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SHADE TOLERANCE POTENTIAL OF SOME TROPICAL FORAGES FOR INTEGRATION WITH PLANTATIONS
1. GRASSES

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RINGKASAN

Ketahanan terhadap naungan bagi 12 jenis rumput tropika telah dinilaikan dengan menggunakan naungan buatan di dalam rumahkaca pada kadar 64%, 30%, 18% dan 9% cahaya yang sesuai untuk fotosintisis (photosynthetic quantum flux – PHAR) berbanding dengan cahaya matahari sepenuhnya. Ini diikuti dengan percubaan di ladang untuk menilai keupayaan enam jenis rumput terpilih pada kadar cahaya 100% (kawalan), 60%, 34% dan 18% PHAR daripada cahaya matahari sepenuhnya dan dipotong setiap enam minggu dan sepuluh minggu.

Dalam kajian di rumahkaca, naungan mengurangkan pengeluaran anak rumput (tiller), hasil bahan kering bagi pucuk, daun, batang, tunggul dan akar dengan berkesan ($P<0.01$), tetapi menambahkan keluasan permukaan daun. Dalam keadaan naungan, pembahagian bahan kering kepada komponen daun yang melebihi akar memberikan peningkatan nisbah pucuk/akar dan daun/batang. Purata pengurangan hasil bahan kering di antara rumput-rumput ialah 28.7%, 63.3% dan 82.4% berbanding dengan kawalan bagi pengurangan cahaya sebanyak 44%, 66% dan 82% daripada cahaya PHAR di dalam rumahkaca. Rumput-rumput yang terbaik dan sesuai di bawah naungan ialah *Panicum maximum, P. maximum* cv. Tanganyika, *Digitaria setivalva* dan *Brachiaria decumbens*. Spesies-spesies *Setaria sphacelata* cv. Kazungula, *Digitaria decumbens* cv. Transvala dan *B. ruziziensis* sangat kurang ketahanannya terhadap naungan. Pada naungan yang banyak (9% PHAR), rumput-rumput tempatan iaitu *Paspalum conjugatum* dan *Axonopus compressus* disenaraikan di tempat ketujuh dan keempat selepas rumput spesies-spesies *Panicum*.

Bagi percubaan di ladang pula, *P. maximum* dan *B. decumbens* memberikan hasil yang tertinggi pada semua paras naungan. Pengurangan hasil purata bahan kering terhadap enam jenis rumput ialah 23.1% dan 37.6% berbanding dengan kawalan bagi cahaya 66% dan 82% PHAR daripada cahaya matahari sepenuhnya. *Axonopus compressus* dan *P. maximum* var. *trichoglume* menghasilkan bahan kering yang tertinggi pada paras naungan sederhana dan dipotong setiap enam minggu atau sepuluh minggu. Rumput-rumput tegak di bawah naungan yang dipotong setiap sepuluh minggu memberikan pengeluaran anak rumput dan hasil bahan kering yang tinggi. Sementara itu potongan setiap enam minggu memberikan hasil yang tinggi bagi rumput-rumput yang bukan berjenis tegak seperti *A. compressus* dan *P. conjugatum*.

Bagi rumput-rumput di bawah naungan yang banyak adalah dicadangkan supaya jangka masa potongan dipanjangkan untuk meninggikan lagi kandungan botani dan kadar penghidupannya. Pada amnya, kandungan nitrogen bertambah mengikut kadar naungan dan jangka masa potongan yang lebih pendek. Rumput-rumput yang kurang penghasilannya, seperti *S. sphacelata* cv. Kazungula dan *A. compressus,* mempunyai kandungan nitrogen yang tinggi. *Panicum maximum* var. *trichoglume* mengandungi paras nitrogen yang terendah.

Keputusan-keputusan lain dibandingkan dalam hubungan terhadap pengurusan pastura di dalam tanaman perladangan.

INTRODUCTION

With the current increasing interest in multiple land use incorporating crops such as pastures with plantation agriculture, there is a void of information on the relative production potential of tropical forage and pasture grasses under a wide range of light regimes as encountered at different stages of plantation crop development in the humid tropics. The problems of integrating pastures, livestock and tree crops have been high-

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lighted by THOMAS (1978). Shading experiments had been attempted to identify shade-tolerant species (WHITEMAN, BOHORQUEZ and RANACOU, 1978; ERIKSEN and WHITNEY, 1981). Results from a grazing trial on some improved tropical forages in 5-year-old oil palm at Serdang indicated few improved species of legumes which were tolerant to very low light regimes (CHEN, CHANG, AJIT and HASSAN, 1978). As the grasses were planted under an already closed canopy, the light limitation and root competition from the existing oil palms could have posed constraints to effective establishment.

In newly established plantations, the interrows are generally wide and receive almost complete or full solar radiation. It is at this early stage of plantation development that the potential for forage integration with plantation crops could be exploited for subsequent utilization in the later years when light gradually becomes limiting.

In order to screen for grass species better adapted to growth in a wide range of light levels that are reflective of the fluctuating light environment as experienced in plantations, two trials were initiated to evaluate tropical grass species for a wide spectrum of shade tolerance. In the first experiment, the effect of different shade levels on the growth and performance of 12 tropical grasses was determined under greenhouse environment. The second trial was to compare the performance of six tropical species in the field under four shade regimes and at 6- and 10-weekly defoliation intervals at MARDI Research Station, Serdang.

MATERIALS AND METHODS

Pot Trial Under Greenhouse Environment

The experiment was initiated in October 1981 to assess the performance of 12 tropical grasses *(Table 1)* under four shade levels (inclusive of a control) in a soil-pot culture at Serdang. The experimental design was a Randomized Complete Block in a split-plot arrangement with three replications.

Soil belonging to Tropeptic Haplorthox series was collected from 0–40 cm depth and mixed with one third by volume of fine sand. The mixture was then sieved through a 0.5 x 0.5 cm screen and air-dried. To each cubic metre of the mixture, 2 kg NPK compound fertilizer (14:14:14) were added and mixed thoroughly before potting. Plastic pots, measuring 16.5 cm in diameter, were each filled with 2.5 kg of the air-dried soil mixture and planted with two or three tillers of the grasses under study.

Dead tillers were replaced until completed establishment was obtained. The established grasses were then allowed to grow for four weeks before a uniform cutting at 5-cm stubble height was undertaken to promote tillering. A second uniform cutting was imposed four weeks later just prior to the introduction of shade levels obtained by varying the density of shade screens. The photosynthetic quantum flux (PHAR) of the transmitted light through the shade screens was measured around noon by a Lambda Li-185 light meter *(Table 2)*.

The pots were randomized weekly and watered twice daily to field capacity. All grasses were harvested to a 5-cm stubble height on 24 February, 27 April and lastly on 7 June 1982, giving a 10-weekly regrowth in the first two harvests and 6-weekly regrowth in the third harvest. After each harvest, NPK fertilizer equivalent to 50 kg N, 20 kg P and 50 kg K/ha was applied. Tiller counts were taken prior to each harvest.

The harvested materials were separated into leaf and stem fractions. The leaf samples were subsampled for leaf area determination in the first and second harvests using an electronic leaf area meter. The leaf and stem fractions were then dried in an oven at 80°C for 48 hours and weighed for dry

Table 1. The 12 tropical grasses selected for study

Botanical name	Common name
Axonopus compressus (Sw.) Beauv.	Carpet grass
Brachiaria decumbens Stapf.	Signal grass
Brachiaria ruziziensis Germain & Evrard	Congo grass
Digitaria setivalva Stent.	MARDI digit
Digitaria decumbens cv. Transvala (Stent)	Transvala digit
Ottochloa nodosa (Kunth) Dandy	'Rumput pahit'
Panicum maximum var. *trichoglume* (Eyles)	Green panic
Panicum maximum Jacq.	Common guinea
Panicum maximum cv. Tanganyika	Tanganyika guinea
Paspalum conjugatum Berg.	Tee grass
Setaria sphacelata var. *sericea* cv. Kazungula (Schumach) Stapf. & C.E. Hubb.	Kazungula setaria
Setaria sphacelata var. *splendida* (Stapf.)	Splendida setaria

Table 2. Light levels under various shade screens in the pot trial

Density of shade screen (layers)	Shade level	PHAR (ME/m^2/s)	% PHAR	
			In greenhouse	Outside greenhouse
0	SG 0	1 350	100	64
1	SG 1	760	56	30
2	SG 2	460	34	18
3	SG 3	245	18	9

PHAR at full sunlight = 2 130 ME/m^2/s

matter (DM) determination. The root and stubble dry weights were recorded at the end of the last harvest.

Field Trial

Another trial was conducted on a similar soil (Tropeptic Haplorthox) at Serdang to determine shade tolerance and defoliation effects on the performance of six selected tropical grasses of different growth habits under field conditions. The six grasses were Carpet grass, Signal grass, Common guinea, Green panic, Tee grass and Kazungula setaria.

The experimental design was a split-split plot with shade as the main plot, defoliation frequencies as the sub-plot and the grasses as the sub-sub-plot treatment with three replications. Each sub-sub-plot measured 2 x 2 metres. The shade levels *(Table 3)* were obtained by using different densities of shade screen mounted on a wooden frame 2 m above ground level. The four sides of each main plot were covered from the top to about 1 m from the ground to minimize morning and evening light transmission.

