (as grown in 1960 and 1961) on average of the six trials in which these two varieties have occurred together (4).

Discussion

The NP treatment seems to be maintaining fertility at its initial level. The general upward trend until about 1968 may have been due to improving standards of management, and the decline since then either to declining fertility or to increased weediness. But in trials like this, no significance can be attached to such short-term trends, which may be due merely to a chance run of a few good, or a few bad, years. Since reliance has been placed on propanil for weed control, much depends on luck with the weather at spraying, (7), and the recent decline in NP yield is certainly due in part, at least, to ineffective spraying in some years.

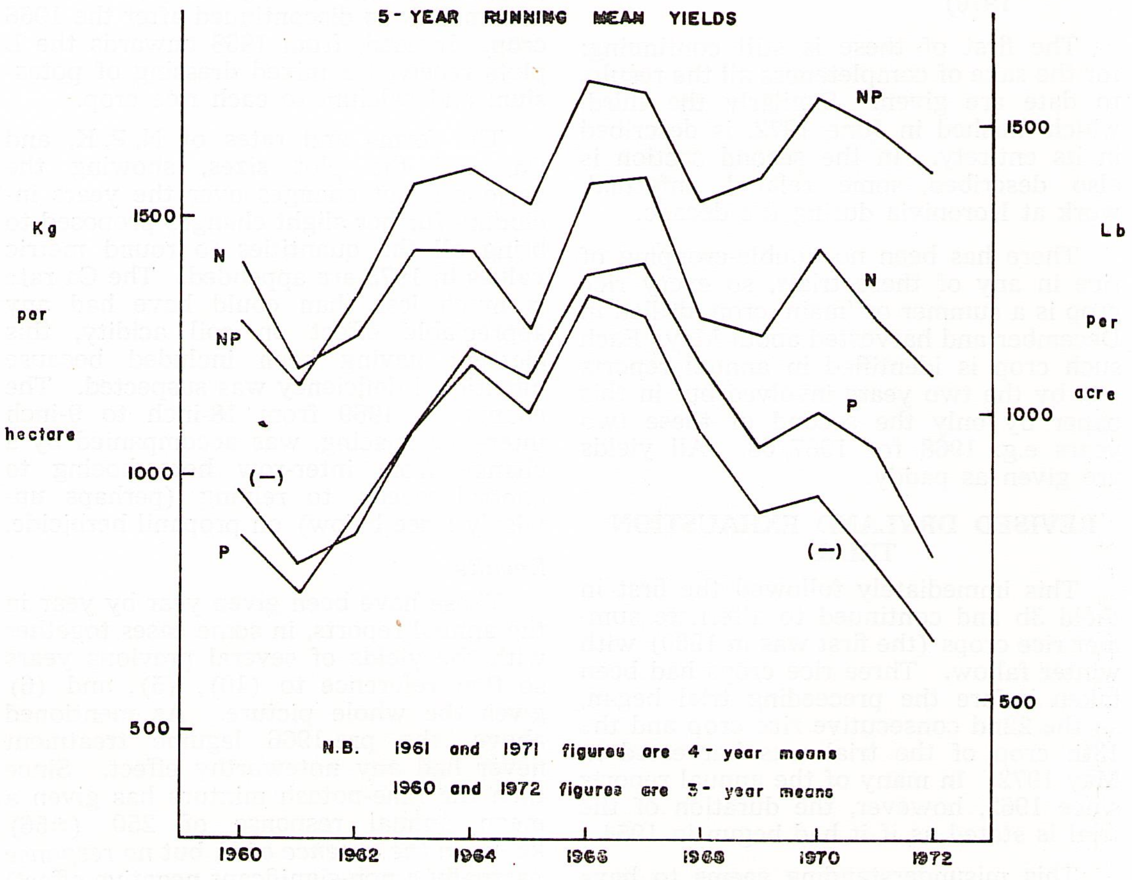

Figure 2. Yields of dryland exhaustion trial.

The main effect of N has been significant throughout and has tended to incerase, from + 200 kg/ha in the time of the 1953-1958 trial, to + 540 kg/ha on mean of the last five years. Thus the yields of the plots without N have tended to decline overall. Initially what little effect P appeared to have was negative, but about 1965 a positive effect appeared and has since become highly significant, averaging 210 (±56) kg/ha during the past five years, so that the yields of the plots not receiving P are now declining. A positive N x P interaction has also appeared during the last five years, significant at about 10% probability.

Future conduct of trial

To bring the trial more in line with good local practice, and to enhance the theoretical interest by hastening the exhaustion, a winter crop will be grown alternately with the summer rice in future. To start (in 1973) kumala (sweet potato) will be grown, rather than the more common local winter vegetables (see concluding discussion), because of its ease of cultivation and reliability.

The application of Ca to the "K/Ca" plots will be discontinued, and a corrective dressing of Ca applied to the plots that have not hitherto had it. The trial will thus become a three-replicate 2N x 2P x 2K factorial. If the recently-noted K-Ca effect does not then continue as a K effect, it will seem that it must have been due to the Ca. Consideration will then have to be given to re-introducing the Ca, which would best be done factorially to make the trial a 1½-replicate 2N x 2P x 2K x 2Ca factorial with the 4-factor interaction confounded with blocks. From November 1972 all measurement will be metricated (see Appendix).

GRASS — RICE ROTATIONS

The 1958-1963 Experiment

This comprised a three-year 'treatment phase' followed by a two year 'test phase'. During the former, four 'treatments' were 'applied' on a randomized block basis to four blocks each of four whole-plots in field 3A (Fig 1). Two test crops of rice were then taken. The 'treatments' were:

(1) 3-years grass: Para grass *(Brachiaria mutica)* from December 1958 to October 1961.

(2) 2½ years grass (called 2-years grass in previous reports): A 1958 rice crop followed by grass to Oct. 1961.

(3) Rice/Fodder: Summer rice in 1958 and 1959 (New Guinea) and 1960 (BG 75/79) with a fodder crop (maize or sorghum/cowpea) each winter.

(4) Rice/Fallow: As (3) but with a fallow instead of the fodder.

Each plot was split into four sub-plots to accommodate the manurial treatments (—), N, P, and NP which were applied to all plots (17) but, according to S. Ali (personal communication) only to the rice during the treatment phase. Also according to S. Ali, the grazing of the leys (17) was soon abandoned because of fencing difficulties, and the grass thereafter mown regularly and left lying.

During the three 'treatment phase' years the rice yields averaged 1670 kg/ha, with practically no difference between the 'Fodder' and the 'Fallow' inter-crop treatments, and with no significant effect of P. There was, however, a highly significant response to N, averaging 380 kg/ha. See (9) for annual yields.

A test crop of BG 79 (75) rice was then (1962) taken over the whole area with the results:

			kg/ha
Rice Following	3 yr. ley	3350	
" "	2½ yr. ley	3120	
" "	rice/fodder	1410	
" "	rice/fallow	1600	
	S.E.	± 92*	

The manurial treatment yields are given in (10). As in the 'treatment phase' the P effects were negligible and non-significant and the N response about 380 kg/ha, with no significant interaction between either N or P and the rotation treatments.

*The significant difference at 5% probability is wrongly given as ±132 lb/ac in (10). The error was due to using the square root of the number of whole plots per treatment (i.e. 4) as the divisor in calculating the S.E. of a whole-plot treatment mean, instead of the number of sub-plots (i.e. 16). The true figure, therefore, is ±269 lb/ac.

The final rice crop was "adversely affected by disease which spoilt the trial" (17). The yield averaged 630 kg/ha with no meaningful or statistically significant difference between treatments.

The Unit Farm Project (1964-1969)

The high rice yield following ley in the preceding trial prompted this study of the economics of farming 16 acres of land in smallholder fashion with cows and rice. Eight fields, halves of 10-13 (Fig 1), were put into the phases of an 8-year rotation : 4 yrs. paragrass/legume ley, 4 yrs. summer rice cropping.

But what had worked well on the sandy-clay loam soil of field 3a, did not succeed on these poorly-drained clays. Although bullock ploughing was soon replaced by tractor working, cultivation difficulties continued. Leys and rice suffered poor weedy, establishment, rice yields were low, and after five years the farmer's net income (return for his labour plus some family labour) was calculated to average only $550 a year, despite all the uncosted supervision: in 1970 the project was written off as a failure (5).

The chief immediate interest is in the yields of the successive rice crops after ley. It was not until 1968 that all the phases were represented. The yields of that year, 1969, and 1970 averaged:

Crop immediately after grass	1650	kg/ha
2nd rice crop after grass	1490	
3rd rice crop after grass	1680	
4th rice crop after grass	1260	

Koronivia Rotational Yields, 1963-1969

In the annual reports of this period (11, 1, 12, 13, 5) the mean yields of rice in the first, second, and third years following 3-year and 6-year leys are given (not all cases in every year). These were the yields of those sections of fields 2 and 7 (Fig 1) at that time being farmed, non experimentally, in grazed-ley/rice rotations. Omitting the 1965 crop of Field 7 (a failure), they averaged:

1st crop following ley	2500	kg/ha
2nd crop following ley	2150	
3rd crop following ley	1620	

During these seven years the NP plots of the 'continuous rice' in the exhaustion trial averaged 1650 kg/ha.

Discussion

These three sets of results all show that rice yielded better after a grass ley, than after several rice crops. In retrospect (no contemporary discussion can be traced) it seems probable that the benefit of leys was largely due to their cleaning (weed suppression) effect, and possible that improvement in soil structure was important. It is unlikely that the nutrient status was much higher following ley, except possibly in the formal experiment where the leys were not grazed.

ARABLE ROTATION TRIAL

Design

This trial compared five 2-year rotations :

(1) Rice — Cassava
(2) Rice — Dalo
(3) Rice/Fallow — Green Manure/Maize
(4) Rice/Fallow — Rice/Fallow
(5) Rice/Fallow — Fallow

The rice and the green manure were summer crops : the maize a winter crop. The roots were usually planted in late-winter and grew for about 9-10 months (dalo) or 12-13 months (Cassava); so that in the these rotations there was about 3 months fallow between rice and roots and 3 or 5 months fallow between the roots and the rice. Each treatment was present in both its phases, in each of four randomized blocks of ten plots (each 0.0075 ha). The trial ran for eight years, so that on each plot four cycles were completed.

This trial immediately succeeded the "Grass-Rice Rotation Trial", described earlier, in Field 3a (Fig 1). After the two years rice/fallow cropping of the whole area that concluded that trial it is likely that the residual effects of the ley treatments were negligible; but it is possible that the phosphate applied for five years to some sub-plots and not others, had some residual effect. As when the dryland exhaustion trial was redesigned, no account was taken of this.

Management

Annual yields are given in (1, 12, 13, 5, and 6) together will varietal, spacing, and manurial particulars for most crops in most years. Cassava seems to have usually been planted during July-Sept., dalo a month or two later (19). In 1968, 1969, and 1970 the dalo plots were split to compare four varieties, with results that are given elsewhere (ref.) The dalo spacing was (3 x 3) ft, ie 4,840 plants/ac, or 12,000 plants/ha. It is now known that yield can be almost doubled by much closer spacing (14).

Results

The annual rice yield (mean of all plots) ranged between 1,800 and 2,900 kg/ha during the first five years but then declined to 1460, 1040, and 690 kg/ha during the last three years. Any apparent 'treatment x linear-time' interaction would be difficult to interpret against this background of declining mean yield (the treatment differences tend to be absolutely greater in the early years of high yield, but proportionately greater in the later years of low yield). Thus formal analysis was confined to the plot-by-plot total yields over the eight years. Table 1 shows the results.

For the root crops, 'time' errors were calculated besides 'spatial' errors (see footnote to Table 1) because of the possibility that, by chance, the eight years in question were predominately unduly favourable to either the cassava or the dalo. For the maize, the individual plot yields for 1967 are missing, the 1970 crop was severely damaged by cattle and excluded from calculations, and the 1972 crop was not grown; so no formal analysis was made.

Discussion

The variation between rice yields (Table 1) is not significant at 5% probability on F-test; but if the treatments are grouped into (a) the three in which some other crop is taken, and (b) the two rice-only rotations, then the difference between groups is significant at about 2% probability, these rice yields being:

	kg/ha
(a) in rotation with other crops	1810
(b) in rice/fallow rotations	1610
Difference	200 (±77)

Thus these results agree with those of the ley studies in showing that rice yields more following a crop (any crop, including grass) than following fallow. Indeed there appears to be an inverse correlation between rice yield and duration of preceding fallow period, the December planted rice yielding best following grass (ploughed up in November) less following cassava or maize, (harvested in Sept.-Oct.), less again following dalo (harvested in June-Sept.) and less well again following rice (harvested in May.) Little statistical significance, however, attaches to the difference between yield following cassava or maize and that following dalo.

