PASTURE SPECIES EVALUATION IN THE SOLOMON ISLANDS

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ABSTRACT

Pasture evaluation trials were undertaken at five regional sites in the Solomon Islands. Species compared included five tropical grasses, Brachiaria mutica *(Para),* B. decumbens *(Signal),* B. dictyoneura *(Koronivia),* Panicum maximum *cv. Hamil and* Ischaemum aristatum *(Batiki Blue) and eight tropical legumes,* Centrosema pubescens *(Centro);* Pueraria phaseoloides *(Puero);* Stylosanthes guianensis *cv. Endeavour (Stylo);* Desmodium uncinatum *(Silverleaf);* Desmodium heterophyllum *(Hetero);* Glycine wightii *cv. Tinaroo (Glycine);* Macroptilium atropurpureum *cv. Siratro (Siratro) and* Vigna luteola *(Vigna).*

On fertile alluvial soils cleared from primary rainforest Para and Signal grass gave the most consistent yields over the two years with dry matter yields up to 30 *tonnes* ha^{-1} yr^{-1} *at the best site. The lower yielding Batiki also grew well on these soils and combined well with legumes, whereas Signal was more competitive and tended to suppress the legume component. Centro, Puero and Hetero were the most productive and persistent of the legumes at these sites.*

Under heavy shade in young coconut plantations Batiki Blue and Signal were the best adapted grasses while the proportional yield of all legumes was much higher. Puero and Centro produced the highest yields under these conditions.

In a less shaded environment under old coconuts on a coral rubble soil of high pH Siratro was outstanding among the legumes whilst Vigna was a good pioneer in the first year. Koronivia was the best of the grasses at this site with dry matter yields of up to 11 *tonnes* ha^{-1} yr^{-1}.

Recommendations are made for grass/legume mixtures for the major soil types in each of the five important land systems covered in this study.

INTRODUCTION

The territory of the Solomon Islands is a scattered archipelago extending 1,770 km southeast from Bougainville between latitudes 4°45′ and 12°30′S and longitudes 155°30′ and 170°30′E. There are six large islands or island groups with numerous smaller islands and atolls. Total land area is 29,800 km². The major islands are Choiseul, the New Georgia Group, Santa Isabel, Guadalcanal, Malaita and San Cristobal (Figure 1). These vary in length from 145 to 190 km and in width from 35 to 50 km. The largest, Guadalcanal, has a land area of 5,120 km².

In 1971, the Solomon Islands Government began a program to develop the local beef cattle industry. This involved importing cattle from Australia and offering subsidies, grants and loans to local farmers for clearing, fencing, planting pastures and purchasing imported stock. The introduction of this scheme has required research into the problems of pasture development in the "small holder sector".

The small holders' approach to pasture development has been to replace vegetation of little or no value for grazing (i.e., tropical rainforest) with a pasture composed of introduced species recommended by the Solomon Island Ministry of Agriculture and Lands. Until 1973, there was no co-ordinated pasture research program and the species recommended, although having broad adaptation to wet tropical areas, were

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not necessarily suited to specific localized environmental conditions. Thus, when a pasture species evaluation program was instigated in 1973, one of the main objectives was to compare the productivity of those species already in use with other potentially useful species over as wide a range of environmental and edaphic conditions as possible.

This paper reports the results of initial investigations from five evaluation sites.

MATERIALS AND METHODS

Site

Five experimental sites were selected, on different islands and covering a range of soil types and environmental conditions (Figure 1). The site location, soil description and analysis of soil samples from each site are presented in Table 1. At Liapari and Lever Point the sites were selected in existing coconut plantations, four years old and seventy years old respectively. At Lokaru and Kaonasughu the sites were in virgin rainforest while at Dala the site was secondary bush regrowth following subsistence gardening. All sites were cleared by hand methods similar to those employed by the local farmers except that trash was not burned. Fallen trees were removed from the sites but large stumps were left *in situ*.

Climate

The climate of the Solomon Islands is moist tropical; seasonal and daily temperatures vary little throughout the year and in coastal regions maximum temperatures seldom exceed 32°C with minimums rarely below 23°C. Relative humidity fluctuates between 60 and 92%. Evaporation rates are low averaging 5 mm a day (Wall and Hansell 1973). Rainfall is high. Seasonal distribution patterns are not marked except on the Guadalcanal plains where from April to October rainfall is relatively low. Elsewhere it is evenly distributed throughout the year with most areas receiving between 2,500 to 4,500 mm annually. Mean annual rainfall over the experimental period was above 3,000 mm at all sites except Liapari where it was 2,960 mm. The rainfall was well distributed throughout each year at all sites and it is unlikely that a soil moisture deficit would have affected pasture yield at any time.

Grass and legume species used

The pasture species were selected for evaluation on the basis of their known adaptation to tropical environments; some were already in use in the Solomons while others were new introductions. The grasses selected were *Brachiaria mutica* (Para), *B. decumbens* (Signal), *B. dictyoneura* (Koronivia), *Ischaemum aristatum* (Batiki Blue), and *Panicum maximum* cv. Hamil (Hamil). The legumes were *Centrosema pubescens* cv. Common (Centro); *Pueraria phaseoloides* (Puero), *Stylosanthes guianensis* cv. Endeavour (Stylo); *Vigna luteola* (Vigna); *Desmodium uncinatum* (Silverleaf); *D. heterophyllum* (Hetero); *Macroptilium atropurpureum* cv. Siratro (Siratro); and *Glycine wightii* cv. Tinaroo (Glycine).

