

Pasture species for the granite and traprock areas of south-east Queensland

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Summary

A range of temperate and tropical pasture species was evaluated under periodic grazing on granite, traprock and sandstone soils in a 650 to 725 mm annual rainfall area of inland south-east Queensland. Establishment fertiliser was always used but annual maintenance dressings were not applied on the sandstone soil.

The outstanding perennial legume was lucerne which was persistent and productive for up to seven years. Siratro and lotononis were moderately persistent but were only sporadically productive whereas other tropical legumes failed to persist.

Some winter annual legumes persisted well and were productive in years with near average winter rainfall. However, their productivity was reduced at times by slow seedling growth and poor nodulation, particularly on the sandstone soil. The best species were the clovers *Trifolium hirtum*, *T. subterraneum* and *T. glomeratum*, and the medics *Medicago littoralis* and *M. truncatula*.

The best tropical perennial grasses were Rhodes grass (*Chloris gayana*) and tall finger grass (*Digitaria smutsii*). Temperate grasses were moderately productive but generally unable to persist through summers with rainfall below average. The most persistent were tall fescue (*Festuca arundinacea*) on the granite soil, and phalaris (*Phalaris aquatica*) and perennial veldt grass (*Ehrharta calycina*) on the sandstone soil.

The granite site had the highest rainfall and was climatically the most suitable for growing improved pastures.

INTRODUCTION

The area under study is the south-eastern Darling Downs of Queensland bounded by the towns of Warwick, Leyburn, Inglewood, Texas, Wallangarra, Stanthorpe and Dalveen. It includes three broad soil types known as granite, traprock and sandstone (derived from Marburg sandstone). Mean annual rainfall varies from 635 mm in the west to 760 mm in the east. A small area to the east of a line from Warwick to Stanthorpe receives up to 890 mm of rain annually. Known locally as the 'wet granite', this area has different pasture species adaptation and is excluded from this study. Two-thirds of the rain in the study area is received in the six summer months (October to March) but the winter rainfall is relatively reliable.

A detailed land inventory including soils, vegetation and land use was prepared by Wills (1976). Soils developed on granite are generally gritty silicious sands or duplex podzolics and solodics. Soils developed on traprock (Paleozoic sediments) are shallow, stony, uniform or texture-contrast soils. Soils developed on sandstone include a range of texture-contrast soils and deep sands, the poorer of which are similar to soils derived from granite.

The vegetation of the area is either open eucalypt forest or a grassland which develops after clearing of this forest.

Land use is predominantly grazing with sheep and beef cattle, plus restricted areas of agriculture, horticulture, forestry and apiculture. The grasslands have a low carrying capacity with shortages of protein and energy in winter (Lee and Rothwell 1966). Improved animal nutrition was initially based on small areas of lucerne and oats to supplement the native pasture. Sowing of improved pastures expanded in the 1950s, encouraged by results

in the New England district of New South Wales and the work of Mr A. Clothier of ACF and Shirleys Fertilizers Ltd. The results of species testing and recommendations at that time are given by Lee (1961). Persistence of lucerne, medics and clovers was sometimes poor because of poor quality *Rhizobium* inoculants which have since been improved, and the absence of lime pelleting of legume seed.

The aim of the present work was to evaluate a wider range of pasture plants for their suitability as grazing species for the area.

MATERIALS AND METHODS

Seed of 76 temperate and 42 tropical grasses and legumes was sown in 15 plantings on three soil types between 1962 and 1968 (Table 1). The granite soil was located at Palgrove, 20 km west of Dalveen. The sandstone and traprock sites were located respectively at Brigalow Park (16 km south of Leyburn) and Warahgai (3 km south of Karara).

