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EVALUATION OF TROPICAL GRASSES IN INCREASING SHADE UNDER COCONUT CANOPIES

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SUMMARY

The yields of eight grass species, *Axonopus compressus, Brachiaria decumbens, B. humidicola, B. miliiformis, Dicanthium caricosum, Ischaemum aristatum, Paspalum conjugatum* and *Stenotaphrum secundatum*, were compared at five sites under different coconut densities giving variations in shade. Light transmission (LT) values were approximimately 100 (adjacent open area), 70, 50, 40 and 20% of full sunlight. Soils were fertile, red-brown clays developed on uplifted coral limestone (typic arguidoll), with marginal K status. *Brachiaria* spp. yielded most in full sunlight, with *B. decumbens* giving 28 t ha^{-1} year^{-1}. *I. aristatum* was less sensitive to shade than the *Brachiaria* spp., at least down to 40% LT. *S. secundatum*, although poor yielding at 100 and 70% LT, gave the best yield of all species at 20% LT. Shaded plants had thinner leaves and larger nitrogen concentrations than unshaded ones. *B. decumbens* and *B. humidicola* are recommended for open plantations (LT > 70%), *I. aristatum* for moderate shade (LT 45-70%) and *S. secundatum* for deeper shade (30-50%) on poor fertility soils.

Several grass species are reputed to be well adapted to shade in coconut plantations. These include *Brachiaria miliiformis, B. decumbens, Ischaemum aristatum* and *Stenotaphrum secundatum* (Plucknett 1979; Reynolds, 1981). Productivity and persistence of these grasses depends not only on their adaptation to shading, but also on defoliation management and on competition from the coconut palms.

Some trials with pasture legumes have attempted to evaluate the relative tolerance of different species by growing them under artificial shade (Eriksen and Whitney, 1977; Whiteman *et al.*, 1978). This system neglects other competitive effects of the established tree crop. Elsewhere, species have been selected because of their good growth in coconut plantations, but in most cases light transmission values have not been measured (Ferdinandez, 1972; McEvoy, 1974; Thomas, 1978).

The comparisons reported in this paper took advantage of the Joint Coconut Research Scheme in the Russell Islands where coconut density trials are in progress within an area of uniform soil. This allowed a range of grass species to be evaluated in a gradient of light regimes in which transmission values varied from 20% to 100% full sunlight under field conditions within a coconut plantation.

MATERIALS AND METHODS

Research site

The trial was conducted on Banika Island, in the Russell Island group (9° S; 159° E), in the Solomon Islands. The species evaluation plots were established at five sites under different coconut densities, all within a 500 m radius and all on the Alokan Land System (Hansell *et al.*, 1975). The plots were on a uniform soil type, described as a typic arguidoll, which is a dark brown, clay soil derived from uplifted coral reef with some volcanic additions (Hansell *et al.*, 1975). Climate at the site is humid tropical or wet equatorial, with a mean annual rainfall of 2900 mm evenly distributed (Ash *et al.*, 1974). Mean daily maximum and minimum temperatures are 30° C and 24° C, respectively, and in most years there are more than 2000 h of sunshine.

Experimental design

The trial, established as a randomized block replicated twice, compared eight tropical pasture grass species at five sites which differed in light transmission. Plot areas were 3 m x 3 m. The following species were compared: *Axonopus compressus* (Mat grass); *B. decumbens* cv. Basilisk (Signal); *B. humidicola* (Koronivia); *B. miliiformis* (Cori); *Dicanthium caricosum* (Nadi Blue); *I. aristatum* (Batiki Blue); *Paspalum conjugatum* (Tee grass) and *S. secundatum* (Buffalo couch).

Plot sites were chosen after measurements of light transmission (LT%) values in trial plots of different varieties of coconuts sown at various densities, viz.

Site A	100% LT	Open area adjacent to coconut trial.
Site B	70% LT	Centre of inter-row of tall palms 20 years old, with rows 13 m apart.
Site C	50% LT	Tall palms, 20 years old (as above) but plots situated under canopies within the row.
Site D	40% LT	As above, but in plots with no missing palms.
Site E	20% LT	In a dense plantation (343 palms ha^{-1}) of Yellow Malay Dwarf coconuts, 14 years old.

Plot establishment

The plot areas were brushed by hand to remove taller weeds, and then all except the mat grass plots, which were not to be planted, were sprayed with glyphosate (100 ml in 20 litres of water for each 0.2 ha site). Soil samples (to 10 cm) were taken from the centre of each plot, bulked over the two replicates at each site, and dried for chemical analysis. Cuttings of the introduced species were taken from nursery plots and planted at 60 cm centres into holes dug with a mattock. Establishment was satisfactory in all cases. Plots were maintained by hand weeding and were not given fertilizers at any stage.

