EVALUATION OF TEMPERATE LEGUMES ON A SOLODIC SOIL AND A GILGAIED CLAY SOIL IN THE SOUTHERN BRIGALOW REGION

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ABSTRACT

The possibility that certain temperate legumes can grow, fix significant amounts of nitrogen and persist in the southern brigalow region was studied on a low fertility solodic soil and a heavily gilgaied clay soil.

The most promising species were annual Medicago *spp. On the solodic soil the* M. truncatula *cultivars Jemalong, Cyprus and Woodside were outstanding in yield, persistence and nitrogen content. On the gilgaied clay* M. truncatula *cv. Cyprus,* M. littoralis *cv. Harbinger and* M. scutellata *showed promise.* Trifolium hirtum *cultivars also persisted over five seasons on the solodic soil although their mean annual production was about half that of the best annual medics.*

On the solodic soil a mean annual medic contribution of up to 50 lb N per acre appears possible.

Establishment of annual medics presents few problems in cultivated areas but some special management involving heavy grazing in late summer may be necessary to allow medics to contribute maximum amounts of nitrogen to the soil-plant system. Application of phosphorus and trace elements appears necessary for satisfactory growth on some solodic soils.

The results suggest that self regenerating, annual temperate legumes can play a supplementary role in this environment both in long term temperate legume-tropical grass pastures and in short term leys in cropping rotations.

INTRODUCTION

The growth of pasture legumes in the southern brigalow region is greatly affected by climate. Rainfall varies from 20-28 inches annually but its distribution is variable with high rainfall per wet day and relatively few wet days per year (Isbell 1957). Although nominally a summer rainfall region the role of tropical legumes is limited by the extremely variable summer rainfall and high evaporation and restricted by the occurrence of low night temperatures and frosts other than during the main summer months (Coleman 1964). On the other hand there is a component of winter rainfall which, although only one-third of the annual rainfall, has the advantage of being relatively more effective than equivalent summer rainfall.

The importance of nitrogen in the brigalow region in affecting the daily growth rate of summer-growing tropical grasses with a high potential for rapid growth has been shown (Russell 1968). There are large areas of infertile soils (mainly solodic) which are very nitrogen deficient. Adequate use of these soils is dependent upon an increase in the amount of nitrogen available for plant growth. Although the more fertile brigalow soils have high initial total nitrogen contents there is some evidence that these decline slowly when cleared and grazed as volunteer grasslands, or alternatively, decline rapidly when cultivated and sown to summer or winter-growing crops. However, the semi-arid conditions and extensive agriculture limit the possible use of nitrogen fertilizers and pasture legumes represent the most feasible means at present of increasing the amount of nitrogen circulating in the soil-plant-animal system.

The possibility that temperate legumes might be able to grow, fix significant amounts of nitrogen and persist under the climatic conditions in the southern brigalow region was examined at two sites in southern Queensland, Tara and

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Meandarra. Experiments were established in 1964 at Tara on a low fertility solodic soil with a light textured surface soil. Experiments were later established at Meandarra on a heavily gilgaied grey and brown clay soil. The results are reported in this paper.

METHODS

Experiments on solodic soil

Three experiments were carried out at Tara adjacent to each other on an area originally carrying mainly ironbark *(Eucalyptus crebra)* and bulloak *(Casuarina lehmannii)* forest which had been ringbarked and cleared for many years but had no previous cultivation. The soil was solodic with a light textured loamy sand surface soil (ca pH 5.8) and a dense heavier alkaline subsoil (ca pH 7.5). Soil nitrogen and phosphorus contents were low. Details of chemical and physical characteristics are given in Russell (1966).

TABLE 1
Species and cultivars sown at Tara in 1964 (Experiment 1)