Table 1. Details of experiments at each site

Locality	Soil	Species type	Sowing date	N on grass plots kg/ha/year	Other fertiliser	
					Establishment kg/ha/year	Maintenance super kg/ha/year
Dalveen	Granite Dy3.41* pH=6.1 Avail. P=11ppm	Tropical	23 Nov 62		Super 500	125
		Tropical	16 Dec 63		Super 500	125
		Temperate	11 Jun 64		Super 500	125
		Tropical	4 Nov 66		Mo Super 500+KCl 125	125
		Temperate	18 Apr 67	0,100	Mo Super 500+Ag. lime 550	250
		Temperate	12 Jul 68	0,100	Mo Super 500	250
Leyburn	Sandstone Dy5.41 pH=6.3 Avail. P=4ppm	Tropical	10 Dec 63		Super 370+S/ A† 185	0
		Temperate	12 May 64		Super 185+S/A 185	0
		Tropical	30 Sep 64		Super 125+S/A 125	0
		Temperate	30 Jun 65		Super 125	0
		Temperate	10 May 67		Super 550+lime 550+KCl 125+Mg,Cu,Zn, Mn, B, Mo.	0
		Temperate	17 May 68		Super 250	0
Karara	Traprock Um5.51 pH=6.0 Avail. P=11ppm	Tropical	26 Oct 66	0,100	Mo Super 500+KCl 125	250
		Temperate	10 May 67	0,100	Mo Super 500+S/A 250 on grass	250
		Tropical	25 Oct 67	0,100	Mo Super 500+S/A 250 on grass	250

* Northcote (1965).

† S/A=Sulphate of ammonia.

All soils were infertile and moderately acid (surface pH 6.0 to 6.3) although the traprock subsoil was alkaline (pH=8.5). Phosphorus deficiency was most severe on the sandstone soil. The surface soil was light textured with low water-holding capacity, at all

sites, and the traprock soil was also hard-setting, leading to high runoff even at a moderate rainfall intensity. The depth of the A-horizon, which is thought to be important for some plants on duplex soils, was 30 cm on the granite and sandstone soils. Soil depth on the traprock site was approximately 60 cm.

A comparison of the climates of the three sites (Table 2) shows that the traprock and sandstone sites are very similar. The granite is a more favourable temperate environment, having a higher rainfall, lower temperatures, lower rainfall intensity and smaller moisture deficit. These differences are associated with its more eastern location and much higher altitude.

Table 2. Climatic averages of the sites, taken from Wills (1976)

	Property name		
	Palgrove	Brigalow Park	Warahgai
Mean annual rainfall (mm)	725	650	650
Summer rainfall (Oct to Mar)	475	425	425
Winter rainfall (Apr to Sep)	250	225	225
Altitude (m)	750	450	450
Mean max. temp. January (°C)	26	29	29
Mean temp. July (°C)	1	3	3
Rainfall intensity:			
All year (mm/day)	10.4	13.0	13.0
January	14.5	17.7	17.7
Moisture deficit (Thornthwaite)	Nov-May	Sep-May	Sep-May

Seed was hand-planted into a fully prepared seedbed in unreplicated plots 4 m×4 m, or in single 4 m rows when seed was scarce. Legumes were inoculated with the appropriate *Rhizobium* bacteria. Nearly all of the tropical species and temperate grasses were perennials, while the temperate legumes apart from lucerne and white clover were annuals (Table 3). While no grass was sown with the legumes, native grasses and weeds invaded the plots in summer.

Establishment fertiliser consisting of superphosphate with or without other nutrients (Table 1) was applied to all plantings but annual maintenance dressings of super were not applied on the sandstone soil. Grasses in the later plantings received fertiliser N at 100 kg/ha/yr on half the plot.

All sites were grazed for short periods with sheep or cattle in summer and winter but generally not in spring. The species were rated for persistence and growth, and notes were made on flowering times, seed set and any observations of special interest. Dry matter yields were measured on 1 October 1969 from a planting made on the granite soil on 18 April 1967.

RESULTS

Quantitative measurements of persistence and productivity of plants under test were rarely possible. However, repeated ratings for up to eight years enabled major trends to be identified. Productivity was judged against the unproductive native grasslands of the area producing 1000 kg/ha/yr of dry matter (DM). The following terms were used to describe persistence and production:

Very persistent=Maintained stand for 4 to 6 years including a drought.

