

Screening Forage Species for Shade Tolerance — A Preliminary Report

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Abstract

A total of 130 grass and legume accessions, many originally collected in shaded habitats, were grown in small plots at the University of Queensland research farm at Redland Bay. Light transmission levels of 100, 70, 50, 35 and 20% were imposed and plots were harvested every 6 weeks to study the yield potential and shade tolerance of the species.

A number of grass and legume accessions were identified which exhibited shade tolerance. Many of these accessions have not previously been used and need to be tested under plantation crops.

Variability in shade tolerance exists between species of the same genus and between accessions of the same species.

THE term shade tolerance is used extensively in discussions on forages for plantation crops. It is normally used to describe those species which grow relatively better than other species in shaded habitats, such as plantations. A common characteristic is that they are better able to maintain their yield with decreasing light than less shade-tolerant species.

Forage species which are successful in plantation crops must be adapted not only to the lower light level but also to the climate (rainfall, temperature, daylength variation), soil (pH, fertility, texture, drainage) and to the management imposed (cutting or grazing regime, fertilizer inputs). Shade tolerance is therefore confounded with these other factors and this may make the interpretation of field results of shading experiments more difficult.

The significance of shade tolerance to the persistence and yield of species under plantation crops varies with shading level. In open pastures, Ludlow (1978) concluded that shade tolerance plays only a minor role in the competition for light between pasture plants, while the ability to gain access to the available light is of prime importance. On the other hand, the significance of shade tolerance increases at lower light levels.

Competition for light between companion forages is primarily determined by plant height as this determines the position of the species in relation to its competitors (Ludlow, 1978). Hence, elongation of stem at low light is a commonly observed response of

non-shade-tolerant species. While this response is advantageous in high light environments, it can be very costly to plants competing in low light environments. There, efficient light capture and use are of utmost importance, particularly under repeated defoliation regimes. There are many instances where forages have yielded well initially in low light but failed to persist under regular cutting or grazing (e.g. Wong et al. 1985, Watson and Whiteman 1981). True shade tolerance in forage species is associated with a number of morphological and physiological adaptations of plants. These include higher leaf area ratios and specific leaf areas, and higher chlorophyll densities which in turn influence the efficiency of interception and use of radiation and therefore growth potential at low levels of radiation.

The purpose of this study was to identify shade tolerance in a wide range of accessions of grasses and legumes which were being concurrently evaluated in adaptation studies under coconuts and rubber in Indonesia and Malaysia respectively (Rika et al.; Kaligis and Sumolang; Ng, these Proceedings).

Materials and Methods

A total of 130 grass and legume accessions were included in the experiment. Most of these were obtained from R.J. Williams, Australian Tropical Forages Genetic Resource Centre, CSIRO. Wherever possible, accessions selected were those which had been collected originally from shaded habitats or had demonstrated a degree of shade tolerance.

The accessions were grown in small plots (0.5 x 0.5 m), each containing nine plants, at the

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University of Queensland research station at Redland Bay. There were five light levels (100, 70, 50, 35 and 20%), which were achieved with shade cloth, and two replicates.

Accessions were germinated, inoculated where appropriate, and grown in small pots in a glasshouse. Vegetative material was multiplied at the same time. Seedlings (or young plants) were transplanted into the field at Redland Bay in early December 1988 and plots were then harvested every six weeks for three growth cycles. Fertilizer was applied at a rate of 65 kg/ha P and 50 kg/ha K before planting. Nitrogen was applied to the grasses only at a rate of 20 kg/ha per growth cycle. The experimental area was irrigated whenever necessary to avoid water deficits. Cutting height varied according to the growth habit of each species. Top dry weight of whole plots was measured at each harvest.

The experiment continued into the second year but, at the time of the workshop, data were available for the first year only. For analysis, data were averaged across all harvests.

Results and Discussion

In this paper, the results are expressed in two ways. Firstly, species were ranked in order of their yield at a particular light level and, secondly, their yield at a particular light level was expressed as percentage of their yield at high light; this was called relative yield. The combination of yield at a particular light level and relative yield was considered to be a measure of shade tolerance. High light was defined as the mean of the yield of the 100 and 70% light transmission treatments. The average of these two treatments was chosen to increase the precision of the relative yield calculation.