Species	Cultivar or No.	Species	Cultivar or No.
Trifolium hirtum	Sirint	*Medicago truncatula*	Hannaford
„ „	Troodos	„ „	Jemalong
„ „	Hykon	„ „	Woodside
„ „	Kondinin	„ „	Cyprus
„ *cherleri*	Beenong	„ „	CPI 19388
„ „	Yamina	„ „	SA 395
„ „	CPI 15638	„ „	CPI 28402
„ *clypeatum*	CPI 14925	„ *littoralis*	Harbinger
„ *glomeratum*	CPI 25871	„ *orbicularis*	N 302
„ *nervulosum*	CPI 15344	„ *scutellata*	CPI 12535
„ *palaestinum*	CPI 22988	„ „	No. 34
„ *resupinatum*	CPI 21968	„ *turbinata*	CPI 19403
„ *spumosum*	S 10	„ *sativa*	Hunter River
„ *stellatum*	CPI 14929	„ „	African
„ *striatum*	CPI 22114	*Vicia angustifolia*	CPI 10402M
„ *tomentosum*	CPI 13946	„ *atropurpurea*	XN1
„ *velvivolum*	CPI 13934	„ „	V222
„ *xerocephalum*	CPI 14949	„ *sativa*	CPI 15504
„ *subterraneum*	Dwalganup	„ „	V221
„ „	Carnamah	„ *dasycarpa*	CPI 9189
„ „	Woogenellup	„ „	CPI 28633
„ „	Geraldton	*Trigonella lesseriana*	CPI 23330
„ „	Northam A	„ *cretica*	CPI 23331
„ „	Bacchus Marsh		
„ „	Clare		
„ „	Howard		

Experiment 1

Forty-nine species and cultivars (Table 1) were sown in 3 replications of plots 25 x 15 links. Two of the replications were initially fertilized at the per acre rate of 4 cwt of superphosphate, 1 cwt of potassium sulphate, 14 lbs zinc sulphate, 7 lbs copper sulphate and 2 oz of molybdenum. The other replication received half rate of the above fertilizers. All replications received 5 cwt per acre of lime and 2.2 cwt/per acre of superphosphate was applied on May 8, 1964. The seed was inoculated with the appropriate *Rhizobium* strain, lime pelleted and sown at the rate of 6 lb per acre by hand under dry conditions on May 24, 1964. The soil was raked by hand to cover the seed.

Annual samplings were made in September each year other than in 1964 when some species were harvested in October and early November. Harvests of plant yield were made by cutting three small quadrats (usually 5 x 2 links) per plot and separating out sown species. In March 1968 three 2 x 2 link random quadrats were thrown in plots of *Medicago* spp. The burrs on the soil surface were collected, weighed and an estimate obtained of the number of seeds per burr. Soil samples were taken in April 1968 with a soil tube. Four hundred and eighty soil samples from 0-5 cm were taken from 60 selected plots. Total nitrogen and pH were determined on the bulked plot samples.

TABLE 2

Species and cultivars sown at Tara in 1964 (Experiment 2)

Species	Cultivar or No.	Species	Cultivar or No.
Trifolium subterraneum	Mt. Barker	*Medicago truncatula*	CPI 19385
,, ,,	Tallarook	,, ,,	CPI 19386
,, ,,	Carnamah x Howard J420	,, ,,	CPI 19387
		,, ,,	CPI 19389
,, ,,	Cranmore x N_1E. 38-19	,, ,,	CPI 19401
		,, ,,	CPI 13925
,, ,,	Bass BxN_1E. J607	,, ,,	SA396
,, ,,	Tallarook x Cranmore 36-64-17	,, ,,	CPI 28399
		,, ,,	CPI 28400
,, ,,	,, 10-16	,, ,,	CPI 28401
,, ,,	Tallarook x Northam 1st early 20-51	,, ,,	CPI 28403

Experiment 2

Eight cultivars of *Trifolium subterraneum* and 11 cultivars of *Medicago truncatula* (Table 2) were sown in a single replicate of 25 x 15 link plots on May 24, 1964. Fertilization was similar to the odd replicate in Experiment 1. Observations in growth were made during the period 1964-68. A harvest was carried out on the *Medicago* spp in September 1968.

Experiment 3

This experiment was of a plaid design in 2 replications. The temperate species were *Medicago truncatula*, cv Jemalong, *M littoralis* cv Harbinger, *M. sativa* cv Hunter River and *Trifolium subterraneum* cv Bacchus Marsh. The six nutrient treatments were (1) 0, (2) P, (3) PL, (4) PTE, (5) PTEL, (6) L, where P = 4 cwt superphosphate per acre, L = 5 cwt lime per acre, PTE = 4 cwt superphosphate plus trace elements Zn 0.08% as $ZnSO_4$, Cu 0.09% as $CuSO_4$ and Mo 0.03% as molybdenum trioxide. Plot size was 20 x 10 links. The fertilizer was hand spread and the species hand sown and cultivated with a sod seeder on 5th May, 1965. Several harvests were made on these plots.