Persistent=Maintained stand for 4 years with minor thinning.

Moderately persistent=Maintained stand for 3 years before major thinning.

Not persistent=Died out in 1 to 2 years.

Very productive=DM yield of 4000 to 6000 kg/ha in favourable years.

Productive=DM yield of 2000 to 4000 kg/ha in favourable years.

Moderately productive=DM yield of 1000 to 2000 kg/ha in favourable years.

Unproductive=DM yield of 0 to 1000 kg/ha in favourable years.

Table 3 shows the suitability of species evaluated at each site, which are referred to by their common names in the text. A rating of +++ indicates valuable persistence and productivity.

Table 3. Evaluation of species sown at each trial site: +++= good persistence, moderately productive; ++= fair; += poor; -= not sown or establishment in sufficient for equaluation

Species	Cultivar	Common name	Granite	Traprock	Sandstone
Tropical legumes					
<i>Lablab purpureus</i>	Rongai	Lablab bean	++	-	++
	CPI 16507*		++	-	-
	CPI 29399		++	-	-
<i>Lotononis bainesii</i>	Miles	Lotononis	-	++	-
<i>Macrotyloma axillare</i>	Archer	Perennial horse gram	-	+	-
<i>Macrotyloma uniflorum</i>	Leichhardt	Horse gram	-	+	-
<i>Macroptilium atropurpureum</i>	Siratro	Siratro	++	+	++
<i>Macroptilium lathyroides</i>	Murray	Phasey bean	+	+	-
<i>Neonotonia wightii</i>	Tinaroo		+	+	+
	Cooper		-	-	-
	CPI 25920		-	+	-
<i>Phaseolus panduratus</i>	CPI 1002		-	+	-
<i>Stylosanthes guianensis</i>	Oxley	Fine stem stylo	+	-	-
<i>Vigna vexillata</i>	CPI 17457	Wild cowpea	+	-	-
Tropical grasses					
<i>Cenchrus ciliaris</i>	Gayndah	Buffel grass	+	-	-
	American		+	-	-
	Cloncurry		+	-	-
	Biloela		++	++	+++
	Boorara		-	++	-
	Lawes		-	++	-
	Tarewinnabar		-	+	-
	Nunbank		-	++	+++
	Molopo		-	+++	++
<i>Chloris gayana</i>	Pioneer	Rhodes grass	+++	++	+++
	Katambora		+++	++	+++
	Callide		+++	+	++
	Nzoia		-	++	-
	CPI 15692		-	+	-
	Samford		-	+	-
<i>Digitaria smutsii</i>	CPI 16776 (<i>syn.</i> 38869)	Tall finger grass	-	+++	+++
<i>Panicum maximum</i>	Gatton	Panic	-	++	+++
		Guinea grass	-	-	+
<i>Panicum maximum</i> var. <i>trichogume</i>	Petrie	Green panic	++	+	++
<i>Panicum coloratum</i>	Burnett	Makarikari grass	+	++	+
	Bambatsi		++	-	-
<i>Paspalum plicatulum</i>	Rodd's Bay	Plicatulum	-	+	-
<i>Paspalum scrobiculatum</i>	Paltridge	Scrobic paspalum	-	-	+
<i>Pennisetum purpureum</i>		Elephant grass	-	-	+
<i>Setaria spacelata</i>	Nandi	Setaria	-	+	-
<i>Sorghum bicolor</i>	Sugardrip	Sweet sorghum	+	-	-
<i>Sorghum</i> spp. <i>hybrid</i>	Redbine	Forage sorghum hybrid	+	-	-
	66×SA1366		-	-	-
	Sudax		-	-	+