The yield and the relative yield of the 30 highest-yielding accessions is presented for the 50% and 20% light transmission treatments (Tables 1 and 2). The 50% treatment approximates the light level experienced in coconut plantations, while the 20% light transmission treatment is similar to the light level in mature rubber plantations. The tables also show the relative yield ranking of each species relative to all 46 grasses and 84 legumes in the experiment, not just those species presented in the tables.

At 50% light transmission, many of the commercially used tropical pasture grasses such as the *Panicum maximum* cultivars had the highest dry matter yields (Table 1). These were tall, upright species which would be expected to have high yields in full sun. The highest-yielding species of the lower growing grasses was *Paspalum wettsteinii*. Grasses with an above average yield (>166 g) and an above-average relative yield (>68%) were *Paspalum malacophyllum*, *Urochloa stolonifera*, *Paspalum wettsteinii*, *Digitaria natalensis* and *Paspalum*

conjugatum. With the exception of *Paspalum conjugatum*, these species have not been widely used under coconuts. While the importance of relative yield is equivocal, the species with the highest relative yields (i.e. *Axonopus compressus* and *Paspalum conjugatum*) are known to be shade-tolerant pasture grasses and successful in coconut plantations (Shelton et al. 1987, Reynolds 1988).

As with the grasses, at 50% light transmission the highest-yielding legumes tended to be the more upright species such as *Aeschynomene americana*, *Desmodium intortum* and *Mucuna* sp. (Table 1). All of the 30 legume species listed in Table 1 had a higher than average yield, (>47 g) and many also had a higher than average relative yield (>60%). The five highest-yielding species were *Aeschynomene americana* cv. Glenn, *Desmodium intortum* cv. Greenleaf, *Vigna luteola* cv. Dalrymple, *Stylosanthes humilis* cv. Gordon and *Stylosanthes humilis* (commercial). *Stylosanthes guianensis* cultivars have been regarded as having a low shade tolerance (Shelton et al. 1987) but it appears that variation in shade tolerance exists between species of the same genus. Other legumes with a relative yield of more than 80% included *Rynchosia minima*, *Centrosema macrocarpum* and *Desmodium heterophyllum* cv. Johnstone. Of these species, *Desmodium heterophyllum* is known to be a shade-tolerant species (Shelton et al. 1987).

The yield ranking of grasses at 20% light transmission was similar to the yield ranking at 50% light transmission. *The Panicum maximum* cultivars remained the highest-yielding grasses at this low light level (Table 2). Species which improved their yield ranking substantially were *Brachiaria humidicola* cv. Tully, *Dichanthium aristatum* cv. Angleton, *Axonopus compressus*, *Digitaria pentzii* CPI 59772 and *Acroceras macrum*. Of the grasses with an above-average yield only *Brachiaria humidicola* cv. Tully, *Paspalum malacophyllum*, *Digitaria milaniana* CPI 41192 and *Axonopus compressus* had a higher than average relative yield. Grasses which had a substantially lower relative yield at 20% than at 50% light transmission were *Setaria sphacelata* cv. Kazungula, *Setaria sphacelata* cv. Splenda and *Urochloa stolonifera*.

The yield ranking of legumes changed to a greater extent than that of the grasses as light transmission was reduced from 50 to 20% (Table 2). Legumes which had a much lower yield ranking at 20 than at 50% light transmission included *Aeschynomene americana* cv. Glenn, *Aeschynomene americana* CPI 56283, *Stylosanthes humilis* cv. Gordon and *Stylosanthes humilis* (commercial) indicating low tolerance of heavy shade. Conversely, accessions which improved their yield ranking by 20 ranks or more were *Arachis pintoii* cv. Amarillo, *Desmodium heterophyllum* CPI 52420, *Desmodium gangeticum*, *Centrosema pascuorum*, *Neonotonia wightii* cv. Tinaroo, *Teramnus labialis* cv.

Table 1. Dry matter yield of forages grown at 50% light (g/plot) and their yield at 50% light relative to their mean yield at 100 and 70% light (%) — the 30 highest yielding accessions.