At each experimental site there were two trials.

1. All the grasses were sown with a common legume (Centro) and all legumes were sown with a common grass (Para), to assess yields and combining ability in mixed swards.
2. Twelve additional grass/legume mixtures were evaluated as combinations. These were: Hamil and Stylo; Hamil and Silverleaf; Hamil and Glycine; Koronivia and Stylo; Koronivia and Glycine; Koronivia and Puero; Batiki blue and Stylo; Batiki blue and Silverleaf; Batiki blue and Puero; Signal and Stylo; Signal and Glycine; Signal and Hetero.

At Lever Point, Puero and Stylo failed to establish even after resowing. The treatments containing Stylo were oversown with Siratro and those containing Puero

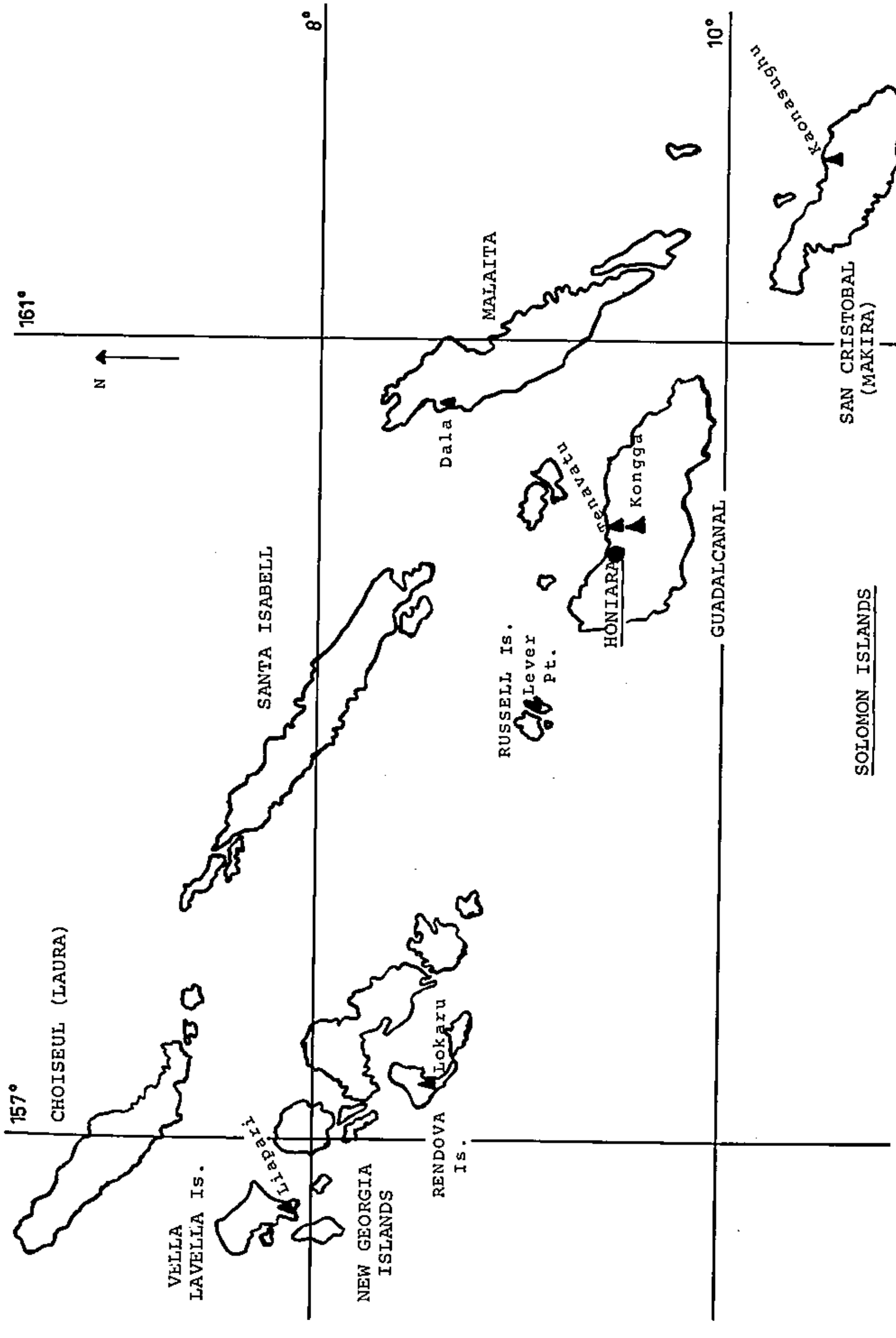

FIGURE 1
Location of the pasture evaluation sites in the Solomon Islands.

