GROWTH OF TROPICAL AND TEMPERATE GRASSES AND LEGUMES UNDER IRRIGATION IN SOUTH-WEST AUSTRALIA

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ABSTRACT

An array of tropical and temperate species was grown on irrigated sands in the Mediterranean-type climate of Perth, Western Australia, for preliminary screening and evaluation.

Pennisetum purpureum *was the highest yielding species tested, with a dry matter production of 42,900 kg/ha.* Eragrostis curvula, Chloris gayana *and* Digitaria decumbens *also showed promise amongst the grasses, and substantially outyielded the legumes.* Medicago sativa, Glycine javanica, Phaseolus atropurpureus *and* Lotononis bainesii *were the most productive legumes.*

The outstanding production from some of the tropical grasses suggests that a pure grass sward well supplied with nutrients may lead to a substantial increase in animal production from irrigated pastures in south-west Australia. This conclusion is being tested with sheep and beef cattle.

INTRODUCTION

The temperate Mediterranean region is regarded as the centre of distribution for more than half of the 40 principal cultivated pasture grass species used throughout the world (Hartley and Williams, 1956). Also a number of temperate legumes from the genera *Trifolium* and *Medicago* have spread from this region (Whyte *et al.*, 1953). There has been a natural tendency to use these species in the dry land and irrigated temperate areas of Australia, and to extend their use into sub-tropical areas.

In recent years there has been an increased interest in the improvement of tropical pastures (C.S.I.R.O., 1964; Davies and Skidmore, 1966). The remarkable responsiveness to heavy fertilizer application of tropical grasses in tropical environments has been demonstrated (C.S.I.R.O., 1962; Henzell, 1963; Vincente-Chandler, 1966). This has raised the possibility that irrigated tropical grasses may also give a high performance during the summer in temperate regions, particularly the Mediterranean-type climate of south-west Australia which is well endowed with high radiation and high temperature conditions. An indication of the growth potential in such a climate was given by Worker and Peterson (1962) who showed that Coastal Bermuda grass can yield more than 28,000 kg/ha in 6 summer months in southern California. It was recognized that a similar potential for use of tropical species may exist in south-west Australia where green feed is in short supply during the summer. In 1961 screening experiments were initiated near Perth to assess this potential on an extensive sand-plain on the west coast (Swan Coastal Plain) underlain by shallow ground water.

THE GENERAL ENVIRONMENT

Perth is centrally situated on the Swan Coastal Plain of Western Australia. This plain extends along the lower west coast from Jurien Bay (30°S lat) to 32 km south of Busselton ($33\frac{1}{2}$°S lat), a distance of some 480 km. The eastern boundary is formed by the Darling Scarp, and the Indian Ocean delineates the western side. The average east-west width is 24 km. The total area is 1,093,500 hectares.

The climate is typically Mediterranean (Rossiter, 1966) with mild, wet winters and hot, dry summers and during the latter solar radiation often exceeds 600 cal cm^{-2} day^{-1} (Table 1).

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TABLE 1

Mean Climatic Data for Perth.*

RAINFALL	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR
(cm)	0.81	1.14	2.06	4.57	12.73	18.34	17.42	14.15	8.05	5.44	2.11	1.47	88.29
TEMPERATURE (°C)													
Mean maximum	29.4	29.7	27.7	24.5	20.6	18.0	17.1	17.8	19.3	21.0	24.6	27.2	23.1
Mean minimum	17.5	17.7	16.4	14.0	11.5	9.9	8.8	9.0	10.1	11.3	13.7	15.9	13.0
EVAPORATION (cm)													
Aust. Std. Sunken Pan Evaporimeter	26.24	22.20	19.71	11.25	7.57	5.00	4.98	6.50	9.50	13.89	19.41	24.11	170.66
SOLAR RADIATION (cal cm^{-2} day^{-1})	653	603	496	356	262	225	236	323	421	538	635	676	—

*From Commonwealth Bureau of Meteorology, Climatic Survey Region 15, Western Australia, 1966.

The soils of the Swan Coastal Plain are predominantly deep infertile sands of two extensive sand dune systems, the Bassendean System (white sands) and the Spearwood System (yellow sands). Ground water occurs at a shallow depth under both dune systems. Pockets of river alluvial soils occur along the eastern side (Bettenay, McArthur and Hingston, 1960).

Agricultural development has been restricted to the better soils of the Swan Coastal Plain. Most of the Spearwood System can be developed with conventional dryland sandplain techniques. The Bassendean System awaits development by special techniques that are being devised to overcome the extreme nutritional and water relations problems.