Table 3. continued

Species	Cultivar	Common name	Granite	Traprock	Sandstone
Temperate legumes					
<i>Lupinus angustifolius</i>	Uniwhite	Narrow-leafed lupin	+	-	-
<i>Lupinus luteus</i>	Weiko III	Yellow lupin	+	-	-
<i>Medicago glutinosa</i>		Glutinosa lucerne	-	-	++
<i>Medicago littoralis</i>	Harbinger	Strand medic	+++	+++	++
<i>Medicago lupulina</i>		Black medic	++	+	-
<i>Medicago sativa</i>	Hunter River	Lucerne	+++	+++	+++
	Du Puits		+++	-	-
	South African		+++	++	-
	Commercial				
	SIRO Peruvian		+++	++	+++
	Indian		-	++	-
<i>Medicago scutellata</i>	Robinson	Snail medic	+	+++	+
<i>Medicago truncatula</i>	Cyprus	Barrel medic	++	++	-
	CPI 13925		-	-	+
	Jemalong	++	+++	++	-
<i>Medicago turbinata</i>			+	-	-
<i>Melilotus alba</i> var. <i>denta</i>	CPI 31637	Bokhara clover	+	-	-
<i>Ornithopus compressus</i>	Pitman	Yellow serradella	++	-	-
	CPI 16622		++	-	-
<i>Ornithopus isthmocarpus</i>	CPI 14440	Serradella	+	-	-
<i>Ornithopus perpusillus</i>	CPI 32013	Serradella	+	-	-
<i>Ornithopus sativus</i>	CPI 14442	Serradella	+	-	-
	French		++	-	-
	CPI 16379		+	-	-
<i>Trifolium cherleri</i>	CPI 27374	Cupped clover	+	-	-
	CPI 15638		+	++	-
	CPI 30445		+	++	-
	Yamina		+	++	-
	CPI 13930		+	-	-
<i>Trifolium globosum</i>	Q5392	Globe clover	++	++	-
<i>Trifolium glomeratum</i>		Clustered clover	+++	+++	++
<i>Trifolium hirtum</i>	CPI 13949A	Rose clover	-	++	-
	West. Aust.				
	Commercial		+++	++	-
	Q7179		-	++	-
	Sirint		++	-	++
	CPI 19949		-	+	-
	Hykon		+++	+++	++
	Troodos		++	-	-
	Olympus		++	++	-
	Kondinin		++	+++	++
<i>Trifolium hybridum</i>		Alsike clover	++	-	-
<i>Trifolium repens</i>	Louisiana	White clover	++	++	-
	Ladino		++	+	-
<i>Trifolium resupinatum</i>	CPI 27375	Persian clover	+	+	-
	CPI 27376		+	+	-
	CPI 27377		+	+	-
	CPI 27378		+	-	-
<i>Trifolium semipilosum</i>		Kenya white clover	-	+	-
<i>Trifolium spumosum</i>	CPI 40617	Bladder clover	-	-	++
	CPI 28418		+	++	-
	CPI 15650		++	++	-
	CPI 14932		+	-	-
	CPI 14933		+	-	-
<i>Trifolium subterraneum</i>	Tallarook	Sub clover	+	+	-
	Yarloop		+++	++	-
	Wooenellup		++	-	+
	Mt. Barker		++	+	+
	Bacchus Marsh		+++	+	-
	Clare		+++	+	+
	Dwalganup		++	++	+
	Howard		+++	-	-
	Geraldton		+++	+++	++
<i>Vicia villosa</i> ssp. <i>dasycarpa</i>		Woolly pod vetch	++	-	-
	Lana (CPI 28633)		+	-	+