Again it must be presumed that the benefit of the arable crops, as of grass, is due largely to weed-suppression and/or improvement of soil structure.

The foregoing is the comparison of rotations in terms of the 'test crop' yield of rice; but the root crops are so much more profitable than the rice as to make this comparison, and hence the trial as a whole, of little practical interest. Whereas at current prices the average rice yield of the trial is worth about \$170/ha (\$70/

TABLE 1. YIELDS OF ARABLE ROTATION TRIAL, 1966-1972.

Rotation	Rice yield per crop mt/ha	Alternate crop yield mt/ha Yield	S.E. (b)*	S.E. (c)*
Rice/cassava	1.88	24.1	±2.0	±2.2
Rice/dalo	1.72	8.0	±0.5	±1.0
Rice/maize	1.83	2.4		
Rice/rice	1.57	†		
Rice/fallow	1.65			
S.E. (a)*	±0.085			

*S.E. (a) and S.E. (b) represent plot to plot variation within the trial area. S.E. (a) is caculated from mean annual yields per treatment per block by conventional analysis of variance. S.E. (b) is calculated, separately for each crop, from mean annual yield per plot, taking out variances due to phases and to blocks, and so has only 3 degrees of freedom. S.E. (c) is calculated from year to year variation in mean yield of cassava, or dalo, over all plots.

†Two rice crops in two years giving a total yield over the rotation of 3,140 kg/ha.

ac) that of cassava is worth about $1,340/ha ($540/ac) and of dalo $1,000/ha ($400/ac), and this last might be doubled by closer spacing (14). Most farmers in the Nausori area switched from sugar-cane to rice as their main cash crop when the sugar mill closed, years ago; but on well drained soils, such as that used for this trial, the better farmers now grow rice only for their household needs, and vegetables and roots for cash.

DRAINAGE TRIAL

Fields 16 and 17 (Fig 1) were divided by drains into six blocks, each about (76 x 72) m, each of which was sub-divided, by drains running parallel to the 76 m side, into four beds with widths (in random order) of 25, 40, 60, and 85 ft (about 8, 12, 18, and 26 m) respectively (1). These constituted the treatments, i.e. the design was one of four treatments in six randomized blocks with plots of unequal size. The inequality of plot size theoretically implies that the pooled error variance will underestimate the error of the treatments with small plots and vice versa but in practice this can be ignored.

The beds were ploughed into a cambered cross-section. Rice was grown every summer from 1964 to 1969; and, as the drainage ameliorated the soil, a winter crop became possible and sorghum was grown in 1968. A second sorghum crop, in 1969 was ruined by 0.4 m rain one day in July, the 1969 rice crop was smothered by weeds, and the trial was then terminated. The mean yields in kg/ha were:

	Rice (1964-68)	Sorghum (1968)
From 8m bed	1680	1280
From 12m bed	1620	1380
From 18m bed	1810	1030
From 26m bed	2110	650
S.E.	± 90	± 170

It was to be expected that sorghum, which needs good drainage, would not grow well on the wide beds, and that the rice would not be so sensitive to drainage. But it was unexpected, and perhaps a chance of experimental error (although statistically significant at 1% probability) that the rice, grown by dryland methods, would do better on the wide beds. As the final report (5) said the proper use for this type of land is for irrigated rice, and it has been so used since.

GENERAL DISCUSSION

Two 'wetland' rice trials were mentioned in the introduction but all the trials reviewed were 'dryland', although two of them (the Unit Farm and the drainage trial) were on land more suited for irrigated rice. It is debatable what place there is for dryland rice in Fiji in the future. Indeed at the relative prices for root crops and rice quoted in the 'Arable rotation' discussion it may be wondered why any is grown now. Most of the present cultivation is in one of the following categories:

(a) Catch crops, often of very short-duration varieties, taken between cane-crops by the dry-zone sugar-cane growers.

(b) Summer crops taken in the Nausori and Sigatoka valley areas, by farmers whose main cash enterprise is the growing of vegetable crops for which the summer is too wet.

(c) On badly drained soil that is unsuitable for other crops.

(d) Subsistence cropping. Most of the rice grown in categories (a) and (b) is for home consumption, but this is intended to cover farmers, especially in areas of poor communication, who cannot grow more profitable crops because of marketing problems so who live by subsistence cropping.

In all of these cases rice has an important role in the system: in (a) and (b) because it is a short-term, summer crop, in (c) because other crops will not grow, and in (d) because of its dietetic value. The trials reviewed, however, are irrelevant to situation (a) which accounts for about 25% of the crop, and have little practical relevance to the other situations under present conditions.

Situation (c) probably accounts for about half the crop, and when it began, the drainage trial was greatly relevant to this situation, particularly in the Nausori area. But much of this land is now scheduled for irrigated rice development.

Delay in implementing these plans, and the fact that they do not extend over all the land in question, still apparently leaves scope for drainage and dryland cropping. But the feasibility of this is doubtful. The crops of the drainage trial were poor, and the cambered-bed cultivation dependant on tractors. Most holdings are too small for economic tractor ownership. In the absence of some extensive drainage scheme (such as was organised by the sugar mill owners in the cane-growing days, or is now being organised by the Government as part of the irrigated rice schemes) it is probable that the best use for this land is its predominate present use: puddled, rain-fed, wet-land rice.

The grass/rice rotation studies are generally inapplicable. On easily-worked, well-drained land, such as that of the formal experiment, vegetables and root crops will generally be very much more profitable than grass. On less well drained land, rice is better grown as puddled, wet-land rice (failing full irrigation), and ley establishment is difficult as the unit farm project showed. In either case, the size of holding is generally much too small for either arable cropping, or dairy farming, to be run economically; still less both. Many small-holders keep a bullock or two for ploughing, or a cow or two for household milk, or both. But on most holdings there is some land particularly unsuited, because of drainage or slope, for arable cultivation, on which these beasts can be kept. The question of rotating their grazing, therefore, seldom arises.

The arable rotation trial was on well-drained land. Some such land, both in the Nausori and the Sigatoka valley areas, is now farmed largely in continuous (summer) rice, with winter fallow. This apparent folly may be due to liability of the land to flooding, ignorance of other crops, indolence, or the fact that the smallholder's chief income comes from off-the-farm employment. (2) Certainly the main argument for growing other crops in rotation with the rice is not that the rice yields will thereby be enhanced, but that the alternating crops are very much more profitable than rice. The better farmers on suitable land in these areas grow winter vegetables, eg. cabbage, chinese cabbage, beans, okra, egg-plant, melons, lettuce, cucumbers, tomatoes, etc, some of which can be extremely valuable, given luck with weather and marketing. At the Nausori market prices of 1971 and the yields, modest by world standards, that have been recorded on Government farms in Fiji, most vegetable crops give a return of over \$300/ac many over \$500/ac, and some in the range \$1,000 - 3,000/ac. Tapioca, dalo and yams can also give returns in the \$300 - 1,000/ac range, but in this case from a 10-12 month crop, whereas the vegetables are 3-6 month crops. By comparison, an excellent yield of rice is worth about \$150/ac.

It is doubtful whether any one arable cropping scheme is appreciably better than any other in terms of rice yield. Any difference appearing in experiments is likely to be due largely to weed variation, and hence largely dependant on what herbicides are used, the luck with the weather, and managerial skill. It would be difficult to distinguish experimentally between these weed effects, and the effects on yield (if any) due to the better soil structure possibly created by some alternate crops are so much more profitable than the rice, and so varyingly more or less profitable than each other, that it would seldom be sensible to determine cropping according to which of these is the best forerunner for rice.

As the soil drainage worsens, so the yields of all the crops decline and the alternate crops in turn become uneconomic. In the case of the rice the declining yield can be countered by switching to the wet-land mode of cultivation; but this practically rules out alternate cropping. Alternatively the soil condition can be improved by drainage. It would probably be best to watch the progress made during the next few years with irrigated rice on the worst (for other crops) of these soils, before restarting research on the drainage and cropping of those more marginal.

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(17) Project 7/58 (19) Project 1/64

APPENDIX: DETAILS OF DRYLAND EXHAUSTION TRIAL

	Plot dimensions gross	net	Net area sq. m.
1960-1968	12 rows (of 18 in) x 82 ft	10 rows x 72 ft	100.3
1969-1972	21 rows (of 9 in) x 82 ft	17 rows x 72 ft	85.2
1972	22 rows (of 25 cm) x 25 m	16 rows x 20 m	80.0

N. 1960 - 1967; as ammonium sulphate, usually at the rate of 336 lb/ac (377 kg/ha) divided equally between top dressings at 6, 10, and 14 weeks from planting.

1968 - 1972: as urea at 168 lb/ac (188 kg/ha) split between 2 top dressings the first 3-4 weeks after planting the second about 10 March.

1973 - : as urea at 189 kg/ha (ie 85 kg N/ha), applied as during 1968 - 1972.

P. Always as single superphosphate

1960-62 at 224 lb/ac drilled with seed

1963-65 at 336 lb/ac drilled with seed

1966 at 336 lb/ac on legumes in L plots, otherwise drilled with seed.

1967-70 at 224 lb/ac drilled with seed.

1971-1972 at 224 lb/ac broadcast and harrowed in before drilling.

N.B. 224 lb/ac = 251 kg/ha

1973 — timing method as for 1971-72.
Single superphosphate, either of 18% quality, at 278 kg/ha, or 20% quality at 250 kg/ha (as available) making 50 kg P_2O_5/ha in either case.

L/K 1960-1966: No fertilizer. Legume green manure.

1967 Nothing

1968-1972: Lime (Ca CO_3) at 336 lb/ac (337 kg/ha) plus Potassium sulphate at 112 lb/ac (125 kg/ha)

1972- : Potassium sulphate at 120 kg/ha (60 kg K_2O/ha)

RICE RESEARCH IN FIJI 1960-70, PART V: FERTILIZER, SEED RATE, AND OTHER STUDIES

by

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SUMMARY

Trials at Koronivia showed that for dryland cultivation of photo-sensitive varieties like BG 79 (75), sowing during late Oct. — early Dec. at a seed-rate of about 90 kg/ha (80 lb/ac) is optimal. Drilling is generally better than broadcasting. Any drill-width in the range 18-46 cm (7-18 in) gives good yield, but a 46 cm width is best for ease of inter-cultivation weed control. There is generally an economic response to N, at 50-60 kg/ha, but not to P (except on red hill soils), nor to K.

For wetland cultivation of the same varieties, trials have shown an upland seed-bed sowing density of about 60 g/m^2 to be best, trans-planting at about 6 weeks old between mid-Nov. and mid-Dec. with 4-6 seedlings per hill. There is generally no response to fertilizer in the wet zone areas.

Some of the later trials reviewed included the newer, short-strawed, non-photo-sensitive varieties and showed that these have very different spacing and fertilizer requirements besides, of course, having no critical sowing dates; but results with these varieties are not con-sidered in detail.

INTRODUCTION

Previous papers in this series have reviewed variety (8), weed-control (13), and long-term (30) trials. This final paper reviews all the other rice field experiments of the period, except that trials sown solely with the introduced non-photo-sensistive varieties are not covered. As appeared in the varietal review (8) and re-appears in this paper, these varieties are so different from the old, tall, leafy, lodging susceptible varieties in their spacing and manurial requirements that the work with them will call for a seperate review in the near future when some five years' work will be covered.

The factors involved in these other trials have been: rates of the manurial elements, N and P (and K in a few trials only), time of application of N, seed rates, spacings, planting methods, and planting date, etc. Many trials have involved two or more of these in factorial combination; and some of these factors have also been involved in combination with varieties, and with herbicides, in factorial trials whose main effects under those headings have been reported in (8) and (13) res-pectively. The interactions in the factorial trials have generally been negligible so, with separate mention of such few inter-actions as are of interest, the results of all these trials are now presented, factor by factor, in terms of main effects (other than those of variety and herbicides).

For each main effect the relevant results of all relevant trials have been pooled, and Standard Errors (SEs) derived from treatments x trials interaction vari-ance. Where necessary the "missing plot technique" has been employed to complete a treatment set-up for a series of trials. Yields and other measurements of the individual trials given in imperial units in the earlier reports are summarized in this paper in metric units. Yields given are of paddy.

