Grassland improvement in subtropical Guangdong Province, China.

1. Evaluation of pasture legumes

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Abstract

Tropical and temperate legumes were evaluated for subtropical grasslands (1522 mm annual rainfall) on high aluminium (Al saturation >87%) Hapludult soils at Lechang in north Guangdong Province, China. The evaluations were of: (1) 82 accessions and cultivars in rows and mini-plots; (2) 31 tropical and temperate legume cultivars sown in spring and autumn on unlimed soil with low fertiliser inputs; and (3) the same legumes compared when spring sown with *Setaria sphacelata* with and without lime. In Experiment 1, the best of the tropical legumes were: *Chamaecrista rotundifolia* (CPI 37234), *Desmodium cuneatum* (CPI 53953), *D. heterocarpon* (CPI 86277), *Glycine* sp. (P7874) and *Stylosanthes guianensis* (Q8442 and CPI 18750a), with the *Ornithopus* genus showing most potential of the temperate accessions. Wynn cassia was the most productive (>1700 kg/ha DM) in Experiment 2 and is recommended for use as a "pioneer" legume. The best temperate species were Maku lotus, Pitman serradella and woolly pod vetch, all of which yielded >1000 kg/ha DM. All *Trifolium* species showed symptoms indicating severe magnesium deficiency. Legumes responded differently to lime application: greenleaf desmodium, siratro, phasey bean and lotononis increased, stylos decreased and cassia was unaffected. In Experiment 3, the temperate legumes failed to establish with setaria, but white clover production in pure stands increased by 2000 kg/ha DM with lime application. The implications of these results with respect to further species selection, liming strategies and fertiliser policy (especially P, Mg and K) for grassland development in south China are discussed.

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Introduction

Soils on 80% of the land area in north Guangdong Province, People's Republic of China, are strongly acid (Michalk and Ryan 1989) and this is suspected of limiting pasture production on much of the 40 M ha of grassland in south China (Hong 1985). The only crops grown are acid-tolerant such as tea, sweet potatoes, cassava, and plantation pines. Nevertheless, agricultural planners in south China are keen to develop these acid soils for pasture-based cattle production (Michalk 1988; Michalk *et al.* 1988) as part of the national program to rapidly increase beef output from rangelands.

Present production from cattle grazing unimproved and poorly managed grassland in north Guangdong Province under traditional management (i.e. herded by day and shedded at night) is only 20-30 kg liveweight gain/ha/yr with an average carrying capacity of about 1 animal to 2 ha. However, improvement of production through legume-based pasture needs species tolerant of high levels of exchangeable aluminium and deficiencies of Ca and Mg, or application of lime to provide a root environment suitable for less tolerant but more productive and palatable species.

Because of a lack of local expertise in pasture improvement, assistance was sought from New South Wales, Guangdong's sister state in Australia, to identify suitable pasture species, determine fertiliser requirements and develop cattle husbandry practices through a cattle project in north Guangdong Province. Finance for the program was provided by the People's Government of Guangdong Province.

In this first paper of a series focusing on grassland improvement in subtropical China, we report results of 3 experiments conducted between 1986-1989 at Lechang Model Cattle Farm (Lechang County). These aimed to identify pasture legumes that would grow and produce with low inputs on unamended acid soil, and to measure the increase in legume yield after application of lime. No previous evaluation of pasture legumes had been undertaken in this region.

Material and methods

Location

The North Guangdong Cattle Project was established on a county farm in April 1986. The site (25°09′N, 113°21′E) is located in a valley basin (elevation 200 m), 10 km east of Lechang township in Lechang County in Shaoguan Prefecture.

Climate

The climate of Shaoguan Prefecture is classified as "transitional subtropical" (Chen 1957) with a predominance of spring-summer rainfall (75% of the 1522 mm annual total), but with a significant winter component (Table 1). Summer storms are particularly intense, and may produce as much as 150 mm in a 24-hour period. January is the coldest month with the lowest temperature on record of –4.6°C, although the monthly average still exceeds 10°C. At least one snowfall is expected each year, typically in the last week of January. The frost period extends over 50 days with an average of 14 frosts per year ending by March. July is the hottest month but the average daily temperature exceeds 18°C for more than 200 days.