Experiments on gilgaied clay soil

Two experiments were carried out at Meandarra on a deep gilgaied clay soil (Isbell 1957, 1962). Characteristics of this area, which was originally covered by an almost monospecific forest of *Acacia harpophylla* (brigalow), were described by Moore, Russell and Coaldrake (1967) and Russell, Moore and Coaldrake (1967). The area where Experiment 5 was carried out was pulled in 1962 and burnt in 1963. No cultivation had been previously carried out. The area of Experiment 4 was cleared much earlier. Cultivation and partial levelling had been carried out. Characteristics of the gilgaied soil are shown in Table 3. The approximate gilgai frequency was 27 an acre and the average depth was 2.7 feet.

TABLE 3

Characteristic of gilgaied soils from the Meandarra site (Experiment 5)

Topographic Position	Depth cm	pH	Conductivity of Sat. Extract mmhos/cm25°C	Total Nitrogen %	Exchange capacity (me/100g)	Exchangeable cations (me/100g)			
						Ca	Mg	K	Na
Top of Microrelief	0-10	5.45	3.02	0.124	31.2	13.4	8.1	0.70	1.3
	30-60	4.12	4.65	0.049	31.3	7.0	8.8	0.13	4.2
	60-90	3.73	9.63	0.042	28.2	5.3	8.4	0.13	5.6
Slope of Microrelief	0-10	7.28	2.71	0.256	35.1	22.5	4.2	0.86	1.3
	30-60	7.70	5.82	0.040	30.8	12.7	11.4	0.40	5.6
	60-90	6.85	7.05	0.025	26.2	7.9	9.0	0.21	6.4
Depression of Microrelief	0-10	7.52	2.45	0.170	40.0	27.9	6.0	1.21	1.4
	30-60	6.50	6.75	0.101	33.8	15.8	7.7	0.83	3.2
	60-90	4.48	8.86	0.037	28.4	6.7	7.6	0.13	5.4

TABLE 4

Rainfall data (in points) at experimental sites

Site	Year	Month												April to Sept.	Total for Year
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.		
Tara Site	1964	177	80	449	161	273	82	155	104	315	472	104	242	1096	2614
	1965	121	35	—	72	11	68	429	111	185	26	201	722	876	1961
	1966	153	336	104	147	30	121	6	330	236	196	232	117	723	2008
	1967	109	53	229	29	74	501	116	113	19	165	201	34	852	1643
	1968	390	71	282	233	125	12	264	183	83	43	57	470	900	2193
Tara P.O.* Frequency	Mean	313	274	270	135	131	155	146	100	104	215	257	317	771	2416
	20%	518	502	419	242	216	265	204	182	185	332	413	531	1085	2956
	40%	291	246	230	156	146	164	147	103	96	227	257	313	844	2634
	60%	214	145	169	60	56	113	97	59	61	140	159	240	656	2313
	80%	119	101	53	27	15	42	49	23	30	70	67	149	455	1822
Meandarra Site	1966	146	191	199	65	34	168	12	501	119	74	101	155	899	1765
	1967	108	59	243	9	174	525	25	23	10	163	110	34	766	1483
	1968	379	68	197	320	107	8	320	129	76	54	—	356	960	2014
Coomrith* Frequency	Mean	297	273	266	121	141	139	152	91	117	168	219	247	761	2231
	20%	445	481	397	210	233	235	228	153	182	291	364	408	1077	2875
	40%	273	238	268	120	125	142	146	89	122	163	243	292	849	2318
	60%	174	152	199	68	56	83	95	46	65	92	136	175	608	2032
	80%	109	62	57	20	1	34	34	18	17	46	50	89	426	1597

*Analysis of Tara and Coomrith rainfall data based on 53 and 76 years respectively. A 20% frequency, for example, means that such a value has been exceeded in 20% of the years examined.

Experiment 4

This experiment was a randomized block design of two replications with plots 50 x 20 links. The temperate species sown were *Medicago truncatula* cultivars Jemalong and Cyprus, *M. littoralis* cv Harbinger and *M. sativa* cv Hunter River. The experiment was sown with 2 lb per acre of *Sorghum almum*. The legumes were sown at 10 lb per acre and the experiment was established in late June 1966. Seed was inoculated and lime pelleted.

Observations were made in 1966 and 1967 and in September 1968 eight 5 x 2 link quadrats were harvested from the plots.

Experiment 5

This experiment was a plaid design of six legume species (split with and without P) and 4 tropical grass species. The temperate species were *Medicago sativa* cv Hunter River, *M. truncatula* cultivars Jemalong and Cyprus, *M. littoralis* cv Harbinger and *M. scutellata* (snail medic). The species were sown into a well worked seed bed on April 6, 1967 with a cover crop of 14 lb an acre of Benton oats.