Sampling

An initial clearing cut was made at a height of 8 cm on 30 December 1980, 3 months after planting. The first sample harvest was cut 6 weeks later, and six subsequent harvests were then taken at 8 week intervals. At each harvest, a central 1 m^2 quadrat was cut at 8 cm with hand shears before the remainder of each plot was cut using a rotary slasher mower. The mown material was left on the plots. Each hand-cut sample was sorted into sown grass, volunteer grass, legumes and weeds, oven dried at 70° C and weighed. Dried samples from harvests 2 and 6 were ground in a laboratory mill and analysed for their N, P and K contents after Kjeldahl digestion. In December 1981, samples of the last fully-expanded leaves were taken from some species for estimation of leaf areas and dry weights. From these data specific leaf areas ($cm^2\ g^{-1}$) were calculated.

Measurement of light transmission

Before establishing the trial, appropriate sites were located by surveying the range of light transmission values within the coconut density plots. This was done by using a Lambda L1 170 meter to take 100 point readings in each coconut plot, and then calculating photosynthetically-active radiation (PAR; 400–700 nm) transmission relative to full sunlight. During the course of the experiment light transmission was monitored several times above each plot. Readings were taken at a height of 1 m and between 10.00 and 14.00 h on clear days. Values were then meaned over species to give averages for each replicate block at each site, and for the overall site. Global (or total) radiation was measured by two methods. The first used the Lambda meter, as above, but with a pyranometer sensor sensitive to a wider range of wavelengths. The other method used integrating pyranometers measuring the same 400–1200 nm range (Kerven and Ison, 1982). One pyranometer was maintained in the unshaded (LT 100%) plots (site A), while the other meters were placed in the shaded plots and allowed to integrate throughout the day, before moving them to other plots. Three days of readings were taken in each plot during the experimental period.

RESULTS

Dry matter yields

Total above-ground dry matter yields, as expected, were greatest in full sunlight and declined with increasing shade (Table 1). Yields of the sown species declined relatively more in deep shade than did total yields, the differences being due to increased weed growth (Table 1).

Signal gave the best yield of the sown species in full sun, followed by Koronivia and Cori grass. Batiki Blue and Nadi Blue were not significantly different ($P<0.05$) and produced intermediate yields, while Tee grass, Mat grass and Buffalo couch formed the smallest-yielding group (Table 1). At the 70% LT site there was a marked drop in yield, but Signal and Koronivia were still the best, with Cori, Nadi Blue and Batiki Blue forming an intermediate group. In the 50% LT regime Batiki Blue maintained its yield and so joined the most productive group, along with Signal and Koronivia. Yields of Cori, Nadi Blue, Mat grass and Buffalo couch were smaller but similar. As shade deepened (40% LT) there was a marked change of order so that Batiki Blue, Buffalo couch and

Table 1. *Total above-ground dry matter (DM; t ha^{-1}) and yield of sown species (t ha^{-1}) over six harvests at each light transmission site, and correlation coefficients (r) between light transmission (%) measured with the integrating pyranometer and yields of the sown species*

	Above-ground DM yields (t ha^{-1})										
	A (100% LT)		B (70% LT)		C (50% LT)		D (40% LT)		E (20% LT)		Correlation coefficient
Species	Total	Sown	Total	Sown	Total	Sown	Total	Sown	Total	Sown	(r)†
Signal	28.2	28.0	12.7	11.0	10.9	9.3	6.1	4.1	3.3	0.7	0.95**
Koronivia	22.8	21.9	13.6	12.4	11.1	9.8	4.7	1.7	2.6	0.7	0.99**
Cori	18.1	17.8	9.8	7.1	7.4	4.4	5.7	3.4	3.3	1.0	0.99**
Batiki Blue	15.3	14.0	8.3	7.8	8.9	8.3	6.7	5.5	3.1	0.3	0.86**
Nadi Blue	14.3	12.8	7.0	4.7	6.9	3.8	3.9	1.8	3.3	0.3	0.93**
Tee grass	11.4	7.8	5.9	2.0	4.3	1.9	4.7	2.6	2.6	1.0	0.56(NS)
Mat grass	9.3	4.6	6.4	4.4	6.1	4.9	3.7	1.9	3.1	1.3	0.70*
Buffalo couch	7.0	5.5	6.5	3.5	6.0	4.0	5.7	4.9	3.3	1.9	0.64*
Mean yield	15.8	14.1	8.8	6.6	7.7	5.6	5.1	3.3	3.1	0.9	
Mean yield as a % of site A	100	100	56	47	49	40	33	23	20	6	
LSD	Spp. x sites		Total	Sown							
	5%		2.8	3.2							
	1%		4.3	4.9							

† Correlation coefficients significant at P = 0.01 (**), P = 0.05 (*), or not significant (NS).