All the grasses were initially established from vegetative cuttings (3–4 tillers per planting point) and planted at 0.5 x 0.5 m spacing. Basal fertilizers comprising 50 kg N/ha as *Nitro 26*, 30 kg P/ha as triple superphosphate and 50 kg K/ha as muriate of potash were applied after planting. The maintenance fertilizer rates were 150 kg N, 40 kg P and 100 kg K/ha/yr as *Nitro 26,* triple superphosphate and muriate of potash respectively, and were split-applied twice annually. All plots received two uniform

Table 3. Light levels under the various shade screens in the field

Density of shade screen (layers)	Shade level	PHAR (ME/m²/s)	% PHAR in full sunlight
0	SF 0	2 300	100
1	SF 1	1 380	60
2	SF 2	780	34
3	SF 3	420	18

defoliations at 15-cm stubble height prior to commencement of the shade treatment, and defoliation at 6- and 10-weekly cuts.

All plots were harvested by hand, weighed fresh and sub-sampled for dry matter yield determination. The dried samples were ground to pass through a 1-mm mesh steel screen, and nitrogen content was determined on the bulked plant tops using Kjeldahl analysis.

Tiller counts were taken in June 1980 and again in November 1981 from five random quadrats (20 x 20 cm) in each plot. Leaf water potential of the most recently expanded leaves of the grasses under the shade levels was determined using a pressure chamber. Soil moisture was determined gravimetrically from soil cores of 0−15 cm depth. At the end of the experiment, roots were sampled from soil cores, each 20 cm^2 x 30 cm deep with the crown root in the centre of the core. The soil cores were washed and the roots collected and oven-dried for dry weight determination.

Meteorological Data

Temperature and relative humidity were recorded by thermohydrographs placed in Stevenson screens in the four shade levels of Replicate 1. Rainfall was obtained from a meteorological site some 100 m from the experimental site. On several cloudless days, diurnal variations of the PHAR of the transmitted light under the shade levels were measured at hourly intervals with a Lambda Li-185 light meter.

Statistical Analysis

Data were subjected to an analysis of variance for a split plot design in the pot trial and a split-split plot in the field trial. The means were ranked for shade-tolerant performance.

RESULTS

Environmental Conditions

Pot trial

Mean daily air temperature and relative humidity at 9 am and 3 pm as well as instantaneous PHAR around noon under the different shade screens in the greenhouse are given in *Table 4.*

The mean daily temperature under the shade screens generally decreased by about 1°C and the mean daily relative humidity increased by 3% to 6% compared with the control. Mean instantaneous PHAR were in the ratio of 100% : 56% : 34% : 18% of the control for the shade treatments in the greenhouse or equivalent to 64% : 30% : 18% : 9% of PHAR in full sunlight (outside greenhouse).

Field trial

In the field trial, the environmental conditions were best depicted by a typical diurnal variation in PHAR, air temperature and relative humidity percentage between 8 am and 6 pm under various shade levels at Serdang on a clear day (10.2.82) *(Figures 1a, 1b* and *1c).*

The mean daily air temperatures under the shade screens were also lowered

Table 4. Mean daily temperatures and relative humidity and instantaneous photosynthetic quantum flux under 4 shade intensities in greenhouse

Shade treatment	Density shade screen (layers)	Instantaneous PHAR			Mean daily temp. (°C)		Relative humidity (%)	
		Quantity (ME/m²/s)	% PHAR in greenhouse	% PHAR in full daylight	9 am	3 pm	9 am	3 pm
SG 0	0	1 350	100	64	27.3	32.0	96	64
SG 1	1	760	56	30	26.4	32.0	96	67
SG 2	2	460	34	18	26.8	32.5	96	67
SG 3	3	245	18	9	27.0	32.1	96	70

PHAR = Photosynthetic quantum flux

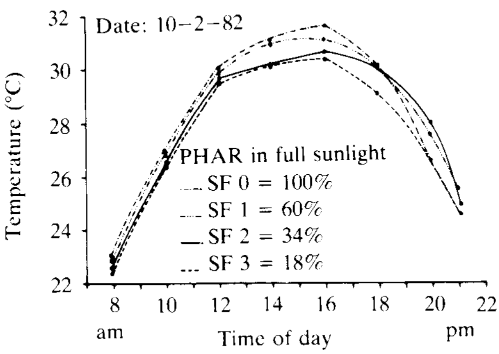

Figure 1a. Diurnal variations in air temperature under 4 shade intensities in the field.

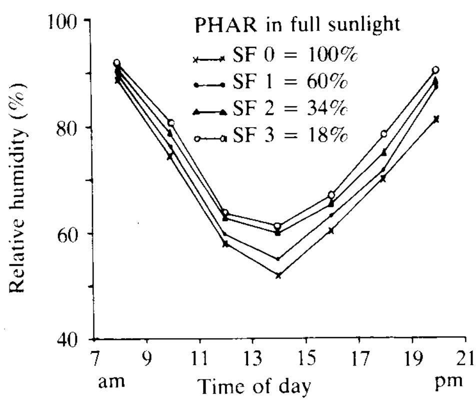

Figure 1b. Diurnal variations in relative humidity under 4 shade levels in the field.

by about 1°C compared with that of the control. The mean relative humidity increased by 3%–7% in increasing shade densities. Phyotosynthetic quantum fluxes were in the ratio of 100% : 60% : 34% : 18% for the four shade levels (inclusive of the control).

Gravimetric measurements of the soil moisture from 0–15 cm depth, and leaf water potential of the six tropical grasses, increased with shade intensity.

Monthly rainfall at Serdang for the experimental period could be described as normal and favourable for plant growth except for a short dry spell in June 1981 *(Figure 1d)*. Dry matter yield and rainfall were not correlated but it was evident that period of high rainfall usually coincided with period of high DM production, particularly at the higher irradiance levels.

Establishment

With adequate water, nutrients and favourable temperature, all the grasses in the greenhouse showed excellent growth. Similarly, in the field trial, the six grasses established well from the vegetatively propagated tillers except for Tee grass. At commencement of the shade treatments, all pots had good growth of grasses, and in the field, the plots comprised almost purely planted grasses.

Tillering

Shade generally increased the stature of tillers (visual observation as height was not taken), the difference being greater between SG 0 and the other levels (SG 1 – SG 3) than between the shade levels themselves. Cumulative tiller production over the three harvests in the 12 grasses was

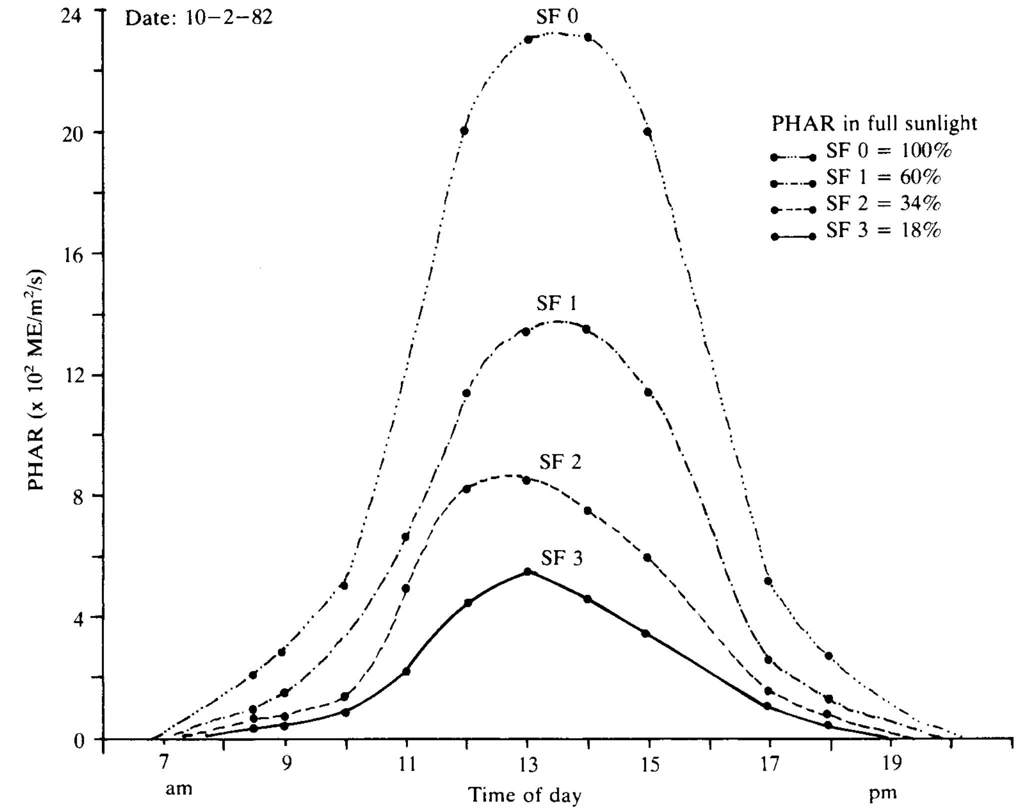

Figure 1c. Diurnal variations in instantaneous photosynthetic quantum fluxes under 4 shade levels.

