PRODUCTION OF TROPICAL AND SUBTROPICAL GRASSES AND LEGUMES, WITH AND WITHOUT IRRIGATION, IN CENTRAL WESTERN NEW SOUTH WALES

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ABSTRACT

Fifteen tropical and subtropical grasses and five tropical legumes were grown in pure swards under rainfed or irrigated (two frequencies) conditions on an alkaline brown clay soil at Trangie in western New South Wales. They were cut every six weeks during the growing season, which extended from October to April.

The highest annual dry matter yield under irrigation (16.7 t ha^{-1}) was produced by the vegetatively established Setaria sphacelata *var.* splendida. *It reached a peak growth rate of 200 kg ha^{-1} day^{-1} in late summer.* Panicum coloratum *was the highest yielding (13.8 t ha^{-1}) grass established from seed;* Paspalum dilatatum *produced 13.0 t ha^{-1}.* P. coloratum *was the highest yielding grass under rainfed conditions where it yielded 1.7 t ha^{-1}. Flood irrigation at the pan evaporation interval of 50 mm compared to 100 mm made no difference to forage yields.*

The tropical grasses, including Brachiaria decumbens *and* Paspalum plicatulum, *failed to survive the winter. The legumes recovered poorly after winter and were not recommended for this environment. Narok setaria, kikuyu and* Paspalum nicorae *were quite tolerant of low winter temperatures but lacked vigour in the summer, yielding less than 10 t ha^{-1}.*

INTRODUCTION

A summer feed deficit is regularly experienced by livestock enterprises in central western New South Wales. Although the rainfall is evenly distributed throughout the year, high rates of evaporation (*c.* 10 mm day^{-1}; Table 1) limit its effectiveness for pasture growth in summer. Furthermore, apart from lucerne (*Medicago sativa*) leys, pastures no longer contain species responsive to summer rainfall. Improved pastures are required for both rainfed and irrigated situations. Irrigation, which is now widely available in western New South Wales, should ensure high production from improved pastures. The aim of this study was to find grass and legume species to improve summer forage production.

Mean daily temperatures at Trangie (32°S, 148°E) often approach 30°C in summer. Such temperatures are optimal for tropical and subtropical grasses (Deinum and Dirven 1976). At Deniliquin (35°S), Squires and Myers (1970) found that the subtropical grasses *Paspalum dilatatum* and *Panicum coloratum* produced high dry matter yields in summer; the latter also yielded more than a temperate phalaris hybrid on an annual basis. Dann (1965) similarly found subtropical grasses superior to phalaris (*Phalaris aquatica*) for summer pasture production at Yanco.

High yielding subtropical grasses are of little use, however, if they fail to survive cool winters. For example *Cenchrus ciliaris* (buffel grass) grew well during the first summer in the Riverina but failed to recover in the second (Dann 1965; Squires and Myers 1970); in contrast *P. dilatatum*, *Setaria sphacelata* var. *sericea*, *Chloris gayana* (Rhodes grass), *P. coloratum* and *Pennisetum clandestinum* (kikuyu) survived into the second and third summers. Such a response accords with Ludlow's (1980) ranking on the basis of frost resistance.

Fifteen grasses, principally species tolerant of low temperatures, were selected for evaluation. Species tested by Dann (1965) at Yanco were included along with additional species found by Stickland (1978) to be high yielding during the cool season in south-east Queensland. There are no reports on the performance of tropical legumes under irrigation in western New South Wales. They were therefore included with the grasses in an assessment of seasonal dry matter production under irrigated and rainfed conditions.

MATERIALS AND METHODS

Site

The pasture species were sown on an alkaline brown clay soil (Ug 5.25: Northcote 1979) at the Agricultural Research Centre, Trangie. The pH was 8.1 at the surface and increased with depth; calcium carbonate concretions occurred at 30 cm. The bulk density increased to a maximum of only 1.3 g cm^{-3} at a depth of 20 cm; a root zone of 1 m depth was assumed in calculating the available soil water capacity to be 150 mm. Maximum and minimum temperatures, solar radiation and rainfall throughout the study are shown in Table 1. In the first winter (1980) 25 frosts were observed between May 19 and August 28, while in the second winter 29 frosts occurred between June 8 and September 4. The minimum terrestrial temperature was -5.6°C in both winters. The average number of frosts at Trangie is 35 between May 21 and September 3.