MATERIALS AND METHODS

Experiment 1

The initial experiment was located on Spearwood sand at Crawley near Perth. Fifty-three grasses and 21 legumes were sown from seed or sprig as pure swards, in 1.7 square metre unreplicated plots during the period 1961 to 1964. Plots received three dressings of fertilizer at 8 weekly intervals during summer (November-April). Each dressing provided 56, 22 and 45 kg/ha of nitrogen, phosphorus aad potassium respectively. The rates were halved for the three dressings during winter (May-October). All legume seeds were inoculated just before planting by dipping in suspensions prepared from appropriate cultures supplied by C.S.I.R.O., Division of Tropical Pastures. Irrigation water was applied twice a week during the summer at an average rate of about 6 cm/week. Observations were made on growth rhythm, total production and persistence, for at least two years. All plots were cut back on six occasions each year. The vigour of regrowth was rated after each cut, and collated to give an assessment of total productivity based on four broad categories.

Experiment 2

In the second experiment begun in January, 1963, twelve of the more productive species (7 grasses and 5 legumes) were planted adjacent to the original experimental plots. Plots were 4.6 square metres with two replicates of each species. Grasses were established in pure swards, and received four dressings of fertilizer at six weekly intervals during the summer of 1963-1964, each dressing provided 58, 25 and 80 kg/ha of N, P and K respectively. The fertilizer rates were halved for the four dressings during May–early October, 1963. The legume plots were established as legume plus *Digitaria decumbens* and received the same rates of phosphorus and potassium as the pure grass plots, but no nitrogen fertilizer. All plots received an initial dressing of 1 kg/ha of copper and 2 kg/ha of zinc. The legumes were inoculated as in Experiment 1 from cultures maintained by the University of Western Australia, Institute of Agriculture. The irrigation schedule was similar to that for Experiment 1.

All plots were cut back on 3rd October, 1963, and three harvests were taken at eight week intervals over summer (October-March). Cutting height varied from 1 cm for the prostrate species to 5 cm for the bunch grasses and quadrat area was 2.3 square metres.

Experiment 3

Chloris gayana and *Digitaria decumbens* were chosen for further study, together with two other high yielding grasses, *Eragrostis curvula* and *Hyparrhenia hirta*. *Medicago sativa, Phaseolus atropurpureus, Glycine javanica* and *Lotononis bainesii* were the selected legumes. These eight species were used in a randomized block layout with three replicates at both of the C.S.I.R.O. research stations at Pinjar, some twenty miles north of Perth. East Pinjar Research Station is situated on the Bassendean Dune System and West Pinjar Research Station is situated on the Spearwood Dune System.

TABLE 2

Evaluation Notes on Grass Species (Experiment 1)

Botanical Name	Accession No.	Common Name	Visual* Growth Rating
Agropyron elongatum	W 296	Tall wheat grass	++
Agropyron pycnanthum	CPI 31649		++
Andropogon distachyus	CPI 14777		++
Brachiaria brizantha	CPI 20584	Signal grass	+++
Brachiaria mutica	—	Para grass	++++
Cenchrus ciliaris cv Biloela	CPI 6934	Buffel grass	+++
Chloris gayana cv Nzoia	CPI 16043	Rhodes grass	++++
Cynodon dactylon cv Hulled Bermuda	—	Couch grass	++
Cynodon dactylon	CPI 15007	Couch grass	++
Digitaria decumbens	CPI 18578	Pangola grass	++++
Digitaria spp	CPI 26833-26840	Finger grass	++++
Digitaria spp	CPI 23847-23850	Finger grass	++++
Eragrostis curvula cv Schagen	CPI 30376	Weeping love grass	++++
Hyparrhenia hirta	CPI 5786	African Bluestem	++++
Panicum coloratum	CPI 18747		+++
Panicum coloratum var *makarikariense*	CPI 16790	Makarikari	+++
Panicum maximum var *trichoglume*	—	Green Panic	+++
Paspalum wettsteinii	CPI 11860	Broadleaf Paspalum	++
Paspalum yaguaronense	CPI 11867		++
Pennisetum clandestinum	—	Kikuyu	+++
Pennisetum purpureum	CPI 20359-20365	Elephant grass	++++
Pennisetum purpureum	CPI 20453-20458	Elephant grass	++++
Pennisetum purpureum cv Cameroon Selection 25	CPI 20463	Elephant grass	++++
Phalaris tuberosa x *P. arundinacea* hybrid	CPI 21553	Ronpha grass	++
Secale montanum	CPI 23282		++
Setaria sphacelata cv stolonifera	CPI 23852	South African Pigeon grass	+++
Seteria sphacelata cv Kazungula	CPI 16341	South African Pigeon grass	++++
Setaria sphacelata cv Nandi	CPI 28709	South African Pigeon grass	+++
Setaria sphacelata cv Dutoitskaal	CPI 29294	South African Pigeon grass	+++
Setaria tenuiseta	CPI 23853		++
Sorghum almum	CPI 12019	Columbus grass	++++
Sorghum arundinacea	CPI 8546		++++
S. halepense x *S. saccharatum* hybrid	CPI 27728		++++

*++++ indicates highest level of yield among the grasses.