Table 3. continued

Species	Cultivar	Common name	Granite	Traprock	Sandstone
Temperate grasses					
<i>Bromus unioloides</i>	CPI 11895	Prairie grass	+	-	-
	Priebe		++	++	-
<i>Dactylis glomerata</i>	Akaroa	Cocksfoot	+	-	-
	Danish		++	-	-
<i>Ehrharta calycina</i>		Perennial veldt grass	-	-	+++
<i>Festuca arundinacea</i>	Demeter	Fescue	+++	-	+
<i>Lolium perenne</i>	9-7-2	Perennial ryegrass	+	+	-
	Grasslands				
	Ruanui		+	+	-
	Clunes		+	+	-
	Kangaroo Valley		++	+	+
<i>L. perenne</i> × <i>L. multiflorum</i>	Grasslands				
	Manawa	Hybrid ryegrass	+	+	-
<i>Lolium rigidum</i>	Wimmera	Annual ryegrass	++	+	+
<i>Phalaris aquatica</i>	Australian	Phalaris	++	+	+++
<i>P. aquatica</i> × <i>P. arundinacea</i>		Ronpha grass	-	-	+++
Other species					
<i>Brassica napus</i> var. <i>napus</i>	Dwarf Essex	Rape	-	-	+
	Giant Kangaroo		-	-	+
<i>Brassica oleracea</i> var.					
<i>acephala</i>	Chou Moellier	Kale	-	-	+
	Thousand-head		-	-	+
<i>Oenothera</i> sp.		Evening primrose	-	-	+

* CPI = Commonwealth Plant Introduction number.

Granite

Tropical legumes

The only persistent legume was Siratro but it required wet summers to make useful growth. Lab lab bean was moderately productive as an annual crop but was frosted before reaching maturity. The failure of most other legumes to persist beyond one year was attributed to frost and inadequate summer rainfall. However, fine stem stylo, possessing a degree of tolerance to drought and frost, as well as flowering in summer, may have failed to set seed in the first year because a December planting was too late.

Tropical grasses

The outstanding grass was Rhodes grass with cultivars Pioneer, Katambora and Callide all being very persistent (at least 6 years) and moderately productive. Although possessing some frost resistance, Rhodes grass was completely frosted during June, July and August. Biloela buffel, green panic and makarikari grass were moderately persistent but less productive.

Temperate legumes

The outstanding legume was lucerne which was persistent and productive for at least 6 years. All strains did well, growing between September and May and being relatively winter-dormant (June to August).

A range of winter annual legumes was persistent and productive in years of near-average winter rainfall. These were Harbinger strand medic, clustered clover, rose clover (Western Australian Commercial and Hykon) and sub clover (Yarloop, Bacchus Marsh, Clare, Howard, Geraldton).

The barrel medics (Cyprus, Jemalong), serradella (Pitman, French), globe clover, white clover and woolly pod vetch all showed some merit. The serradellas were hindered by poor regeneration except for Pitman which gradually improved over several years. White

clovers behaved as annuals in most years but some plants were perennial in wet years. Woolly pod vetch was adapted to the soil type but was erratic.

Most annual legumes appeared to suffer from slow nodulation and consequent slow early growth, which restricted their productivity.

Temperate grasses

Most grasses showed poor persistence through summer and only tall fescue, which was moderately productive, survived beyond the third year. Species with moderate productivity but persistence of only 2 to 3 years were prairie grass, cocksfoot, Kangaroo Valley ryegrass, Wimmera ryegrass and phalaris.

Traprock

Tropical legumes

The only species with any persistence was lotononis which was sporadically productive. It set seed in summers with favourable rainfall.

Tropical grasses

The species with outstanding persistence and moderate productivity were Molopo buffel and tall finger grass (*Digitaria smutsii* CPI 38869) which maintained strong stands after four years. Others with moderate persistence were buffel grass (Biloela, Boorara, Lawes and Nunbank), Rhodes grass (Pioneer, Katambora and Nzoia), Gatton panic and Burnett makarikari grass. Productivity was generally low and similar to that of adjacent native grassland except where N fertiliser and above-average rainfall were received.

Temperate legumes

The outstanding legume was lucerne, with all cultivars sown being productive, but Hunter River showing superior persistence (5 years) over South African Commercial, Siro Peruvian and Indian (2 to 3 years).

A range of winter annual legumes similar to that on the granite soil, was found to be persistent and moderately productive on the traprock. The medics were a little better and the sub clovers worse than on the granite. The best species were annual medics (Jemalong, Robinson, Harbinger), rose clover (Hykon and Kondinin), Geraldton sub clover and clustered clover. Cupped clover and bladder clover performed better than on the granite. Productivity of legumes generally was restricted by poor early nodulation and slow growth.