TABLE 1

Soil description and chemical analyses of soil samples from five pasture evaluation sites in the Solomon Islands

Site	Parent Material	Soil Type		Drainage	pH	Total Organic		Available P (p.p.m.)		Available K
		0-8 cm	8-16 cm			N%	C%	NH_4F+HCl	$NaHCO_3$	Meq. $100g^{-1}$ODS
LIAPARI	Coral Limestone	Very dark brown 10yr2/2 Silty clay loam	Dark reddish brown 5yr2/2 Silty clay loam	well drained	6.4	0.58	4.70	—	20	0.62
LOKARU	Alluvium	Very dark grey brown 10yr3/2 clay loam	Dark brown 10yr3/3 clay loam	well drained	6.4	1.01	12.09	17.5	—	3.42
LEVER POINT	Coral detritus and coral rock fragments	Very dark brown 10yr2/2 organic slightly peaty loam	Light brownish grey 10yr6/2	imperfectly drained	8.0	0.37	2.03	—	22.4	0.26
DALA	Reef limestone with water deposited volanic impurities	Very dark brown 10yr2/2 loamy clay	Dark brown 10yr3/3 silty clay	well drained	6.4	0.71	7.47	16.5	—	0.33
KAONASUGHU	Alluvium derived from basalts	Very dark grey brown 10yr3/2 clay loam	Dark greyish brown 10yr4/2 clay	poorly drained	6.0	0.75	9.07	8.5	—	2.52

were oversown with *Desmodium intortum* (Greenleaf) six weeks after establishment of the trial.

In both trials at all sites a randomized block design was used with 3 replications of 12 plots, each plot 9 m^2.

Procedure

The grasses, Para, Signal, Koronivia, Batiki Blue and the legume Hetero were planted as vegetative cuttings. Hamil grass and the other legumes were planted as seed at the following rates:

Hamil, 9 kg ha^{-1}; Centro, 11 kg ha^{-1}; Puero, 5 kg ha^{-1}; Stylo, 5 kg ha^{-1}; Glycine, 9 kg ha^{-1}; Siratro 9 kg ha^{-1}; Silverleaf, 9 kg ha^{-1}; and Vigna, 9 kg ha^{-1}.

All legume seed was inoculated with the appropriate commercially available *Rhizobium* strain before sowing.

At Dala, all species were planted/sown together on the 27th September 1973. Seed was broadcast in the appropriate plots and the soil surface lightly raked. Bundles of vegetative cuttings were then hand planted into the appropriate plots on a 0.75 m grid.

At the other sites all legumes (including Hetero) and Hamil were sown in December 1973 (except for Lever Point which was sown in February 1974) and after approximately six weeks growth the other grasses were planted into the appropriate plots on a 1 m grid. At this stage the Hamil grass plots were cut to a height of 30 cm.

The first harvests were taken seven weeks after planting the grasses and subsequent harvests followed at eight week intervals for a total of 12 harvests. At each harvest a 0.5 m^2 quadrat was sited at random within the plot after allowing for a 1 m border. All plant material within the quadrat was cut at 8 cm above ground level and sorted into grass and legume components. During the first year the plots were hand weeded. At harvest 6, weeding was discontinued and at harvest 7 and thereafter weeds were included as a third component for botanical composition. At a number of sites *Desmodium heterophyllum* and *D. triflorum* volunteered; these legumes formed a fourth component. After sampling the remainder of the plot was cut by hand and the herbage removed.

Sorted samples were oven-dried at 70°C for 48 hours and weighed. The dried samples from harvest 11 at all sites were finely ground and the nitrogen, phosphorus and potassium contents of the plant material determined using a Technicon Autoanalyser after acid digestion by the Kjeldahl technique.

Fertilizer use

As far as was possible all trials were conducted without the addition of fertilizer, but at Dala, Liapari and Lever Point potassium deficiency symptoms were apparent by the third harvest and it became necessary to apply potassium fertilizer. Three dressings of 200 kg ha^{-1} potassium chloride (KCl) were applied during the 2 year trial period at Dala, two dressings of 100 kg ha^{-1} KCl were applied at Liapari and one dressing of 100 kg ha^{-1} KCl at Lever Point. Potassium uptake was monitored at Dala and Liapari by measuring the potassium contents of plant tops in the Para and Centro treatment at all harvests and in all species in the harvests immediately before and after application of fertilizer.

RESULTS

Dry matter yields

Comparison of sites

Mean total dry matter yields at the five sites for both years are presented in Table 2.

TABLE 2

Total dry matter yields (grass and legume) over two years at five evaluation sites in the Solomon Islands (1000 *kg ha*$^{-1}$)

SITE	TRIAL 1			TRIAL 2		
	1974	1975	Total	1974	1975	Total
LIAPARI	11.9	9.0	20.9c	16.1	12.3	28.4b
LOKARU	18.8	30.3	49.1a	18.1	29.8	47.9a
LEVER POINT	10.0	8.9	18.9c	10.2	9.2	19.4c
DALA	24.4	19.0	43.4a	23.4	18.7	42.1a
KAONASUGHU	16.6	17.2	33.8b	19.0	16.1	35.1b

Total yields with different subscripts differ significantly at $P < 0.05$.

The lowest overall yields were recorded at the Lever Point and Liapari sites both of which were located within coconut plantations. Highest yields were recorded at Lokaru and Dala while yields from Kaonasughu were intermediate. At Liapari, Lever Point and Dala, yields declined in the second year. On the cleared rainforest site at Lokaru yields increased substantially in the second year, while at Kaonasughu yields were similar in both years. Thus major differences in site potential were demonstrated.