The grasses and legumes were established as separate pure swards in 4.6 square metre plots. All plots at East Pinjar received an application of lime (1,100 kg/ha) before sowing. An initial dressing of 1 kg/ha of copper and 2 kg/ha of zinc was applied at both sites. Grasses received six dressings of fertilizer at monthly intervals during the summer, each dressing providing 28, 11 and 30 kg/ha of N, P and K respectively. The legumes received the same rates and total amounts of P and K but no N. The winter rates were half those for summer. The legumes were inoculated as in Experiment 2. Water was applied three times per week, at an average rate of 4.5 cm per week.

Plots were harvested on six occasions at two monthly intervals during 1966. Cutting height varied from 1 cm for the prostrate species to 5 cm for the bunch grasses and quadrat area was 2.3 square metres.

RESULTS

Experiment 1

A list of species together with performance ratings is presented in Tables 2 and 3.

The grasses were more productive than the legumes. Outstanding production was obtained from *Pennisetum purpureum, Chloris gayana, Eragrostis curvula* and *Digitaria decumbens. Brachiaria mutica, Digitaria* spp., *Hyparrhenia hirta, Setaria sphacelata* ("Kazungula") and the *Sorghum* species also yielded well. Of the legumes *Medicago sativa, Phaseolus atropurpureus, Glycine javanica, Lotononis bainesii, Trifolium repens, Trifolium fragiferum, Dolichos lablab* and *Leucaena leucocephala* were moderately productive. The growth of *Leucaena leucocephala* was restricted by poor nodulation. Both grasses and legumes made most of their growth during the summer.

Of the more productive grasses only *Eragrostis curvula* and *Hyparrhenia hirta* made much growth in winter. All the productive legumes with the exception of *Phaseolus atropurpureus* and *Glycine javanica* made some winter growth.

All the grasses other than the sorghums persisted well. The legumes were more variable. The most productive species were also the most persistent. Unproductive species such as *Cajanus cajan, Centrosema pubescens, Clitoria ternata, Desmodium intortum, Stylosanthes guyanensis* and *Trifolium semipilosum* showed poor persistence. The remainder were intermediate for persistence.

In this experiment the legumes varied markedly in the ease with which nodulation occurred. In *Desmodium intortum, Indigofera spicata* and *Trifolium semipilosum* poor nodulation appeared to be the main reason for the lack of persistence; there were few nodules on excavated sample plants, and there was a ready response to a dressing of nitrogen. With other legumes such as *Clitoria ternata, Centrosema pubescens* and *Stylosanthes guyanensis* nodulation was poor but they showed little or no response to a dressing of nitrogen.

Experiment 2

Yield data for this experiment are summarized in Table 4.

Results were analysed by analysis of variance on logarithmic transformations of raw data, and comparisons made using the method of orthogonal contrasts.

There was a significant difference ($P<0.001$) in production between species. *Pennisetum clandestinum* and *Paspalum dilatatum*, two grasses sometimes used as components in irrigation areas in south-west Australia, give significantly ($P<0.001$) lower yields than the other grasses tested. With the exception of these two species the yield of the pure grass plots exceeded that of the legume plus *Digitaria decumbens* plots. Similarly, the yield of *T. repens/D. decumbens* was significantly ($P<0.001$) lower than that of the sub-tropical species *L. bainesii/D. decumbens, P. atropurpureus/D. decumbens* and *G. javanica/D. decumbens*. Summer yields from the experiment ranged from 42,900 kg/ha for *Pennisetum purpureum*, to 6,200 kg/ha for *T. repens/D. decumbens*.

TABLE 3

Evaluation Notes on Legume Species (Experiment 1)

Botanical Name	Accession No.	Common Name	Visual* Growth Rating	Visual* Nodulation Rating
Cajanus cajan	CPI 20133	Pigeon pea	+	++
Centrosema pubescens	CPI 25355	Centro	+	++
Clitoria ternata	CPI 17228	Clitoria pea	+	+
Desmodium intortum	CPI 18009	Greenleaf Desmodium	+	+
Desmodium uncinatum	CPI 8990	Silverleaf Desmoduim	+	+
Dolichos axillaris	CPI 17814		++	++++
Dolichos lablab	CPI 32007	Lablab bean	+++	++++
Glycine javanica cv Cooper	CPI 25702	Glycine	+++	+++
Indigofera spicata	CPI 16110	Creeping Indigo	++	+
Kennedya prorepens	W 370		++	++
Kennedya rubicunda	W 454		++	++
Leucaena leucocephala cv Peru	CPI 18614	Leucaena	++++	++
Lotononis bainesii cv Miles	CPI 16833	Lotononis	+++	+++
Medicago sativa cv Hunter River	—	Lucerne	++++	+++
Phaseolus atropurpureus	Q 403	Siratro	+++	+++
Stylosanthes guyanensis	CPI 5630	Stylo	+	+
Trifolium fragiferum cv Palestine	W 728	Strawberry clover	+++	+++
Trifolium repens cv New Zealand	—	White clover	+++	+++
Trifolium semipilosum	CPI 31996	Kenya white clover	+	+