There seem to have been no noteworthy trials before 1950, and not enough during 1951-1959 to merit separate presentation in this "Introduction". These few early trial results therefore have been averaged with the relevant later ones. There have been too many trials to list all the details, but in each section the numbers of trials involved are given. The great majority were done during 1960-1968 and the individual trial descriptions and results have been given by Rhodes (16-26). Description and results of other trials are in other annual reports of the 1950-1970 period.

Under the heading 'Phosphate responses' no mention is made of field and pot trials comparing Lau-phosphate with conventional phosphate fertilizers, which have been described elsewhere (1,2,28).

DRYLAND RICE TRIALS

Cultural practices for dryland rice in Fiji and climatic conditions have already been discussed in (13,23,32) and (8,24) respectively. All the trials reviewed, except a few extensive fertilizer trials, were on research stations, most on Koronivia.

Date of Sowing

Five trials at Koronivia, one each season from 1963 to 1967, on the photosensitive variety BG 79 (75) were drilled in rows at 46 cm apart using a seed rate of 90 kg/ha. The results averaged:

Date Sown	Date Flowered	Duration Range, Days Sowing — Flowering	Yield-Paddy kg/ha
8.-12 Oct.	7-15 April	181-186	1800
29 Oct.-3 Nov.	9-15 April	162-164	2120
19-22 Nov.	10-15 April	142-146	2200
11-14 Nov.	12-17 April	123-127	2100
30 Dec.-4 Jan.	16-23 April	105-110	1650
21-26 Jan.	28 Apr-3 May	95-100	1450
		S.E.	±146

Thus these trials clearly defined the limited sowing-date range of the photosensitive varieties. Sowing earlier than 29th Oct. is likely to lead to severe lodging, and sowing later than 14th Dec. gives declining yield due to the shortening of the period available for vegetative growth.

Spacing, Seed Rate, etc

Table 1 shows the mean yields and other particulars of the 20 trials which involved different spacings, alone or in combination with different seed rates, fertilizer application, varieties etc. The very poor yields at 15 cm, in the trials in which this spacing occurred (Rice 2/57 and 3/59) were due to weeds, especially grasses which were not controlled by the phenoxy herbicides used.

No trials were done to evaluate seed rates for broadcasting. Only one trial involved different seed rates alone, at Dobuilevu Station in 1965 on a short term variety, Mutmuria 3M, drilled at 23 cm (22). Seed rates were also evaluated in combination with spacing in projects 'A 3/51' and 'Rice 1/61', with the results given in (7) and (20) respectively. Table 2 summarizes the yields and other details of all these trials.

Dryland rice in Fiji is always direct-sown, either drilled or broadcast. Trials were done at Dobuilevu Station in the project 'Rice 8/63' to evaluate methods of establishment and methods of management. Results obtained from individual trials were reported by Rhodes (23) and also referred to in Part III of this series (13). Table 3 shows the average results.

TABLE 2

RESULTS FROM DRYLAND RICE SEED RATE TRIALS

(Yield of paddy kg/ha)

Project :-	A3/51	Rice 1/61	Rice 8/63
No. of Trials :-	4	4	1
Variety :-	New Guinea	BG 79 (75)	Mutmuria 3M
Spacings (cm) :-	18, 36	30,46,60	23
Seed Rates kg/ha			
45	1650	—	—
56	—	2550	—
67	1770	—	—
90	1910	2450	1400
112	1840	—	1240
134	—	—	1240
157	—	—	1220
179	—	—	1280
S.E.	±58	±69	±198

TABLE 1

RESULTS FROM DRYLAND RICE SPACING TRIALS

Yield in paddy, kg/ha

	Older Type Varieties					Improved Varieties		
Rice Projects	A3/51	2/57 & 3/59	1/61	5/63	8/63 & 3/67	8/63, 2/67 & 3/67	2/67 & 3/67	3/67
Variety	New Guinea	Serendah Kuning	BG79 (75)	BG79 (75)	Various*	IR 8	FK 135	IR 5
Seed Rates kg/ha	45,67, 90, 112	90	56, 90	90	90	90	90	90
No. of trials	4	3	4	4	4	5	4	3
Ref. for detail results	7	15, 17	18,19,20	22, 25	9,10,12, 21,22,23, 25,26	9,10,23 25,26	9,10,25	9,10,25
Spacing Treatments								
Drilled 15cm rows	—	1000	—	—	—	—	—	—
Drilled 18cm rows	1820	—	—	—	—	—	—	—
Drilled 23cm rows	—	—	—	—	1740	4200	2450	2810
Drilled 30cm rows	—	1830	2670	—	—	—	—	—
Drilled 36cm rows	1770	—	—	2560	—	—	—	—
Drilled 46cm rows	—	1670	2560	2460	1960	3220	2130	2270
Drilled 61cm rows	—	—	2260	—	—	—	—	—
S.E.	±40	±59	±85	±141	±200	±80	±84	±132

*Various tall, leafy, lodging susceptible varieties like Saraya, Sonacalif, Mutmuria, Mahsuri, BPI-76, BG79 (75) etc.

These trial results suggest that broadcasting is as good a method as drilling. But in farm practice broadcasting has often failed to give a good even stand. It has also been observed that broadcast crops suffer more from dry soil conditions, bird damage, and soil and seed disturbance by rain (23). Considerable variation in the yields from broadcast plots was observed, indicating the unreliability of this method.

In considering spacing and allied factors weed control is crucial. This subject was fully discussed and conclusions stated in Part III of this series (13).

Fertilizer Investigations

Altogether 77 trials involved fertilizer comparisons, 26 on research stations and 51 extensive trials. In all of these rate of N was a factor, sometimes in combination with time of application; 34 included rate of P; and 2 of these also involved rate of K (ie were N x P x K factorials).

The rates of N almost always included one rate in the 50-60 kg N/ha range. Table 4 shows the mean response to this rate in (a) the research station and (b) the extensive trials, each subdivided according to whether the varieties were traditional or improved. On average the response was greater on farms than on research stations, presumably due to the higher N status of the latter due to years of fertilizer use. But the response on farms was very variable and sometimes lower than the research station average because of poor management, as reflected also in lower mean yield. Note the substantially higher yield and mean response to N of the improved varieties.

TABLE 3

RESULTS FROM DRYLAND RICE METHOD OF ESTABLISHMENT AND MANAGEMENT TRIALS

(Yield — paddy kg/ha)

Variety/Varieties	Mutmuria Saraya 4M. Sonacalif	Sanocalif	IR8
No. of trials	3	1	1
Treatments			
Broadcast + propanil*	2030	2490	6810
Drillied 46 cm rows and Inter-row cultivated	—	2410	—
Drilled 23 cm + propanil*	1880	2320	6890
S.E.	±121	±285	±157

*Propanil at 3.4 kg a.i./ha

Results of *time of N application* were inconsistent and often confusing. Individual trial results, are given, mostly under the heading 'Project Rice 4/61' in (15,18, 19,21,22, and 25). Two treatments were common to 12 trials (application 5 to 6 weeks after sowing; and later, about panicle initiation stage) and 8 of these trials included a third treatment (application split between these two dates). The treatment mean yield differences over all relevant trials were entirely negligible and non-significant.

Rates of P have been studied in 8 trials on research stations (5 at Koronivia, 3 at Dobuilevu) all on alluvial soils, and in 26 extensive trials 21 of which have been on alluvial and 5 on 'Red Hill' soils. In none of the trials on alluvial soils has there

TABLE 4

DRYLAND RICE NITROGEN RESPONSES

		Extensive	Research Stn.	Average
Traditional varieties	N_0 N	1530	1830	
	50-60 kg N/ha	1940	1940	
	Response	410 (±183)	110 (±83)	210(±89)
Improved varieties	N_0 N	1360	3210	
	50-60 kg N/ha	1700	3580	
	Response	340 (±160)	370 (±87)	360(±78)

been a significant response to any rate of P (the rates tested ranging from 36 to 75 kg P_2O_5/ha) and the mean P effect over all 34 trials is almost exactly zero. In the five extensive trials on red hill soils, however, the mean yield was much lower and there were highly significant effects of P and N x P interactions, as now shown with the alluvial soil mean yields for comparison:

		Yield in kg/ha		
		N_0N.	50-60 kg N/ha	
Red hill Soils	N_0 P_2O_5	750	1240	± 100
	70 kg P_2O_5/ha	830	1890	
Alluvial Soils	N_0 P_2O_5	1630	2080	
	Various rates of P_2O_5	1690	2080	

Rates of K had no significant effect in the two short-term trials; but the results of these short-term trials must be considered in conjunction with those of the *long term trials* presented by Vernon (30). Both types of trials agree in showing that there is generally a substantial economic response to nitrogen applied at about 50 kg N/ha. Under continuous rice cultivation this response increases in time, and possibly larger dressings might be economic. In the short-term neither P nor K generally gives an economic response on alluvial soils, but there is a big response to the former on red hill soils, provided N is also applied. In the long term, one trial at Koronivia is now suggesting that P, and possibly K, may be needed.

Interactions

Apart from the N x P interaction on the red hill soils, the factorial trials have disclosed no significant interactions between any of the foregoing factors, manurial or cultural. But there have been important interactions between varietal type (i.e. old or new) and (a) spacing and (b) nitrogen, as shown in Tables 1 and 4 respectively, and as discussed by Muralidharan (8).

WETLAND TRIALS

About half the rice acreage of Fiji is 'wetland' defined as rice grown on puddled soils usually, but not necessarily with water retaining bunds. As described in Part I of this series (11) a few hundred acres are now irrigated (and irrigation schemes now planned total about half the present wetland acreage) but almost all the present wetland acreage is now rain-fed. The trials now reviewed were all, except the extensive trials, at Koronivia Research Station. Most of the pre-1963 trials were rain-fed, otherwise they were irrigated.

Seed-bed Manurial Trials

Trials on the effects of nitrogen and phosphorus on an upland nursery did not give any consistent results. Although the final yields were not influenced by the fertilizers it was observed that healthy, dark green, vigorous seedlings were obtained from fertilized nurseries (6).

Density of Seedbed Sowing

To evaluate the optimum density for sowing a dry nursery, two trials each with varieties BG 79 (75) and New Guinea were carried out. All trials were transplanted at 30 x 30 cm spacing using four seedlings per hill; but in trials with the New Guinea variety, seedlings of different ages were included. The 1959 trial on New Guinea gave very variable and poor yields due to various disturbances. The yields of the remaining three trials, given separately in (18) and (19), average as now shown, together with the requirements of seed and seed-bed-area that, for each treatment, are needed to transplant one hectare, as calculated from measurements made on the two BG 79 (75) trials.

Seed bed Sowing densities		Required to plant one hectare seed	Area of	Yield of paddy
g/m²	oz/sq yd	kg	seed bed m²	kg/ha
252	7.40	49.0	194	3080
126	3.70	33.5	266	2970
63	1.85	19.0	302	2940
42	1.23	18.0	429	2990
31.5	0.93	19.5	619	3110
			S.E.	±246

Thus with decreasing density of seed-bed sowing, down to about 60 g/m², there is a decrease in seed-requirement and no great increase in seed-bed size, but with further decrease in density there is no saving in seed, merely an unnecessary increase in seed bed area, as no apreciable yield increase results.

Date of Transplanting and age of seedlings

Four trials were done on BG 79(75) using six to seven week old seedlings transplanted at 30 x 30 cm spacing. Table 5 shows the results. These apear to leave open the possibility that seed-bed-sowing in mid September and transplanting in early November might give heavier yields; but the trend of rising yield with earlier sowing during October is negligible and the possibility of low rainfall in September, together with experience that very long pre-flowering growth tends to induce lodging, practically rule out planting earlier than the first date of Table 5. From then on the trend is for lower yield with later planting, but with no appreciable drop in yield until later than mid-Dec. transplanting.

Similar trends were seen in a trial in 1965 under the same project 'Rice 3/61', on a late maturing local selection from a Japonica x Indica hybrid, planted at 46 x 20 cm and using six weeks old seedlings (22).