The legume growth indices at Lechang (Figure 1) are similar to those at Lismore (68°48′S, 153°17′E) suggesting that legumes used for commercial grassland improvement in subtropical Australia should be well suited.

Soils

Ultisols are the most common soil order in south China (Zhao and Shi 1986), and occupy 73% of Shaoguan Prefecture. The soils of Lechang Farm belong to the Chinese groups 4-1-5 and 4-1-7 which are described as "red earths", most of which are classified as Hapludults (Michalk and Ryan 1989).

These soils are acid ($pH_{(NaCl)} < 4.3$), reddish-brown in colour, gradational in texture, well-structured and free-draining. They are physically suited to cultivation and pasture development (Zhao and Shi 1986). Aluminium saturation exceeds 80% with low calcium, magnesium and potassium probably depleted by leaching

Table 1. Rainfall, evaporation and temperature statistics for Lechang Model Cattle Farm.

Month	Rainfall at Lechang Farm				Evaporation mean	Temperature			
						Mean		Absolute	
	Mean[1]	1986	1987	1988		Min	Max	Min	Max
	(mm)				(mm)	(°C)			
Jan	49	9	13	20	72	5.5	14.7	–4.6	28.6
Feb	76	99	39	98	63	7.5	15.4	–3.0	31.1
Mar	126	80	194	313	79	11.6	19.2	–1.2	32.1
Apr	186	116	159	190	94	16.9	23.7	4.9	32.9
May	237	158	283	157	124	20.9	28.2	11.6	35.6
June	257	211	148	101	134	23.2	30.5	15.1	37.4
July	145	190	250	161	191	24.4	33.3	19.5	39.4
Aug	187	123	63	128	187	24.3	33.2	19.5	38.4
Sep	91	88	109	24	163	22.1	31.2	12.2	37.8
Oct	79	49	51	44	134	17.3	27.2	–4.0	35.7
Nov	50	38	146	30	100	11.9	21.8	–0.7	31.7
Dec	39	17	3	15	77	7.1	16.9	–2.9	29.3
Total	1522	1178	1458	1281	1418				

[1]Mean for 30-year period (1953-1983) for Lechang County Weather Station.