Signal comprised the largest-yielding group. Yields of all species declined markedly with intense shading (20% LT); Buffalo couch was the most productive species in this situation.

The proportional yields at 20% LT relative to those in full sun were greatest in the species which produced generally poor yields, Buffalo couch (34%), Mat grass (27%) and Tee grass (13%), whereas the other species yielded only 2% to 6% of their yields in full sunlight.

Weeds and other species constituted a minor proportion of harvested material, except in Mat and Tee grasses at 100% and 70% LT, but were more prevalent at and below 50% LT. Overall, Batiki Blue and Signal had the smallest weed contents, but in the deepest shade (20% LT) Buffalo couch was most competitive.

Following a lenient clearing cut, yields at the first harvest were large (mean 4.4 t ha^{-1}). They were small at harvest 2 (1.2 t ha^{-1}), and relatively constant thereafter (1.8 to 2.6 t ha^{-1}). Cori grass declined markedly after flowering in July 1981, and had almost disappeared in all shaded plots by the last harvest.

Light transmission measurements

Light transmission values measured as PAR or global radiation during the course of the experiment are compared in Table 2.

In general, transmission of PAR was similar to that of global radiation as

Table 2. *Mean values of light transmission (LT; % full sunlight) measured by three methods on three occasions at each site*

	LT (% full sunlight) at each site				
Method	A	B	C	D	E
PAR (Lambda)	100	69	54	43	17
Global (Lambda)	100	72	62	51	37
Global (Integrating pyranometer)	100	67	62	45	32

measured by the pyranometer, except at the most shaded site where PAR was reduced relatively more than total radiation. Global radiation transmission values based on measurements using the Lambda meter were usually slightly greater than those measured by the pyranometer.

Correlation analysis between dry matter yield of each sown species and light transmission estimated with the integrating pyranometer showed that linear relations were most significant for the largest-yielding species group ($r = 0.86$ to 0.99), less closely related for the two poorer yielding species Buffalo couch and Mat grass ($r = 0.70$ and 0.64, respectively), and were not significant for Tee grass (Table 1).

Specific leaf area

Increasing shade reduced leaf thickness (Table 3). With Signal and Koronivia, which had the thickest leaves in full sun, specific leaf areas increased linearly with decreasing light transmission, while in Batiki Blue, Mat grass and Buffalo couch, leaves were thinnest at 40–50% LT.

Soil chemical analyses

Analyses of bulked samples from each area revealed that sites B and D had inferior P and K status compared with the others (Table 4). Nutrient contents were greatest in the open area, away from uptake by the coconut roots. While P and K contents were marginal and NO_3^- values were small at sites within the plantation, all other macro- and micro-nutrients were adequate. Soils were slightly acidic in the plantation and neutral in the unshaded area.

Table 3. *Effect of shading on specific leaf area ($cm^2 g^{-1}$) of the last fully-expanded leaf of selected species*

	Specific leaf area ($cm^2 g^{-1}$) at different sites				
Species	A (100% LT)	B (70% LT)	C (50% LT)	D (40% LT)	E (20% LT)
Signal	198	222	224	236	–
Koronivia	155	186	207	228	–
Batiki Blue	228	292	315	293	–
Mat grass	218	236	282	258	256
Buffalo couch	241	282	238	290	272

Table 4. *Chemical analyses of soils (0–10 cm) from each site*

Attribute	Site A	 B	 C	 D	 E
NO_3 (ppm N)	3.9	2.8	1.8	1.9	5.4
P (ppm P)†	11	7	14	9	19
K (ppm K)	146	58	75	51	116
Ca (ppm Ca)	>6000	1850	2160	1635	2865
Mg (ppm Mg)	428	212	278	212	345
Fe (ppm Fe)	20	20	16	18	29
Cu (ppm Cu)	8.9	9.0	10.2	10.6	7.0
Mn (ppm Mn)	>100	>100	>100	>100	>100
Zn (ppm Zn)	>20	3.5	13.5	3.9	8.2
Na (ppm Na)	63	37	62	42	52
Cl (ppm Cl)	23	25	25	13	20
SO_4 (ppm S)	17.0	24.5	28.5	45.0	18.0
pH (1:5 water)	7.1	5.7	5.7	5.6	6.0
Conductivity (mmho cm^{-1})	0.19	0.06	0.07	0.06	0.08
Organic carbon (% C)	3.51	2.17	2.62	2.13	3.04

† Acid extract.

Plant chemical analyses

Nitrogen concentrations in dry matter tended to increase with increasing shade, but P and K concentrations were little affected (Table 5). Potassium concentrations in all species were significantly smaller at site B than elsewhere. There were no consistent differences between species in the respective concentrations of N, P or K in above-ground dry matter.