Establishment

Pasture seeds were broadcast by hand and covered with harrows on November 1, 1979. This method was used to avoid sowing the small seeded grasses too deeply. Some species (see Table 2) were established from cuttings sown on a 50 cm grid. *Paspalum nicorae* and *Digitaria pentzii* were established from glasshouse-grown seedlings, transplanted at the same 50 cm spacing. In the plots sown with legumes the pre-emergent herbicide pendimethalin was incorporated at the rate of 2 l ha^{-1}. The plots were spray irrigated until emergence was complete (3–4 weeks).

Superphosphate (30 kg P ha^{-1}) was applied prior to sowing and again at the start of the second growing season. Ammonium nitrate was applied at sowing and two months later, to give a total of 155 kg N ha^{-1}. In the second growing season a total of 200 kg N ha^{-1} was applied in two equal applications.

Treatments and design

The species listed in Table 2 were sown in nine randomised blocks; individual plots were 3 × 10 m. All blocks were flood irrigated to avoid moisture stress in the first summer. At the commencement of the second growing season the following treatments were imposed, each on three replicates:

(a) Irrigation on a pan evaporation interval of 50 mm (frequent)
(b) Irrigation on a pan evaporation interval of 100 mm (infrequent)
(c) Nil irrigation (rainfed)

Treatments (a) and (b) represented available soil water depletions of 33% and 67% respectively (rainfall in excess of the available water capacity was considered lost, while other rainfall was automatically adjusted for in the pan evaporation measurement). Only the species established from seed were included in the infrequent and nil irrigation treatments.

Measurements

Sampling commenced on February 11, 1980 when two 1 × 0.5 m quadrats were cut from the legume plots; the grasses were still too small for sampling. After sampling, all plots were forage harvested to a height of 6–8 cm and the forage removed. Two more samplings at six weekly intervals were taken in the first season; the last sampling in May was not forage harvested to encourage winter survival. Barnyard grass (*Echinochloa* spp.), which infested the sown grass plots in the first year, was not included in the sampled dry matter. In the second growing season, sampling commenced on October 13, 1980 and four more six weekly cuts were taken. The third growing season was first sampled on November 3, 1981 and the experiment was concluded on December 14, 1981, just over two years after sowing. All treatments were sampled simultaneously.

TABLE 1

Average temperatures, rainfall and evaporation at Trangie, together with readings for 1980 and 1981.

		Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Maximum temperature (°C)	Av.	34.0	32.7	30.2	25.8	19.7	16.4	15.6	17.2	20.6	25.4	29.5	33.2
	1980	32.8	33.0	32.1	26.4	19.7	15.0	14.2	17.8	22.9	28.6	31.3	33.2
	1981	36.5	33.9	30.1	26.6	19.5	14.6	14.4	15.2	22.9	25.7	25.8	32.7
Minimum temperature (°C)	Av.	18.6	18.0	15.9	11.2	6.2	4.3	2.9	4.1	6.4	10.4	13.3	16.7
	1980	17.9	18.7	15.5	12.2	9.3	5.0	3.3	2.8	5.3	12.2	15.3	18.1
	1981	22.8	21.0	14.6	12.1	9.5	5.7	4.6	3.5	6.6	11.8	13.6	17.1
Solar radiation (MJ m^{-2} day^{-1})	1980	24.2	25.0	22.2	16.6	11.6	7.7	9.0	13.1	19.3	23.1	28.9	28.7
	1981	27.8	23.8	22.0	16.1	10.5	5.8	8.7	12.4	18.2	21.3	23.2	26.8
Rainfall (mm)	Av.	65	72	53	39	37	30	37	39	32	61	47	42
	1980	67	24	22	11	111	36	21	17	0	24	4	26
	1981	14	70	2	8	51	56	73	10	9	78	54	5
Evaporation (mm)	Av.	297	235	203	140	84	57	60	79	116	172	225	295
	1980	295	285	258	171	89	47	49	83	165	245	341	340
	1981	373	266	264	174	91	49	52	73	121	192	192	333

TABLE 2

Grass and legume species sown at the rates indicated in pure swards at Trangie.