Plots were 270 x 50 links long and 100 lb per acre of superphosphate was applied to half of each legume plot.

Sampling was carried out in August and September 1967 and in September 1968. Separation into oats, sown legume and weed in 1967 and sown legume and weed in 1968 were made on the basis of topography into top, slope and depression positions of the microrelief.

RESULTS

The rainfall recorded near the Tara site during 1964-68 and near the Meandarra site during 1966-68 is shown in Table 4. A frequency analysis of the 53 year record at Tara and the 76 year record at Coomrith is also shown. At Tara the mean April-September rainfall is 7.71 inches. This was exceeded in 4 of the 5 years of the study although in 3 of these years the excess was less than 1.5 inches. 1966 was below average. In fact the rainfall during the growing season of the temperate species was even less than that shown (7.23 inches) since 1.50 inches fell on September 29 after the legumes had been harvested. At Meandarra the April-September rainfall was about equal to the mean during 1967 and was slightly in excess of the mean during 1966 and 1968. In each of these years the total annual rainfall was below average.

Temperate legumes on solodic soil

Although experiments 1 and 2 were sown dry excellent establishment of all species (other than *T. resupinatum*) was obtained. Yield differences between species in the first year were not significant, but satisfactory growth of many of the species, including cultivars of *T. subterraneum*, was obtained. The highest yield was obtained with *T. subterraneum* (Bacchus Marsh) though greatly influenced by outstanding growth on one of the replicates.

Regeneration of some of the species was obtained in 1965 and 29 species were sampled. Growth was much less and only 10 species were harvested in 1966. In 1967, 27 species were sampled but the yield of 5 of these was below 100 lb dry matter per acre. In 1968, 27 species were harvested and in this year some of the highest yields were obtained. *Medicago truncatula* cultivars in particular gave high yields.

TABLE 5

Mean yields of nine annual temperate legumes on solodic soil at Tara

Species	Cultivar	Yield dry matter lb/ac 1964	1965	1966	1967	1968	Mean 1964-68
Trifolium hirtum	Sirint	720	340	50	110	810	407
" "	Troodos	530	290	130	350	650	390
" "	Hykon	520	710	100	430	700	489
" "	Kondinin	770	740	110	350	1270	648
Medicago truncatula	Hannaford	390	1150	370	720	850	696
" "	Jemalong	630	1260	480	1370	1670	1080
" "	Woodside	540	830	670	1250	1450	946
" "	Cyprus	710	700	780	1260	1470	984
Medicago littoralis	Harbinger	520	490	340	410	1210	594
Standard Error		220	260	245	340	300	230

TABLE 6

Mean yields of certain temperate species at Tara

Species	Cultivar or No.	Yield dry matter lb/ac 1964	1965	1966	1967	1968
Trifolium cherleri	Beenong	570	400	—	20	70
" "	Yamina	—	270	40	200	860
" "	CPI 15638	—	130	—	20	310
" *clypeatum*	CPI 14925	210	—	—	—	70
" *glomeratum*	CPI 25871	—	130	—	—	—
" *spumosum*	S10	240	80	—	40	290
" *tomentosum*	CPI 13946	—	—	—	180	790
" *velvivolum*	CPI 13934	—	680	—	170	270
" *subterraneum*	Dwalganup	290	—	—	—	—
" "	Carnamah	280	—	—	—	—
" "	Woogenellup	830	—	—	—	—
" "	Geraldton	370	—	—	40	140
" "	Northam A	230	—	—	—	—
" "	Bacchus Marsh	910	830	—	10	30
" "	Clare	580	170	—	—	—
" "	Howard	770	270	—	—	—
Medicago truncatula	CPI 19388	440	590	—	220	280
" "	SA395	—	120	—	140	600
" "	CPI 28402	500	580	—	780	1400
" *orbicularis*	N 302	570	360	—	270	510
" *scutellata*	CPI 12535	500	150	—	390	500
" "	No. 34	470	170	—	260	450
" *turbinata*	CPI 19403	10	80	—	120	270
" *sativa*	Hunter River	170	410	—	100	100
" "	African	320	230	—	—	—
Vicia atropurpurea	XN1	890	—	—	—	—
" *sativa*	CPI 15504	500	—	—	—	—
" *dasycarpa*	CPI 9189	400	—	—	180	290
" "	CPI 28633	440	70	—	430	420
Trigonella lesseriana	CPI 23330	470	80	—	—	—
Standard Error		220	260	—	340	300