Species performance at each site

Liapari. In the early stages of growth most plots were legume dominant, and in the first year yields of Puero, Centro and Stylo were higher than the other legumes. The highest yielding grasses were Hamil and Signal in all legume combinations, while Batiki gave high yields with Silverleaf but was suppressed when in combination with the Puero. Highest total yields (grass and legume) in the first year were produced by the Hamil/Stylo and Hamil/Centro mixtures, followed by Signal/Glycine.

In the second year yield of the legumes in most combinations declined markedly (Tables 3 and 4). Vigna, Stylo and Siratro had virtually disappeared by the end of the trial, while Silverleaf was persisting but only as a minor component. Glycine declined in most plots except in the Koronivia combination. Hetero invaded many plots and gave reasonable yields with Para but was suppressed by Signal grass. Puero and Centro maintained higher yields than the other legumes; Puero even suppressing Koronivia and Para.

Within the grasses, highest yields were again obtained with Hamil, Signal and Batiki. Signal was highly competitive and suppressed legume yield in all combinations. The combinations which maintained a good legume/grass balance were Para/Centro, Para/Hetero, Hamil/Centro, Koronivia/Glycine and Batiki/Puero. The highest yielding combinations were Hamil/Centro (11.7 t ha^{-1}) and Batiki/Puero (10.8 t ha^{-1}).

Weed invasion was high at this site especially in the more open Para and Hamil swards, particularly where the legume component was weak (Table 4).

Lokaru. In the first year highest legume yields were achieved by Centro, Stylo and Puero. Hamil, Signal and Para gave the highest grass yields while yields of Batiki and Koronivia were substantially lower. In the second year all grass yields increased dramatically but again Batiki and Koronivia were significantly lower yielding than the other species when grown with Centro (Table 3). In all combinations except Hetero/Para, legume yield declined in the second year. By the end of the second year Siratro, Vigna, Stylo, Glycine and Silverleaf had disappeared from a number of plots and where present were contributing very little to total yield. On the other hand Puero

TABLE 3

Grass and legume yields (1000 kg ha^{-1}) in the second year from two pasture evaluation trials at five sites in the Solomon Islands

TREATMENTS	LIAPARI		LOKARU		LEVER POINT		DALA		KAONASUGHU		SITE MEANS	
	GRASS	LEG	GRASS	LEG	GRASS	LEG	GRASS	LEG	GRASS	LEG	GRASS	LEG
TRIAL 1												
Para + Centro	3.9	4.8	30.7	2.3	2.0	0.6	16.8	4.2	16.4	4.6	13.9	3.3
Para + Stylo	3.5	0.5	29.0	0.4	1.9	5.2*	11.9	4.0	12.7	1.2	11.8	1.5
Para + Silverleaf	2.9	0.8	32.6	0.4	3.0	2.7	10.5	1.3	14.3	0.8	12.7	1.2
Para + Hetero	5.1	2.6	29.0	2.0	3.8	0	21.4	3.5	12.1	2.9	14.3	2.2
Para + Glycine	2.9	3.0	30.9	0.2	2.0	1.4	12.9	0.3	15.2	2.4	12.8	1.5
Para + Puero	1.9	5.6	31.0	3.5	3.7	0.1	15.8	2.2	13.8	2.9	13.2	3.6
Para + Siratro	5.2	1.8	27.7	0.8	2.4	5.4	14.0	1.3	14.0	2.0	12.7	2.2
Para + Vigna	4.5	0	28.1	0	2·5	0.2	14.2	0·2	15.3	0	12.9	0.1
Ham. + Centro	8.9	2.8	26.9	4.4	4.0	0.4	21.3	2.2	15.6	3.6	15.3	3.8
Kor. + Centro	1.5	2.7	20.5	6.3	11.0	0.1	16.5	3.1	8.5	6.9	12.8	3.8
Bat. + Centro	13.3	1.4	20.5	3.5	6.4	0.1	12.6	3.4	10.4	4.9	12.6	2.7
Sig. + Centro	12.3	0.8	29.8	2.5	9.1	0.1	20.7	2.8	16.9	3.2	17.8	1.9
TREATMENT MEANS	6.0	2.3	28.0	2.2	4.3	1.4	15.7	2.4	13.8	2.9	—	—
L.S.D. 5% Grass yield within sites			5.3				L.S.D. 5% Treatment Means Grass				2.4	
Legume yield within sites				1.9			L.S.D. 5% Treatment Means Legume					0.8
TRIAL 2												
Ham. + Stylo	11.0	1.5	28.8	0.6	4.7	2.0*	18.8	1.4	14.1	1.5	15.5	1.3
Ham. + Glycine	9.6	1.5	31.1	0.1	5.0	1.2	18.3	0.8	14.2	0.6	15.6	0.8
Ham. + Silverleaf	9.8	0.6	28.9	0.4	4.8	0.2	16.2	2.3	14.0	0.9	14.8	0.9
Kor. + Stylo	9.0	1.3	26.4	0.6	11.4	0.7*	15.2	0.9	15.8	0.1	15.5	0.7
Kor. + Glycine	4.9	4.2	36.5	1.7	12.0	0	14.7	1.0	17.6	0.6	17.2	1.5
Kor. + Puero	2.0	6.4	24.4	2.8	10.1	0	19.4	0.7	15.5	1.8	14.3	2.3
Bat. + Stylo	9.3	0.2	24.4	0.7	4.9	0.6*	13.6	2.4	11.8	0.7	12.8	1.0
Bat. + Silverleaf	11.6	1.2	20.6	1.0	4.9	0.1	11.0	1.9	12.9	0.2	12.2	0.9
Bat. + Puero	6.6	4.2	20.0	3.7	4.7	0	15.4	2.4	12.8	0.5	11.9	2.2
Sig. + Stylo	14.5	0.1	35.4	0.2	7.1	2.1*	18.9	0.7	18.5	0.3	18.9	0.3
Sig. + Glycine	15.9	0.1	36.3	0.1	6.2	0.5	21.5	0.1	18.8	2.0	21.8	0.6
Sig. + Hetero	17.8	0.2	32.3	0.5	7.9	0	20.0	2.3	14.5	3.2	18.5	1.2
Site Means	10.2	1.8	28.6	1.0	7.0	0.6	17.0	1.4	15.0	1.0		
L.S.D. 5% Grass yield within sites			6.3				L.S.D. 5% Treatment Means Grass				2.8	—
Legume yield within sites				1.5			L.S.D. 5% Treatment Means Legume				—	0.7