Species/cultivar	Germination %	Seeding rate (kg ha^{-1})	Habit†
Grasses			
Setaria sphacelata var. *sericea* cv. Narok	78	4	b
Setaria sphacelata var. *splendida* CPI* 15899		veg	b
Paspalum dilatatum	72	8	b
Paspalum nicorae CPI 39970+		**	s
Paspalum plicatulum cv. Bryan	11	43	b
Cenchrus ciliaris cv. Molopo (buffel)	52	18	s
Panicum maximum var. *trichoglume* (green panic)	23	10	b
Panicum coloratum cv. Bambatsi	21	12	b
Brachiaria decumbens	42	3	s
Pennisetum clandestinum cv. Whittet (kikuyu)	80	13	s
Chloris gayana cv. Callide (Rhodes grass)	60	2	s
Digitaria smutsii CPI 38869+		**	b
Digitaria pentzii CPI 40700+		**	s
Pennisetum americanum × *P. purpureum* (hybrid pennisetum)		veg	b
Cynodon dactylon accession 710		veg	s
Legumes			
Desmodium uncinatum cv. Silverleaf	89	20	
Desmodium intortum cv. Greenleaf	89	6	
Neonotonia wightii cv. Tinaroo	60	43	
Neonotonia wightii cv. Cooper	60	43	
Macroptilium atropurpureum cv. Siratro	80	67	

* Commonwealth Plant Introduction number
+ Supplied by Mr. R. Strickland, C.S.I.R.O., St Lucia, Qld.
† b = bunch or tufted type; s = stoloniferous
** seedlings sown

The forage samples were dried at 80°C in a forced air oven. Plant height (to the top ligule of grasses) was measured at the last two harvests in 1980–81.

Dry matter yields were analysed as split plots in time. Growth rates or rates of dry matter accumulation were calculated as means over the six weeks of regrowth.

RESULTS

Establishment and persistence

The legumes, especially *Macroptilium atropurpureum* (Siratro), established more quickly than the grasses. The grasses had to compete with barnyard grass; however, two cuts were still obtained in the first growing season (Fig. 1). Rhodes grass was the most vigorous during establishment; by the end of the first growing season it was beginning to invade other plots and had to be constantly checked. Buffel grass also established quickly. The seedlings of *P. nicorae* and *D. pentzii* achieved a complete ground cover mid-way through the second summer. The cuttings of *S. sphacelata* var. *splendida* and *Pennisetum americanum* × *P. purpureum* (hybrid pennisetum) rapidly formed tufts 20–25 cm in diameter. Plots of *D. smutsii* were contaminated with Rhodes grass, apparently from impure seed, and required weeding in the second summer.

The plots of *Brachiaria decumbens* and *P. plicatulum* failed to recover after the first winter while *Panicum maximum* var. *trichloglume* (green panic) plots were partially killed; surviving plants were slow to recover in the spring. Rhodes grass and buffel grass were also slower to recover than the *Setaria* spp., *P. dilatatum*, *P. coloratum* and *Pennisetum clandestinum* (kikuyu). Of the legumes, Siratro was most extensively winter killed; moreover, it was mid-summer before remaining plants fully recovered. *Desmodium intortum* (Greenleaf desmodium) and *Neonotonia wightii* (Cooper glycine) recovered most rapidly after the first winter and were the only legumes to survive the second winter.

After survival into the third summer was conclusively ascertained, irrigation and measurement of growth was terminated. Growth after this time (December 1981) was observed but without irrigation the growth of most species was severely limited.