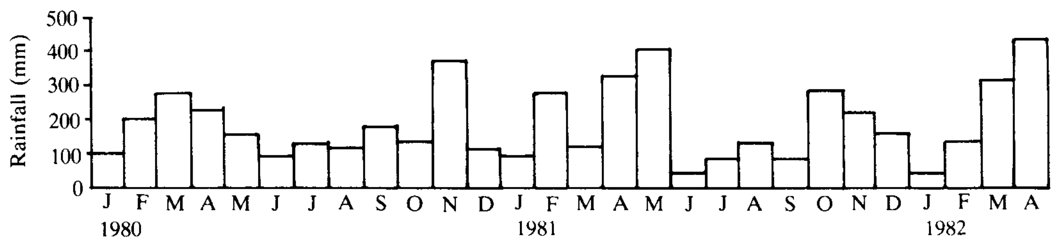

Figure 1d. Monthly rainfall at MARDI Research Station, Serdang during the experimental period (January 1980 to April 1982).

reduced significantly (P<0.01) by shade intensity *(Figure 2).*

The overall mean tiller number of the 12 grasses declined from 131.5 at SG 0 to 26.6 at SG 3 *(Table 5).* Tiller production also decreased (P<0.01) with each successive harvest irrespective of shade intensity in the greenhouse. The stoloniferous grasses were generally higher in tiller production across all shade levels. Carpet grass ranked the highest (P<0.05) with over 162 tillers/pot followed by MARDI digit (114 tillers/pot), Transvala digit (112 tillers/pot) and 'Rumput pahit' (100 tillers/pot). The *Panicum* spp. and Signal grass were intermediate in tillering capacity under shade. Congo grass and Splendida setaria gave the lowest tiller production *(Table 5).*

In the field trial, the tillering response to shade was similar to that in the pot trial. Tillering also declined with time and was higher (P<0.05) for the 10-weekly cut than the 6-weekly cut *(Table 6).*

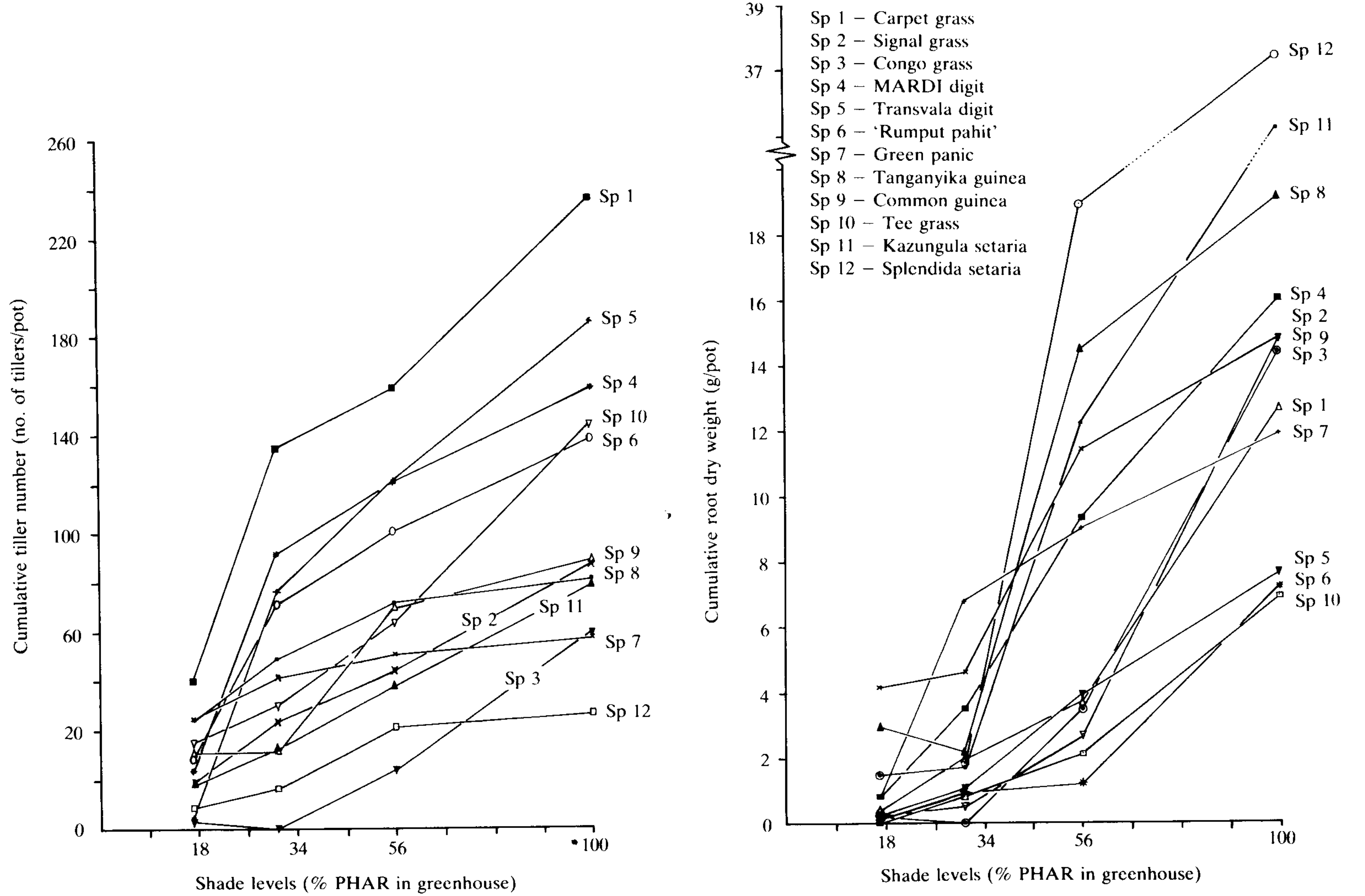

Figure 2. The influence of shade levels on cumulative tiller production and root dry weight of 12 tropical grasses grown under greenhouse environment.

Table 5. Overall mean DM yield and growth characteristics of 12 tropical grasses grown under 4 shade levels in the greenhouse and their correlation coefficients

Parameter	Agronomic attributes															Leaf H_2O potential (−bar)	SM (%)
	DM yield (g/pot)	Dry weight (g/pot)				Leaf/ stem ratio	Shoot/ root ratio	Tiller no./ pot	Leaf area (dm^2/pot)	SLA (cm^2/g)	DM (%)	% Whole plant					
		Stubble	Root	Stem	Leaf							Stubble	Root	Stem	Leaf		
Shade level (% PHAR)																	
SG 0 (100)	41.4	11.5 a	16.5 a	19.7 a	22.0 a	1.12	2.53	131.5 a	25.1 a	170.7	30.4 a	16.4	23.7	28.3	31.6	12.4a	24.6
SG 1 (56)	29.5	5.7 b	7.7 b	13.2 b	16.3 b	1.24	3.83	91.9 b	24.9 a	226.8	23.3 b	13.3	18.0	30.8	38.0	10.7b	25.9
SG 2 (34)	15.2	1.7 c	2.2 c	5.9 c	9.3 c	1.56	7.08	63.2 c	22.9 a	331.8	19.0 c	9.1	11.3	31.2	48.5	8.7c	26.1
SG 3 (18)	7.3	0.9 c	1.1 c	2.6 d	4.7 d	1.82	6.71	26.6 d	12.3 b	354.4	16.1 d	9.8	11.7	27.8	50.6	7.7c	27.1
Correlation coefficient (r)	0.98	0.99	0.99	0.98	0.97	−0.92	−0.93	0.98	0.72	−0.96	0.99	–	–	–	–	–	–
Grass																	
Common guinea	33.9 a		8.8 bcd	11.8 c	22.1 a	1.9	4.3	76.3 cd	32.1 a	211.3							
Tanganyika guinea	31.4 a		9.7 bc	9.4 de	22.0 a	2.4	3.5	65.4 de	23.8 bcd	161.4							
Green panic	29.8 b		7.2 cde	16.0 a	13.9 c	1.3	6.7	63.3 de	24.5 bc	249.8							
Kazungula setaria	19.5 cd		12.7 ab	8.5 e	11.0 de	1.4	5.1	52.0 e	18.6 cd	255.0							
Splendida setaria	21.8 c		14.9 a	9.6 de	11.8 d	1.3	3.3	27.8 f	20.7 cd	299.5							
Transvala digit	22.0 c		3.2 ef	14.5 ab	7.4 f	1.6	3.3	111.9 b	10.1 f	175.8							
MARDI digit	28.1 b		7.4 cde	8.4 e	19.7 b	2.8	4.4	113.6 b	22.3 bcd	247.5							
Tee grass	16.9 de		2.5 f	9.2 de	7.7 f	1.0	11.2	82.9 c	21.8 bcd	341.8							
Carpet grass	14.7 c		4.7 def	5.8 f	8.9 ef	1.7	7.0	162.3 a	17.9 de	295.5							
'Rumput pahit'	20.4 c		2.4 f	11.1 cd	9.3 ef	1.0	23.7	99.8 b	26.8 b	360.8							
Congo grass	15.6 de		4.6 def	6.4 f	9.2 ef	–	–	25.9 f	13.1 ef	–							
Signal grass	28.3 b		4.6 def	13.9 b	13.9 c	1.1	18.3	58.3 c	23.8 bcd	326.3							

SLA = Specific Leaf Area SM = Soil Mixture Means followed by the same letter are not significantly different ($P<0.05$)

Table 6. Effects of 4 shade levels on the DM yield and growth components of 6 tropical grasses grown in the field and defoliated at 2 frequencies and their correlation coefficients