Species	Dry matter yield at 50% light		Yield at 50% light relative to mean yield at 100 and 70% light	
	(g/plot)	Rank	(%)	Rank
Grasses				
<i>Panicum maximum</i> cv. Rumuruti	498	(1)	53	(37)
<i>Panicum maximum</i> cv. Riversdale	461	(2)	65	(19)
<i>Panicum maximum</i> cv. Petrie	454	(3)	66	(17)
<i>Panicum maximum</i> cv. Gatton	430	(4)	57	(33)
<i>Urochloa mosambicensis</i> CPI 60148	340	(5)	62	(23)
<i>Setaria sphacelata</i> cv. Kazungula	325	(6)	68	(15)
<i>Panicum maximum</i> cv. Embu	298	(7)	62	(23)
<i>Setaria sphacelata</i> cv. Splenda	283	(8)	59	(29)
<i>Brachiaria decumbens</i> cv. Basilisk	244	(9)	55	(34)
<i>Paspalum malacophyllum</i> CPI 27690	218	(10)	97	(6)
<i>Digitaria milanjana</i> CPI 59721	211	(11)	61	(25)
<i>Urochloa stolonijera</i> CPI 47173	197	(12)	69	(14)
<i>Paspalum wettsteinii</i> (commercial)	189	(13)	94	(8)
<i>Digitaria endlichii</i> CPI 59768	188	(14)	45	(42)
<i>Digitaria natalensis</i> CPI 59689	183	(15)	86	(10)
<i>Brachiaria brizantha</i> CPI 15890	181	(16)	58	(31)
<i>Digitaria milanjana</i> CPI 59748	177	(17)	60	(27)
<i>Paspalum conjugatum</i> CPI 60059	166	(18)	126	(2)
<i>Digitaria swynnertonii</i> CPI 59749	159	(19)	66	(17)
<i>Paspalum scrobiculatum</i> cv. Paltridge	156	(20)	74	(12)
<i>Digitaria milanjana</i> CPI 59773	146	(21)	60	(27)
<i>Digitaria milanjana</i> CPI 41192	144	(22)	65	(19)
<i>Paspalum commersonii</i> CPI 15705	142	(23)	65	(19)
<i>Paspalum plicatulum</i> cv. Bryan	141	(24)	54	(36)
<i>Digitaria pentzii</i> CPI 41190	139	(23)	65	(19)
<i>Paspalum dilatatum</i> (commercial)	137	(26)	100	(5)
<i>Brachiaria humidicola</i> cv. Tully	133	(27)	52	(38)
<i>Digitaria milanjana</i> CPI 59775	122	(28)	55	(34)
<i>Axonopus compressus</i> (local) Brisbane	120	(29)	150	(1)
<i>Paspalum notatum</i> cv. Competidor	89	(30)	95	(7)
Mean of 46 grasses	166		68	
Legumes				
<i>Aeschynomene americana</i> cv. Glenn	143	(1)	62	(39)
<i>Aeschynomene americana</i> CPI 56283	125	(2)	45	(70)
<i>Desmodium intortum</i> cv. Greenleaf	102	(3)	63	(36)
<i>Mucuna</i> sp. CPI 11843	96	(4)	58	(49)
<i>Vigna luteola</i> cv. Dalrymple	94	(5)	63	(36)
<i>Aeschynomene americana</i> CPI 70244	92	(6)	53	(58)
<i>Desmodium intortum</i> (Grp J) CPI 46552	89	(7)	55	(50)
<i>Stylosanthes humilis</i> cv. Gordon	80	(8)	82	(6)
<i>Stylosanthes humilis</i> (commercial)	78	(9)	68	(24)
<i>Desmodium intortum</i> (Grp C) CPI 43201	78	(9)	54	(54)
<i>Calopogonium mucunoides</i> CPI 58541	74	(11)	76	(10)
<i>Cassia rotundifolia</i> CPI 10057	72	(12)	68	(24)
<i>Rynchosia minima</i> CPI 87555	70	(13)	84	(5)
<i>Vigna hosei</i> CQ 729	66	(14)	67	(26)
<i>Stylosanthes guianensis</i> cv. Endeavour	65	(15)	54	(54)
<i>Stylosanthes hamata</i> cv. Amiga	63	(16)	45	(70)
<i>Centrosema macrocarpum</i> CPI 92731	63	(16)	91	(3)
<i>Calopogonium mucunoides</i> (commercial)	63	(16)	70	(21)
<i>Vigna lasiocarpa</i> (Grp A) CPI 34436	62	(19)	60	(43)