Seasonal and annual dry matter yields

The legumes, except for Cooper glycine, yielded over 8 t ha^{-1} in the first growing season. In the first cut, three months after sowing, Siratro yielded 4.5 t ha^{-1} (Fig. 1). However, it was lower yielding in the autumn. From just two cuts in the first growing season, Rhodes grass yielded 6.2 t ha^{-1}. This was 50% more than buffel grass, the next highest yielding grass established from seed. In the second growing season Rhodes grass yielded 10.4 t ha^{-1} but was surpassed by *S. sphacelata* var. *splendida* (16.7 t ha^{-1}), *P. coloratum* (13.8 t ha^{-1}) and *P. dilatatum* (13.0 t ha^{-1}). *S. sphacelata* var. *splendida*, an extremely vigorous, late flowering bunch grass, reached a height of 50 cm in February; Narok setaria and *P. dilatatum* grew to a similar height and *P. coloratum* to 90 cm. Kikuyu was very prostrate (13 cm) as was *P. nicorae* (37 cm). *C. dactylon* was similarly prostrate (33 cm) but yielded 8.6 t ha^{-1} in the second growing season and was high yielding again at the start of the third growing season (Fig. 1). In the third growing season the same species, namely *Setaria* spp., *P. dilatatum* and *P. coloratum* were again prominent. Without nitrogen fertilizer, however, yields decreased in the third growing season.

The growing season for the best adapted grasses extended from October to April, a period of 5–6 months. This period coincided with mean daily temperatures above 20°C or minimum temperatures above 10°C (Table 1). The growth rates increased during spring and early summer as temperatures increased. However, in December growth rates were either similar to or less than the preceding six week period, despite higher temperatures (Fig. 1). During January–February the growth rate of *S. sphacelata* var. *splendida* reached 200 kg ha^{-1} day^{-1} while *P. dilatatum* and *P. coloratum* reached 120–130 kg ha^{-1} day^{-1}. The growth rates fell sharply in March to less than 30 kg ha^{-1} day^{-1}, coinciding with the decrease in temperature. In the first