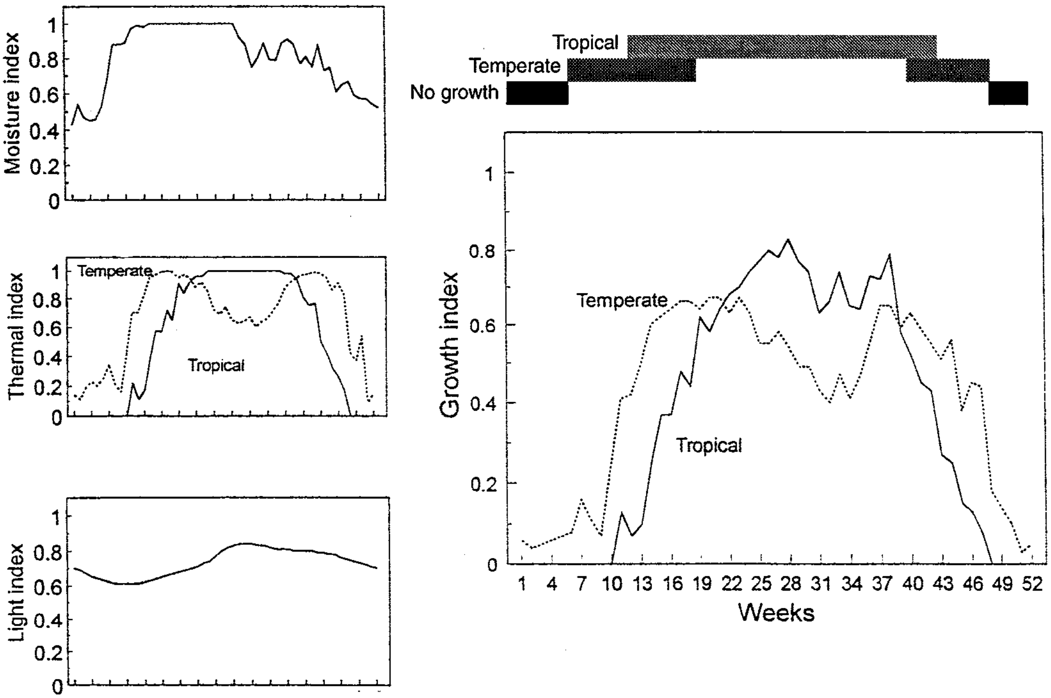

Figure 1. Moisture, thermal, light and growth indices for tropical and temperate legumes in Lechang County.

(Table 2). They are also deficient in phosphorus. Aluminium toxicity extends down the profile within the entire root zone.

Unimproved grassland vegetation

The original vegetation of the lower hill areas of north Guangdong consisted of evergreen oak and lauraceous forest (Wang 1961), but most has been cleared and replaced with pines (*Pinus massoniana*), bamboo (*Phyllostachys edulis*) and other secondary vegetation (Fenzel 1929). The current complement of 20 grasses and 3 legumes (Table 3) includes some which are considered useful species for cattle. A community of short-season grasses and weeds has developed under the high local cutting and grazing pressures. The natural grasses and shrubs are used for domestic fuel, or as a potassium source for crop land.

Experimental procedures

A series of 3 experiments was undertaken: Experiment 1 — an evaluation of 82 accessions

Table 2. Chemical properties of unamended soils at Lechang Farm.

Depth	pH	Exchangeable cations					Total CEC	Avail.[1] P
	(NaCl)	Ca^{++}	Mg^{++}	K^{+}	Al^{+++}			
(cm)		(meq/100 g)					(meq/100 g)	(mg/kg)
0-10	4.1	0.21	0.05	0.06	2.3	(87)[2]	2.52	2
10-20	4.3	0.15	0.05	0.06	2.1	(85)	2.36	2
20-30	4.3	0.12	0.02	0.03	2.1	(93)	2.27	1
30-40	4.3	0.06	0.02	0.02	1.9	(95)	2.00	1
40-50	4.2	0.09	0.02	0.02	2.0	(94)	2.13	1
50-60	4.3	0.08	0.02	0.02	1.7	(93)	1.82	1

[1]Available P measured by Bray test.
[2]Bracketed figures are % Al saturation.

Table 3. Herbaceous species identified in unimproved grassland at Lechang Farm.

Grasses	
Arthraxon hispidus	*Arundinella hirtue*
Baeckea frutescens	*Capillipodium parviflorum*
Chrysopogon aciculatus	*Cynodon dactylon*
Digitaria fibrosa	*Eragrostis pilosa*
Eremochloa ciliaris	*Eriachne pallescens*
Eulalia speciosa	*Heteropogon contortus*
Imperata cylindrica	*Ischaemum indicum*
Paspalum commersonii	*Paspalum conjugatum*
Rhynchospora rubra	*Schizachne purpurescens*
Schizachyrium sanguineum	*Sorghum intidum*
Legumes	
Desmodium microphyllum	*Desmodium heterophyllum*
Desmodium stracifolium	*Lespedeza striata (?)*
Desmodium triflorum	

or cultivars of tropical-subtropical (Table 4) and temperate (Table 5) legumes sown in single rows or mini-plots; Experiment 2 — an evaluation of 31 cultivars of tropical and temperate legumes (Table 6) sown on unlimed soil with low inputs of P, K and S fertilisers in spring (June 23) and autumn (October 24) 1986; and Experiment 3 — an evaluation of the same legumes sown in spring (April 19) 1987 on both unlimed and lime-treated soil with moderate inputs of P, K and S fertilisers.

In Experiment 1, scarified, inoculated and pelleted seed was sown in single 2 m rows on weed-free seedbed with 1 m buffers on April 14, 1986 (tropical-subtropical legumes) or in unreplicated, weed-free 2.25 m^2 mini-plots on October 30, 1986 (temperate legumes). Vegetative growth, height, density and reproductive performance (flowering, seed set) were measured in Year 1 and the source of regeneration was noted at the start of Year 2.