The yields of nine of the most persistent and high yielding species are shown in Table 5. Although significant differences did not occur between these species in 1964 differences were evident in subsequent years and for the five year mean. The outstanding species were *Medicago truncatula* (cultivars Jemalong, Cyprus and Woodside), *M. littoralis* and *Trifolium hirtum*. Other species also persisted over the five year period including several species of *Trifolium* such as *T. cherleri, T. spumosum* and *T. velvivolum* (Table 6). However it was noticeable that although quite good growth was obtained by *T. subterraneum* cultivars at the end of the first season by the fifth season most of these had disappeared entirely and only odd plants of two cultivars persisted. A number of other *Medicago* species grew well in the fifth season.

TABLE 7

Data on surface burr levels of Medicago spp sampled in March, 1968 at Tara

Medicago spp	Cultivar or No.	Burr on Surface Soil lb/ac	N content of burr % (air dry)	Estimated seed per acre x 10^6 on surface
M. truncatula	Hannaford	113	—	1.0
,, ,,	Jemalong	392	2.29	7.4
,, ,,	Woodside	174	1.93	2.3
,, ,,	Cyprus	622	2.35	13.3
,, ,,	CPI 19388	37	—	0.2
,, ,,	SA 395	49	—	0.3
,, ,,	CPI 28402	398	—	5.9
M. littoralis	Harbinger	184	1.81	3.6
M. orbicularis	N 302	18	—	0.8
M. scutellata	CPI 12535	130	2.19	0.5
,, ,,	No. 34	102	—	0.2
Standard Error		120	—	2.8

Data on burr yields of some of the *Medicago* spp are shown in Table 7. Large amounts of burr were found after 4 seasons with Cyprus medic the highest. About 15 pound of nitrogen per acre was immobilized in the surface burr of this species.

TABLE 8

Nitrogen content of plant species and plot soils at Tara

Species	Cultivar	N(%)* at harvest	Mean above ground N content lb/acre*	Soil N(%)† 0-5 cm
Trifolium resupinatum	CPI 21968	—	—	0.100
Trigonella lesseriana	CPI 23330	—	—	0.088
Vicia sativa	V221	—	—	0.081
,, *dasycarpa*	CPI 9189	3.43	8.1	0.086
,, ,,	CPI 28633	3.87	16.4	0.092
Trifolium subterraneum	Geraldton	2.41	2.2	0.086
,, ,,	Bacchus Marsh	2.79	0.6	0.118
,, *hirtum*	Sirint	1.87	9.3	0.096
,, ,,	Troodos	2.25	11.4	0.081
,, ,,	Hykon	2.42	13.6	0.095
,, ,,	Kondinin	2.74	22.4	0.108
,, *cherleri*	Yamina	2.14	11.5	0.100
Medicago sativa	Hunter River	3.15	8.5	0.092
,, *scutellata*	CPI 12535	3.28	16.0	0.081
,, *littoralis*	Harbinger	2.93	16.8	0.094
,, *truncatula*	Hannaford	3.30	25.8	0.101
,, ,,	CPI 28402	3.13	34.2	0.096
,, ,,	Jemalong	3.52	53.6	0.101
,, ,,	Woodside	3.36	45.4	0.091
,, ,,	Cyprus	2.87	39.6	0.087
Standard Error		0.09	2.9	0.008

*Means of 1967 and 1968 harvests only.
†Sampled April, 1968.

Soil nitrogen contents of some of the plot soils and the nitrogen content of sampled plant material are shown in Table 8. The soil values are the mean of 3 replications. Mean values varied from 0.081 to 0.118 per cent N. Plant nitrogen values were affected by stage of growth but at the time of sampling values varied from 1.66 to 3.69 per cent N. Soil pH values did not vary greatly and the overall mean was 5.63 and the range 5.33 to 6.11.

The pattern of species persistence in Experiment 1 was repeated in Experiment 2. All *Trifolium subterraneum* cultivars had disappeared but most of the *M. truncatula* cultivars persisted and produced over 1000 pounds dry matter during 1968.