DISCUSSION

In the unshaded situation, unaffected by competition for light from the coconuts, Signal grass was the most productive species and gave a total yield of 28 t ha^{-1}. This large yield demonstrates the adequate fertility of soil in the open site, and supports evidence of the adaptation of Signal grass to this environment, as shown in other species evaluation trials in the Solomon Islands (Gutteridge and Whiteman, 1978; Watson and Whiteman, 1981). As found in previous trials too, Koronivia was again shown to be well-adapted here.

In modest shade (70% LT; site B) there was a marked decline in yield, but

Table 5. *Concentrations (%) of nitrogen, phosphorus and potassium in oven-dry, above-ground material from two harvests (2 and 6) meaned over sown grass species*

Element	Site and harvest A		B		C		D		E	
(g 100 g^{-1})	H2	H6	H2	H6	H2	H6	H2	H6	H2	H6
N	1.02	1.32	0.99	1.51	0.98	1.51	1.17	1.53	1.34	1.66
P	0.13	0.15	0.09	0.13	0.10	0.14	0.11	0.14	0.14	0.17
K	1.63	1.85	0.71	0.84	0.96	1.07	1.29	1.43	1.80	1.84

this was due in part to the poorer fertility status of soil at this site. Soil potassium content was small due, apparently, to a longer period of uptake by the coconut crop. Potassium concentrations in the harvested grass may be less than that considered adequate for optimum yield of tropical grasses. Although Hacker and Jones (1969) have suggested 1% K in tops as a *critical value* for *Setaria*, Smith (1974) points out that it is difficult to be precise about such values since they depend upon the concentration of available N and the balance of other ions. For Rhodes grass, Smith (1974) suggests a minimum specific K requirement of 0.5% if it is associated with a cation–anion balance larger than 800 meq kg^{-1} dry weight. On this evidence we can only suggest that K contents of grasses grown in competition with coconuts at site B were 'marginal'. Previous trials on this same soil type on the Alokan Land System on Banika Island failed to record a response to applications of N, P or K by Signal grass under coconuts (Watson and Whiteman, 1981). However, there is obviously variation between areas in K status, and K fertilizer is applied to coconuts on this land system.

The important comparisons in this trial are the relative changes in yield among species with increasing shade. The most productive species, Signal and Koronivia, maintained their yield superiority down to 50% LT, but in deeper shade their yields declined rapidly. Cori grass showed less relative decline in yield than Signal or Koronivia, supporting its reputation for adaptation to shade (Eriksen and Whitney, 1977). However, Cori grass had produced most of its yield in the first 6 months, and died back after flowering in June–July. Bogdan (1977) records *B. miliiformis* as an annual species, as was evident here, and so better adapted to monsoonal environments such as are found in Sri Lanka, rather than to the humid tropical environment of the Solomons.

Batiki Blue also demonstrated good shade tolerance. Although its yield was not large in full sunlight, it showed proportionally less decline with shade than the more productive species, and maintained weed-free stands at least down to 40% LT. This confirms evidence from another study in the Solomons (Litscher and Whiteman, 1982), where Batiki Blue was the most persistent sown species under small-holder coconut plantations. Nadi Blue had no particular merit in this trial. It was not shade-tolerant or well adapted to the climatic or soil conditions. It seems to be better adapted to areas with grey clay soils and a distinct dry season (Partridge and Ranacou, 1974).

In the smallest-yielding group, Tee grass was not particularly well adapted to this site. It is a prominent species under shade in newly-cleared forest land (Macfarlane and Whiteman, 1980) but may require more fertile soils, or be unable to compete with coconuts. The other naturalized species, Mat grass, although the most common species found under coconuts, produced only small yields at the 40% LT and 20% LT sites. Survival of this species in plantation grazing systems may be due more to its prostrate growth habit rather than to a particular adaptation to shading below 50% LT. On the same soil type, Mat (or Carpet grass) pastures with legumes were able to produce up to 411 kg ha^{-1}

year^{-1} of liveweight gain under coconuts with 60% LT (Watson and Whiteman, 1981), demonstrating that this species is well adapted to average conditions in mature coconut plantations.

Buffalo couch was the best adapted species to increasing shade. It showed the least reduction in yield, and the largest yield of the sown species at the 20% LT site. Buffalo couch is the most important grass under coconuts on poorer fertility soils in Vanuatu, where it supports large stocking rates at moderate levels of animal production (Weightman, 1977). It is also competitive (giving good weed control) and palatable to cattle. Further studies are needed with Buffalo couch subjected to grazing in order to determine (a) whether it will support improved animal production under coconuts compared with the naturalized Mat grass pastures, (b) whether legumes can be maintained, and (c) what effects it may have on copra yields.

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