*These plots were resown with Siratro.

TABLE 4

The proportion of sown legume, (1974, 1975) *and weed in two pasture evaluation experiments at five sites in the Solomon Islands*

TREATMENTS	LIAPARI			LOKARU			LEVER POINT			DALA			KAONASUGHU		
	% Sown	% Sown	%	% Sown	% Sown	%	% Sown	% Sown	%	% Sown	% Sown	%	% Sown	% Sown	%
	Leg 1974	Leg 1975	Weed 1975	Leg 1974	Leg 1975	Weed 1975	Leg 1974	Leg 1975	Weed 1975	Leg 1974	Leg 1975	Weed 1975	Leg 1974	Leg 1975	Weed 1975
EXP. I															
Para + Centro	54	50	9	25	7	>0	12	8	66	18	19	3	43	22	>1
Para + Stylo	60	9	23	37	1	>1	28	58*	21	17	23	6	24	8	6
Para + Silverleaf	33	17	23	13	1	0	34	28	41	>1	9	14	10	5	7
Para + Hetero	37	30	12	9	6	0	13	>1	52	12	14	>1	22	18	8
Para + Glycine	55	41	22	22	>1	>1	48	18	55	2	2	12	31	14	2
Para + Puero	87	75	1	40	10	0	1	9**	47	15	12	5	36	17	2
Para + Siratro	58	24	7	9	2	>1	80	62	10	4	8	6	22	12	6
Para + Vigna	39	>1	25	13	0	>1	51	3	69	4	1	15	14	>1	3
Ham. + Centro	25	24	1	13	14	>1	6	4	52	18	9	1	25	19	>1
Kor. + Centro	70	25	4	44	23	>1	5	1	3	26	16	0	71	45	>1
Bat. + Centro	38	9	1	42	15	0	14	2	6	35	22	0	76	32	0
Sig. + Centro	23	6	>1	27	8	0	4	1	14	18	12	>1	35	16	>1
EXP. II															
Ham. + Stylo	40	11	4	8	2	>1	3	19	37	7	7	3	9	10	2
Kor. + Stylo	79	12	4	46	2	0	5	6*	3	17	6	>1	41	>1	>1
Bat. + Stylo	64	2	5	50	3	0	4	11*	4	23	15	>1	52	5	0
Sig. + Stylo	36	>1	1	39	1	0	8	19*	14	8	3	1	29	2	1
Ham. + Silverleaf	7	6	10	2	2	>1	3	3	21	3	12	4	8	6	3
Ham. + Glycine	18	13	5	2	>1	>1	21	1	31	7	4	3	3	4	2
Kor. + Puero	89	75	2	65	10	0	0	0**	3	15	4	>1	60	11	0
Kor. + Glycine	64	44	5	46	5	0	33	>1	7	8	7	>1	51	4	0
Bat. + Puero	73	39	>1	65	16	0	4	0	12	31	13	0	54	4	0
Bat. + Silverleaf	23	10	>1	17	5	0	16	1	9	1	14	3	9	2	0
Sig. + Glycine	11	1	>1	17	1	>1	47	6	27	1	>1	1	13	10	1
Sig. + Hetero	16	1	>1	4	2	0	0	0	17	5	10	>1	13	18	2

*These treatments were oversown with Siratro

**These treatments were oversown with Greenleaf Desmodium and Centro although declining in yield were maintained in the plots and contributed substantially to yield. Hetero increased in yield with Para. The highest legume yield was achieved in the Koronivia/Centro mixture, but Hamil, Para and Batiki all had adequate levels of Centro or Puero in the mixture. Yields of legumes in combination with Signal were suppressed. Weed and volunteer legume invasion was minimal at this site (Table 4).

Lever Point Site. This was the lowest yielding site and some species (Puero and Stylo) suffered from iron deficiency and failed to establish while other species grew poorly throughout the experimental period. Siratro, Vigna, Glycine and Silverleaf established well but only Siratro maintained yield in the second year (Table 4).