Parameter	DM yield (t/ha/yr)			Root DW (g/soil core)			Tiller no./dm^2			Botanical comp. (%)			Nitrogen (%)			Mean LAI
	6-wk	10-wk	Mean	6-wk	10-wk	Mean	6-wk	10-wk	Mean	6-wk	10-wk	Mean	6-wk	10-wk	Mean	(6-wk regrowth)
Shade levels (% PHAR)																
SF 0 (100)	11.6	11.7	11.7 a	18.7	21.6	20.2 a	17.8	22.0	19.9 a	65.6	61.5	63.6 a	1.64	1.23	1.44	6.7a
SF 1 (60)	11.9	11.9	11.9 a	16.3	20.6	18.5 b	16.3	21.3	18.8 a	67.3	65.3	66.3 a	1.92	1.55	1.74	7.2a
SF 2 (34)	8.7	9.2	9.0 b	13.5	17.4	15.5 c	10.5	18.7	14.6 b	49.5	65.6	57.6 a	2.37	1.77	2.07	8.3a
SF 3 (18)	6.0	8.5	7.3 c	8.6	11.8	10.2 d	9.7	13.9	11.8 c	42.8	51.6	47.2 b	2.65	2.00	2.33	5.3b
Mean	9.6a	10.3b	10.0	14.3a	17.9b	16.1	13.6a	19.0b	16.3	56.3a	61.0a	58.7	2.15a	1.64b	1.90	6.9
Correlation coefficient	–	–	0.82	–	–	0.89	–	–	0.90	–	–	0.75	–	–	−0.98	0.17
Grass																
Carpet grass	6.0	4.9	5.5 c	8.9	10.2	9.6 c	13.3	19.6	16.5 bc	78.2	54.5	66.4 c	2.00	1.81	1.91ab	2.9d
Signal grass	16.1	19.3	17.7 a	17.4	23.1	20.3 a	22.2	15.1	18.7 a	69.9	93.7	81.8 a	2.16;1.57.87bc		7.2bc	
Common guinea	15.1	17.6	16.4 a	13.8	19.5	16.7 b	14.8	20.1	17.5 ab	71.5	86.4	79.0 ab	2.17	1.46	1.82c	12.3a
Green panic	6.4	6.2	6.3 bc	15.3	18.5	16.9 b	14.6	21.7	18.2 a	38.6	43.8	41.2 c	1.84	1.70	1.77d	5.9c
Tee grass	3.7	2.7	3.2 d	–	–	–	10.1	16.0	13.1 c	15.6	13.3	14.5 d	1.90	1.70	1.80cd	3.0d
Kazungula setaria	9.3	8.5	8.9 b	14.6	19.6	17.1 b	17.5	18.0	17.8 ab	69.2	79.5	74.4 abc	2.44	1.64	2.04a	8.7b

LAI = Leaf Area Index
Means followed by the same letter within and between column are not significantly different (P<0.05) for each attribute.

Plant Parts Composition

In the pot trial, shade greatly affected the distribution of dry matter in the plant parts. The root dry weight (DW) was significantly ($P<0.01$) depressed by shade levels resulting in a decreasing root DW percentage of the whole plant but a higher shoot/root ratio *(Table 5* and *Figure 2)*. The root DW at SG 1, SG 2 and SG 3 comprised 46.7%, 13.3% and 6.7% of the control (SG 0).

The erect grasses were higher in root DW than the stoloniferous grasses. *Setaria* spp. produced the highest mean root DW (13.8 g/pot) at all shade levels, followed by *Panicum* spp. (8.6 g/pot), MARDI digit (7.4 g/pot), Congo grass and Signal grass (4.6 g/pot). 'Rumput pahit' (2.4 g/pot) and Tee grass (2.5 g/pot), both with shallow roots, had the lowest root DW *(Table 5)*.

In the field environment, root DW responses to shade intensity were similar. Ten-weekly defoliation produced higher ($P<0.05$) root DW than the 6-weekly cut *(Table 6)*.

The stem DW declined significantly ($P<0.01$) with increasing shade intensity *(Figure 3)* but stem DW percentage of whole plant increased slightly until it declined at SG 3 *(Table 5)* except for Transvala digit, MARDI digit, Tee grass and 'Rumput pahit' which had reduction in stem DW percentage at all shade levels.

Overall mean reductions in stem DW from SG 0 to SG 1, SG 2 and SG 3 were 33%, 70% and 87% of that of the control (SG 0). Surprisingly, Green panic (16 g/pot) and Transvala digit (15 g/pot) emerged the highest in stem DW, followed closely by Signal grass (14 g/pot). Common guinea (12 g/pot) ranked fourth and 'Rumput pahit' (11 g/pot) was fifth. The stoloniferous grasses like Carpet grass, and Congo grass were lowest in stem DW *(Table 5)*.

Leaf DW declined with increasing shade ($P<0.01$) but leaf DW percentage of the whole plant increased with shade intensity up to SG 2 before it declined at SG 3 *(Figure 3* and *Table 5)*.

The leaf DW reduction from SG 0 to SG 1, SG 2 and SG 3 were 26%, 58% and 79% of the control respectively. As a consequence of the higher increase in leaf composition of the total plant, the leaf/stem ratio of the grasses under shading was enhanced from 1.1 at SG 0 to 1.8 at SG 3 *(Table 5)*.

The high yielding grasses, namely Common guinea and Tanganyika guinea, produced significantly ($P<0.01$) the highest total leaf DW (22.0 g/pot) than the other grasses *(Table 5)*. This was followed by MARDI digit (19.7 g/pot), Green panic and Signal grass (13.9 g/pot). Carpet grass averaged about 8.9 g/pot and Tee grass 7.7 g/pot. Although these two grasses were lowest in leaf DW, they were ranked fourth and fifth respectively at SG 3. Transvala digit and Congo grass were the poorest yielders in leaf DW (< 1.0 g/pot) at SG 3.

Leaf Area and Specific Leaf Area

Leaf area usually increased from SG 0 to SG 1 and then declined non-significantly with further shade increase except at SG 3 where leaf area was significantly ($P<0.05$) lower than those at the other shade levels *(Figure 4)*. Common guinea produced significantly ($P<0.05$) the highest leaf area (32 dm^2/pot) followed by 'Rumput pahit' and Green panic, each with 26 dm^2/pot and Tanganyika guinea and Signal grass, each with 24 dm^2/pot *(Table 5)*.

In the field trial, the leaf area index (LAI) increased non-significantly with shading but declined at SF 3 *(Table 6)*. As expected, Common guinea produced the highest LAI while the stoloniferous grasses *viz.* Tee grass and Carpet grass were the lowest.

The specific leaf area which was the ratio of leaf area to leaf DW presents a measure of leafiness of a grass under shade

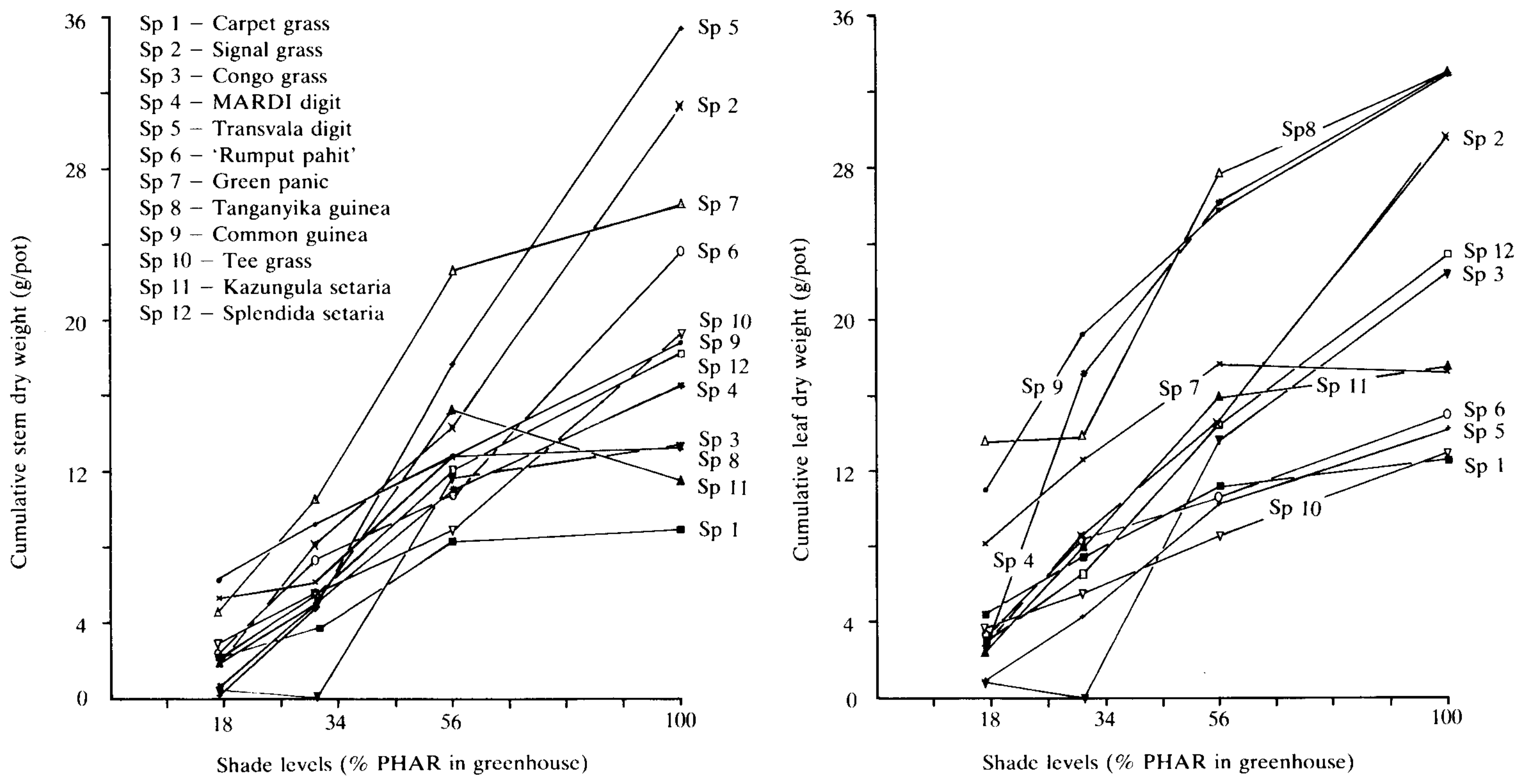

Figure 3. The influence of shading on the cumulative stem and leaf dry weight production of 12 tropical grasses grown under greenhouse environment.