Experiments 2 and 3 were cutting studies conducted on 4 × 4 m plots replicated 3 times. Legumes were sown at recommended seeding rates (Table 6) into weed-free, cultivated seedbeds and lightly raked after sowing. Seed was scarified using hot water treatment, inoculated with commercial *Rhizobia* in peat and pelleted (with either rock phosphate or lime) prior to planting. Experiment 2 was fertilised with 300 kg/ha superphosphate (18 kg/ha P) at sowing and topdressed with 100 kg/ha muriate of potash on May 20, 1987. A basal dressing of 600 kg/ha superphosphate (36 kg/ha P) and 150 kg/ha muriate of potash was applied to both unlimed and limed (4 t/ha) sites in Experiment 3. Plots in Experiment 3 were sown with 6 kg/ha *Setaria sphacelata* cv. Kazungula which grows well at Lechang Farm (Michalk and Huang 1994).

Dry matter production was assessed by ranking yield (0-10 scale) and ground cover (%) in the establishment year in Experiment 2, where sward development was slow due to late sowing, and by harvesting the entire plot with hand shears to a height of about 5 cm in November in the second and third years. Harvested material was weighed in the field and subsamples taken to determine dry matter content and botanical composition. Production in Experiment 3 was assessed by hand cutting in the establishment year only.

Statistical analyses

Yield data for Experiments 2 and 3 were analysed using Duncan's multiple range test to differentiate between legume yields.

Results

Experiment 1

Growth, height, and reproductive development of tropical-subtropical accessions for Year 1 and regeneration observed in Year 2 are given in Table 4. Twenty-two accessions failed to establish and only 6 [*Chamaecrista rotundifolia* (CPI 37234); *Desmodium cuneatum* (CPI 53953); *D. heterocarpon* (CPI 86277); *Glycine* sp. (P 7874); *Stylosanthes guianensis* (Q 8442) and *S. guianensis* (CPI 18750a)] grew well. Six of the *Lespedeza* spp. established and perennated into the second year, but like the local ecotypes, production was poor.

Five of the temperate accessions and cultivars failed to establish, and only 3 (*Vicia villosa* ssp. *dasycarpa* cv. Namoi, *Ornithopus compressus* cv. Avila and *Trifolium usambarense*) produced yield ratings above 4 (Table 5). As a group, the *Ornithopus* genus showed most potential with all representatives flowering and seeding in the establishment year and regenerating in Year 2.

Experiment 2

Of the 17 tropical legumes tested under cutting on unlimed soil (Table 6), only Wynn cassia, lotononis and 3 stylos yielded more than 1000 kg/ha in the year following establishment when sown in spring and, except for Oxley stylo, more than 800 kg/ha when sown in autumn

Table 4. Growth, reproduction and regeneration of tropical and subtropical legumes (Experiment 1).