Koronivia was the best adapted grass, forming dense swards which suppressed the legume component. Signal gave reasonably high yields in the first year but declined in yield in the second year when it was not significantly different ($P > 0.05$) from Koronivia. The other grasses were poorly adapted to this site and showed severe chlorotic symptoms.

Weed invasion was particularly high in plots where establishment or growth of the sown species was poor (Table 4).

Dala. At Dala, where the grasses and legumes were sown at the same time, total yields in all combinations were higher in the first year. The drop in grass yields from the first to the second year accounted for a large proportion of the decline in total yields.

Most of the legumes declined in yield from the first to the second year and Vigna, Stylo and Siratro were only very minor components at the conclusion of the trial. Puero, Silverleaf and Glycine gave reasonable yields in some plots while Centro and Hetero contributed substantially.

All the grasses performed reasonably well but Para was outstanding for its yielding ability and compatibility with the legume component. As at other sites weed invasion was greater in the more open Para and Hamil swards growing with a weak legume.

Hamil/Centro and Para/Centro gave the highest total yields in the first year and were not significantly different from each other ($P > 0.05$). In the second year Para/Hetero, Para/Centro, Hamil/Centro, and Signal/Centro were the highest yielding mixtures. Although Batiki/Centro and Batiki/Puero gave significantly lower grass yields, these combinations maintained good legume yields.

Kaonasughu. At Kaonasughu most combinations in Trial 1 increased in yield in the second year due to the large increases in the grass components after suppression in the first year by well established legume associates. In Trial 2, however, most combinations declined in yield in the second year.

All grasses grew well, especially Para and Hamil, although Hamil yields dropped considerably over the last few harvests when the site became water logged. Batiki and Koronivia were significantly lower yielding ($P < 0.05$) than the other grasses, and this was reflected in significantly higher yields ($P < 0.05$) of the associated Centro.

Centro was the highest yielding legume, maintaining good yields into the second year while most of the other legumes declined in yield. Hetero also gave good yields and even competed well with Signal which was not as aggressive as at other sites. Hetero spread rapidly throughout the site and invaded many plots where the sown legume component had decreased. Weed invasion was not a major problem at this site.

Chemical composition of herbage

Nitrogen

At all sites the nitrogen content of the legume component was higher than that of the associated grass. The nitrogen contents of the grasses at Liapari and Lever Point where dry matter yields were lower, were higher than at other sites (Table 5).

TABLE 5

Nitrogen, phosphorus and potassium contents (%) of pasture species from five evaluation sites in the Solomons (Harvest 11)

SPECIES	LIAPARI			LOKARU			LEVER POINT			DALA			KAONASUGHU		
	%N	%P	%K	%N	%P	%K	%N	%P	%K	%N	%P	%K	%N	%P	%K
PARA	1.1	0.11	1.2	0.8	0.17	1.8	1.4	0.10	1.3	0.8	0.29	1.4	0.9	0.16	2.9
SIGNAL	1.3	0.14	0.8	0.8	0.17	2.1	1.3	0.12	0.9	0.8	0.24	1.3	0.9	0.16	2.6
KORONIVIA	1.3	0.13	0.9	0.8	0.17	1.9	1.0	0.10	0.7	0.8	0.28	1.3	0.9	0.14	2.2
BATIKI	1.3	0.13	1.0	1.0	0.18	2.3	1.5	0.14	0.9	0.8	0.19	1.4	0.9	0.15	2.2
HAMIL	1.4	0.13	1.1	1.0	0.18	2.1	1.4	0.11	1.5	1.1	0.30	1.7	0.9	0.17	2.8
CENTRO	3.0	0.16	0.9	2.8	0.19	1.7	2.3	0.14	0.8	3.0	0.23	0.9	2.8	0.18	2.4
PUERO	2.7	0.15	1.1	2.5	0.18	2.1	—	—	—	2.8	0.23	0.8	2.5	0.18	2.3
STYLO	2.2	0.14	0.9	2.0	0.14	1.6	—	—	—	2.3	0.20	1.5	2.1	0.16	2.4
GLYCINE	2.3	0.16	1.5	1.8	0.20	2.1	2.3	0.14	1.6	2.4	0.20	1.5	2.2	0.20	2.7
SIRATRO	2.3	0.15	1.2	2.7	0.20	2.5	2.2	0.13	1.2	2.7	0.21	1.0	2.4	0.20	2.9
SILVERLEAF	2.4	0.16	0.9	2.5	0.20	1.6	2.2	0.15	0.8	2.2	0.20	1.1	2.4	0.19	2.2
HETERO	2.4	0.16	1.1	2.2	0.17	1.4	1.8	0.11	1.0	2.5	0.28	1.2	2.6	0.21	2.4
VIGNA	—	—	—	—	—	—	2.4	0.14	1.1	—	—	—	2.9	0.27	3.5
MEAN	2.0	0.14	1.1	1.8	0.18	1.9	1.8	0.13	1.1	1.8	0.24	1.3	1.9	0.18	2.6

Centro had the highest nitrogen content except at Lever Point where its growth was poor. There were no consistent differences between the other species.