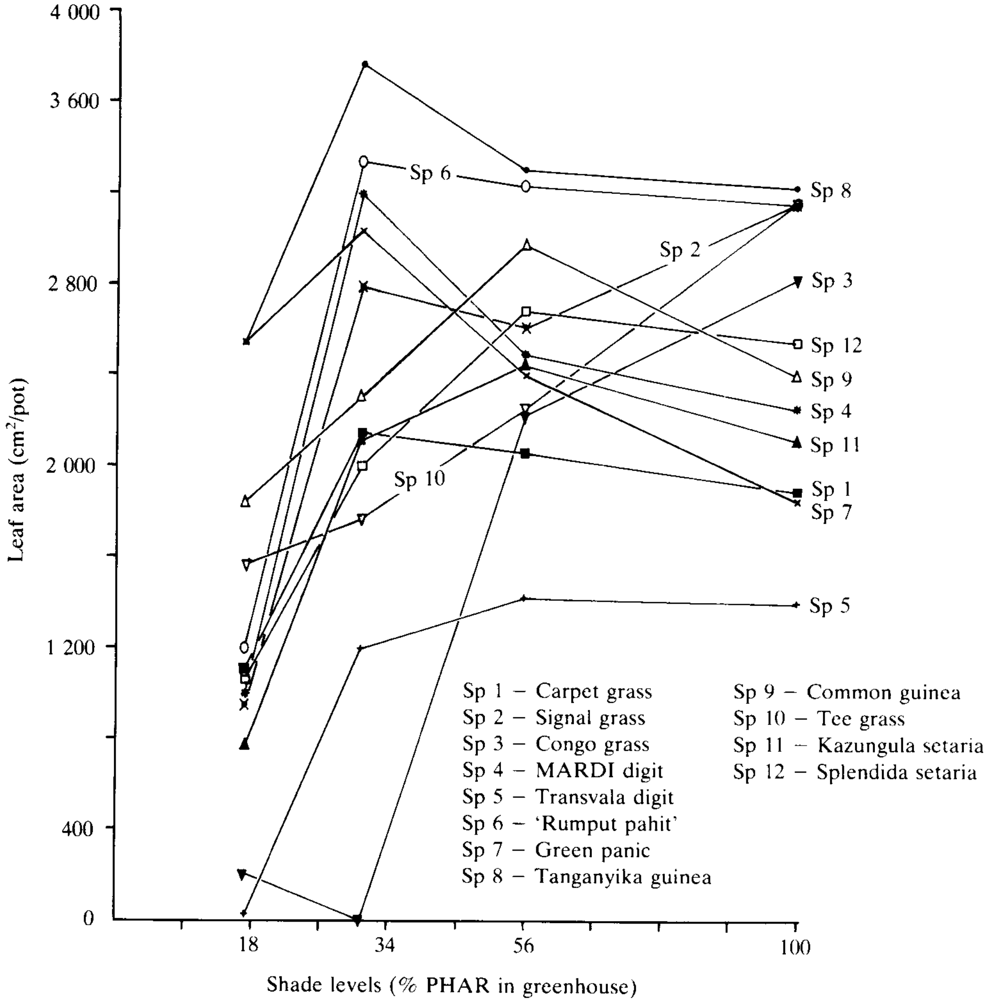

Figure 4. The influence of shading on leaf area production of 12 tropical grasses grown under greenhouse environment.

as an adaptive sensitivity to reduced light. Specific leaf area increased ($P<0.01$) with shading but was negatively correlated to DM yield ($r = -0.96$). 'Rumput pahit' and Tee grass were highest in specific leaf area compared to the *Panicum* spp. and *Digitaria* spp. *(Table 5)*. Nevertheless, specific leaf area increase was greatest in the *Panicum* spp. (data not shown).

Dry Matter Production

Under the greenhouse environment, the DM yield of the 12 tropical grasses declined significantly ($P<0.01$) with shade intensity *(Table 5)*. The mean DM percentage of the plant tops across the grasses were 30.4%, 23.3% 19.0% and 16.1% at SG 0, SG 1, SG 2 and SG 3 respectively. Cumulative DM yields of the plant tops over the three harvests among the grasses at different shade intensities are illustrated by their regression curves *(Figure 5)* and regression equations *(Table 7)*.

Overall mean DM yield of the plant tops in the 12 grasses at SG 1, SG 2 and SG 3 were 71%, 37% and 18% respectively of that obtained in control (SG 0). At SG 0, Signal grass produced the highest cumulative DM yield (60.8 g/pot) followed by Tanganyika guinea (51.6 g/pot), Transvala

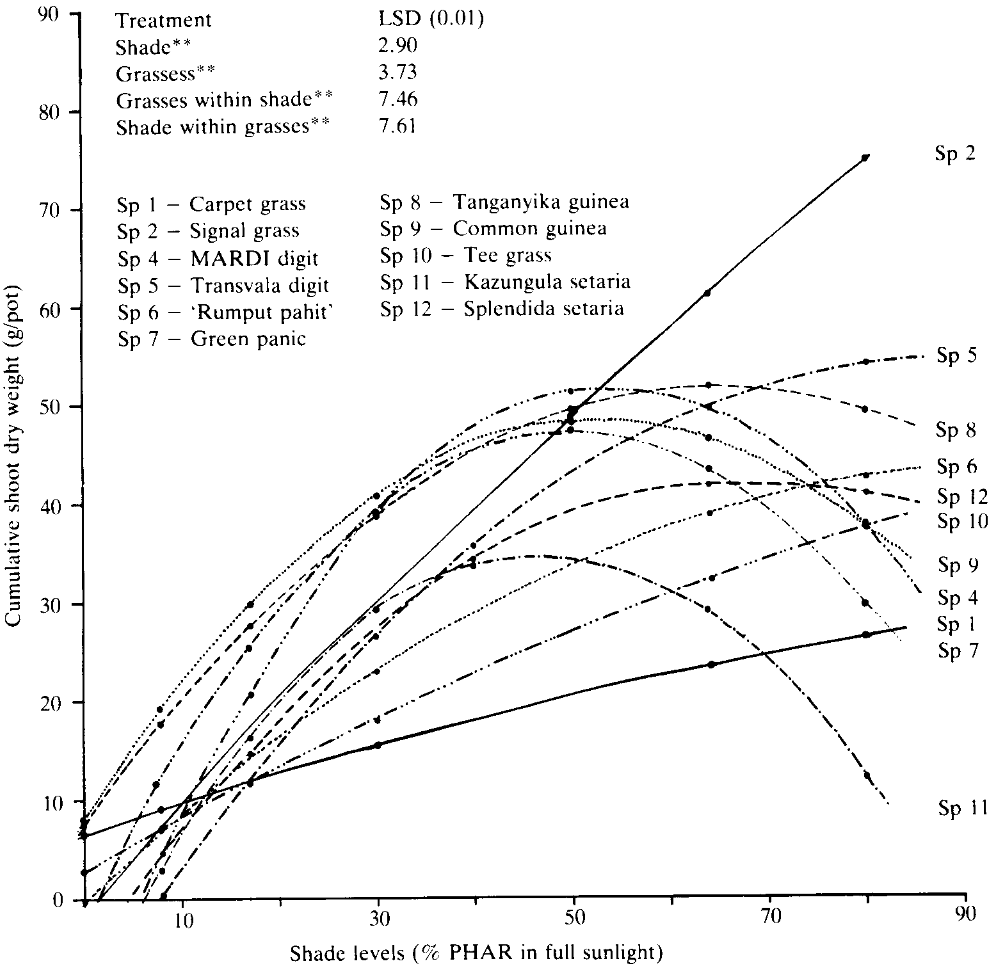

Figure 5. Regression curves of the effect of shading on the cumulative dry matter yield of the top growth in 11 tropical grasses grown under greenhouse conditions. Species 3 (Congo grass) was omitted.

Table 7. Regression equations for dry matter yield of the tropical grasses as affected by shade

Grass	Cumulative dry matter yield (g/pot)	
	Regression equation	Correlation of determination (r^2)
Carpet grass	$Y = 6.34 + 0.32S - 0.0009S^2$	0.71**
Signal grass	$Y = -1.62 + 1.08S - 0.0016S^2$	0.98**
MARDI digit	$Y = -13.46 + 2.37S - 0.0021S^2$	0.83**
Transvala digit	$Y = -11.5 + 1.53S - 0.0089S^2$	0.93**
'Rumput pahit'	$Y = -0.40 + 0.91S - 0.0047S^2$	0.93**
Green panic	$Y = -3.12 + 2.01S - 0.02S^2$	0.69*
Common guinea	$Y = 7.30 + 1.37S - 0.011S^2$	0.80**
Tanganyika guinea	$Y = 7.87 + 1.53S - 0.0145S^2$	0.81**
Tee grass	$Y = 2.57 + 0.52S - 0.0009S^2$	0.96**
Kazungula setaria	$Y = -12.11 + 2.036S - 0.0217S^2$	0.60*
Splendida setaria	$Y = -6.75 + 1.43S - 0.0105S^2$	0.92**

Y = Yield, S = Shade level (% PHAR outside greenhouse)
*Significant (P = 0.05)
**Significant (P = 0.01)

digit (49.6 g/pot) and MARDI digit (49.5 g/pot).