In four trials, age at transplanting was studied. Three of these, summarized in (18), had treatments ranging from 5 to 15 weeks old at transplanting, secured by planting seed beds on a range of dates and transplanting all treatments on 1 - 3 Feb. This was unduly late for BG 79(75), the variety in one trial, and seedlings aged 7-11 weeks all did almost equally well. For the weakly photo-sensitive 'New Guinea', the variety in the other two trials, sowing date was not critical; but in one of these trials the 5-week old treatment was severely damaged by birds and 9-week old seedlings did best, whereas the 5-week-old was best in the other. In the fourth trial, reported in (19), all the seed was sown on the same date, and age of seedlings was thus confounded with date of tarnsplanting. The youngest transplant age (4 weeks of age on 15 Nov.) gave 4710, transplanting at 6 weeks 4940, (±218) kg/ha and thereafter yield declined with later planting much as shown in Table 5 for seedlings of the same age.

These trials, therefore, were inconclusive and transplanting at 4-6 weeks of age has been since practised on research stations and recommended to growers more because world experience has shown this best, rather than because of these results.

Spacing etc

In three trials (4, 5, 6) with BG 79(75) at (30 x 30) cm a comparison was made of 1, 2, 4, 6, and 8 seedlings per hill (s.p.h.). In five other trials (18, 19, 20, 21) with that variety, 4 and 6 s.p.h. were compared factorially with four spacings, and in two trials (15, 31) with Serendah Kuning 2, 4, and 6 s.p.h. were compared factorially with three spacings.

TABLE 5. WETLAND RICE: RESULTS OF DATE-OF-PLANTING TRIALS

Date Seedbed Sown	Date Planted	Date Flowered	Mean Duration Seeding-Flowering	Yield Paddy kg/ha
1-4 Oct.	15 Nov.	6- 8 Apr.	187	3640
15-18 Oct.	29 Nov.	6- 9 Apr.	174	3610
29 Oct.-1 Nov.	13 Dec.	7-10 Apr.	160	3580
12-15 Nov.	27-28 Dec.	7-10 Apr.	146	3200
26-29 Nov.	10 Jan.	8-11 Apr.	134	3220
10-13 Dec.	24-30* Jan.	10-13 Apr.	122	2600
23-27 Dec.	7 Feb.	12-17 Apr.	112	2250
S.E.				±134

*Planting of only one trial was delayed up to 30th January due to dry conditions. All the three remaining trials were planted on 24th January.

There were no significant interactions between s.p.h. and spacing; and the main effects were also mostly non-significant. In the 3 trials in which the '1s.p.h.' treatment occurred it yielded 3160 kg/ha compared with 3800 kg/ha for '2 s.p.h.', (each ± 210). Over the other trials there was a slight trend of increasing yield with 4, and again with 6, as opposed to 2 s.p.h. In all seven spacing trials the following three treatments occurred with the following mean yields:

(23 x 23) cm, ie 189,000 hills/ha	2970		
(30 x 30) cm, ie 111,000 hills/ha	2920	}	±100 kg/ha
(38 x 38) cm, ie 69,000 hills/ha	2750		

The trend of falling yield with wider spacing is significant at about 10% probability. The fourth treatment in five of the trials was to secure 111,000 by a rectangular, (46 x 20) cm, spacing instead of the square, (30 x 30) cm. The mean difference was negligible.

Method of Establishment

Before the introduction of double cropped, irrigated, rice cultivation, it was possible to prepare fields under dry conditions. Drilling and transplanting of BG 79 (75), FK 135 and IR8, were compared in several trials, in some of which broadcasting was also included. Transplanting was generally better than drilling while broadcasting gave encouraging results (22, 25).

With the introduction of double cropping under irrigation, it was observed that in the short time available between two crops it was not possible to dry out fields and prepare them in a dry condition; making drilling impracticable. Trials with several varieties compared broadcasting and transplanting in fields prepared under wet conditions. The results (10, 14, 25) showed considerable variation in the yield between seasons, varieties and methods of establishment. With lodging-susceptible varieties like New Guinea, Peta, Mahsuri etc. transplanting generally gave higher yields, most probably because they lodged more severely, and earlier, when broadcast. Improved, lodging-resistant, varieties like IR8 included in some of these trials, and recent trials with such varieties, showed no appreciable difference between the two methods of establishment. Yields recorded from field scale planting of improved varieties on the Lakena irrigation scheme have also shown little difference between broadcasting and transplanting (3). It seems in general that yields from transplanting and broadcasting of lodging resistant varieties under good management practices do not differ appreciably.

Fertilizer Trials

There were very few fertilizer trials on wetland compared to dryland rice, presumably because of the discouragement of the significant negative response to N, and tendancy to negative responses to P and K, in the long-term trials reviewed elsewhere (30). It was concluded that fertilizers would not raise the yield of wetland rice grown on poorly drained, or undrained, Tokotoko clay (19) nor, probably, on other similar wet-zone soils (29) and the project was terminated.

Fertilizer treatments, usually only N, were also included in a few short term trials, but with no meaningful results (16, 25).

Interactions

'Spacing x number of seedlings per hill', 'age of seedlings x density of nursery seed-bed', and 'varieties x methods of established' occurred in factorial combination, but in no case was there any significant interaction of effects.

Peat soil trials

All the foregoing work was on soils at Koronivia described by Twyford & Wright (29) as Navua clay loam, Tokotoko clay loam and Nausori clay. For normal arable cropping these soil-types are a progressively worsening series, as regards waterlogging. For irrigated rice no appreciable difference has been noted between them, in ease of working or in growth of rice.

The progression is continued, on Koronivia, with the sequence Nausori peaty-clay, Melimeli clayey-peat/muck, and Melimeli peat. From 1967 to 1971, Field 26, across which there is a transition from clay, through peaty-clay, to clayey-peat, was double cropped with rice; and in 1967, and again in 1968, main crops were taken on Fields 36 and 37b, which are almost pure peat about 2 metre in depth.

These latter were in the form of manurial trials. The results, given in detail in (25), were inconclusive but suggested that in the absence of fertilizer yields of only about 1600 kg/ha could be obtained, rising to 2200-2500 kg/ha with P, K, and lime with K probably the most important element. There was no suggestion of response to N or copper. In Field 26, the more-peaty section of the field (26B) yielded about 700 kg/ha less than the less-peaty-section (26A) in the two seasons when they carried comparable crops.

Drainage of these peats is costly, and it would be quite uneconomic to use them for rice cultivation if good yields could be obtained only with heavy fertilizing. Moreover, cultivation is difficult. In Field 26, tractors could work at the better end, but at the peaty end bullocks had to be used. On the pure peat it is impossible to keep the fields flooded in dry weather. Studies are now being made of vegetable, pineapple, and voi-voi (a local fibre-producing *Pandanus*) cropping on these peat soils, and their use for rice has ceased.

Irrigation and double-cropping

By 1966 it had been decided that rain-fed wetland rice cultivation was unsatisfactory. "Planting is often delayed past optimum time. Heavy rain may fall, and then it dries up again, so that planting becomes a stop-go operation and seedlings are not of optimum age. Levelling and and bunding would improve the situation but lack of water control is still a serious disadvantage. Permanent swamps can be planted at any time but are difficult to cultivate and cannot be drained for harvest" (Rhodes, 25, slightly edited).

In 1963 3.2 ha of Koronivia were set up with irrigation channels, bunds, and drains, and main crops of BG 79 (75) in 1964 and 1965 yielded in the range of 2,600 to 4,100 kg/ha, substantially more than rain-fed crops of this variety had averaged in the past. The area was increased to 4, 4.8, 5.2 and 10 ha in the years 1966 to 1969 respectively.

During 1965 to 1967 only a small part of the irrigated area was cropped in the 'off' (winter) season, but in 1968 about half was so cropped, and in 1969 all of the 10 ha.

Most of this land was in experiments, so that simple bulk crop yields cannot be given; but main-crop BG 79 (75) continued generally to yield at about 3,000-3,500 kg/ha, while the improved varieties were more variable, with yields anywhere in the 3,000-6,000 kg/ha range in both main and 'off' seasons.

In 1965 the research station irrigation canals were extended to serve 11 ha of neighbouring farmland (comprising 9 smallholdings), and bunds, drains, etc. provided. The object was to test the farmers' reactions, gain experience for larger schemes, and to test cultivation methods on a larger scale. It also provided a larger area for double cropping, thus diluting bird-damage to the research station winter crops.

In 1967 work began on a second scheme about a mile to the south, in order to broaden the basis of the work and include other soil types. By the end of 1968 this scheme comprised 33 ha.

Before the first scheme started, surveys showed that less than half of the 11 ha were usually cultivated as dryland rice each year, with an average production of about 1300-1500 kg/ha. The rest of the area was used for rough grazing with a very small area of subsistance crops. In irrigated rice the 1967 and 1968 main crops averaged 3,180 and 3,110 kg/ha respectively (over the whole area) and the 1967 winter crop 1,930 kg/ha, despite severe loss to birds. Full yield records were not taken for the 1968 winter crop and the 1969 crops; but in 1970 when the running of the scheme passed from the Research to the Extension Division of the Department it was estimated that the better farmers were averaging 6-7 mt/ha annual total yield of both crops.

Similar results were obtained on the second scheme, which was also taken over by Extension Division in 1970. It was on the basis of the results of these pilot schemes that the large-scale schemes in the Nausori area were begun in 1969.

Cultivation developments

At the time of the introduction of irrigation only one crop a year was grown and the land preparation by ploughing, discing etc. was done under dryland conditions. With the introduction of the system of double cropping under irrigation, it was observed that it would not be possible to dry out fields in the short time available between two crops under commonly prevelent weather conditions, so a study of land preparation under wetland conditions was started.

In the early stages, wetland preparation was done using disc and spike harrow pulled by a Massey-Ferguson 35 tractor fitted with cage wheels. This tractor was found to be under-powered for the job and was replaced by a Massey-Ferguson 135 (S. Ali, personal communication). Towards the end of 1967 a rotovator was introduced and was found that good land preparation can easily be obtained with this implement. The Massey-Ferguson 135 fitted with various types of cage wheels, used initially for rotovation was also found to be under powered for the job and was replaced with Ford 4000 (S. Ali, personal communication). A wider (254 cm i.e. 100 in) rotovator has been successfully used with a Ford 4000 tractor fitted with cage wheels.

After rotovation, field are kept submerged; and about three weeks later puddling and levelling is done using wooden or iron beams attached to a Ford tractor fitted with cage wheels. Under normal conditions, good land preparation can be easily obtained by one rotavation followed by puddling, and levelling at a suitable interval.

Hand harvesting and threshing by stationary Garvie Thresher operated by either a small petrol engine fitted to it, or mounted on a tractor and driven through connection to PTO shaft, was common at Koronivia station and on adjacent schemes. In 1969 the first combine harvester, a clayson 975, was introduced. Early trials were promising, and it was used with some success on suitable fields at the irrigation schemes (27); but later its performance, on the whole, on these schemes has proved unsatisfactory. At Koronivia Research Station a much smaller Iseki combine harvester has been tried for harvesting experimental plots, and found unsatisfactory for various reasons.

GENERAL CONCLUSIONS

Dryland rice trials have mostly been on mid - season varieties like BG 79 (75) and results presented here are applicable where such varieties are grown. The new introduced varieties like IR 5 have been found superior over the traditional varieties even in dryland conditions (8). However to obtain the maximum yields these varieties should be sown at a closer spacing and require high levels of management. It is likely that the traditional varieties wil remain in cultivation for some time. The results of the dryland trials therefore are still applicable in Fiji.

The most important of these results have been those showing the criticality of sowing date for the photo-sensitive varieties like BG 79 (75) and the profitability of nitrogen fertilizer in general, and phosphorus on red hill soils.

Much of the dryland rice in Fiji is grown in the dry zone areas where short term varieties are cultivated as a subsistance broadcast catch crop in rotation with sugarcane. Trials on such varieties have unfortunately been very few indeed.

The important wetland studies have been those showing the advantage of irrigation, new varieties and double cropping. On irrigation scheme areas double cropping of improved varieties is practiced and the results obtained from the trials of the traditional varieties are largely inapplicable. Although small but increasing acreage are now irrigated and it is aimed to increase to 8000 acres in the near future, substantial acreage will remain under rainfed conditions and the results of the work with the traditional varieties now reviewed will continue to be of some relevance. Among the more important results are those showing the criticality of planting date, and that spacing is not critical provided that there are at least 110,000 hills per hectare (43,560 per acre).

It is felt that by adopting proper practices based on the results discussed above and by observing other common practices e.g. proper land preparation, pest and weed control etc. yields obtained from the traditional varieties under rainfed wetland conditions can be improved. The newly introduced improved varieties have been found promising even in rainfed wetland conditions (8) but to realise their full potential, much improvement in the general management and growing practices seen among Fiji farmers will be required.

