The Effect of Shade on Forage Quality

B.W. Norton*, J.R. Wilson, H.M. Shelton* and K.D. Hill***

Abstract

The effects of shading on the nutritive value and chemical composition of five tropical grasses was investigated in two experiments. The grasses used were setaria *(Setaria sphacelata* cv. Kazungula), green panic *(Panicum maximum* var. *trichoglume* cv. Petrie), guinea grass *(Panicum maximum* cv. Riversdale), signal grass *(Bruchiaria decumbens* cv. Basilisk) and bahia grass *(Paspalum notatum).* In the first experiment, grass grown in full sun or under shade (50% light transmission) was cut, dried and fed to sheep in pens. Shading decreased the yield of herbage and increased the N content of all grasses except bahia grass. Bahia grass had an increased yield as well as an increased N content when grown under shade. There were no significant effects of shading on cell wall composition, voluntary feed intake (VFI) or in vivo dry matter digestibilities (DMD) of the grasses. The DMDs of setaria and signal grass were significantly higher (66.8 and 64.2% respectively) than that of other grasses (range 55.9–59.5%). Sheep consuming herbage grown under shade had higher ammonia and propionic acid, but lower acetic acid, concentrations in the rumen. They also had higher N-balances than did sheep fed sun-grown pastures. These differences were greatest for setaria and signal grass.

In the second experiment, the same grasses were grown at light levels of 100, 68, 50 and 30% of full sunlight, and yields and chemical composition were measured for four successive, 6-8-weekly regrowths. Decreasing light level decreased herbage yields at the initial harvests but increased yield at the final harvest. Shade decreased herbage dry matter content and increased protein content but had no consistent effect on either the proportion of leaf or the chemical composition of the plant cell walls. The effect of low light on DMD was variable between species and harvests, with a tendency toward a small decrease in DMD at the lowest light level. It was concluded that, for the grasses studied, shading (50% light transmission) had little effect on their cell wall composition or on their VFI or DMD when fed to sheep. However, the increased N-content of shaded plants may improve nutritive value if the N-content of sun-grown plants is low (< 10 g N/kg DM).

FORAGE quality is directly related to the extent to which the plant provides nutrients for grazing animals. Quality is often measured as the product of voluntary feed consumption and the digestibility of nutrients consumed. The chemical composition of the plant may also be used as a guide to forage quality. The effects of shade on pasture growth were recently reviewed by Wilson (1988), and for most tropical grass species yield decreases with decreasing light (Ludlow 1978). However, the 'shade tolerant' grasses often show little yield depression or even increased yield under moderate light levels (Wong et al. 1985, Samarakoon et al. 1990a). It is these species which may be useful forage plants in plantation crops.

The effects of shading on the nutritive value of forage are less clear. Shading usually reduces the total non-structural carbohydrate of grasses (Hight et al. 1968; Wilson and Wong 1982; Samarakoon 1987) but has variable (positive and negative) effects on cell wall content and composition, lignin and in vitro digestibility of plant dry matter (Wilson 1988).

There have been only two studies where shaded and unshaded forages were evaluated as a feed for animals (sheep). Hight et al. (1968) compared shaded ryegrass (2-3 days shading at 22% light transmission) with unshaded ryegrass and found that this shading decreased soluble carbohydrate content by 3.7% units, dried forage digestibility by 0.6-3.6% units, and voluntary feed intake by 12-15%. However, since the shading period was very short, the results may have little relevance to the interpretation of the longer-term effects of shading on tropical pasture grasses grown under plantation crops. The other study (Samarakoon et al. 1990b) studied the effects of much longer periods of shade (50% light transmission) on the nutritive value of buffalo grass *(Stenotaphrum secundatum)* and kikuyu grass *(Pennisetum clandestinum)* for sheep. There were no significant effects of shading on digestibility (in vivo and in

*Department of Agriculture, The University of Queensland, Queensland, Australia

**CSIRO, Division of Tropical Crops and Pastures, Cunningham Laboratory, Queensland, Australia

vitro) or cell wall composition but there was a marked depression (28-33%) in feed intake of sheep given shaded kikuyu grass. These workers have suggested that the decreased intake was associated with the increased stem content of shaded kikuyu grass, but this effect was found in only one of the harvests fed. An alternative explanation for this depression in intake may be decreased palatability of the feed.

The following experiments were conducted to investigate further the effects of shading on the voluntary feed intake and digestibility of tropical grasses by sheep. The relationship between changes in plant composition during shading and nutritive value were of particular interest, since this information may permit the prediction of shade effects on nutritive value.

Materials and Methods

Two experiments are described in this paper. The first investigated the effects of a single level of shading on the voluntary intake and digestibility of five tropical grasses when fed to sheep, and the second studied the effect of decreasing light levels on the chemical composition and in vitro digestibility of seven tropical grasses.