Phosphorus

The phosphorus content of the legumes was generally higher than that of the grasses at all sites except Dala. At Dala where the highest plant phosphorus concentrations were recorded, the grasses had higher phosphorus concentrations (Table 5).

Potassium

The potassium contents of the pasture species from the Kaonasughu site were higher than for any other site. In general there were no marked differences between species and between associated grass and legume at the same site (Table 5).

DISCUSSION

Since the main aim of this work was to be able to recommend pasture mixtures for immediate use, or at least for further evaluation, it is proposed to discuss each site in turn and come to some recommendations on adapted grass/legume combinations. As each site is representative of a large land system it is hoped that the recommendations can be applied on similar soils throughout that land system.

Liapari

At this site the shading from the young coconut palms reduced light transmission by 50% at noon and had a marked effect on productivity and botanical composition. In general, the grasses were less productive than at some of the other sites and the legume Puero in a number of mixtures maintained dominance throughout the trial period. Ludlow *et al.* (1974) found that the reduction in Relative Growth Rate and Net Assimilation Rate due to shading was more marked in two tropical grasses than in two legumes. This effect could partly account for the more favourable legume balance at this site. Puero was the most productive legume and completely suppressed Para and Koronivia in heavily shaded plots and formed a well balanced mixture with Batiki Blue. Centro gave similar yields to Puero when sown with Para but when sown with an aggressive grass (such as Signal) it declined in yield and proportion in the sward. Hetero was a strong component when sown with Para grass and readily invaded other Para plots.

Signal, Hamil and Batiki were the highest yielding grasses at this site. The performance of Batiki Blue at this site indicated some shade tolerance as its dry matter yields were only slightly less than those of Signal. Shade tolerance in *Ischaemum timorense*, a similar grass to Batiki Blue was reported by Macmillan (1962). On the basis of yield and legume content Batiki/Puero appears to be the best adapted mixture for this site. Batiki/Centro and Koronivia/Glycine mixtures are worthy of further evaluation.

The use of potassium fertilizer would be essential for long term pasture productivity on these soils especially for the maintenance of a strong legume component and the prevention of weed invasion particularly from the ferns *Sphaerostephanos unitus* and *Thelyptris* sp. Responses to phosphorus fertilization may also be obtained as herbage P contents were generally below the "critical levels" for tropical grasses (Andrew and Robins 1971), and are marginal in the legumes.

Lokaru

This was the most productive of all sites. There was no competition for light from a tree crop and very little weed competition. The soil was a fertile alluvium which had been cleared from virgin rainforest, it was well drained and well supplied with all essential nutrients. Thus there was no sign of nutrient disorder in any of the species at any time throughout the trial period. Grass yields were very high particularly in the second year and compare favourably with yields from other wet tropical regions (Adegbola and Onayinka 1966, Roberts 1970, Gallasch 1971 and Kretschmer *et al.* 1973) especially as they were obtained without the use of nitrogen fertilizer.

At this site, because of good growth conditions, the grasses completely dominated the legumes even though the legumes were sown and were well established before the grasses were planted. The defoliation levels imposed on these swards in the trial would also tend to favour the grass component. Puero was one of the most susceptible legumes to these management conditions and had virtually disappeared from the trial, while on the grazed pastures adjacent to the trial site, originally sown to a mixture of grasses and legumes, Puero was beginning to dominate and in some areas had completely smothered the grass. This illustrated the importance of management in maintaining a well balanced pasture.

All grasses, at this site, gave high yields but on the basis of total yield and legume content mixtures of Para/Centro or Para/Puero would be recommended. Although giving lower grass yields Koronivia/Centro had high legume yields and would be a useful mixture.

Lever Point

The outstanding feature of this site was the soil conditions which gave rise to the iron chlorosis problem in a number of species. This far outweighed the relatively minor shading effect of the coconut canopy where light transmission was between 75 and 97%. The iron chlorosis effect varied from extremely severe on the legumes Puero and Stylo to slight on Siratro and Vigna, with intermediate effects on the other legumes. All the species had low P contents and responses to P fertilization may be expected. The high nitrogen content of the grasses at this site, would be related, most probably, to the lower yields. The "dilution effect" experienced under good growing conditions at other sites would not occur here.

Invasion from weed was a major problem as most of the weed species were well adapted to the soil conditions so that iron chlorosis only occurred to a very minor degree in some species. The worst of the weeds was blue rat's tail, *Stachytarpheta jamaciensis.*

Koronivia, the highest yielding grass, did not show chlorotic symptoms and tended to suppress the Siratro. The yield of Signal grass was not significantly different from Koronivia but it appeared less vigorous and chlorotic, and maintained a significantly higher ($P < 0.05$) Siratro yield. Further studies are required with Koronivia/Siratro and Signal/Siratro to evaluate the mixtures under grazing on this land system.

Dala

Here the main limiting factor to pasture productivity was potassium. All other nutrients were in adequate supply especially phosphorus as indicated by the phosphorus concentrations in the herbage. When supplied with potassium, growth of all grasses was good; however, Hamil grass was particularly susceptible to potassium shortage and suffered from reduced growth rate during periods of marginal potassium supply.