The indigenous grasses namely Carpet grass (21.7 g/pot) and Tee grass (32.3 g/pot) were the lowest yielders at SG 0. However, under heavy shade (SG 3), they ranked on par with Signal grass but were higher yielding than the *Setaria* spp. and *Digitaria* spp. *(Figure 5).*

At moderate shade levels (SG 1 and SG 2), the *Panicum* spp. continued to be the best yielders particularly Tanganyika guinea and Common guinea. This was closely followed by MARDI digit. However, Signal grass showed a marked decline in DM yield from SG 1 onwards. Transvala digit performed poorly under shade and was ranked 11th at SG 2 and SG 3. MARDI digit yielded poorly at SG 3 while the indigenous grasses continued to be poor in DM production. Nevertheless, the indigenous grass persisted well at SG 3, especially Carpet grass but not 'Rumput pahit'.

In the field trial, the annual DM yields of the six grasses at 6- and 10-weekly cutting intervals in four shade levels are shown in *Figure 6.* Cumulative DM yield was highest at 6-weekly cut compared to 10-weekly cuts for Carpet grass, Green panic, Tee grass and Kazungula setaria. In contrast, Signal grass and Common guinea maintained a higher DM production under the 10-weekly cut.

Across all the shade levels, Signal grass was the highest yielder at both cutting frequencies with 16.1 t/ha/yr at 6-weekly cuts and 19.3 t/ha/yr at 10-weekly cuts. Common guinea produced an average yield of 15.1 t/ha/yr at 6-weekly cuts and 17.6 t/ha/yr at 10-weekly cuts. Kazungula setaria yielded about 9 t/ha/yr for both cutting intervals while Green panic produced about 6 t/ha/yr and was sensitive to 6-weekly cuts under heavy shade (SF 3).

The two indigenous grasses, Carpet grass and Tee grass, were the lowest yielders of dry matter. Carpet grass performed poorly at SF 0 but its DM yield increased to 7.9 t/ha/yr at SF 1 and 7.4 t/ha/yr at SF 2. Tee grass behaved in similar way under shade but was less persistent and less productive.

Plant Survival and Botanical Composition

At the end of the pot trial, all grasses in the three replicates survived at SG 0 and SG 1 but under heavy shade (SG 3), mortality of grasses in all the replicates was evident. Green panic, Common guinea and Carpet grass were the only three grasses which had 100% survival in all replicates at SG 2 and SG 3. Tanganyika guinea had 100% mortality in one replicate at each shade level, SG 2 and SG 3, while Signal grass and 'Rumput pahit' each had 100% mortality in two replicates at SG 3. Congo grass died out completely in all the replicates at SG 2 and SG 3. The *Setaria* spp., *Digitaria* spp. and Tee grass did not survive in all replicates at SG 3, indicating poor tolerance of these grasses to heavy shade.

In the field, the botanical composition (as DW%) of the six grasses were almost 100% pure in the swards at commencement of trial. After 28 months of defoliation, the planted grass composition declined with shade intensity *(Table 6).*

However, at 10-weekly cuts, the botanical composition of the planted grasses was generally higher than that of the 6-weekly cuts. On the other hand, Carpet grass increased tremendously in botanical composition with shade level, indicating its adaptation to lower irradiance. At 6-weekly cuts, Carpet grass composition increased from 26% at SF 0 to almost 100% at SF 3 while at 10-weekly cuts, its composition was enhanced to 96% at SG 2 but declined to 52% at SG 3.

Botanical composition of Signal grass declined from 100% at SF 0 to 50% in the 6-weekly cuts and to 75% in the 10-weekly

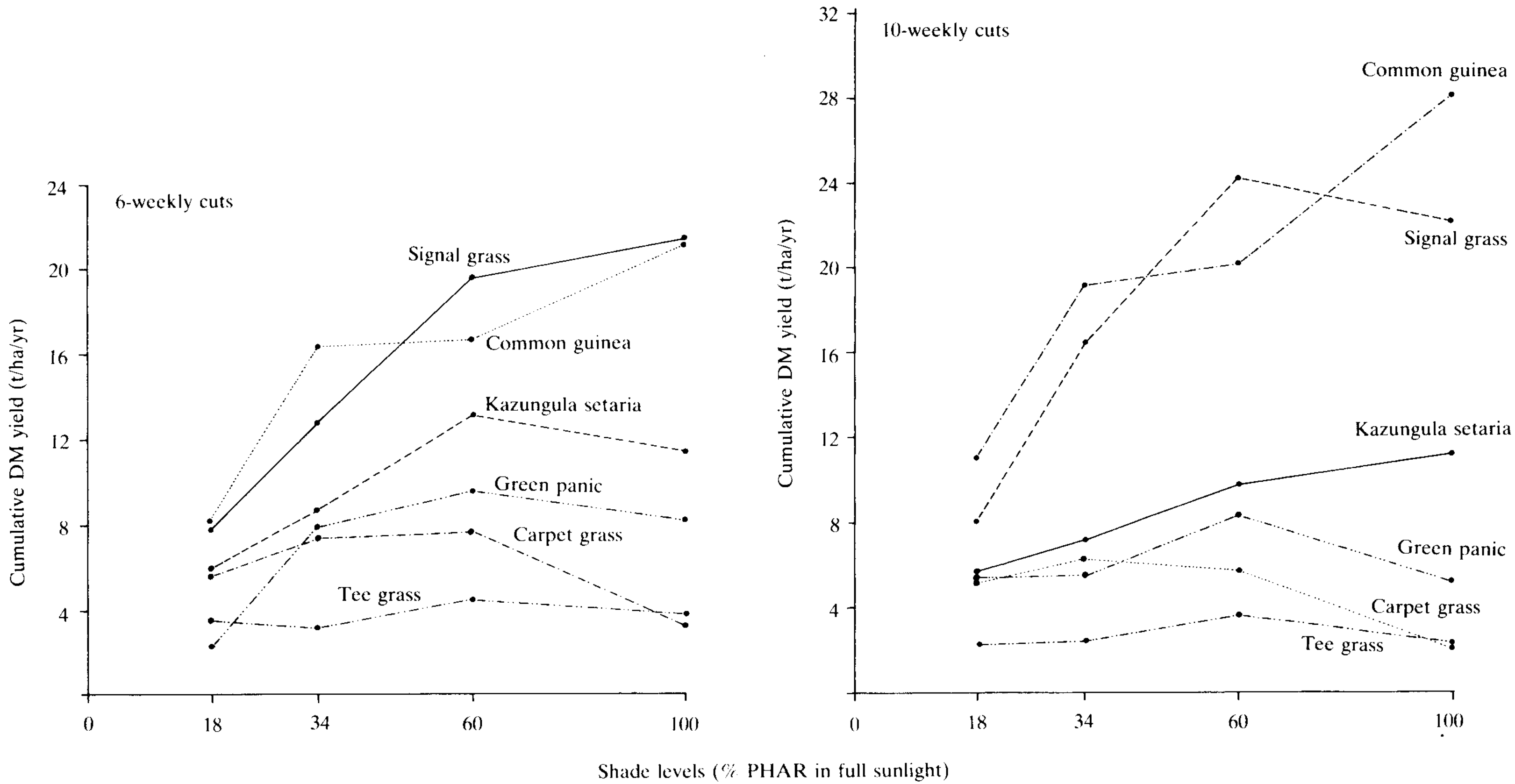

Figure 6. Mean annual dry matter production of 6 tropical grasses grown under 4 shade intensities and defoliated at 6- and 10-weekly intervals.

cuts at SG 3. Common guinea and Kazungula setaria also showed similar declines with shade intensity. Green panic, not being persistent at 6-weekly cuts, died out under heavy shade (SG 3). Tee grass was generally poor in botanical composition at all shade levels and at both cutting intervals, reflecting its instability in such environmental and management conditions.

Generally, the weed component increased with shading. The weed species were mainly *Nephrolepis biserrata, Lygodium flexuosum, Imperata cylindrica, Phymatodes scolopendria, Mikania cordata, Melastoma malabathricum* and *Lantana camara.*

Overall Assessment of Shade Tolerance

There was great similarity in the responses to shade of the grasses in the pot trial and in the field. Most of the agronomic attributes responded in a similar pattern to shading. Correlation coefficients between the DM yield, tillering and root dry weight of the pot trial with those of the field experiment were 0.92, 0.97 and 0.85 respectively (significant at P = 0.01). Hence, the overall assessment of shade tolerance in the grasses was based on the pot trial results.

The overall comparison of the grass performance under various shade levels was by rank comparison and mean rank. If all the grasses were ranked (1 = best to 12 = worst, with respect to each of the desirable attributes), the grasses were thus selected to ascertain the best compromising attributes for tolerance to different shade intensities. The best grasses are those that have the lowest mean rank.

The shade tolerance of the grasses ranked from the nine agronomic attributes at four shade levels is illustrated in *Appendix 1*. Of the 12 grasses studied, the *Panicum* spp. emerged the best at all four shade levels *(Table 8)*. At SG 0 (control), Signal grass ranked first followed by Common guinea and MARDI digit. Tanganyika guinea and Tee grass were ranked fourth and fifth respectively. Carpet grass and Green panic were the lowest of all the grasses in shade tolerance at SG 0.