Experiment 1.

Thirty weaner sheep (Border Leicester x Merino) were held in metabolism cages during the 28-day feeding trial. The following grasses were grown in replicated plots (5) either in full sunlight or under shadecloth (50% light transmission). The grasses were setaria *(Setaria sphacelata* cv. Kazungula), green panic *(Panicum maximum* var. trichoglume cv. Petrie), guinea grass *(Panicum maximum cv.* Riversdale) and signal grass *(Bruchiaria decumbens* cv. Basilisk). The grasses were fertilised with 125, 25 and 50 kg/ha N,P,K to maintain a good growth rate. All plots were slashed to 10 cm and then harvested for the feeding experiment after 6 weeks regrowth. An established stand of bahia grass *(Paspalum notatum)* growing under the shade (approximately 50% light transmission) of *Eucalyptus grandis* trees at Samford Research Station (CSIRO) and an adjacent open area with the grass growing in full sun were slashed in March, and the herbage from both plots harvested after a period of after-&weeks regrowth. All harvested material was weighed, dried, chaffed and stored for subsequent feeding.

The design of the feeding trial was therefore five grass species by two light treatments (sun and shade) by three sheep per treatment. Measurement of voluntary feed consumption, feed digestibility, nutrient balances and sampling of rumen fluid took place in the last week of the 4-week feeding period. Feed, refusals and faeces were analysed for dry matter (DM), ash, neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin. Cellulose (ADF-lignin) and hemicellulose (NDF-ADF) contents were calculated from the organic matter content of the detergent fibre fractions. Total N and P contents were determined on these fractions and in urine. In vitro digestibility was determined by incubation with cellulase and pepsin (McLeod and Minson 1978). Rumen fluid was collected with a stomach tube before the morning feed and was analysed for ammonia, volatile fatty acid (VFA) concentrations and proportions. Analysis of variance was used to determine the significance of differences between treatments.

Experiment 2.

This experiment was designed to investigate the effects of decreasing light level (100, 68, 50 and 30% light transmission) on the growth and chemical composition of seven tropical grass species. The following species were sown in replicated plots at Redland Bay Research Station in southeast Queensland: setaria *(Setaria sphacelata cv.* Kazangula), green panic *(Panicum maximum* var. trichoglume cv. Petrie), guinea grass *(Panicum maximum* cv. Riversdale), signal grass *(Brachiaria decumbens* cv. Basilisk), buffalo grass *(Stenotaphrum secundatum)* and a mixture of mat grass *(Axonopus compressus)* and sour grass *(Paspalum conjugatum).* Each plot was successively harvested at 6-8-weekly intervals after an initial clearing cut after establishment. The plots were fertilized with 25, 64 and 50 kg/ha N,P,K at establishment. Total dry matter yields and proportions of leaf, stem and dead material were determined at each sampling. The material taken from harvests 2 and 4 was chemically analysed for the components described in Experiment 1. Total non-structural soluble carbohydrates were analysed by the technique described by Weier et al. (1977). Results were statistically analysed by analysis of variance.

Results and Discussion

Experiment 1

Table 1 shows mean values for yield and chemical composition of the five grasses grown under shade for the sheep feeding trial. Shading decreased the yields of setaria (45%), green panic (25%), guinea grass (40%) and signal grass (6 1%). Shading increased leaf and decreased stem fractions in setaria, but no changes were seen in the proportions of leaf in the other species. The yield of bahia grass *(Paspalum notatum)* was increased under shading but this effect cannot be compared directly with the other grasses because of the different environment in which it was grown. Wilson et al. (1990) have previously reported this response of bahia grass to shade.

Table 1. The effects of shade (50% light transmission) on yield and chemical composition of five tropical grass species harvested after six weeks regrowth.

Component		Setaria	Bahia grass	Green panic	Guinea grass	Signal grass	Mean
DM yield	Sun	4568	2542	3951	4321	7284	4533
(kg/ha)	Shade	2519*	3431*	2963*	2963*	2840*	2943*
Leaf (%)	Sun	35	97	54	43	34	52
	Shade	53*	99	57	42	40	58
Stem(%)	Sun	58	0	43	40	54	40
	Shade	42*	0	40	43	47	38
Dead (%)	Sun	4	3	0	17	6	6
	Shade	2		0	15	4	4
Inflorescence (%)	Sun	3	0	3	0	6	3
	Shade	3	0	3	0	9	4
NDF	Sun	781	778	775	770	784	778
(g/kg DM)	Shade	742*	777	757	774	778	766
	Sun	463	453	502	484	473	475
(g/kg DM)	Shade	467	435	537*	502	437*	476
Lignin	Sun	96	77	93	79	82	85
(g/kg DM)	Shade	103	63	117	82	76	88
Nitrogen	Sun	14.2	11.5	15.7	14.0	10.1	13.1
(g/kg DM)	Shade	21.2*	10.8	16.9	17.5*	20.4*	17.4*
Phosphorus	Sun	1.72	1.54	1.82	1.57	1.48	1.63
(g/kg DM)	Shade	1.76	1.67	1.78	1.63	2.08	1.78

* Significant difference ($P < 0.05$) between sun and shade values.