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PIG FEEDING STUDIES 1968-1972

By

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SUMMARY

The profitability of the ration of cassava and protein meal that was being recommended to pig-farmers, and proving a moderate commercial success in 1968, was reduced by increasing costs during 1969 and 1970 so that by 1971 it was only marginally profitable, even to up-country farmers with access to cheap cassava. Production of pig-meat failed to keep up with demand and imports rose during 1969 to 1970. Some trials during this period studied variation in the protein component, chiefly methionine and lysine additions. Results were inconclusive; but theoretical calculations suggest that the main defect of the ration was that the animals did not eat enough cassava to fulfill their energy requirements.

INTRODUCTION

Newman (5) reviewed the progress of the pig industry in Fiji to 1968, and the studies made by the Department of Agriculture from 1930 to 1968. Efforts to encourage local production met with considerable success in 1968, increasing local production by about 24%; but this rate of increase was not maintained in 1969, and by 1970 production was virtually static and imports rising, the total pig-meat production, and importation in these years in metric tonnes being :

	Local Production	Imports	Consumption
1966	137	143	280
1967	177	160	337
1968	219	106	325
1969	251	114	365
1970	252	168	420
1971	282	156	438

Results since 1969 have been disappointing, although in general agreement with the conclusion of Newman (5) in that year: 'At the moment the future seems to hold promise for a continuing slow growth in production'. Now, the rate of growth does not show promise of satisfying local demand within a reasonable period. One of the chief reasons for this has been the failure of the 'dry' (i.e. non-skim milk) ration recommended by Newman (6), i.e. 2.3 kg (5 lb) cassava plus 0.5 kg (1 lb) of a 40% protein meal per pig per day. (The 'PC' ration, below). Even in 1968 the economics of this feed were dubious, because although the rate of liveweight gain more than paid for the cost of food, at 1968 pig values and food costs, this rate was so slow (only about 0.32 kg per pig per day) that there would have been little profit per unit time to offset the labour and building cost overheads. Only in small up-country piggeries, where labour and buildings would not be costed (and cassava is cheap), could this ration have been attractive.

During 1969 and 1970, however, the relevant cents/kg costs changed as follows :

	1968	1969	1970	1971
Cassava ex Nausori market	3.5	3.5	4.4	6.0
40% protein meal ex Crest Mills	10.9	10.9	11.5	11.5
PC Ration (mixed)	4.6	4.6	5.8	6.9
Porker liveweight (butcher's price)	43.2	43.2	46.1	50.9
Return per kg of PC ration*	+0.5	+0.5	−0.4	−0.9

*Assuming a liveweight gain of 0.32 kg/day.

In areas remote from markets, cassava would have appreciably lower value, and pigs might be raised in 'stockade' conditions with a slight cash profit; but the return per manhour would be slight.

As Newman (5) pointed out, a substantial part of the 1968 production came from a few large piggeries (two held 2,000 and 3,000 pigs respectively while five others held more than 100, and seven others more than 10). These large piggeries rely on meat offal, hotel swill and skim milk for their protein source. The production from these piggeries has remained satisfactory; but supplies of offal, swill and skim milk are limited. If production of pig-meat in Fiji is to meet demand, it is necessary to devise an economic 'dry' ration.

EXPERIMENTAL WORK

Newman's recommendations were not based on any formal feeding trials, but the 'Development Work' he described established with some certitude that with good management a liveweight gain of about 0.32 kg per pig per day (0.7 lb per day) was usual. From 1967 to 1970, there was still no thorough, conclusive, experimentation but a few simple trials were directed to the problem of the protein supplement (the 40% meal) of the recommended pig ration.

Newman (7), using pigs believed to be affected with protein malnutrition on farms feeding the 40% protein meal cassava ration, compared the following daily treatments:

(a) PC + oral dose of sulphamezathine.

(b) PC + high level of vitamins A, B and D.

(c) 6.8 kg skim milk + 2.3 kg cassava per pig.

Treatments (a) and (b) gave no significant improvement while (c) resulted in a daily liveweight gain of 0.5 kg per pig. When ration (a) was supplemented with skim milk, the pigs showed a marked increase in liveweight. However, the addition of reconstituted, roller-dried skim milk to (b) gave a lower liveweight gain. Newman suggested that what was probably lacking from the dried skim milk was a heat labile amino acid which was destroyed by the process of roller drying. This view was reinforced by information from the University of Hawaii (W. I. Hugh, pers. comm.) that Tuna fish meal is deficient in methionine, and Australian meat meal in methionine and lysine. Tuna fish meal, and this meat meal, comprise about 64% of the 40% protein meal.

Newman (7) and Johnson (2, 3) independantly studied the addition of lysine and methionine to the PC ration. Newman, comparing the PC ration against PC supplemented with methionine and lysine, found 'healthier' pigs on the latter ration; liveweight gain being 10 lb more on average in 49 days. A similar observation trial showed an apparent response from 50% of the pigs. Johnson's work (2) showed a tremendous variation between and within treatments. In his first trial, the average liveweight gains were 0.29 kg and 0.15 kg per pig per day for the supplemented and non-supplemented rations respectively. In his second trial however, where pigs were selected after a standardization period, the daily liveweight gain per pig was 0.25 kg for both groups. A further trial by Johnson (3) compared the following daily treatments :

(a) PC ration.

(b) PC + methionine and lysine.

(c) 1.1 kg 18% protein meal per pig.

The daily liveweight gains obtained were 0.28 kg, 0.28 kg and 0.35 kg per pig respectively.

Thus the results from Newman's and Johnson's work on methionine and lysine supplements were inconslusive.

Theoretical calculation by McIntyre (4), however, showed a near 50% deficiency in digestible energy in the recommended PC ration. He therefore, followed this up with the trial described in the following paper (4). This showed a disappointingly low rate of liveweight gain (less than 0.2 kg per head per day) from pigs on the PC diet, but relatively good rates of liveweight gain, 0.42-0.44 kg per head per day, from the skim milk based rations also tested. The trial has emphasized the need for a better 'dry' ration suitable for wider use by farmers.

DISCUSSION

As pointed out, the reliance on skim milk as a protein source is limiting to production in Fiji. With the current expansion of the Dairy industry, there should be a parallel increase in pig production in the near future. Maximum use may also be made of this limited source of protein by using less than the recommended level of 6.8 kg skim milk per head per day. Danish work (1) has shown that optimum growth rate can be obtained from pigs fed up to 2.8 kg skim milk per head per day in conjunction with barley meal. The use of maize, or maize-cassava as the energy source, with vitamin and mineral supplements, may realize this lower level of skim milk feeding. However, the potential of lower levels of skim milk fed in conjunction with cassava alone is limited in terms of good liveweight gain.

Past pig ration work and recommendations have been centred on the maximum use of local foodstuffs and the use of crops already familiar to the farmer. Thus the use of cassava was widely publicised. While cassava root is highly palatable and easily digested by pigs, its bulky nature does offer a certain limitation to its value as a sole energy source in pig feeding. Recent calculation shows that the recommended 2.3 kg of cassava (a near maximum amount that can be consumed by a pig in the weight range of 18-55 kg liveweight) is not sufficient to supply the energy requirement.

The reported liveweight gains of about 0.32 kg per head per day, (3, 7) in relation to the near 50% deficiency of digestible energy in the ration consumed is perhaps strange. It is apparent that pig feeders must turn to other high quality energy sources such as maize, sorghum, wheat or barley as substitutes for cassava, or use these in combination with cassava or other local energy feeds such as coconut meal, molasses and rice bran to supply the required energy for growing and finishing pigs. Investigation of some of these possible substitute crops is going on at present and success would be a tremendous aid to local pig production.

The development of soyabean locally, presents another encouraging possibility of a protein source for pig rations. Fish residues manufacturers into fish meal is a possible longer term prospect.

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The reported [illegible] of about 0.22 kg per head per day [illegible] in relation to the near 30% [illegible] energy [illegible]. It is apparent [illegible]

[illegible]

Fiji agric. J. (1972) 34, 85—90

A COMPARISON OF THE RATES OF GROWTH OF PIGS ON THREE SKIM-MILK-BASED RATIONS AND ONE DRY RATION

by

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SUMMARY

In a trial of four pig rations, three rations using skim-milk (one with maize, one with cassava, and one with a commercial pig-feed) all gave a daily rate of weight gain per pig of about 430 gm (0.95 lb), while the fourth ration, a high-protein commercial pig feed plus cassava, gave only 180 gm (0.4 lb). These rates were from weaning to 18 weeks, when the males were slaughtered as porkers. During the next 9 weeks, to when the females were slaughtered as baconers, the daily rates of weight gain were 545 gm (1.2 lb), 430 gm (0.95 lb) and 360 gm (0.8 lb) for pigs on skim-milk plus maize, pig meal, and cassava respectively, and 360 gm (0.8 lb) for those on pig-concentrate plus cassava.

At the prices ruling at the time of the trial (1970), the cost of food for the 'pig-concentrate plus cassava' ration was more than the sale price of the pigs; but all the skim-milk rations were profitable, particularly those using maize or cassava. The chief change since has been a big rise in cassava price, making the 'dry-ration' still more unprofitable, and the skim-milk plus cassava less profitable than skim-milk plus maize.

INTRODUCTION

The progress of the pig-meat industry of Fiji, and related research, up to 1968 have been reviewed by Newman (5) and from 1968 to 1972 by Teleni (7). Increases in local pig-meat production in recent years have not kept pace with increasing consumption, so that imports have increased undesirably. Two of the main limiting factors in Fiji, as in other Pacific territories, are the shortage of grains suitable for feeding to pigs, (maize sorghum etc) and the lack of local constituents for the processed high-protein feeds (meat-meal, fishmeal, soyabean meal, etc) which are needed to provide a balanced diet if local starchy foods are to be used.

Pig production in Fiji now falls in three categories according to whether the protein in the diet comes from

(a) garbage eg. slaughterhouse offal, hotel swill, poultry-farm scraps, etc.

(b) processed meals eg. meatmeal, fishmeal, (now made largely with imported ingredients, although greater use could in time be made made of local products)

(c) skim-milk from dairy farms.

Every large piggery in category (a) has unique problems, and expansion of this type of production is limited, so research in this field would be inappropriate.

Category (b) has received most attention in recent years. The initially promising results reported by Newman (5) have been followed by the disappointing progress and inconclusive experiments reviewed by Teleni (7).

The experiment now reported aimed to test a category 'b' ration more thoroughly than had hitherto been done under experimental conditions, in comparison with three category 'c' rations using skim milk as the protein source. Most dairy farmers in Fiji cannot economically market whole milk, but rather separate and market the butter-fat. The more progressive of these farmers use the skim-milk for pig feed. No quantitative study seems to have been made in Fiji hitherto, however, of the relative merits of different local starch foods — eg. cassava (tapioca) sweet potato, copra-meal, bananas, maize — that could be fed in conjunction with skim milk, although some work on these has been done in New Guinea (6).

EXPERIMENTAL DETAILS

Treatments and design

Each of the 14 litters used for the trial was assigned a feed treatment from birth. From farrowing to weaning this treatment was fed to the mother sow, after weaning to the experimental animals. The treatments and numbers and breeds of litters were:

1. Skim milk + maize (3 litters: 1L, 2 L x W)
2. Skim milk + cassava (3 litters: 3 L x W)
3. Skim milk + P.S.R. (4 litters: 3 L x W, 1W)
4. P.C.R. + cassava (4 litters: 2L, 1 L x W, 1W)

L = landrace; W = Large white; L x W = crossbred.

P.S.R. = pig starter ration } Commercial preparations, constituents shown in Appendix 1.
P.C.R. = pig concentrate " }

These were fed to the mother sows *ad lib* until weaning, at 8 weeks, then to the trial pigs at the rates shown in Table 1, which also shows the digestible protein and energy contents of these rations. Table 2 shows their chemical constitution. tion.

Procedure

All the sows farrowed during May-July 1970. The young pigs remained with the dams from birth to eight weeks old when they were weaned. Excluding deaths during the first three weeks due to 'lying-over' by sows and congenital abnormalities there were 26, 23, 35, and 40 piglets respectively on Treatments 1, 2, 3, and 4. All of those on the skim-milk treatments (1, 2, and 3) survived to 18 weeks, but 12 of the 40 on Treatment 4 died in that time. At that age, of the 112 survivors the 57 males were slaughtered as "porkers" and the 55 females carried on to be slaughtered as baconers at 29 weeks.