Species	Accession No.[1]	Observations at:			
		End of first growing season			Start of second growing season
		Growth[2]	Height (cm)	Reproduction[3]	Regeneration[4]
Adesmia punctata	P16014	F			
Aeschynomene americana	37138	2	60		R
Aeschynomene villosa	37229	2	20		R
Alysicarpus vaginalis	P16027	2	20		L
Alysicarpus rugosa	52354	F			
Arachis sp.	8627	F			
Cassia mimosoides	P11832	F			
Cassia mimosoides	P15789	1	30	Fl,S	R
Cassia pilosa	57503	2	30	Fl,S	L
Chamaecrista rotundifolia	37234	5	50	Fl,S	L
Chamaecrista rotundifolia	16358	3	30	Fl,S	L
Centrosema sagittatum	51037	1	20		L
Centrosema pubescens	51038	2	30		L
Clitoria ternata	P16019	F			
Desmanthus sp.	38220	1	60	Fl,S	L
Desmanthus virgatus	85177	0.5	20		L
Desmanthus virgatus	78373	1	25		L
Desmanthus virgatus	78372	F			
Desmanthus virgatus	89197	1	40		L
Desmodium adscendens	60195	F			
Desmodium barbatum	76072	F			
Desmodium canum	37436	1	30		L
Desmodium cuneatum	53953	5	20		L
Desmodium heterocarpon	86277	5	40		L
Desmodium salicifolium	52428	1	10		L
Desmodium sp.	37144	2	40		L
Desmodium sp.	78390	F			
Glycine tabacina	P7874	F			
Glycine tomentella	P8175	F			
Glycine sp.	P7874	4	10		L
Glycine sp.	P11819	3	10		
Indigofera schimperi	69495	3	10		
Kennedia rubicunda	P4955	F			
Lespedeza cuneata	P15796	2	60	Fl,S	L
Lespedeza juncea	P7866	1	20	Fl,S	L
Lespedeza stipulacea	P15801	1	25	Fl,S	L
Lespedeza striata	P15802	1	15	Fl,S	L
Lespedeza striata	P15803	1	10	Fl,S	L
Lespedeza striata	P15804	1	15	Fl,S	L
Lespedeza striata	P15805	F			
Macroptilium heterophyllum	90783	1	15	Fl,S	L
Macroptilium gibbosifolium	36631	1		Fl,S	L
Phaseolus adenanthus	P12738	F			
Psoralea tenax	P6518	F			
Rhynchosia minima	P7683	F			
Rhynchosia sublobata	52728	1			L
Stylosanthes guianensis	11491	2	10		L
Stylosanthes guianensis	Q8442	5	70	Fl,S	L
Stylosanthes guianensis	18750a	4	50	Fl,S	L
Stylosanthes scabra	34570a	3	80	Fl	L
Teramnus gilletti	70292	F			
Vicia lutea	P16842	F			
Vigna luteola	21347	1			L
Vigna parkeri	cv. Shaw	F			
Vigna vexillata	P8177	F			
Zornia glochidiata	P11935	3	50	Fl,S	
Zornia reticulata		2	20	Fl,S	

[1]All numbers without an alphabetical prefix are Australian CPI (Commonwealth Plant Introduction) numbers; P indicates introductions for NSW Agriculture; and Q for Queensland Department of Primary Industries. [2]F = failed to establish; 1 indicates low vigour, and 5 very high vigour. [3]Fl = flowered; S = set seed. [4]R = regenerated from seed; L = regenerated from crown, rhizomes or other plant parts.

Table 5. Growth, reproduction and regeneration of accessions of temperate legumes (Experiment 1).

Species	Accession No.[1]	Observations at:			
		End of first growing season			Start of second growing season
		Growth[2]	Density (no./m^2)	Reproduction[3]	Regeneration[4]
Astragulus hamosus	cv. Ioman	F			
Medicago aculeata	19416	F			
Medicago murex	cv. Zodiac	1	19	Fl	
Medicago polymorpha	cv. Circle Valley	F			
Medicago truncatula	cv. Sephi	F			
Melilotus alba	P14675	F			
Ornithopus compressus	GT046	1	12	Fl,S	R
Ornithopus compressus	GM107	2	25	Fl,S	R
Ornithopus compressus	cv. Avila	5	>30	Fl,S	R
Ornithopus compressus	MC1	1	>30	Fl,S	R
Ornithopus compressus	cv. Pitman	2	>30	Fl,S	R
Ornithopus perpusillus	GM034	1	>30	Fl,S	R
Ornithopus pinnatus	GS066	3	>30	Fl,S	R
Trifolium burchellianum	24132	1	20		
Trifolium mattirolianum	37936	2	>30	Fl	
Trifolium rueppellianum	20744	1	3		
Trifolium steudneri	25348	F			
Trifolium steudneri	37947	1	5	Fl	
Trifolium tembense	20746	1	>30		
Trifolium usambarense	22165	4	>30		
Vicia lutea	P16842	3	>30		
Vicia sativa ssp. *nigra*	P9081	2	>30	Fl,S	
Vicia villosa ssp. *dasycarpa*	cv. Namoi	5	20	Fl,S	R

[1]All numbers without an alphabetical prefix are Australian CPI (Commonwealth Plant Introduction) numbers; P indicates introductions for NSW Agriculture; Q for Queensland Department of Primary Industries; and MC for mutant line. [2]F = failed to establish; 1 indicates low vigour, and 5 very high vigour. [3]Fl = flowered; S = set seed. [4]R = regenerated from seed.