The effects of shading on the cell wall content (NDF), ADF (cellulose + lignin), lignin or P content of the grasses sampled were generally small and inconsistent between species, with few differences reaching statistical significance.

There was a significant increase in the N content of setaria, guinea grass and signal grass under shade. It may be calculated that while DM yield was decreased by 25 to 61%, N yield was only decreased by 14 to 21%. The yield of N from the tops of shaded bahia grass was greater than that from sun-grown bahia plants. These aspects of the N economy in shaded plants have been discussed elsewhere (Wilson et al. 1990).

It is usually found that the soluble carbohydrates of plants decrease under shading, and this decrease in cell contents leads to an apparent increase in the cell wall fraction (NDF) of the dry matter cell. Similarly, where the protein content increases, this may also result in an apparent decrease in cell wall fraction. Since these soluble fractions are fully digested, the changes in plant digestibility are predictable.

Cell walls are the major fraction available for digestion and it is important to determine whether shade affects their composition (and hence herbage digestibility). Table 2 shows values for the cellulose, hemicellulose and lignin contents of the cell wall fraction of shaded and unshaded plants in this study. The ratios of hemicellulose to cellulose and lignin to cellulose (lignin proportion of ADF) tend to be constant for a species and may be used as an independent measure of shade effects on the composition of the cell wall. While the species differences are clearly shown in this table, the differences between sun and shade treatments in these values and in in vitro digestibility were small, inconsistent and statistically not significant.

Table 3 gives mean values from the feeding trial conducted with sheep. There was no consistent effect of shade on voluntary feed intake or on the digestibility of any of the components measured. As with feed chemical composition and dry matter, there were significant differences between species. The P content of these feeds was adequate as indicated by the positive balance of all sheep. However, sheep given feeds grown under shade (particularly setaria and signal grass) had higher N-balances than those given sun-grown feeds. It is relevant to note that it was these feeds which had the greatest increase in N concentration under shade. The N requirement of the ruminant needs to be satisfied in two ways: firstly, there is need for sufficient soluble plant N to maintain ammonia levels in the rumen sufficient for the effective action of the microbial population (40-60 mg N/l rumen fluid). Secondly, it is desirable that some plant protein pass to the small intestine for direct absorption (undegraded protein). Although liveweight changes were not measured in this study, it was expected that the increased N balance would be accompanied by higher liveweight gains.

Table 2. Effects of shade on the chemical composition of plant cell walls and in vitro digestibility of five tropical grass species.

Component		Setaria	Bahia grass	Green panic	Guinea grass	Signal grass	Mean
Cellulose (g/kg)	Sun	314	349	376	381	367	357
	Shade	243	352	381	391	338	341
Hemicellulose (g/kg)	Sun	318	327	288	285	319	307
	Shade	286*	339	243*	252*	338	292*
Hemicellulose/cellulose	Sun	1.02	.093	.076	0.75	0.87	0.87
	Shade	1.18	0.96	.064	0.65	1.00	0.89
Lignin in ADF (%)	Sun	20.6	17.1	18.5	16.2	17.3	17.9
	Shade	22.0	14.5	21.7	16.3	17.4	18.4
In vitro digestibility (%)	Sun	50.0	45.0	50.9	49.5	52.1	49.5
	Shade	52.9	47.8	50.3	50.1	52.2	50.7

* Significant difference ($P < 0.05$) between sun and shade values.

Table 3. Shade effects on the voluntary feed intake. digestibility and nutrient retention of five tropical grass species by sheep.

Component		Setaria	Bahia grass	Green panic	Guinea grass	Signal grass	Mean
Voluntary feed intake							
g DM/day	Sun	376	577	480	591	528	510
	Shade	385	620	438	487	516	489
g DM/kg.^{075}/day	Sun	36.9	54.4	46.3	53.7	52.4	48.7
	Shade	38.7	56.4	42.3	44.3	49.6	46.3
Digestibility							
Dry matter	Sun	68.3	55.0	61.4	57.3	65.1	61.4
	Shade	65.2	60.2	57.5	54.5	63.2	60.1
Cellulose	Sun	62.0	65.5	63.9	60.7	74.1	65.2
	Shade	70.6	77.0	61.4	63.5	65.4	67.6
Hemicellulose	Sun	83.0	76.1	78.1	75.7	81.0	78.8
	Shade	76.3	75.6	77.4	67.7	84.2	76.2
Nitrogen	Sun	67.1	46.0	69.1	63.6	52.7	59.7
	Shade	76.4	42.3	64.2	65.6	73.6	64.4
Phosphorus	Sun	17.1	6.5	15.2	22.2	10.7	14.3
	Shade	6.5	18.8	1.8	21.9	30.9	16.0
Nitrogen balance							
g retained/day	Sun	2.5	1.7	4.1	3.0	0.9	2.4
	Shade	4.7*	1.4	3.3	2.7	5.5*	3.5*
% ADN retained	Sun	46.7	52.5	60.6	51.1	29.1	48.0
	Shade	57.0	47.0	55.7	44.4	61.1*	53.0
mg P retained/day	Sun	157	64	153	239	89	140
	Shade	48	201	15	197	379	168
% ADP retained	Sun	80.3	93.8	97.4	95.0	92.1	91.7
	Shade	56.3	98.5	60.0	89.3	97.6	80.3