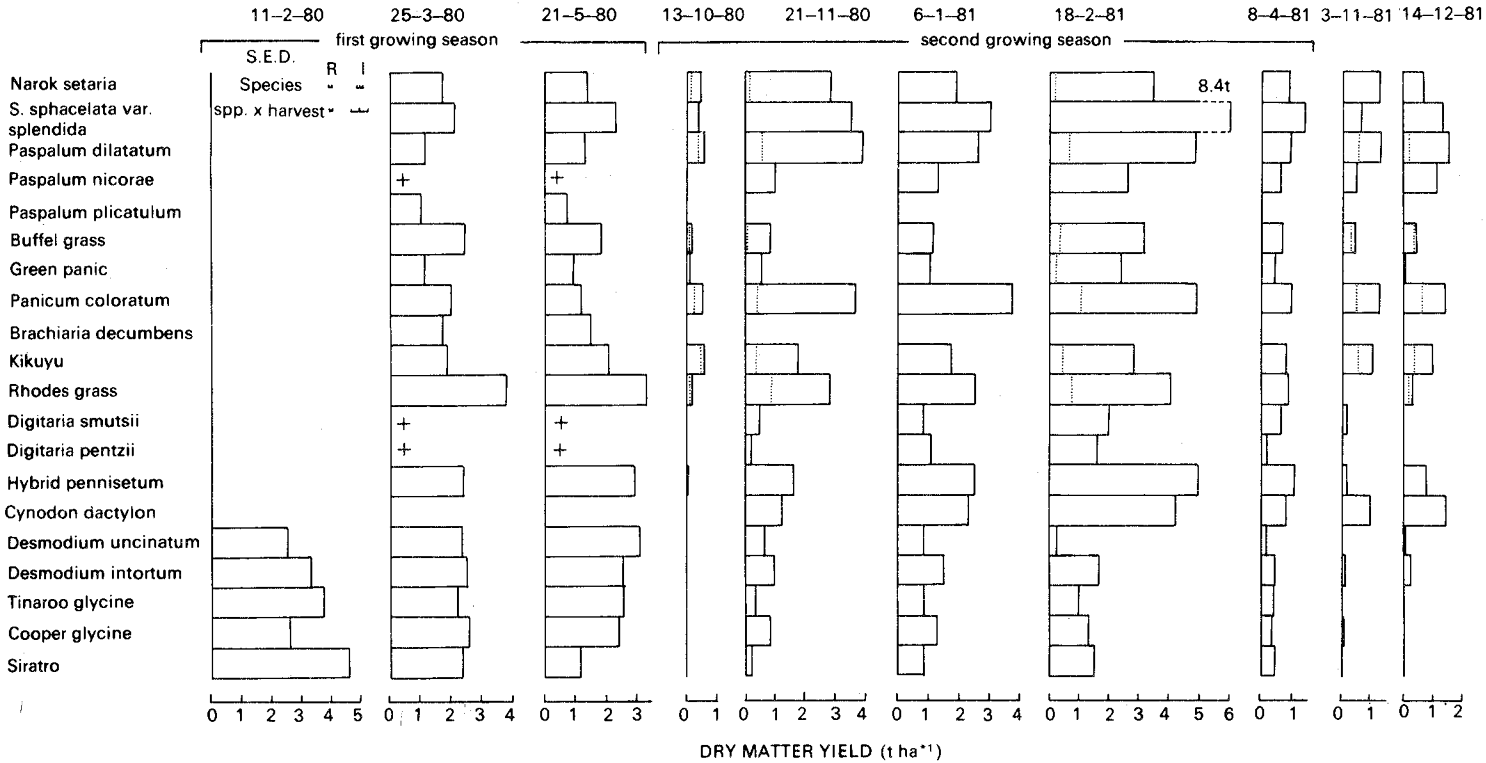

FIGURE 1.

The dry matter yield at each sampling of tropical and subtropical grass and legume species grown in pure swards. Results are the mean of the two irrigation treatments with the rainfed treatment shown separately (. . .). (+ = not established). Twice the standard error of the difference of means (SED) is shown for the rainfed (R) and irrigated (I) treatments for comparison between species within a harvest and between species across harvests.

growing season higher temperatures in autumn (Table 1) allowed pasture growth into early May.

Irrigation regimes

Without irrigation, dry matter yields were very low during the 1980–81 growing season. Indeed, dry matter was only obtained at three samplings, two in spring and one in summer after 57 mm of rain (Fig. 1). This rainfall stimulated growth to the extent of 0.7–0.8 t ha^{-1} in Rhodes grass and *P. dilatatum*, and over 1.0 t ha^{-1} in *P. coloratum*. The latter produced a total of 1.7 t ha^{-1} under rainfed conditions, only 12% of the irrigated yield. The best legumes without irrigation, namely Siratro and Cooper glycine, only yielded 0.3 t ha^{-1}; these failed to persist into the third season.

Irrigation increased yields although there was no significant difference ($P > 0.05$) between the evaporation intervals of 50 and 100 mm. There was no significant interaction between the two irrigation intervals and species, although the interaction between irrigation and sampling time was significant ($P < 0.05$). Early in the growing season grass yields tended to be lower with frequent irrigation while in mid-summer there was a slight advantage in the more frequent irrigation. This may have arisen because of the difficulty in enforcing the regimes during summer; indeed the 50 mm interval necessitated irrigation every 5–6 days.

DISCUSSION

Panicum coloratum and *Paspalum dilatatum* were the most productive summer growing grasses under irrigation on the brown clay soils. Squires and Myers (1970) similarly found *P. coloratum* high yielding, but because of establishment problems abandoned it in favour of *P. dilatatum*. No special problems were encountered with the establishment of *P. coloratum* in this study at Trangie, although all the grasses, with the possible exception of Rhodes grass were difficult to establish in this hot, dry environment. The small seeds cannot be sown deeply and therefore can suffer dehydration as the surface soil rapidly loses moisture under high spring/summer temperatures. It is suggested that sowing on a raised hill or bed and 'watering up' is the only reliable method of establishment. Rapidly germinating species such as Rhodes grass (Watt and Whalley 1982) can be more easily and reliably established.