Temperate grasses

The traprock was too dry for temperate grasses which, although moderately productive, generally did not persist beyond two years. The only exception was Priebe prairie which persisted as a perennial for at least five years where N was applied, and was moderately productive.

Sandstone

Tropical legumes

Of the three legumes which were successfully established, lab lab bean was moderately productive as an annual forage, while Siratro was persistent but only sporadically productive in wetter summers. *Neonotonia wightii* (Tinaroo) perished in a heatwave in its first summer.

Tropical grasses

Five grasses persisted for at least four years (which included the 1965 drought) and were moderately productive. These were tall finger grass (very persistent), Rhodes grass (Pioneer and Katambora), buffel grass (Biloela and Nunbank) and Gatton panic. Other species with moderate growth and persistence were Callide Rhodes, Molopo buffel and green panic.

Temperate legumes

Lucerne was again the outstanding legume, with Hunter River and Siro Peruvian being productive and persistent for at least four years. Glutinosa lucerne also persisted well.

Winter annual legumes were moderately productive in the first year but suffered severely thereafter from poor growth including poor nodulation and were unproductive. The best species were annual medics (Jemalong, Harbinger), Geraldton sub clover and rose clover (Sirint, Hykon, Kondinin). Clustered clover and bladder clover, although sparse, persisted and remained relatively healthy.

Temperate grasses

Three temperate perennial grasses, namely Australian phalaris, ronpha grass (established vegetatively) and perennial veldt grass all persisted for at least four years and were moderately productive. The ryegrasses grew well in the first year but failed to persist.

Other species

Rape, kale and evening primrose were unproductive on this soil type.

Yield measurements

Dry matter yields of winter annual legumes on the granite, when ungrazed during winter and spring and sampled at ground level on 1 October 1969, are shown in Table 4. Rainfall during the winter (April to September) was nearly average at 212 mm. The highest yield was recorded from Kondinin rose clover with 6190 kg/ha. Six cultivars were very productive with yields above 4000 kg/ha. African lucerne produced only 1270 kg/ha in the same time.

More recent experience from numerous experimental and commercial sowings is also incorporated in the comments which follow.

Table 4. Oven dry yield of winter annual legumes and lucerne on a granite soil on 1 October 1969 from a planting in 1967

Species	Cultivar	Yield (kg/ha)	Species	Cultivar	Yield (kg/ha)
<i>T. hirtum</i>	Kondinin	6190	<i>M. scutellata</i>	Robinson	2800
<i>T. subterraneum</i>	Bacchus Marsh	5640	<i>M. littoralis</i>	Harbinger	2800
<i>T. hirtum</i>	Olympus	5360	<i>T. repens</i>	Louisiana	2750
<i>O. sativus</i>	Pitman	4460	<i>T. cherleri</i>	Yamina	2730
<i>T. hirtum</i>	Hykon	4430	<i>T. globosum</i>	Q5392	2440
<i>T. hirtum</i>	Troodos	4120	<i>M. truncatula</i>	Jemalong	2170
<i>T. hirtum</i>	Sirint	3920	<i>M. truncatula</i>	Cyprus	2130
<i>T. subterraneum</i>	Clare	3370	<i>M. sativa</i>	African	1270

DISCUSSION

These experiments have identified a range of legumes and grasses suitable for further evaluation as sown pastures in the granite and traprock area of south-east Queensland. The most important of these is lucerne, supplemented by winter annual legumes. Lucerne was persistent and productive on all soil types, with dry matter yields around four times those of native pasture (Clarkson and Andrew 1976). African lucerne produced less dry matter than the winter annual legumes on the granite in a favourable winter, apparently because of dormancy. Use of more winter-vigorous cultivars of lucerne which are now available could increase its cool-season growth.