* Significant difference ($P < 0.05$) between sun and shade values.

Table 4 shows mean values for the concentration of ammonia and volatile fatty acids in the rumen of sheep given the shaded and unshaded grass diets. Sheep given feeds from shaded pastures had significantly higher concentrations of ammonia in rumen fluid than did sheep given sun-grown feeds. The increased N content of the feed was associated with an increase in rumen ammonia concentrations

Samarakoon, S.P., Wilson, J.R. and Shelton, H.M. 1990a. Growth, morphology and nutritive value of shaded *Stenotaphrum secundatum, Axonopus compressus* and *Pennisetum clandestinum*. Journal of Agricultural Science, 114, 161-169.

Samarakoon, S.P., Shelton, H.M. and Wilson, J.R. 1990b. Voluntary feed intake by sheep and digestibility of shaded *Stenotaphrum secundatum* and *Pennisetum clandestinum* herbage. Journal of Agricultural Science, Cambridge, 114, 143-150.

Weier. K.L., Wilson, J.R. and White, R.J. (1977). A semi-automated procedure for estimating total non-structural carbohydrates in grasses, and comparison with two other procedures. CSIRO Division of Tropical Crops and Pastures Technical Paper No. 20.

Wilson, J.R. 1988. Ecological constraints to production and nutritive quality of pastures under tree crops. In: Livestock-Tree Cropping Production Systems. Proceedings FAO/MARDI International Workshop, 5-9 December, 1988, Serdang, Malaysia.

Wilson, J.R., Hill, K., Cameron, D.M. and Shelton, H.M. 1990. The growth of *Paspalum notatum* under the shade of a *Eucalyptus grandis* plantation canopy or in full sun. Tropical Grasslands, 24, 24-28.

Wilson, J.R. and Wong, C.C. 1982. Effects of shade on some factors influencing nutritive quality of Green panic and Siratro pastures. Australian Journal of Agricultural Science, 33, 937-949.

Wong, C.C., Mohd. Sharudin, M.A. and Rahim, H. 1985. Shade tolerance potential of some tropical forages for integration with plantations. I. Grasses. MARDI Research Bulletin 13, 225-247.

Table 5. The effects of varying light transmission on the mean yield, dry matter content, leaf proportion, nitrogen concentration, soluble carbohydrate, hemicellulose, cellulose, and lignin fractions, and in vitro digestibility of six grasses.

Parameter	Light level (% light transmission)			
	100	68	50	30
Dry matter yield (t/ha)				
Harvest 2	1.90a	1.10b	1.05b	0.67b
Harvest 3	4.14a	3.10b	2.36c	2.10c
Harvest 4	4.28	6.07	5.42	5.98
Dry matter content (%)				
Harvest 2	15a	13b	13b	11c
Harvest 4	33	33	28	27
Green leaf (% DM)				
Harvest 2	73	75	74	71
Harvest 3	33a	45b	44b	41b
Nitrogen concentration (% DM)				
Harvest 2	2.23	21.6	2.21	2.56
Harvest 4	0.86a	0.92ab	1.02bc	1.08c
Soluble carbohydrate (% DM)				
Harvest 2	10.7	12.4	9.9	9.6
Harvest 4	12.3	11.9	12.2	11.7
Hemicellulose (% DM)				
Harvest 2	33.1	32.3	31.2	30.6
Harvest 4	34.9	34.7	33.6	33.5
Cellulose (% DM)				
Harvest 2	26.8	29.1	26.9	27.0
Harvest 4	23.7	28.2	25.6	27.3
Lignin (% DM)				
Harvest 2	9.6	9.4	10.4	11.5
Harvest 4	14.3	11.7	14.1	13.9
In vitro dry matter digestibility (% DM)				
Harvest 2	68.5a	68.9a	67.4ab	64.3b
Harvest 4	58.6	58.5	60.0	57.6

Means in rows followed by different letters are significantly different ($P < 0.05$).