Each mother sow was confined, before farrowing, to an individual pen (9 m^2) with a concrete floor, farrowing rail, feed trough, and nipple drinker, and fed on a commercial preparation containing 14% crude protein. After farrowing each sow

TABLE 1. FOOD QUANTITIES GIVEN DAILY

Treatment constituents	AGE 8 weeks to 18 weeks of age			AGE 18 weeks to 29 weeks of age		
	Feed intake (lb/pig/day)	Digestible protein (lb/pig/day)	Digestible energy (kcal/pig/day)	Feed intake (lb/pig/day)	Digestible protein (lb/pig/day)	Digestible energy (kcal/pig/day)
1. Skim-milk	15.0	0.61	7601	7.5	0.41	6186
Maize	3.0			3.0		
2. Skim-milk	15.0	0.40	5430	7.5	0.20	4015
Tapioca	5.0			5.0		
3. Skim-milk	15.0	0.84	6678	7.5	0.56	5263
"Pig starter" ration	2.5			2.5		
4. "Pig concentrate" ration	1.0	0.27	4129	1.0	0.27	4129
Tapioca	5.0			5.0		

TABLE 2 COMPOSITION OF FEED CONSTITUENTS

	Moisture (%)	Crude fat (%)	Crude fibre (%)	Crude protein (%)	total ash (%)	Nitrogen free extract (%)
Maize	14.9 ± 0.4	3.0 ± 0.6	1.7 ± 0.2	8.2 ± 0.2	2.9 ± 1.3	69.2 ± 0.7
Tapioca	57.3 ± 1.4	0.7 ± 0.2	6.0 ± 2.9	1.5 ± 0.2	2.5 ± 1.3	33.2 ± 0.5
"Pig Starter" Ration	10.7 ± 0.8	6.8 ± 0.9	5.0 ± 0.7	19.4 ± 0.5	8.1 ± 0.4	50.0 ± 0.8
"Pig Concentrate" Ration	9.1 ± 0.4	7.8 ± 0.6	2.9 ± 0.4	35.8 ± 0.2	21.9 ± 1.2	22.5 ± 1.1

went onto its appropriate treatment ration, *ad lib.* After weaning, each litter was kept in a separate pen, and fed its appropriate ration, in troughs, in equal quantities twice daily at 0700 and 1400 hr. All the rations were consumed within 15 minutes except for the tapioca in Treatments 2 and 4, which was eaten relatively slowly. This was fed chopped into small pieces after the raw roots had been allowed to dry for about 24 hrs.

Measurements

All pits were ear-marked and weighed at birth, then weighed again at 3 and 8 weeks of age, then weekly to slaughter at 18 to 29 weeks.

The pigs were weighed immediately before slaughter and after dressing, hence dressing-out percentages were determined. The carcases were stored in a cool room before being sawn down the spine into 2 sides from which the following determinations were made :—

(a) length of each side from the front of the first rib where it joins the vertebra to the front of the aitch-bone.

(b) backfat thickness opposite the first rib, the last rib and the last lumbar vertebra.

RESULTS

Deaths and disorders

As mentioned above 12 (ie 30%) of the pigs on the dry ration died, in most cases slaughtered for humane reasons after three successive weeks loss of weight. There were no such deaths after the third week among the pigs on skim milk.

Scouring was also prevalent in the pigs on the dry ration, and evident, but to a lesser extent, on those on skim milk plus pig concentrate. The former was also relatively unpalatable. Both these problems could have been due to the high copra meal content in the prepared meals (see appendix). Copra meal has been shown (4) to be unpalatable to pigs.

Weight gains

The weights at 18 and at 28 weeks were analysed by "fitting constants" for breeds and taking birth weights into account by co-variance. Table 2 shows the results.

Carcass characters

Table 2 shows these also, but without the calculated standard errors. The differences between the pigs on the 'dry'-ration and those on skim-milk were significant throughout. Otherwise none of the length and back-fat measurements differed significantly at porker age but at baconer age the superiority in back-fat thickness of the pigs on maize (with skim milk) over those on cassava or pig-meal was significant.

Economics

The prices of the various feed constituents during the time of the trial (May-July 1970) and during the same months of 1972, were:

	cents/lb		cents/kg	
	1970	1972	1970	1972
Maize	3.0	5.0	6.6	11.0
"Pig starter" ration	4.1	4.3	9.0	9.5
"Pig concentrate" "	5.0	5.0	11.0	11.0
Cassava	1.0	3.0	2.2	6.6
Skim-milk	0.2	0.2	0.4	0.4

TABLE 2 LIVEWEIGHTS, CARCASS CHARACTERS AND ECONOMICS

	Skim milk and maize	Skim milk and tapioca	Skim milk and 'pig starter'	'Pig concentrate' and tapioca
Birth to 8 weeks L.W.G. (lb/pig/day)	0.45	0.51	0.42	0.32
Liveweight at 8 weeks (a)	28 (± 1.3) lb	32 (± 1.3) lb	26 (± 1.1) lb	21 (± 1.1) lb
PORKERS (18 weeks)				
8 to 18 weeks L.W.G. (lb/pig/day)	0.95	0.92	0.96	0.39
Liveweight at 18 weeks (a)	95 (± 6.5) lb	96 (± 6.5) lb	93 (± 5.6) lb	40 (± 5.6) lb
Dressing fraction	70%	72%	69%	67%
Dressed weight (b)	67 (± 4.5) lb	69 (± 4.7) lb	64 (± 3.9) lb	27 (± 3.8) lb
Length of sides	25 inches	25 inches	25 inches	20 inches
Backfat thickness (c)	1.0/0.5/0.6 in	1.0/0.6/0.6 in	0.9/0.4/0.5 in	0.6/0.2/0.2 in
Selling price/lb dressed weight (d)	27.7 cents	27.5 cents	27.6 cents	23.4 cents
Gross return per pig (± $1.20) (e)	$18.60	$19.00	$17. 70	$ 6.30
Return per lb L.W.G. 8-18 weeks	13.1 cents	12.6 cents	12.7 cents	3.0 cents
Cost of feed per pig 8-18 weeks	$ 8.40	$ 5.60	$ 9.30	$ 7.00
Cost per lb L.W.G. 8-18 weeks	12.5 cents	8.8 cents	13.9 cents	37.1 cents
Net return per pig (± $1.20) (g)	$ 4.70	$ 7.00	$ 3.40	-$4.00
BACONERS (29 weeks)				
18-29 weeks L.W.G. (lb/pig/day)	1.19	0.79	0.96	0.80
Liveweight at 29 weeks (± 7.2 lb) (a)	187 lb	157 lb	167 lb	110 lb
Dressing fraction	79%	77%	76%	74%
Dressed weight (± 5.5 lb) (b)	148 lb	121 lb	127 lb	81 lb
Length of sides	32 in	30 in	30 in	27 in
Backfat thickness (c)	1.5/0.9/1.0 in	1.1/0.8/0.8 in	1.2/0.6/0.8 in	0.9/0.5/0.4 in
Selling price/lb dressed weight (d)	28.8 cents	29.4 cents	30.0 cents	29.1 cents
Gross return per pig (± $1.60) (e)	$42.60	$35.60	$38.10	$23.60
Return per lb L.W.G. 8-29 weeks	36.2 cents	28.3 cents	32.2 cents	19.1 cents
Cost of feed per pig 8-29 weeks (f)	$16.50	$10.60	$18.40	$14.80
Cost per lb L.W.G. 8-29 weeks	10.4 cents	8.5 cents	13.0 cents	16.6 cents
Net return per pig (± 1.60) (g)	$19.70	$17.70	$13.80	-$4.30

Notes :

(a) Adjusted for breed differences by fitting constants, and for differences between mean birthweight of litters by co-variance analysis.

(b) Adjusted in proportion to liveweight.

(c) Figures 1/2/3 represent fat thickness opposite (1) first rib (2) last rib (3) last lumbar vertebra.

(d) From actual sale records.

(e) Based on adjusted dressed weights. S.E. approximate.

(f) Based on amounts of feed given daily (Table 1).

(g) Post-weaning. Calculated from L.W.G. since weaning, multiplied by return per lb L.W.G., minus feed cost.

The feeding costs of each treatment, at 1970 prices, are shown in Table 2 together with 'gross' and 'net' returns. Note that the latter are gross returns less feed costs, and take no account of building and labour costs.

DISCUSSION

Practical

The weight gain to porker age of the pigs on the dry ration, 180 gm (0.4 lb) per pig per day was worse than those previously recorded in controlled trials (5, 7). This is no doubt because in previous trials the sows had been fed, while suckling, with skim milk and the piglets at weaning had averaged about 14 kg (30 lb). In the present trial the period of lowest daily weight gain (and most deaths) was between weaning, at an average weight of only 9.5 kg (21 lb) and attaining a weight of 15 kg (32 lb). Thereafter the daily weight gain per pig was much as in previous trials, ie about 0.32 kg (0.7 lb).

Thus the present trial was not altogether a fair test of the dry ration recommended by Newman (5) specifically for raising 'weaners', raised on milk-fed sows and sold by the Department to farmers at an average weight of about 15 kg (32 lb).

It is clear, however, that even at the best daily weight gain per pig ever recorded for this ration, ie about 360 kg (0.8 lb), it was uneconomic at 1970 prices and would be completely out of the question with cassava at 1972 prices.

As between the three skim-milk rations, there was little difference in daily rate of weight gain per pig up to porker age, this being about 430 gm (0.95 lb) in every case; but there were significant differences in this rate between porker and baconer ages, with the skim-milk plus maize best at 545 (1.2 lb), then the "plus starter" at 430 gm (0.95 lb) and then the "plus cassava" at 360 (0.8 lb), with associated significant differences in dressed weight and carcass measurements. At both 1970 and 1972 prices the "plus maize" ration is more profitable than the "plus starter". At 1970 prices the "plus cassava" was a little more profitable than "plus maize" to porker age, and a little less profitable to baconer age; but at 1972 prices it would be much less profitable than "plus maize" throughout.

Theoretical

The previous recommendation (5) of the "skim-milk + cassava" and the "Pig concentrate + cassava" rations, at the 8-18 week rates of this trial, has always been dubious because the former gives only 48 and 50% respectively of the theoretical requirements of digestible protein and digestible energy of pigs of that age, and the latter 71 and 66% respectively, according to U.K. National Research Council calculations of theoretical requirement (1).

CONCLUSION

Neither of the locally prepared pig meals is satisfactory. At the rates fed, the resulting growth rates were uneconomic. Moreover, because of their unpalatability and tendency to cause scouring, higher rates of feed may be impracticable; and even if practicable, are unlikely to be economic. Later informal trials with improved versions of these feeds have tended to confirm this.

Cassava (tapioca) is generally considered, in tropical countries, a cheap source of calories. In Fiji recently, however, root-crop prices have soared to levels out of all proportion to the dietic value of these foods. Unless these trends are soon reversed, cassava is ruled out for pig feed: imported maize is cheaper, merely as a calorie source, besides having an appreciable protein content. In the trial the skim-milk maize ration was profitable, and it is to be hoped that a maize-based profitable dry ration can be found, and that maize production in Fiji, now negligible, will increase so that pig production can be based on home-grown maize.

The growth rates and carcass quality of the trial pigs on the skim-milk rations were good by Fiji standards, but not by those of temperate countries where daily growth rates per pig of 0.7 to 0.9 kg (1.5 to 2.0 lb) are common (2). The amounts of feed given by all the trial rations from 18 to 29 weeks were insufficient, again according to (1) Pigs are most efficient in their rate of conversation of feed to body protein from 16 to 20 weeks of age (2). It would seem logical, where possible, to feed on an *ad lib* basis to pigs in this age range to capitalize on this maximum level of conversion efficiency. Instead of selling 'porkers' at about 45 to 50 kg (100-120 lb) liveweight, or about 18-20 weeks old it may be more economic to keep them slightly longer.

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APPENDIX 1 CONSTITUENTS OF THE TWO COMPOUNDED RATIONS

(Supplied by Crest Mills)

(a) Pig starter ration

Constituent	%
Coconut meal	44.0
Salt	0.1
Broiler premix†	3.2
Wheat pollard	22.0
Meat meal	3.5
Fish meal	3.2
Sugar	5.2
Wheat or maize meal	16.0
Molasses	2.8

(b) Pig cancentrate

Constituent	%
Coconut meal	41.8
Fish meal	18.4
Meat meal	34.2
Molasses	5.6

†The "Broiler pre-mix" consists of (parts per 100 lb) :— wheat or maize meal 46.2 lucerne meal 46.0, wheat pollard 5.6 with small amounts of muriate of potash, choline chloride, manganese oxide, ferrous sulphate, methionine, lysine, ethoxyquin and traces of nicotinic acid, oleandomycin, oxytetracycline, riboflavin, pyrridoxine, folic acid, potassium iodide, zinc oxide, copper oxide, and Vits A, B_{12}, and K.