Table 1. (Continued)

Species	Dry matter yield at 50% light		Yield at 50% light relative to mean yield at 100 and 70% light	
	(g/plot)	Rank	(%)	Rank
<i>Macroptilium atropurpureum</i> cv. Siratro	62	(19)	61	(41)
<i>Stylosanthes hamata</i> cv. Verano	60	(21)	47	(65)
<i>Desmodium scorpiurus</i> CPI 108338	60	(21)	74	(12)
<i>Cassia rotundifolia</i> CPI 85836	60	(21)	48	(62)
<i>Desmodium aparine</i> CPI 33814	57	(24)	55	(50)
<i>Clitoria ternatea</i> CPI 52395	57	(24)	51	(60)
<i>Stylosanthes guianensis</i> cv. Graham	56	(26)	52	(59)
<i>Centrosema plumieri</i> CPI 58568	55	(27)	65	(32)
<i>Neonotonia wightii</i> cv. Malawi	54	(28)	63	(36)
<i>Macroptilium atropurpureum</i> CPI 94058	54	(28)	64	(34)
<i>Desmodium heterophyllum</i> cv. Johnstone	54	(28)	82	(6)
<i>Centrosema pubescens</i> (common)	54	(28)	73	(14)
Mean of 84 legumes	47		60	

Table 2. Dry matter yield of forages grown at 20% light (g/plot) and the yield at that light level relative to the mean yield at 100 and 70% light (%) — the 30 highest yielding accessions.

Species	Dry matter yield at 20% light		Yield at 20% light relative to mean yield at 100 and 70% light	
	(g/plot)	Rank	(%)	Rank
Grasses				
<i>Panicum maximum</i> cv. Petrie	128	(1)	19	(19)
<i>Panicum maximum</i> cv. Rumuruti	127	(2)	14	(35)
<i>Panicum maximum</i> cv. Gaton	126	(3)	17	(25)
<i>Panicum maximum</i> cv. Riversdale	125	(4)	18	(21)
<i>Panicum maximum</i> cv. Embu	98	(5)	20	(17)
<i>Urochloa mosambicensis</i> CPI 60148	85	(6)	16	(29)
<i>Setaria sphacelata</i> cv. Kazungula	77	(7)	16	(29)
<i>Brachiaria humidicola</i> cv. Tully	76	(8)	30	(7)
<i>Setaria sphacelata</i> cv. Splenda	62	(9)	13	(38)
<i>Paspalum malacophyllum</i> CPI 27690	59	(10)	26	(10)
<i>Brachiaria decumhens</i> cv. Basilisk	59	(10)	13	(38)
<i>Digitaria endlichii</i> CPI 59768	57	(12)	13	(38)
<i>Digitaria milanjana</i> CPI 41192	56	(13)	25	(11)
<i>Dichanthium arisratum</i> cv. Angleton	50	(14)	21	(15)
<i>Axonopus compressus</i> (local) Brisbane	50	(14)	62	(1)
<i>Urochloa stolonifera</i> CPI 47173	49	(16)	17	(25)
<i>Digitaria milanjana</i> CPI 59773	45	(17)	18	(21)
<i>Paspalum wettsteinii</i> (commercial)	44	(18)	22	(13)
<i>Paspalum conjugatum</i> CPI 60059	44	(18)	34	(5)
<i>Digitaria milanjana</i> CPI 59748	44	(18)	15	(32)
<i>Digitaria milanjana</i> CPI 59721	41	(21)	12	(41)
<i>Paspalum plicatulum</i> cv. Bryan	38	(22)	15	(32)
<i>Paspalum dilatatum</i> (commercial)	38	(22)	27	(8)
<i>Digitaria pentzii</i> CPI 59772	38	(22)	19	(19)
<i>Digitaria milanjana</i> CPI 59775	38	(22)	17	(25)
<i>Acroceras macrum</i> CPI 62 122	38	(22)	34	(5)
<i>Brachiaria hrizantha</i> CPI 15890	37	(27)	12	(41)
<i>Digitaria swynnertonii</i> CPI 59749	36	(28)	15	(32)
<i>Digitaria pentzii</i> CPI 41190	35	(29)	17	(25)
<i>Paspalum scrobiculatum</i> cv. Paltridge	33	(30)	16	(29)
Mean of 46 grasses	47		21	