At moderate shade (SG 1), both Tanganyika guinea and Common guinea became the top two in shade tolerance while MARDI digit was ranked third, followed by Green panic and Signal grass. Poorest performance was from Congo grass and Tee grass, but Carpet grass improved to rank number nine.

At SG 2, Common guinea and Tanganyika guinea continued to rank at the top in shade tolerance with 'Rumput pahit' and Green panic being ranked third. Congo grass, Transvala digit and Tee grass were the lowest in shade tolerance rating at SG 2.

Under heavy shade (SG 3), the *Panicum* spp. again ranked top with Carpet grass following after. Signal grass and Tee grass were ranked fifth and seventh respectively. The lowest were from Congo grass, Transvala digit and Kazungula setaria.

Nitrogen Content

The percentage of nitrogen in the dried forages of the six tropical grasses increased significantly ($P<0.01$) with increasing shade intensity. The grasses were also significantly different ($P<0.01$) from each other in N content *(Table 6)*. Kazungula setaria and Carpet grass had significantly higher ($P<0.01$) nitrogen content than the other grasses. Green panic had the lowest nitrogen content.

There were also significant differences ($P<0.01$) in defoliation intervals on nitrogen content as well as defoliation x grass interaction *(Table 6)*. The 6-weekly cuts gave higher nitrogen content in dry matter than the 10-weekly cuts.

DISCUSSION

From data on all the agronomic attributes measured in the 12 grasses for shade tolerance, many of the grasses behave like sun plants. All seemed to make the best

Table 8. Ranking of 12 tropical grasses grown under 4 shade levels under greenhouse environment for overall shade tolerance based on the mean rank score of 9 agronomic attributes

Ranking	Shade levels (% PHAR in greenhouse)			
	SG 0 (100)	SG 1 (56)	SG 2 (34)	SG 3 (18)
1	Signal grass	Tanganyika guinea	Common guinea	Tanganyika guinea
2	Common guinea	Common guinea	Tanganyika guinea	Green panic
3	MARDI digit	MARDI digit	Green panic	Common guinea
4	Tanganyika guinea	Green panic	'Rumput pahit'	Carpet grass
5	Tee grass	Signal grass	MARDI digit	Signal grass
6	'Rumput pahit'	Splendida setaria	Signal grass	'Rumput pahit'
7	Splendida setaria	Kazungula setaria	Carpet grass	Tee grass
8	Transvala digit	'Rumput pahit'	Kazungula setaria	MARDI digit
9	Congo grass	Carpet grass	Splendida setaria	Splendida setaria
10	Kazungula setaria	Transvala digit	Tee grass	Kazungula setaria
11	Carpet grass	Tee grass	Transvala digit	Transvala digit
12	Green panic	Congo grass	Congo grass	Congo grass

growth at or close to full sunlight except for Kazungula setaria, MARDI digit and Green panic with projected optimum DM production around 50% full sunlight. The mean yield reductions across the grasses were 28.7%, 63.3% and 82.4% of that of the control (SG 0) for a 44%, 66% and 82% PHAR reduction in the greenhouse respectively.

Tillering capacity and leaf, stem and root growths were greatly depressed by shade intensity in both experiments. In the field experiment, a similar PHAR percentage reduction at higher irradiance also resulted in DM yield reduction but the degree of reduction was not commensurate with the intensity of PHAR reduction especially at the higher light level (from SF 0 to SF 1). By contrast, two grasses, namely Carpet grass and Green panic, produced maximal yields under partial shade (SF 1 and SF 2). It appeared that there were constraints that militated against productivity and the realization of maximal yield potential in full sunlight.

The current fertilizer rate of 150 kg N/ha/yr could be inadequate to support maximum yield potential as a rate of 365 kg N/ha/yr has been quoted as insufficient to enable tropical grasses to fully exploit the incoming radiation in the full sunlight (ERIKSEN and WHITNEY, 1981).

Water stress could limit the general growth of the grasses in full sunlight, as partially shaded plants were under less water stress *(Table 5)*. The leaf water potential of the six grasses under shade were generally higher than those in full sunlight (control). Soil moisture under shade was higher, possibly due to lower evapotranspiration brought about by reduced solar radiation on the shaded plants. Hence, maximal yields were achieved under partial shade in a low nutrient input system.

Of the 12 grasses evaluated, the *Panicum* spp. and Signal grass ranked top in DM production at the various shade intensities in both experiments. The 10-weekly cuts of the field trial produced a higher (42%) overall DM production than the 6-weekly cuts at SF 3. Nonetheless, Signal grass outyielded the other grasses at SG 0 in the pot trial and at full sunlight in the field. Average DM yields of 21 and 24 t/ha/yr at 6- and 10-weekly cuts were obtained respectively. Such yields were comparable to those recorded in earlier cutting experiments at Serdang (WONG, 1980).

Even at moderate shade (SF 1), the yield of Signal grass was still high (20–24 t/ha/yr). At SF 2, 13–16 t/ha/yr were obtained. Despite the yield decline with shade intensity, Signal grass continued to show its superiority in DM yield over the other grasses except for the *Panicum* spp. even at SF 3. However, under heavy shade (SF 3), its growth, vigour and persistence were reduced as indicated by the low tillering capacity, marked leaf area decline, low root DW and finally poor botanical composition in the swards especially under the 6-weekly cutting management. Poor performance of Signal grass under heavy shade had also been reported in Solomon Islands (SMITH and WHITEMAN, 1983) and at Serdang (CHEN and BONG, 1984). Its sensitivity to heavy shade and at short cutting frequency could thus only favour its use in moderate shade and under lax cutting or grazing.

Common guinea, like Signal grass, maintained high DM yield across all shade levels, with 21–28 t/ha/yr for both 6- and 10-weekly cuts respectively at SF 0, 17–20 t/ha/yr at SF 1 and SF 2, 8–10 t/ha/yr at SF 3. The prolonged cutting (10-week) interval enhanced DM yield, tillering and botanical composition in swards at SF 3.

Green panic performed poorly in the field experiment despite its better growth under shade. Its average yield was about one-third that of Signal grass or Common guinea. It was rather sensitive to 6-weekly cuts under heavy shade. Its poor performance could be attributed to its poor adaptation to the humid tropics.

Tanganyika guinea in many respects was similar to Common guinea in shade responses except its ranking was better than Common guinea under heavy shade. CHEN and BONG (1984) reported best growth of Tanganyika guinea at 4-monthly cutting interval under a closed oil palm canopy. The potential of this grass under shade deserves further attention.

The genus, *Panicum* has been known to have species adapted to shaded habitats (BROWN, 1977). Good growth from *Panicum* spp. under light shade had been reported (SANTHIRASEGARAM, FERDINANDEZ and GOONASEKERA, 1969). In this study, even at SF 3, the DM yield was about one-third that of the control and two to three times more than those of the indigenous grasses, indicating that the *Panicum* spp. were still by far the higher yielding and better adapted grasses under shade. This could be attributed to the erect habit of the grass as well as the morphological adaptive changes in their shoot/root ratio and larger leaf area under shade (LUDLOW, WILSON and HESLEHURST, 1974). Furthermore, WONG and WILSON (1980) indicated that the stature of a *Panicum* sp. under shade was taller and leaf area well-distributed throughout the canopy, resulting in low light extinction coefficients. All these could thus contribute to its better performance than the other grasses under heavy shade. Its ability to persist under grazing in plantation had been proven (SUKRI, ROSMAWATI and MUSADDIN 1982). The more prostrate grasses such as Carpet grass and Tee grass, were the lowest yielders at all shade levels but they were ranked fourth and seventh respectively, at SG 3. They generally preferred shorter cutting intervals (6-weekly cuts). However, under partial shade, Tee grass in the field experiment was not as aggressive in growth as Carpet grass. Although both species were highlighted as persistent grasses under heavy shade (<15% sunlight) by CHEN and BONG (1984), DM production of Tee grass was generally 40% lower than that of Carpet grass in the field trial. No Tee grass plants survived at SG 3 in all three replicates in the greenhouse. Even in the field, its botanical composition was low (<10%) whereas, in the case of Carpet grass, growth improved with shade. Higher botanical composition in a sward was obtained at 6-weekly cuts and under moderate to heavy shade.

In Solomon Islands, Carpet grass was also found to be the most common grass under coconut (SMITH and WHITEMAN, 1983). It was not surprising that at SF 3, its

DM yield was at least 30% of that of the control and thus was a favoured grass for intense shade. Its tillering was the highest among the grasses assessed. Due to its shallow rooting system, Carpet grass is thus prone to environmental stress and hence it performed better under partial shade.

'Rumput pahit' was also noted for its luxuriant growth under moderate shade but did not persist well in SG 3, where only one replicate survived. Its rapid decline in leaf area with shading and low root DW probably contributed to its poor shade tolerance. It was ranked sixth at SG 3.

With the exception of the poor performance of Kazungula setaria at SG 0, the *Setaria* spp. in the pot trial were generally average in their responses of DM yield, tillering, specific leaf area and leaf area to moderate shade. Under SG 3, they were among the least shade-tolerant grasses *(Table 5)*.

The *Digitaria* spp. generally grew well at SG 0 but Transvala digit was sensitive to shading, resulting in poor ranking at SG 2 and SG 3 *(Table 8)*. By contrast, MARDI digit remained good in growth up to SG 2, but produced poorly in DM yield and tillering at SG 3. Similar responses were also reported in Mealani digit in Hawaii where yield was markedly depressed under heavy shade (27% sunlight) (ERIKSEN and WHITNEY, 1981). The forage potential for MARDI digit would be for utilization under moderate shade only.