TABLE 9

Effect of fertilizer treatment on yield and chemical composition of temperate species at Tara (Experiment 3)

Characteristic	Fertilizer Treatment						Standard
	O	P	PL	PTE	PTEL	L	Error
Mean yield* lb dry matter/acre	176	342	444	515	530	88	129
Phosphorus (%)†	0.20	0.24	0.24	0.24	0.23	0.19	0.01
Calcium (%)	0.79	0.91	0.87	0.99	1.01	0.73	0.06
Copper (ppm)	7	5	4	9	7	8	0.9
Zinc (ppm)	53	41	40	56	50	55	6
Manganese (ppm)	70	65	84	58	73	70	8

*Mean dry matter yield is of *M. sativa, M. truncatuta* and *M. littoralis* harvested in September, 1965 and 1967.

†Chemical composition is a mean of 4 species in 1965.

TABLE 10

Chemical composition of three species sampled at Tara, September, 1967

Species	Chemical composition as %					
	N	P	Ca	Mg	K	Na
*M. truncatula** cv Jemalong	2.56	0.16	0.70	0.58	1.24	0.82
M. littoralis cv Harbinger	2.35	0.14	0.82	0.60	1.18	0.71
M. sativa cv Hunter River	2.77	0.10	1.12	0.63	1.36	0.33
Standard Error	0.13	0.02	0.10	0.05	0.11	0.13

*Values are mean of all nutrient treatments.

The effect of nutrients on the growth of certain temperate legumes on the solodic soil at Tara (Experiment 3) is shown in Tables 9 and 10. The main effect was due to superphosphate which significantly increased yields. The application of Cu, Zn and Mo further increased yields but the differences were not significant. Lime alone had no beneficial effects and even with superphosphate and trace elements the effects were variable with indications of species interactions. In this experiment as in Experiments 1 and 2, *T. subterraneum* did not regenerate significantly after the first year. Also comparatively poor growth was obtained of species other than *M. littoralis* after 1967 but this may have been due to the complete cutting of these plots which was carried out in 1967 as well as the lack of additional fertilization beyond the original application in 1965.

The mean nutrient content of four temperate species sampled in 1965 is shown in Table 9. Superphosphate significantly increased the P and Ca contents of the plants. Applied alone superphosphate was associated with decreased Cu and Zn contents but application of Cu and Zn restored the content of these elements to the unfertilized levels. The mineral nutrient content of three species sampled in 1967 is shown in Table 10. These show lower P contents than in 1965 and in the case of lucerne the level suggests deficiency (Chapman 1966). The cation data indicate that growth of some species on solodic soils is characterised by low Ca and high Mg and Na levels (Russell unpublished).

Temperate legumes on gilgaied clay soil

The yields of five species sown in 1966 on partially levelled gilgai soil and sampled in 1968 are shown in Table 11. The highest yielding cultivar was the Cyprus strain of *M. truncatula* which significantly outyielded Jemalong. *M. littoralis* also yielded exceptionally well.

The excellent growth of *M. truncatula* Cyprus was also shown on a virgin gilgaied area where it significantly outyielded Jemalong in September 1967 and 1968

TABLE 11

Yields (in lb dry matter/acre) of legumes on partially levelled gilgaied clay soil (Experiment 4) sampled in September, 1968

Species	Cultivar	Yield
Medicago truncatula	Cyprus	3000
„ „	Jemalong	370
„ *littoralis*	Harbinger	2090
„ *sativa*	Hunter River	1190
Standard Error		640

TABLE 12

Yield (in lb dry matter/acre) of temperate legumes, oats and other species in various topographic positions on gilgaied clay soil (Experiment 5)

Species	Cultivar	Date of Sampling	Topographic Position Top	Slope	Depression	Standard Error	Weighted Mean* Yield
M. truncatula	Cyprus	8/67	245	340	120	65	270
„ „	Jemalong	„	295	225	100		240
M. littoralis	Harbinger	„	145	20	5		70
M. scutellata	Snail	„	120	125	—		105
M. sativa	Hunter River	„	40	100	5		65
M. truncatula	Cyprus	9/67	745	865	40	50	690
„ „	Jemalong	„	365	305	25		290
M. littoralis	Harbinger	„	95	120	—		95
M. scutellata	Snail	„	330	285	130		280
M. sativa	Hunter River	„	90	65	30		70
M. truncatula	Cyprus	9/68	960	2040	1045	90†	1445
„ „	Jemalong	„	135	105	105		120
M. littoralis	Harbinger	„	720	810	410		715
M. scutellata	Snail	„	400	685	530		545
M. sativa	Hunter River	„	635	1230	345		855
A. sativa	Benton	8/67	3480	2280	1400	160	2660
„ „	„	9/67	5735	5440	2040	550	5085
Other species		8/67	230	55	5	30	120
		9/67	470	130	60	85	260
		9/68	1015	940	1270	135	1020

†Standard error for Depression values 225.
*Relative areas of topographic components are assumed to be Top 42%, Slope 44% and Depression 14%.