Rhodes grass yielded as well as *P. dilatatum* during summer but slow recovery in the spring limited its total yield. Dann (1965) similarly found Rhodes grass slightly inferior to *P. dilatatum* in the second year although on sandy soils it is superior to *P. dilatatum* (Roberts and Carbon 1969). Nonetheless, Rhodes grass tends to be low in protein and digestibility (Dann 1965; Minson and McLeod 1972). Both *P. coloratum* and *P. dilatatum* have a higher digestibility than Rhodes grass (Taylor *et al.* 1976).

Setaria spacelata var. *sericea* cv. Narok persisted, at least when irrigated, but lacked vigour during summer (cf. Michalk *et al.* 1977). The cultivar Narok was selected for its cold tolerance; however, other more vigorous cultivars such as Kazungula may persist and be more productive in summer. Kemp (1975) obtained 13–17 t ha^{-1} from Kazungula setaria. Kikuyu was even lower yielding than Narok setaria, possibly because of its inefficient use of fertilizer nitrogen (Kemp 1975) or physiological reaction to high evaporation rates (Murtagh 1978).

Paspalum nicorae and *Digitaria pentzii*, found by Strickland (1978) to be more productive than kikuyu during the cool season, performed poorly in this study. They persisted but annual production was below kikuyu and other cold tolerant species. The relatively poor performance of *P. nicorae* may be attributable to soil characteristics at the site of this experiment.

Setaria sphacelata var. *splendida* produced the highest dry matter yield of all grasses in this experiment. Other workers (Hacker 1972; Forde *et al.* 1976) have similarly noted its high yield potential; consequently the fertility of this setaria is being increased through breeding (Hacker and Bray 1981). Although less frost tolerant than *S. sphacelata* var. *sericea* (Forde *et al.* 1976), and hence slower to recover in the spring, *S. sphacelata* var. *splendida* had very high growth rates in summer. This tall bunch grass should, like hybrid pennisetum and perennial sorghum species, be considered and managed as a perennial forage crop. Indeed its annual yield was higher than the perennial sorghum cv. Silk and similar to the regularly cut annual forage sorghums (Muldoon 1985).

The growing season of the subtropical grasses was restricted to 5–6 months. This was slightly less than in a coastal environment at 32°S (Kemp 1975), and much less than in south-east Queensland (Hacker and Bray 1981). Strickland (1978) reported April to September yields which were 14% of the total whereas in western New South Wales no growth occurred during this period. Nevertheless, growth rates in summer were comparable to those found by Kemp (1975). Moreover, Kemp (1975) also reports a similar mid-summer depression in the growth rate, the cause of which is not readily apparent.

Irrigating more frequently than an evaporation interval of 100 mm was not warranted on this soil type. This means allowing the soil to dry to an available water content only 30–40% of the maximum if the effective rooting depth is around 1 m. In contrast Squires (1971) reported a large decrease in the yield of a temperate grass when the irrigation interval was extended to 100 mm of evaporation. This difference suggests tropical C4 grasses may benefit from an extensive root system in addition to their greater physiological water use efficency compared to temperate C3 grasses (Downes 1969). Nonetheless, without irrigation yields were very low in this semi-arid environment. *P. coloratum* was the highest yielding species in the absence of irrigation and warrants further evaluation as a dryland pasture in this region.

Dry matter yields of 13–15 t ha^{-1} from irrigated subtropical grasses will alleviate the summer feed deficit in western New South Wales. Higher yields may be obtained with higher rates of nitrogen, however *P. coloratum* and *P. dilatatum* should also be evaluated in combination with a legume such as white clover (*Trifolium repens*). A temperate legume seems preferable since the tropical legumes, apart from Greenleaf desmodium were not productive beyond the first year.

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