Although our successful lucerne establishment using lime pelleted inoculated seed was repeated in adjacent experiments on the granite (Clarkson and Andrew 1976) and traprock

sites (C.S. Andrew, pers. comm.), there are substantial areas where lucerne has not been grown successfully (Swann 1982). These soils are less fertile and more acidic (pH below 5.7) and early death of lucerne seedlings has been observed, for example on the sandstone soils (Leslie *et al.* 1967). Establishment has been improved by applying broadcast lime at least a year before sowing, followed at sowing by drilled lime, high rates of inoculum, and a fungicide to control *Pythium* (McKenzie *et al.* 1972). Poor persistence has still limited the usefulness of lucerne on these soils but newly released varieties with greater disease resistance may prove superior.

The experiments identified adapted winter annual legumes to supplement lucerne, particularly in the genera *Trifolium* and *Medicago*. These species will reduce the gap in winter and spring growth as lucerne dies out. Both climatic and edaphic factors determine the best habitat for each genus. The annual *Medicago* species, although climatically suited to the whole region, require copious lime (Robson 1966; Russell 1966) and are suited only to the less acid (pH > 6) and more loamy soils. The annual *Trifolium* species, requiring less lime, are more suited to the more acidic sandy soils. However, they generally require a higher rainfall than the *Medicago* species. Sub clover is more productive on the granite belt than on the drier traprock and sandstone soils to the west. Clustered clover, despite being late flowering, is hardy on all three soils types and resistant to aphids.

Serradella, needing little lime, could also become useful on the more acid sandstone and granite soils, particularly as it is resistant to aphids (Swann 1982). Tests in other states have shown it is deep-rooted and thrives on some sandy soils where sub clover will not persist. In Western Australia it requires a deep (>40 cm) sandy soil (Gladstones and McKeown 1977), indicating that our soils were a little shallow.

Woolly pod vetch also prefers well drained deep soils. This may partly explain its erratic production on our shallow soils which are easily waterlogged. It has been useful in mixtures with oats, and is valuable for its resistance to aphids.

The slow early growth and nodulation of winter annual legumes in our experiments may have been improved by using the methods developed later for lucerne. However, on the sandstone soil this problem greatly reduced their value after the first year. Although our sowings did not receive maintenance dressings of superphosphate, applications elsewhere on the property did not overcome the problem. Susceptibility to nematodes is also a problem for legumes on this soil (R.C. Colbran, pers. comm.). Rose clover is also prone to nodulation problems (A. Diatloff, pers. comm.) and should not be sown on the poorer soils.

Periodic poor regeneration of annual legumes appeared to follow premature germination of seed in wet summers, particularly with rose clover on the granite soil. A higher level of hardseededness in *Trifolium* cultivars and perhaps *Ornithopus*, appears desirable. This has led recently to the use of Seaton Park as the preferred sub clover in the area. High levels of hardseededness in annual *Medicago* species (Hagon 1974) may explain the better persistence of annual medics on the traprock soil.

Most temperate grasses were suitable only for short-term use on the granite soil, even with its relatively favourable rainfall. Tall fescue was the most persistent perennial, and has become useful commercially on all three soil types where rainfall exceeds 700 mm. Phalaris also prefers a higher rainfall. Wimmera ryegrass, a useful annual species (Swann 1982), gradually builds up in sown pastures on all soils. On better soils with a rainfall exceeding 700 mm/yr, Kangaroo Valley and Tamar rye grasses have proved superior to Wimmera.

The failure of most tropical legumes to persist was attributed to low summer rainfall and winter frost. It is unlikely that even the best species (lotononis and Siratro) will be of major importance due to low productivity. However, recent encouraging results with *Stylosanthes* species including Oxley at Leyburn suggest that further testing is warranted.

Although some tropical grasses persisted well, their role is in old cultivations where natural pasture regeneration is very slow. Water stress and nitrogen deficiency limit their use as replacements for native pastures, with the possible exception of tall finger grass which was palatable and showed long-term ability to persist and spread under grazing. This species should be tested on granite soils.

These results are in general agreement with those of Jones and Rees (1972) who tested a wide range of tropical and temperate pasture species, and Ivory (1982) who examined temperate grasses in more detail. Both programmes included clay soils on the eastern Downs with annual rainfall similar to the granite site (700 mm), but did not test the species on poor soils at this rainfall.