Fiji agric. J. (1972) **34**, 91–96

NUTRIENT SHORTAGES OF SOME POTENTIAL PASTURE SOILS IN FIJI

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SUMMARY

Pot trials carried out between 1960 and 1965, designed to investigate the nutrient status of potential pasture soils with specific reference to legumes, have confirmed the need for P and K, and have clearly indicated the importance of Ca at low rates of application on latosolic soils.

They have also shown the need for further studies on molybdenum and possibly zinc, the former with particular reference to legume crops.

INTRODUCTION

Future economic development of both the dairy and the beef industries in Fiji will depend heavily upon the establishment of improved pastures. Grass and legume species of potential have been imported and are being screened for suitability in local environments (2, 3, 4) as an essential preliminary stage in production improvement. Field trials at present are concerned with the establishment and maintenance fertilizer requirements of early species selection on key soil types of importance to the two industries.

A part of this work has been the use of the greenhouse pot trial method with suitable indicator crops (6, p. 144) to assess qualitative and to a lesser degree quantitative nutrient requirements of main soil types.

Early, general pot test work with Fiji soils was reported by Twyford and Wright (6); this was followed, 1960-1965, by the further work of W. F. Wildin and later still of Roberts (4, 5), both with specific reference to potential pasture soils.

The results of Wildin's investigations, not hitherto published, are presented in this paper. Relevant results obtained by Twyford and Wright and by Roberts are also discussed.

EXPERIMENTAL PARTICULARS

Soils

Five soil types were examined and were selected as representatives of four important soil series (6) in the grazing areas. These are humic latosols, red-yellow podzolic soils, ferruginous latosols and nigrescent soils. The first two soil series are important in the dairy areas and the last three in the drier beef areas.

The five soil types tested were:

A. Lodoni Clay.

A humic latosol developed over basic andesite and augite basalt occuring, though not extensively, in rolling, hilly country in the wet to intermediate areas, of Viti Levu. It is strongly acid, of low status in bases particularly exchangeable potassium and calcium, and with very low acid-soluble phosphate.

B. Bua Clay.

A ferruginous latosol, typical of the soils referred to as 'Talasiga'. It is formed from andesites and andesitic tuff and occurs in the drier, rolling country mainly on Vanua Levu. The soil is acid with low acid-soluble phosphate; exchangeable potassium and calcium levels are low.

C. Matawailevu Clay and (D) Kabisi Clay

Nigrescent soils developed on rolling country in the intermediate rainfall zone (respectively the North East and the South West of Viti Levu). They are both dark coloured (as their soil group name implies), moderately to slightly acid with high base status i.e. high potassium, calcium and magnesium, but with low-acid soluble phosphate.

E. Koronivia Sandy-Clay Loam

A red-yellow podzolic soil, poorly draining, and of low general fertility. It is derived from rhyolitic outwash with a high proportion of quartz sand.

Test-plant species

Nine species were used: Glycine *(Glycine whitti* var. tinaroo); eggplant *(Solanum melongena);* carrot *(Daucus carota);* centro *(Centrosema pubescens);* stylo *(Stylosanthes guyanensis);* phasey bean *(Phaseolus lathyroides);* siratro *(Phaseolus atropurpurea);* cenchrus *(Cenchrus ciliaris);* setaria *(Setaria sphacealata).*

Treatments and Designs

(a) Multinutrient, subtractive designs. Eight trials were of this type, as described by Webb (7), and consisted of a treatment with all nutrients applied (plus All), a treatment with no nutrients applied (minus All), and a series of treatments with a single nutrient omitted (minus X, where X is the missing element). The chemical compounds and the rate of each used, were:

Element	Chemical	Rate kg/ha
P	Na_2HPO_4	378
K	K_2SO_4	251
Ca	$CaSO_4$	378
Mg	$MgSO_4$	126
Mn	$MnSO_4$	16
Fe	Fe citrate	31
Zn	$ZnSO_4$	8
Cu	$CuSO_4$	8
B	$Na_2B_4O_7$	35
Mo	NH_4 molybdate	0.3
Co	$CoSO_4$	0.3
V	NH_4 vanadate	1.1

But it should be noted that neither Mo nor B would have been totally excluded from the minus Mo or B treatments by the use of A. R. grade chemicals alone. Reference to Table 1 will also show that in some of the trials there were other specific treatment omissions; in particular, nitrogen was not included at all because the principal indicator crops were legumes and the primary interest was with this type of crop in composite pastures.

(b) Single nutrient rate trials. Seven trials were of this type, each concerned with various rates of a single element; four trials with Ca (as lime) one with P (as single superphosphate) and two with K (as potassium sulphate. The rates are given in Tables 2 and 3.

In both types of trial there were three replicates, i.e. three pots for each treatment.

Catalogue of trials

The test plants listed were used in the two types of trial on soils A to E as follows:

Soil	Test plant species: Multi-nutrient trials	Single nutrient trials
A	Glycine, carrot egg plant	Glycine (Ca)
B	—	Phasey bean, Siratro, cenchrus (Ca)
C	Glycine, centro	—
D	Carrot	Phasey bean, setaria (K)
E	Glycine, stylo	Stylo (P)

Thus there were 15 trials in all.

Methods

Soil samples were taken as spade slices 5 cm thick, 15 cm wide, and 20 cm deep (depth of soil permitting, occasionally only 12 cm) from substantially random points over the soil type in question, but avoiding localized areas considered unrepresentative. All samples from one soil type were taken at one time, the whole batch pulverized, thoroughly mixed, stones and vegetable debris discarded, and the soil then sun dried and stored in a dry place until use.

All the nutrients used were A.R. grade chemicals. Calcium was applied as $CaCO_3$ mixed with the upper two inches of the soil in the pot; all others were applied as solutions. The soil was kept moist but not wet for at least five days before sowing the seeds. Legume seeds were first inoculated with the appropriate Rhizobia.

Seeds were hand planted about 12 mm deep. Seedlings were thinned to a uniform number per pot. There was daily watering to field capacity with deionized or distilled water, and random rearrangement of pots in the greenhouse to avoid localized environmental differences.

Test plants were harvested at ground level, when the more advanced ones had reached the early flowering stages, or after a definite period of growth. The shoots were then dried at 85°C for 18 hours.

This method is somewhat inappropriate for one of the test species, carrot, which has been bred and selected for its below-ground growth. In the multinutrient type trials on soil A it was notably less responsive than glycine or eggplant and it is a pity that it was the only test plant used for this type of trial on soil D.

The dry matter yields were subjected to conventional statistical analysis in all cases. But in addition, the multi-nutrient trial data were classified as suggested by Chenery (1). Treatment yields due to nutrients being witheld were expressed as a percentage of the complete nutrient treatment which was taken as 100%. Four classes were recognised, namely:

1. Non deficient — more than 80% of the 'complete' yield.
2. Moderately deficient — 51 to 80% of the 'complete' yield.
3. Severely deficient — 11 to 50% of the 'complete' yield.
4. Acutely deficient — less than 11% of the 'complete' yield.

RESULTS

The mean yields of shoot dry matter per plot from the four rates of lime trials are shown in Table 1, of the eight multinutrient trials in Table 2, and of the three rates of P or K trials in Table 3.

Londoni Clay

In all the multinutrient trials there was a significant P deficiency, severe with glycine and eggplant, and moderate with carrot. The one test, with glycine, that included a minus Ca treatment showed a severe deficiency of this nutrient (in agreement with the 'rates of lime trial': see below). Otherwise the results were inconsistent. The K effect was severe and significant for glycine, and non-existent for carrot. Omitting either Ca or Mo gave a significant decrease in yield with glycine, but the latter gave a highly significant increase with carrot.

In the 'rates-of-lime' trial, stylo responded to low rates but the yield declined steadily at rates exceeding 1 mt/ha, suggesting a nutrient rather than a soil amelioration role for Ca.

Bua Clay

This soil was used for three rates-of-lime trials. The results (Table 1) show statistically significant increases in response with increasing rate of lime up to 250 Kg/ha in the case of the grass, (cenchrus), and up to 500 Kg/ha in the case of the legumes (phasey bean and siratro). Further non-significant, but substantial, yield increases accompany increased lime rate up to 750 Kg/ha in the

TABLE 1

YIELDS OF SINGLE NUTRIENT (LIME) TRIALS

gm dry matter per pot

Rate of lime mt/ha	SOIL, CROP AND YIELD			
	Londoni clay	Bua clay		
	Glycine	Phasey bean	Siratro	Cenchrus
0.00	1.9	0.9	0.7	0.8
0.25	2.4	3.6	2.2	1.3
0.38	2.6	—	—	—
0.50	2.7	3.7	2.4	1.3
0.62	2.9	—	—	—
0.75	3.0	3.8	2.5	1.7
1.00	3.4	3.9	2.5	1.7
1.25	2.9	4.0	2.5	1.8
1.88	2.8	—	—	—
2.50	—	5.1	2.7	1.5
5.00	1.9	—	—	—
7.50	1.8	4.9	3.4	1.2
10.00	1.4	—	—	—
12.55	—	4.8	3.1	1.4
S.E.±	—	0.6	0.5	0.3

TABLE 2

YIELDS OF MULTINUTRIENT POT TRIALS
(gm dry matter per pot)

Treatment	SOIL, CROP, AND YIELD							
	Londoni Clay			Matawailevu Clay		Kabisi Clay	Koronivia Loam	
	Glycine	Egg plant	Carrot	Centro	Glycine	Carrot	Stylo	Glycine
+ All	21.	3.0	0.9	2.9	1.0	7.3	6.0	2.2
— All	0.5	0.4	0.4	1.5	0.3	3.8	0.5	0.3
— P	0.5	0.4	0.6	1.7	0.4	6.4	0.7	0.4
— K	1.6	1.3	1.0	1.6	1.2	6.5	5.1	0.4
— Ca	0.7	—	—	—	—	—		
— Mg	2.2	2.9	1.0	1.8	0.9	6.4	4.9	3.0
— Mn	2.1	2.7	0.9	3.5	1.7	6.7	6.4	2.6
— Fe	1.9	2.6	1.0	4.2	1.6	7.1	6.8	3.3
— Cu	1.2	2.8	0.8	2.6	1.5	6.7	6.7	2.7
— Zn	1.8	2.9	1.0	2.8	0.8	6.7	5.8	1.8
— B	1.7	—	0.8	2.0	1.4		6.3	2.2
— Mo	1.2	2.5	1.8	2.5	0.6		5.7	1.4
— Co	—	—	—	—	—	—	—	—
— V	—	—	—	2.6	1.5	6.8	6.9	2.5
S.E. ±	0.3	0.1	0.1	0.5	0.2	0.3	0.3	0.05
C. of V. %	26	19	24	29	21	7	7	3

case of the grass, and up to 2.5-7.5 mt/ha in the case of legumes. Pooling the two legume results, the yield at a lime rate of 7.5 mt/ha is about 30% more than at 500 kg/ha and this increase is significant at about 5% probability.

This suggests that whereas the lime has only a nutrient role with respect to the grass, with respect to legumes it may be having a pH raising role also. But the evidence is slender.

Matawailevu Clay

There was a substantial response to P in both the trials with this soil, significant at the 5% level in the glycine trial, and at 10% in the centro trial, with the deficiency rating as 'severe' in the former and 'moderate' in the latter. Otherwise the results were inconclusive with apparently moderate, but non-significant, deficiencies of K, Mg, B, and Mo appearing in one or the other test (but see below as regards Mo).

Kabisi Clay

There was a substantial, but non-significant, response to P in the only multinutrient trial, with (unfortunately, as discussed above) carrot as the test crop. The rate of K trials (Table 3) were more informative. The grass did not respond to the basal dressing, but the legume yield was trebled by it; and both grass and legume gave a significant response of about 35% to 250 Kg/ha of K_2SO_4, with no further response to the higher rate.