The nitrogen contents in the grasses were above the critical level (7% crude protein) below which DM intake of the grasses would be affected (MILFORD and MINSON, 1966). In fact, nitrogen content increased with shade intensity, with 6-weekly cuts giving a higher percentage than the 10-weekly cuts in all the six grasses assessed *(Table 6)*.

Tropical grasses are generally known for their low crude protein content and the shaded grasses with enhanced nitrogen contents, ranging from 1.46% to 2.44%, were considerably higher than those reported by WONG (1980) for grasses fertilized at 400 kg N/ha/yr at Serdang. The enhanced nitrogen content of the shaded grasses could be an advantage in otherwise low-nitrogen tropical grasses receiving little nitrogen fertilization. Increased nitrogen content in the tropical grasses under shading had also been recorded elsewhere (ERIKSEN and WHITNEY, 1981; SMITH and WHITEMAN, 1983). Nevertheless, the nutritive value of the grasses needs to be studied as forage quality could be reduced by shade (WILSON and WONG, 1982).

Agronomic Implications

The results indicate that improved grasses, particularly *Panicum* spp. and Signal grass, have maximum potential in forage production during the juvenile stages of plantation crops and could be further extended for utilization in plantations until the light levels (about 30%) become a major limiting factor to their DM production. Below this light level, indigenous grasses such as Carpet grass could take over through weed invasion until total solar radiation is cut off by the closed canopy.

Although these trials were carried out under artificial shade without competitive effects of the established plantation crops, the findings on the spectrum of shade tolerance in the grasses could be adopted for further verification in plantations. Nevertheless, the grasses identified had been shown in field trial elsewhere to be suitable for integration with plantation crops (SUKRI *et al.*, 1982).

Since the DM yield declined with shading, the carrying capacity of the grasses under shade would also decrease. Based on the DM production of the grasses under various shade levels, and the estimated DM intake of 9 kg DM per cattle per day, the projected stocking rate of the promising grasses would be about 4 heads/ha at 60% 3 heads/ha at 34% and 2 heads/ha at 19% light. However, the loss of ground space by the standing tree crops should be taken into consideration in the extrapolation of the possible carrying capacity of the shaded pasture.

In view of the declining DM yield with shade and the sensitivity of improved grasses to defoliation under shade, careful management of the grasses is necessary to ensure the continual DM productivity and persistence of the grasses. Limited grazing at low stocking rates or lenient cutting would be recommended to ensure that consumption by the cattle per unit area does not exceed DM productivity under the varying shade levels. Under such circumstances, varying the stocking rate according to the shade intensity would be the best approach to promote efficient utilization of the available pastures in the plantation as well as to avoid damage to the main crops, especially during the juvenile stage, as often, feed shortage is the main cause of such destruction.

Finally, the need to look at other shade-tolerant species (ferns) at low light levels (<10% sunlight) besides grasses and legumes as possible feeds for livestock deserves immediate attention.

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ABSTRACT

Shade tolerance of 12 tropical grasses was evaluated under artificial shade in greenhouse conditions with transmission of 64%, 30%, 18% and 9% photosynthetic quantum flux (PHAR) of the full sunlight followed by a field experiment to assess the performance of six selected grasses under light transmission of 100% (control), 60%, 34% and 18% of PHAR of the full sunlight and defoliated at 6- and 10-weekly cutting intervals.

In the greenhouse trial, shading significantly (P<0.01) reduced tiller production, cumulative dry matter yields of shoot, leaf, stem, stubble and root, but enhanced specific leaf area. Increased partitioning of dry matter to the leaf component at the expense of root under shade resulted in higher shoot/root and leaf/stem ratios. Mean dry matter yield reduction across the grasses were 28.7%, 63.3% and 82.4% of that of the control for a 44%, 66% and 82% reduction in PHAR in the greenhouse trial. The best shade-tolerant grasses were *Panicum maximum, P. maximum* cv. Tanganyika, *Digitaria setivalva* and *Brachiaria decumbens*. The least shade-tolerant species were *Setaria sphacelata* cv. Kazungula, *Digitaria decumbens* cv. Transvala and *B. ruziziensis*. However, at dense shade (9% PHAR transmission), the indigenous grasses, *Paspalum conjugatum* and *Axonopus compressus* were ranked seventh and fourth respectively.

In the field experiment, *P. maximum* and *B. decumbens* were the best yielders across all shade levels. Mean dry matter (DM) yield reduction of the six grasses were 23.1% and 37.6% of the control for a 66% and 82% PHAR reduction in full sunlight. *Axonopus compressus* and *P. maximum* var. *trichoglume* produced higher DM at moderate shade under both defoliation intervals. The 10-weekly cut gave higher DM yield and tiller production under shade in the erect grasses, while the 6-weekly cut resulted in higher yield for the prostrate grasses, *viz. A. compressus* and *P. conjugatum*.

Prolonged cutting intervals were preferred under heavy shade to enhance survival and botanical composition of the sown grasses. The nitrogen content of the grasses generally increased with shading and under shorter cutting interval. Low-yielding grasses, namely *S. sphacelata* cv. Kazungula and *A. compressus*, had higher nitrogen contents while *P. maximum* var. *trichoglume* had the lowest.

The significance of the findings was discussed in relation to pasture management under plantations.

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Appendix 1. The overall mean and agronomic attribute ranking for the 12 tropical grasses grown under 4 shade levels in a greenhouse

Shade level	SLA	Leaf area	Dry matter			Shoot/root ratio	Leaf/stem ratio	Tillering	DM yield	Mean rank
			Root	Leaf	Stem					
SG 0 (100% PHAR)										
Carpet grass	3	10	8	12	12	9	7	1	12	8.22
Signal grass	7	3	5	2	2	4	9	7	1	4.44
Congo grass	4	5	7	6	8	12	4	10	9	7.22
MARDI digit	12	8	4	1	7	7	2	3	3	5.22
Transvala digit	10	12	10	10	1	1	12	2	3	6.78
'Rumput pahit'	2	2	11	9	3	2	10	5	8	6.67
Green panic	9	11	9	8	10	5	6	11	6	8.33
Common guinea	8	1	6	4	5	6	3	8	2	4.78
Tanganyika guinea	11	7	3	3	9	8	1	6	5	5.89
Tee grass	1	4	12	11	4	3	10	4	10	6.55
Kazungula setaria	5	9	2	7	11	11	5	9	11	7.78
Splendida setaria	6	6	1	5	6	10	8	12	7	6.78
SG 1 (56% PHAR)										
Carpet grass	4	11	8	8	12	5	4	1	11	7.11
Signal grass	6	5	10	6	4	2	8	9	6	6.22
Congo grass	5	10	9	8	8	12	6	12	9	8.78
MARDI digit	12	6	5	1	9	7	1	2	4	5.22
Transvala digit	9	12	7	11	2	4	12	2	8	7.44
'Rumput pahit'	1	2	12	10	10	1	9	4	10	6.56
Green panic	8	8	6	4	1	6	11	8	2	6.00
Common guinea	10	1	4	3	5	8	3	5	3	4.67
Tanganyika guinea	11	3	2	2	6	9	1	6	1	4.55
Tee grass	2	9	11	12	11	3	10	7	12	8.56
Kazungula setaria	7	7	3	5	3	10	7	10	5	6.33
Splendida setaria	3	4	1	7	7	11	5	11	7	6.22

SLA = Specific Leaf Area.
Ranking: 1 = Best and 12 = Worst.

Shade level	SLA	Leaf area	Dry matter			Shoot/root ratio	Leaf/stem ratio	Tillering	DM yield	Mean rank
			Root	Leaf	Stem					
SG 2 (34% PHAR)										
Carpet grass	2	7	5	8	11	10	4	1	9	6.33
Signal grass	3	5	11	5	3	1	9	8	5	5.56
Congo grass	12	12	12	12	12	12	12	12	12	12.00
MARDI digit	10	2	3	2	9	8	1	2	4	4.56
Transvala digit	6	11	8	11	10	5	11	3	11	8.44
'Rumput pahit'	1	3	9	6	4	2	8	4	6	4.78
Green panic	7	4	1	4	1	11	6	6	3	4.78
Common guinea	9	1	2	1	2	9	3	5	2	3.78
Tanganyika guinea	11	6	4	3	5	3	2	10	1	5.00
Tee grass	4	10	10	10	6	4	10	7	9	7.78
Kazungula setaria	8	8	7	7	8	6	5	9	7	7.22
Splendida setaria	5	9	6	9	7	7	7	11	8	7.67
SG 3 (18% PHAR)										
Carpet grass	8	6	9	4	4	3	7	1	6	5.33
Signal grass	1	9	6	8	8	2	9	8	4	6.11
Congo grass	11	11	6	11	5	12	11	12	12	10.11
MARDI digit	2	8	6	9	2	8	10	7	10	6.88
Transvala digit	12	12	10	12	1	6	12	11	11	9.67
'Rumput pahit'	5	5	11	6	10	1	5	6	7	6.22
Green panic	6	2	5	3	6	4	3	2	3	3.78
Common guinea	9	1	1	2	7	8	1	3	2	3.88
Tanganyika guinea	10	3	2	1	3	7	2	5	1	3.78
Tee grass	4	4	12	5	11	11	4	4	4	6.55
Kazungula setaria	7	10	3	10	12	5	8	9	9	8.11
Splendida setaria	3	7	3	7	9	10	6	10	8	7.00

SLA = Specific Leaf Area.
Ranking: 1 = Best and 12 = Worst.