The results are similar in identifying these drier areas as being too dry for white clover, with the exception of the cultivar Haifa which is showing considerable promise (Swann 1982), but suitable for lucerne and medics. There is also agreement on the poor persistence and productivity of temperate grasses, although my results with tall fescue were more encouraging. The performance of tropical legumes and grasses was poorer than reported by Jones and Rees (1972), as expected from the harsher environment, but greater emphasis was placed in our work on the value of tall finger grass.

A major difference in this study was that annual *Trifolium* species showed more promise than the annual *Medicago* species, particularly on the granite soil. This is adequately explained by the sharp contrast in soil fertility between our light-textured poor soils and the relatively fertile heavy clay soils used in earlier work, together with the relatively favourable temperate environment of the granite belt.

I concluded that pasture improvement with exotic species should therefore be based on lucerne and winter annual legumes, well fertilised with superphosphate supplemented by lime on very acid soils, to establish productive and persistent stands. This should in turn provide improved conditions for growth of native grasses as the soil nitrogen fertility is improved. Where native grasses have been removed by repeated cultivation, tall finger grass and Rhodes grass appear to be the best tropical grasses, while in the wetter areas tall fescue is the best adapted temperature grass.

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References

- Clarkson, N. M. and Andrew, C. S. (1976), Mineral nutrition and persistence of lucerne on the granite belt of south-east Queensland, *Tropical Grasslands* 13, 75.
- Gladstones, J. S. and McKeown, N. R. (1977), *Serradella-a pasture legume for sandy soils*, Western Australian Department of Agriculture Bulletin No. 4030.
- Hagon, M. W. (1974), Regeneration of annual winter legumes at Tamworth, New South Wales, *Australian Journal of Experimental Agriculture and Animal Husbandry* 66, 57.
- Ivory, D. A. (1982), Evaluation of temperate grass species for the Eastern Darling Downs of Queensland, *Tropical Grasslands* 16, 63.
- Jones, R. M. and Rees, M. C. (1972), Persistence and productivity of pasture species at three localities in subcoastal south east Queensland, *Tropical Grasslands* 6, 119.
- Lee, G. R. (1961), To improve pastures in the traprock and granite soils of south-east Queensland, *Queensland Agricultural Journal* 87, 149.

- Lee, G. R. and Rothwell, W. E. M. (1966), Effects of grazing lucerne supplementation and stocking rate on sheep and native pasture productivity in the Queensland traprock region: Progress report 1962-65, *Queensland Journal of Agricultural and Animal Sciences* 23, 287.
- Leslie, J. K., Mackenzie, J. and Glasby, T. J. (1967), Species and mineral nutrition studies on deep sands of solodic associations—a progress report, *Tropical Grasslands* 1, 187.
- McKenzie, J., Glasby, T. J. and Diatloff, A. (1972), The role of nodulation and damping-off in lucerne establishment on acidic sandy soils on the Darling Downs, *Australian Journal of Experimental Agriculture and Animal Husbandry* 57, 428.
- Northcote, K. H. (1965), *A factual key for the recognition of Australian soils*, CSIRO Division of Soils, Divisional Report 2/65, Adelaide.
- Robson, A. D. (1966), Soil factors affecting the distribution of annual *Medicago* species, *Journal of the Australian Institute of Agricultural Science* 35, 154.
- Russell, J. S. (1966), Plant growth on a low calcium status solodic soil in a subtropical environment. I. Legume species, calcium carbonate, zinc and other minor element interactions, *Australian Journal of Agricultural Research* 17, 673.
- Swann, I. F. (1982), Pastures on the traprock, sandstone and dry granite lands of the Warwick district, *Queensland Agricultural Journal* 108, 50.
- Wills, A. K. (1976), *The granite and traprock area of south east Queensland*, Division of Land Utilisation Technical Bulletin No. 13, Queensland Department of Primary Industries, Brisbane.

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