(Table 12). *M. sativa, M. littoralis* and *M. scutellata* also grew well in this situation. In 1967 all species in this experiment were established under oats. These were not grazed and, due to the favourable conditions, the oats grew prolifically and may have resulted in the relatively low yields of the temperate legumes. Although weed growth was pronounced in 1968 regeneration of the annual medic species was obtained.

Sampling in the various topographic positions of the microrelief is desirable in this environment. In 1967 yields were low in the depression areas because of waterlogging in the gilgais in June. In 1968 this effect did not occur and yields in the depressions were comparable with those in the higher parts of the microrelief.

The microrelief also has to be considered in the interpretation of effects of applied phosphorus (Russell, Moore and Coaldrake 1967). Response of the oats was of the order of 25-30 per cent increase in yield (Table 13). Significant responses were obtained on the top and slope positions but not the depressions. Effects on the legumes in 1967 were confounded by the fact that the large yield of oats may have suppressed legume growth. However in 1968 some residual effects of phosphorus were evident even in the depressions.

TABLE 13
Yields (in lb dry matter/acre) of oats and Medicago species as influenced by superphosphate on gilgaied clay soil

Date of Sampling	Species	Superphosphate lb/acre	Top	Topographic Position Slope	Depression	Weighted Mean Yield
8/67	*A. sativa*	0	3070	2000	1510	2380
		100	3890	2550	1280	2940
	Standard Error			225		
8/67	*Medicago* spp	0	135	185	60	145
		100	205	140	35	155
	Standard Error			40		
9/68	*Medicago* spp	0	485	930	315	655
		100	650	1020	660	815
	Standard Error		80	80	160	

DISCUSSION

Major requirements for pasture legumes in this environment are persistence and the ability to grow when climatic conditions are favourable. In this respect, the annual medic species and particularly cultivars of *Medicago truncatula* have certain advantages. They will germinate as early as February or March and, with favourable moisture conditions, will continue to grow well into September. However, where moisture stress occurs in late winter (a common occurrence since mean August rainfall is less than any other month) these species appear to have the ability to set seed. In 1968, for instance, flowering was observed in the Cyprus cultivar of *M. truncatula* and also *M. littoralis* as early as July 25th. However if subsequent rain falls (as it did in 1968) these plants appear able to resume vegetative growth. The persistence of these species is assisted by the large amount of burr produced and also by hardseededness. Germination and subsequent mortality following early summer rains has been observed but if satisfactory seed set has occurred this is unlikely to seriously deplete seed reserves (Table 7). Of the various cultivars of *M. truncatula* the most outstanding was Cyprus. At both sites at Meandarra this cultivar gave the highest yield and at the second site produced 3000 lb per acre dry matter in 1968. At Tara on the light textured soil its yield was less than Jemalong, but the difference was small and non-significant. However, even at Tara the amount of Cyprus burr was greater than Jemalong. Advantages of Cyprus appear to be that it is earlier than Jemalong, that it sets a high proportion of its dry matter into burr and possibly possesses a greater tolerance of moisture stress and high temperatures. The Woodside cultivar is a selection of *M. truncatula* observed at Giligulgul in the late 1950's. Although not superior in the experiments at Tara this cultivar may be more suitable in other environments. Certainly it was higher yielding than the current Hannaford cultivar.

Two *Medicago* species which appear to do better under conditions of the heavy soil at Meandarra were *M. littoralis* (Harbinger) and *M. scutellata* (Snail). The former was also quite persistent at Tara with heavy seed production. Most of the annual Medicago species persisted into the fifth season. One of the *M. truncatula* cultivars, CPI 28402, had comparatively high production but was not superior to Jemalong or Cyprus.

The four *Trifolium hirtum* cultivars persisted at Tara during the five years of the experiment and their yield in the fifth year exceeded that in the first. The yield of these species was less than that of the more productive medics, flowering time was more critical and they did not appear to have the ability to resume vegetative growth if favourable moisture conditions occurred after flowering.

Although the dry matter yield of the temperate legumes was not large their nitrogen contributions appear significant (Table 8). Thus the nitrogen content of *M. truncatula* at Tara when harvested was generally in excess of 3.00 per cent.