Species	Dry matter yield at 20% light		Yield at 20% light relative to mean yield at 100 and 70% light	
	(g/plot)	Rank	(%)	Rank
Legumes				
<i>Desmodium intortum</i> cv. Greenleaf	56	(1)	34	(7)
<i>Mucana</i> sp. CPI 11843	39	(2)	24	(26)
<i>Vigna luteola</i> cv. Dalrymple	38	(3)	26	(21)
<i>Desmodium intortum</i> (Grp J) CPI 46552	36	(4)	22	(38)
<i>Macroptilium atropurpureum</i> cv. Siralro	35	(5)	35	(5)
<i>Aeschynomene americana</i> CPI 70244	29	(6)	17	(57)
<i>Vigna hosei</i> CQ 729	28	(7)	28	(15)
<i>Culopogonium mucunoides</i> (commercial)	28	(7)	31	(10)
<i>Arachis pintoii</i> cv. Amarillo	27	(9)	48	(1)
<i>Desmodium intortum</i> (Grp C) CPI 43201	26	(10)	18	(53)
<i>Desmodium heterophyllum</i> (Grp B) CPI 52420	25	(11)	33	(8)
<i>Centrosema plumieri</i> CPI 58568	25	(11)	30	(13)
<i>Vigna lasiocarpa</i> (Grp A) CPI 34436	24	(13)	23	(32)
<i>Desmodium aparine</i> CPI 33814	24	(13)	23	(32)
<i>Centrosema pubescens</i> (common)	24	(13)	32	(9)
<i>Culopogonium mucunoides</i> CPI 58541	24	(13)	25	(23)
<i>Desmodium heterophyllum</i> cv. Johnstone	21	(17)	31	(10)
<i>Clitoria ternateu</i> CPI 52395	21	(17)	18	(53)
<i>Cassia rotundifolia</i> CPI 85836	21	(17)	17	(57)
<i>Aeschynomene americana</i> cv. Glenn	21	(17)	9	(75)
<i>Desmodium gangeticum</i> CPI 105779	20	(21)	30	(13)
<i>Centrosema pascuorum</i> CPI 40060	20	(21)	18	(53)
<i>Desmodium scorpiurus</i> CPI 108338	19	(23)	23	(32)
<i>Aeschynomene americana</i> CPI 56283	19	(23)	17	(57)
<i>Neonotoniu wightii</i> cv. Malawi	18	(25)	21	(41)
<i>Neonotonio wightii</i> cv. Tinaroo	18	(25)	23	(32)
<i>Centrosema pubescens</i> CPI 97066	18	(25)	24	(26)
<i>Cassia rotundifolia</i> cv. Wynn	IX	(25)	20	(45)
<i>Teramnus lahialis</i> cv. Semilla Clara	17	(29)	27	(18)
<i>Pueraria phaseoloides</i> (commercial)	17	(29)	22	(38)
<i>Macrotyloma axillare</i> cv. Archer (Grp A)	17	(29)	17	(57)
<i>Macroptilium atropurpureum</i> CPI 94058	17	(29)	20	(45)
<i>Desmodium heterocarpon</i> cv. Florida	17	(29)	27	(18)
Mean of 84 legumes	16		22	

Semilla Clara and *Desmodium heterocarpon* cv. Florida. Many of the legumes with an above-average yield also had an above-average relative yield. The ten legumes with the highest relative yields and above-average absolute yields were *Desmodium intortum* cv. Greenleaf, *Macroptilium atropurpureum* cv. Siratro, *Calopogonium mucunoides*, *Arachis pintoii* cv. Amarillo, *Desmodium heterophyllum* CPI 52420, *Centrosema pubescens* (common) and *Desmodium heterophyllum* cv. Johnstone.

Conclusions

The experiment has identified a number of grass and legume accessions which have shown a high yielding capacity at 50 and 20% light transmission, and many

of these also had a high relative yield. These species can be regarded as being shade tolerant. Most of these accessions have not previously been used and need to be tested under plantation crops. Selection of accessions will need to take into account particular environmental conditions and the proposed management of the species.

A large variability was apparent between species of the same genus and there were also differences between accessions of the same species.

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