Koronivia sandy clay loam

In both multinutrient trials (Table 2) and in the rates of P trial (Table 3) there was a big response to P. The former showed a 6-8 fold increase in yield with 380 kg/ha of Na_2HPO_4, and the rates trial showed a twelve-fold increase with 500 as apposed to 63 kg/ha of single super, with approximately linear intermediate points. Deficiencies of K and Ca also appeared in both multinutrient trials, 'moderate' and only slightly significant in the stylo trial, but highly significant and 'severe' in the case of Ca on the glycine trial.

The only other notable feature was a highly significant response to Mo in the glycine trial, which tends to confirm that the substantial, but separately not highly significant, responses of glycine to Mo in the Matawailevu and Londoni soil trials were genuine. The relevant figures are:

	Londoni Clay	Matawailevu Clay	Sandy Clay Loam Koronivia
All	2.1	1.0	2.2
-Mo	1.2	0.6	1.4
S.E.	±0.3	±0.17	±0.05

The yield of glycine is reduced by about 45% in the absence of molybdenum.

DISCUSSION

Londoni Clay and Koronivia Loam Soils

These results confirm those of Twyford and Wright (5) and Roberts (5) in showing deficiencies of P, K, and Ca on Londoni clay, and of P and Ca on Koronivia sandy clay loam. The Mo deficiency that was suspected on Londoni clay is confirmed, and a similar deficiency revealed on the Koronivia soil, but seriously affecting only glycine of the test plants now used.

The previously reported (6) suggestion of B and Fe deficiencies on Koronivia sandy clay loam are not confirmed; indeed the absence of these elements (particularly Fe in the glycine trial) tended to increase yield in the trials now reported.

Bua Clay

The liming trial results show a degree of agreement between the ferruginous latosol (Bua clay) and the humic latosol (Londoni clay) suggesting that these results may be typical of a wide range of soils. In both cases there is a big response, (doubling to quadrupling of yield) in all tests to 250 kg/ha of lime and no general, or in any one case highly significant, response to any application in excess of 1 mt/ha. This suggests that the lime is acting as a calcium nutrient supply rather than as a soil ameliorating factor. In soils buffered as strongly as these, such low rates of liming will have very little effect on pH.

There is a suggestion, in the legume results on the Bua clay, of some further response to application in the 1.0-2.5mt/ha range, with one figure suggesting a further response to 7.5 mt/ha, but no great significance attaches to this.

Matawailevu and Kabisi clays

The response to P, substantial in all trials (assuming the response to the basal dressing in the rates of K trial was primarily to the P component) is undoubtedly common to all soils of this type. The deficiency was either 'severe' or on the border line of 'severe' by Chenery's criterion in all trials. Both Twyford and Wright (6) and Roberts (5) have reported P responses in pot trials and the latter in early field trials also. There is evidence (although inconclusive in the case of Matawailevu clay) of K deficiency in both soils; and suggestions of Mg deficiency. Again Twyford and Wright (6) report variable responses to K in the nigrescent soil series and Partridge (Pers. Comm.)

TABLE 3

YIELDS OF SINGLE NUTRIENT (P or K) TRIALS

gm dry matter per pot

Rate of P* or K† kg/ha	P Trial Koronivia Loam Stylo	K Trials Kabisi Clay Setaria	K Trials Kabisi Clay Phasey Bean
O	—	5.7	0.6
Basal‡	—	5.9	1.8
63	0.6	5.9	1.9
126	1.7	7.1	2.0
252	3.3	8.2	2.5
504	7.5	7.6	2.5
S.E.	±1.1	±0.3	±0.2

*$Ca(M_2PO_4)_2$, Single superphosphate.

†K_2SO_4, Potassium sulphate.

‡Basal treatments given as follows: 252 Kk/ha single superphosphate; 126 Kg/ha lime; 4 Kg/ha $ZnSO_4$ and 0.3 Kg/ha each of NH_4 molybdate and $CoCl_2$.

has recently recorded field responses to K on these soil types in the Western Division.

On the Matawailevu clay, there was also the apparent deficiency of Mo when glycine is the test crop, that has appeared on every soil so tested.

Zinc

In no one trial has the depression in yield caused by omitting zinc been statistically significant; but it is noteworthy that, except in the carrot test on Londoni clay, the yield without Zn is always less, usually 5-15% less than the 'all yield.

CONCLUSIONS

These trials, in conjunction with earlier pot studies (4, 5, 6) have served a useful purpose in showing that besides P and K, which would, in any case have been included in field trials, and S, the need for which has been suggested by earlier work (5), Ca is also likely to give field responses when applied at a 'nutrient' level on latosolic soils, and some crops are likely to respond to Mo.

Field trials of N, P. K, S and Ca are, in general, now more needed than further pot trials; but it is important to know whether the responsiveness of glycine to molybdenum is peculiar to that species, or whether other pasture legumes behave similarly, and this can best be done by more pot trials. The effect of Zn also needs further study.

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FERTILISING PASSIONFRUIT IN THE SIGATOKA VALLEY

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SUMMARY

In a two-replicate NPK factorial fertilizer trial on yellow passionfruit *(Passiflora edulis var. flavicarpa)* on alluvial soils in the Sigatoka Valley, one replicate under good management produced a first year mean yield of 30.7 mt fruit/ha (27,400 lb/acre) while the other under poor management, produced 5.8 mt/ha (5,150 lb/acre). Under good management the application of 0.1 kg (0.25 lb) urea plus 0.1 kg (0.25 lb) potassium sulphate per vine every three months from transplanting gave a yield increase valued at $1600/ha ($635/acre) for a fertiliser cost of $40/ha ($16/acre).

INTRODUCTION

Yellow passionfruit *(Passiflora edulis var. flavicarpa)* has been grown in the Sigatoka Valley for the past ten years. Fruit for juice extraction is sold to two local processing factories.

Due to the expansion of overseas markets, the factories wish to double the area under fruit from about 30 ha to 70 ha. Although a good yield of fruit is 28 mt/ha with top claimed yields of 39.2 mt/ha, the factory intake showed the average for the 1969/1970 season to be only 13.4 mt/ha.

The previous fertiliser recommendation was for a mixture of 35 parts of urea, 25 of superphosphate and 40 of sulphate of potash applied at the rate of 1 lb/vine every three months. (1) This rate was later altered to 3 lb per vine every three months (2) The recommendations were made on the basis of fruit analyses and on Hawaiian fertilizer practice.

The alluvial soils of the Sigatoka Valley are regarded as fertile, with very high P and K levels and many farmers felt that their fertilizer applications were only producing excessive leaf, so a factorial trial was undertaken to establish satisfactory fertilizer applications.

EXPERIMENTAL DETAILS

Design

The trial was located on two private farms (Sites 1 and 2) at Bilalevu in the Sigatoka Valley, with one replicate of a 3N x 3P x 3K factorial at each site. The soil particulars at each site were:

	Site 1	Site 2
Soil type	Silty clay loam	clay loam
pH (Ca Cl_2)	5.60	5.50
Total N	0.11%	0.11%
Available P_2O_5	782 ppm	839 ppm
" K_2O	328 ppm	360 ppm

Passionfruit vines are grown on wire trellis in quarter acre (0.1 ha) blocks as this size is suitable for daily hand pollination of the flowers with the labour of one family. Such a block has 55 vines, so it was decided to fit the 27 plots into this area by using a plot size of two vines.

The 27 treatment combinations were completely randomised in each block. The treatments were N (urea), P (single superphosphate) and K (potassium sulphate) each at 0, 0.11 kg (0.25 lb), 0.22 kg (0.50 lb) per vine every three months in all combinations. The lower rate is equivalent to 246 kg/ha (220 lb/ac) on the standard 0.1 ha (quarter acre) block.

Method

Passionfruit seedling vines were planted in the normal manner on 4/3/70 on site 1 and 26/3/70 at site 2. At site 2, the planting holes were soil sterilized with Vapam (sodium methyl dithiocarbonate) as a protection against collar rot *(Phytophthora cinnamoni)*.

Half rates of fertilizer were applied at this time and full rates routinely at three monthly intervals thereafter. Although the farmers were responsible for regular weeding and hand-pollination their efforts were supplemented with one mowing and four paraquat sprayings during the year. At site 2, the farmer became disinterested prior to a change of lease and the new farmer could only occasionally be persuaded to weed. One inter-row weeding was carried out with a tractor-drawn disc harrow, and then occasionally by cane knife, additional to the paraquat application by research staff. The disc-harrow banked up earth on either side of vines, leaving a deep hollow along the top of the ridge. Heavy rain caused localised waterlogging and several vines died of collar rot. Additional plant damage was caused by careless weeding with the cane knife. Young dead seedlings were replaced. Mature vines were also damaged by horses tethered to the trellis poles.

Thus conditions were relatively weed-free at Site 1 but general weedy at Site 2. The pollination of the flowers was satisfactory at Site 1 but was irregular at Site 2.

The vines at Site 1 were also sprayed by mist-blower with malathion and Rogor 40 against fruit fly and red spider mite, and with one spray of Benlate against anthracnose.

Ripe fruit was collected weekly throughout the season and the numbers and weights of marketable and unmarketable fruit from each plot recorded.

RESULTS

Annual total yield

Because of the large differences in yields between replicates, each was analysed separately at the end of the first harvest season (December 1970 to July 1971).

At site 1, under good management, the mean yield was 30.7 mt/ha (27,400 lb/acre) with highly significant effects of N and K.

	Yields of fruit,		mt/ha
Fertilizer Level	N	P	K
0	20.3	31.4	26.3
1	35.1	30.7	32.3
2	37.0	30.3	33.9
	±2.6	±2.6	±2.6

The P effect was negligible and non-significant, as were the linear components of the two-factor interactions, using the three-factor interaction as error.

At site 2, under poor management, the mean yield was 5.8 mt/ha (5,150 lb/acre). No main effect or interaction was significant at 5% probability, but the main effect of K was significant at about the 10% level.

	Yields of fruit,		mt/ha
Fertilizer Level	N	P	K
0	5.0	5.0	4.5
1	6.6	6.2	6.1
2	4.8	5.9	6.8
	±0.9	±0.9	±0.9

Seasonal Distribution

At Site 1 the crop was distributed through the year as follows :

	Weekly rate of yield,		kg/ha
	N_0K_0	N_1K_1	N_2K_2
December	40	600	770
January	60	740	680
February	30	320	350
March	550	1,680	1,920
April	160	560	610
May	840	1,770	2,030
June	1,000	2,070	2,000
July	550	1,050	1,330

Thus the absolute effect, of N and K together, was about the same throughout the bearing period; but proportionately the effect was much greater early in the season. Whereas in the absence of N and K only 4% of the total crop has come by 28 February, and another 22% by 30 April, in the presence of N and K at the high rates these fractions are respectively 20% and 27%.

DISCUSSION

Management, mainly careful weeding and hand pollination of flowers, seems largely to determine the profitability of growing passionfruit. The trial plots were so small that extrapolation from yield per plot to yield per hectare may be somewhat unreliable; but it is nevertheless noteworthy that the yield of the NK plots in the better trial were equivalent to 41,300 kg/ha 36,870 lb/ac), which is slightly above the previous claimed top yield. Moreover, this could probably have been increased still further by better weeding and pollination. The effect of crop protection against red spider mite is a factor for future investigation. Although the trials were not badly affected except on old leaves, more serious infestations on commercial blocks have been noted recently.

At the current factory price of 6.6c per kg (3c per lb) of fruit, the value of the fruit from the main treatment combinations at Site 1 and the cost of fertilizer are given in Table 1. There was no significant difference between the N_1 and N_2 levels.

It will be seen that the application of fertilizer can be highly profitable under good management and could increase the present average overall yield of 13.4 mt/ha.

The monthly production figures show drops in production in February and April. This is likely to be due to wet periods three months earlier, at the time of pollination eg. November 243 mm and January 580 mm. Wet periods can reduce hand pollination but also any stigma wetting within two hours of pollination results in the destruction of pollen by grain burst (3).

ACKNOWLEDGEMENT

I thank the Tropic Frut factory and Valley Industrial Co-operative Association for financial support in this project, Ram Narayan on whose farm the work was conducted and S. Chandra for his technical assistance.

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TABLE 1

Values and costs at Site 1

Treatment	Yield kg/ha	Value $/ha	Cost $/ha
N_0 K_0	13.6	900	0
N_0 K_1	21.5	1,400	15
N_0 K_2	26.0	1,700	30
N_1 K_0	33.5	2,200	25
N_1 K_1	37.4	2,500	40
N_1 K_2	34.1	2,250	55
	±2.6	±170	

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