The mean nitrogen percentage of Jemalong in particular was 3.52 per cent for 1967 and 1968 and the above ground nitrogen content exceeded 50 lb N per acre for those years. Values were less for other cultivars and other years. However the yield data suggest a mean value for Jemalong in this experiment of about 35 lb N per acre per year. Including root material the total nitrogen content could be estimated as at least 50 lb N per annum.

In assessing the effect of temperate legumes on soil nitrogen levels several observations were made. Although no grass species were sown on the low fertility soil at Tara some volunteer grasses became established. The growth of these grasses following rainfall during summer was much more vigorous on plots which had high legume yields suggesting that available nitrogen levels had been increased. Soil analyses were made at two profile sites near the plots before establishment. These had nitrogen contents of 0.070 and 0.116 per cent N for the 0-5 cm horizon, indicating initial variability. Analysis of the 0-5 cm horizon of plot soils after 4 seasons (Table 8) also showed wide variability and there was no significant increase in soil nitrogen content. Thus no conclusions regarding effects of different legumes on soil total nitrogen can be drawn at the present time. However there is evidence to suggest that total soil nitrogen changes under pasture may be slow in some environments (Russell 1962). The annual nitrogen uptake by exotic grasses fertilized with phosphorus at Tara appears to be about 30-40 lb N. Taking the higher value and a soil nitrogen content (0-15 cm) of 1300 lb N this suggests an annual soil breakdown of about 3 per cent. Assuming a first order equation the half-life of nitrogen equilibration would be 23 years (i.e. $t\frac{1}{2} = \frac{0.693}{0.03}$)

Due to the shorter time period, the smaller mean legume yields, the initially higher soil nitrogen content and the variability due to micro-relief no measurements were made of soil nitrogen changes on the gilgaied clay soils.

The data at Tara were obtained during five consecutive years. However these years were generally below-average total rainfall, well below average summer rainfall but average or above average winter rainfall (Table 4). The extent to which the 5 year data at Tara is representative of long term records and the extent to which the results on this site can be extrapolated to other areas of the brigalow region is being studied in more detail using a similated climatic model programmed for a digital computer. However, even a brief examination of rainfall records suggests that there will be seasons when little or no winter growth of annual temperate legumes can be expected. The main question is whether the annual legumes can survive these periods. There are sound grounds for optimism particularly in relation to *M. truncatula* cultivars with their characteristics of early flowering, prolific seeding and hard seededness. It is possible that growth may be more consistent on soils with coarse textured surface soils where light precipitation is more effective than on fine textured soils although in years with above average winter rainfall growth may be greater on the latter.

There is little information about the management of annual temperate legumes or of temperate legume-tropical grass pastures in this environment. The seasonal conditions during this study were such that the amount of plant growth in late summer was low and there was little competition or shading for winter growing species. It has been observed that heavy grazing during early autumn increases the chances of good germination and growth of the *Medicago* species. Thus it is not improbable that growth and nitrogen fixation of these species can be assisted by grazing in late summer or early autumn and, indeed, that some management of this type may be necessary under conditions of prolific tropical grass growth.

The widespread use of annual temperate legumes in this environment presents few difficulties as regards establishment on cultivated land. Large areas are sown to cereals for both fodder and grain. The associated sowing of *M. truncatula, M.*

littoralis and *M. scutellata* through a small seed box is a satisfactory method of establishment. These species can be sown at rates as low as ½-2 lb per acre and at current seed prices the cost per acre is low. However the occurrence of soil deficiencies has to be considered. Solodic soils are low in phosphate and application of phosphorus is essential. The trace element pattern is complex but deficiencies of Mo occur on a number of solodic soils (Russell, unpublished data). Deficiencies of Cu, Zn, and B may also occur. Phosphorus is also deficient on some of the brigalow soils. The general response of applied phosphorus appears greater in winter than in summer. The effect of low soil temperatures in enhancing phosphorus response has been observed elsewhere and Sutton (1969) has discussed some of the factors involved.

The unique contribution of temperate legumes is likely to be their addition of nitrogen to the soil-plant system. The nitrogen deficit of the rapidly growing summer grasses can be quite extreme on low fertility soils in this environment and represents a major limiting factor in the utilization of these soils. Although immediate benefits may be expected on low fertility soils in terms of associated summer-growing grass yields, the effects on soil nitrogen levels appear likely to be of a long term nature.

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