At this site both grasses and legumes were planted at the same time, so the legumes suffered from competition from the outset. The low potassium status also affected the legume and in some plots legume establishment was negligible. When potassium was applied and grass growth rates declined due to nitrogen shortage, some of the legumes began to increase in proportion in the sward. These included Centro, Puero, Hetero and Stylo. Centro and Hetero maintained good yields throughout the trial but both Puero and Stylo began to decline in the second year due to an interaction of cutting height, cutting frequency and potassium deficiency. In the field both Hetero and Centro seemed to be more tolerant of potassium deficiency than either

Puero or Stylo. Nitrogen appeared to limit grass growth in plots where the legume component was very weak or non-existent.

Para and Signal were the best of the grasses when supplied with potassium and Centro and Hetero were the outstanding legumes. Mixtures of Para/Centro and Signal/Hetero would be recommended.

Kaonasughu

Total yields in the second year were high but in the last three harvests the site became waterlogged and in a number of species, particularly Hamil and Signal, yields began to decline rapidly. Para grass, however, was particularly adapted to this site as it was not restricted by the waterlogged conditions. Its yields were always high and again it was compatible with the legumes.

Puero, although maintaining a higher proportion in the sward than it did at Lokaru and Dala, again suffered from competition from the grass under the severe cutting regime. Again in adjacent grazed areas under less severe utilization it began to dominate the sward. Centro was the best of the legumes maintaining high yields throughout and was compatible with all the grasses. It completely suppressed the less aggressive Batiki Blue and Koronivia in the first year. Hetero at this site was flourishing by the end of the trial period. It appeared to be favoured by the waterlogged conditions and spread through the trial area invading many plots.

A combination of Para grass with both Centro and Hetero would give a well balanced highly productive pasture in this area.

General

It was apparent that there were quite marked differences in adaptations and degrees of compatibility between the species at different sites. In open fertile sites Para was the most widely adapted of the grasses. It was very easy to establish, it produced good yields and combined well with most of the legumes. Signal and Hamil also gave good yields but tended to suppress the legume component. In these conditions Centro and Puero were more competitive and higher yielding.

Under heavily shaded conditions Batiki Blue or Signal were best adapted but additional work is required on other species such as *Brachiaria miliiformis* and *B. brizantha* which have performed well under coconuts in Sri Lanka (Santhirasegaram and Fernandez 1967).

At most sites, Stylo behaved as a short term pioneer species giving high yields in the first six to eight months after establishment but with competition from the grass under the management conditions imposed it did not persist into the second year. Hetero, on the other hand, persisted and spread at most sites particularly in the waterlogged conditions at Kaonasughu. Its performance in these trials may have been somewhat underestimated as a greater proportion of this low growing legume lay below the cutting height than was the case with other legumes. It was relatively slow to establish and yields in the second year were generally higher than in the first. Hetero could easily be incorporated into a pasture by including it in grass nurseries and planting it vegetatively with the grass cuttings.

It is obvious that further studies are required to evaluate the recommended mixtures under grazing. The mixtures recommended from this study appear to be the best adapted to the conditions at each site, combining adequate yield levels with a good balance between grass and legume.

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REFERENCES

ADEGBOLA, A. A., and ONAYINKA, B. (1966)—The production and management of grass, legume mixtures at Agege. *Nigerian Agricultural Journal*, **3**: 84-91.

ANDREW, C. S., and ROBINS, M. F. (1971)—The effect of phosphorus on the growth, chemical composition and critical phosphorus percentages of some tropical grasses. *Australian Journal of Agricultural Research* **22**: 693-706.

BRYAN, W. W., SHAW, N. H., EDYE, L. A., JONES, R. J., MANNETJE, L. 't., and YATES, J. J. (1964)—*In* Some concepts and Methods in sub-tropical Pasture Research. Commonwealth Agricultural Bureaux **47**: pp. 123-44.

GALLASCH, H. (1971)—Grass species evaluation at Popondetta in the Northern District of Papua. *Papua and New Guinea Agricultural Journal*, **22**: 63-8.

KRETSCHMER, A. E., BROLMANN, J. B., SNYDER, G. H., and GASCHO, G. J. (1973)—Production of six tropical legumes each in combination with three tropical grasses in Florida. *Agronomy Journal*, **65**: 890-2.

LUDLOW, M. M., WILSON, G. L., and HESLEHURST, K. R. (1974)—Studies on the productivity of tropical pasture plants (5) Effect of shading on growth, photosynthesis and respiration in two grasses and two legumes. *Australian Journal of Agricultural Research*, **25**: 425-33.

MACMILLAN, H. F. (1962)—Tropical Planting and Gardening with special reference to Ceylon. Fifth Edition. Macmillan and Co., London, pp. 425.

SANTHIRASEGARAM, K., and FERNANDEZ, D. E. F. (1967)—Yield and competitive relationships between two species of *Brachiaria*. *Tropical Agriculture*, Trinidad, **44**: 229-34.

WALL, J. R. D., and HANSELL, J. R. F. (1973)—Soils of some Quaternary marine terraces in the British Solomon Islands Protectorate and some problems in their agricultural use. *New Zealand Journal of Agricultural Research*, **16**: 271-86.

WALL, J. R. D., and HANSELL, J. R. F. (1975)—The Land Resources of the British Solomon Islands Protectorate. Vols. II, III, IV. Land Resources Division, Surbiton, England.

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