*++++Indicates highest level of yield (Column 4), or many nodules on excavated plants (Column 5).

* +Indicates little or no growth (Column 4), or little or no nodulation on excavated plants (Column 5).

TABLE 4

Summer Dry Matter Production (KG/HA) for an Irrigated Cutting Trial at Crawley (Spearwood Sand) (Experiment 2)

Pure Grass Treatments	D.M. (kg/ha)
Pennisetum purpureum (Elephant grass CPI 20454)	42931
Chloris gayana (Rhodes grass CPI 16043)	23639
Brachiaria mutica (Para Grass)	21439
Digitaria decumbens (Pangola Grass CPI 18578)	21047
Setaria sphacelata cv Kazungula (CPI 16341)	20294
Paspalum dilatatum	13785
Pennisetum clandestinum (Kikuyu)	11993
Legume/Grass Treatments	
Phaseolus atropurpureus (Siratro Q 403) + Pangola Grass	16226
Lotononis bainesii (CPI 16833) + Pangola Grass	15352
Glycine javanica (Cooper CPI 25702) + Pangola Grass	14652
Medicago sativa ("Hunter River" lucerne) + Pangola Grass	13190
Trifolium repens ("New Zealand" White Clover) + Pangola Grass	6192

TABLE 5

Total Annual Dry Matter Production (KG/HA) for Irrigated Cutting Trials at Pinjar Research Stations (Experiment 3)

Grass Species	Yield East Pinjar (Bassendean Sand)	West Pinjar (Spearwood Sand)
Eragrostis curvula (Weeping lovegrass CPI 30380)	28275	32808
Hyparrhenia hirta (African Bluestream)	23914	30318
Chloris gayana (Rhodes Grass CPI 16043)	24149	26207
Digitaria decumbens (Pangola Grass CPI 18578)	19371	21513
Legume Species		
Medicago sativa ("Hunter River" lucerne)	7462	22439
Lotononis bainesii (CPI 16833)	8268	16333
Phaseolus atropurpureus (Siratro Q 403)	5648	4740
Glycine javanica (Cooper CPI 25702)	4334	5481

Experiment 3

Dry matter yields for this experiment are given in Table 5.

Results were analysed by the same method used in Experiment 2. The yields differed significantly ($P<0.001$) between the eight species at both sites, and within the four grass species and also the four legume species at both sites. These effects were more pronounced at West Pinjar.

Eragrostis curvula (CPI 30380) was the highest yielding grass and performed well on both sand types. *Medicago sativa* was the best legume, performing well on the Spearwood sand but poorly on the Bassendean sand.

DISCUSSION

Our experiments have shown that much higher dry matter production of irrigated pastures can be achieved in the Mediterranean-type climate of south-west Australia than was previously considered possible. This high production has been obtained by using tropical grasses well supplied with nutrients and an abandonment of the traditional practice of incorporating summer-growing legumes in the irrigated pasture. With this system yields obtained from the most productive grasses compare very favourably with the best of those reported from tropical environments, both in Australia (Wilson and Barkus, 1965; Evans, 1967) and overseas (Haines *et al.* 1963; Vincente-Chandler, 1966).

Although the protein content of the high yielding tropical grasses was generally about half that of the legumes the highest protein yield per hectare was still obtained from the grasses, because of their outstanding dry matter yields.

The expected advantages of the new system have yet to be fully explored and tested with grazing animals. Then an appraisal should be made of its significance in the economics of animal production on spray irrigated pastures in warm temperate climates.

However, in current experimental work species such as *Eragrostis curvula, Chloris gayana* and *Digitaria decumbens* are supporting high rates of stocking under a system of rotational grazing. Moreover, the lack of winter productivity of many tropical species seems to be easily rectified by incorporating winter annual grasses and legumes, such as *Lolium rigidum* and *Trifolium subterraneum*. As a result, interest is now centred on the selection of long lived cultivars with sustained high production during October to March.

A better understanding of water and nutrient requirements for maximum pasture growth on sands may raise productivity levels even further.

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