(Table 7). Wynn cassia was the most productive legume in both spring and autumn sowings. Although slow to establish, Amarillo peanut and jointvetch produced satisfactory yield by Year 3, but only when sown in spring (Table 7).

Of the 14 temperate legumes tested in an autumn sowing on unlimed soil (Table 6), only Maku lotus, Pitman serradella and woolly pod vetch yielded over 1000 kg/ha (Table 8).

All *Trifolium* plants exhibited marked symptoms of nutrient deficiency; older stunted leaves borne on 'bowed' petioles showed reddening and necrosis on the margins and on the leaf crescent, while young leaves were yellow and unhealthy.

Experiment 3

Species responded differently ($P<0.05$) to lime with yield increasing in some and decreasing in others (Table 9). Yield of greenleaf desmodium, siratro, phasey bean and lotononis improved with lime application but only lotononis and phasey bean yielded over 2000 kg/ha. There was a trend towards reduced yield of all stylos in plots treated with lime, whereas cassia was not affected.

White clover, Kenya clover and serradella were the only temperate species field tested for response to lime, but none was successful, possibly due to a combination of spring sowing and intense competition from setaria. The few white clover plants present in the limed plots showed symptoms similar to those observed in Experiment 2 on unlimed soil.

The legumes had no effect on setaria production, but overall the setaria responded significantly ($P<0.01$) to lime.

Discussion

Tropical-subtropical legumes

Wynn cassia performed most consistently and is recommended for use as a pioneer legume because it is easy to establish and it persists and remains productive with low P inputs. However, it may need extra potassium to compete with tropical grasses such as setaria (Michalk and Huang 1993b).

Table 6. Name, sowing rate, sowing time and first-year establishment of legume species tested at Lechang Farm in spring and autumn sowings.

Botanical name	Common name & cultivar	Sowing rate	Sowing time[1]		Establishment[2]		
					Spring		Autumn
					Exp. 2	Exp. 3	
		(kg/ha)					
Aeschynomene falcata	Jointvetch cv. Bargoo	2	Sp	Au	Y		T
Arachis pintoi	Forage peanut cv. Amarillo	9	Sp	Au	Y		Y
Centrosema pubescens	Centro cv. Belalto	6	Sp	Au	N	N	N
Chamaecrista rotundifolia	Round-leafed cassia cv. Wynn	6	Sp	Au	Y	Y	Y
Desmodium intortum	Desmodium cv. Greenleaf	3	Sp	Au	Y	Y	Y
Desmodium uncinatum	Desmodium cv. Silverleaf	3	Sp	Au	N	Y	N
Lotononis bainesii	Lotononis cv. Miles	1	Sp	Au	Y	Y	Y
Lotus pedunculatus	Lotus trefoil cv. Grasslands Maku	2		Au		Y	
Macroptilium atropurpureum	Siratro cv. Siratro	3	Sp	Au	Y	Y	Y
Macroptilium lathyroides	Phasey bean cv. Murray	6	Sp		N	Y	
Macrotyloma axillare	Axillaris cv. Archer	6	Sp	Au	Y	Y	Y
Medicago sativa	Lucerne cv. Hunter River	6		Au		Y	
Medicago sativa	Lucerne cv. Sequel	6		Au		Y	
Neonotonia wightii	Glycine cv. Tinaroo	4	Sp	Au	T	N	N
Ornithopus compressus	Yellow serradella cv. Pitman	7	Sp	Au		Y	Y
Stylosanthes hamata	Caribbean stylo cv. Verano	6	Sp	Au	Y	Y	N
Stylosanthes guianensis	Common stylo cv. Cook	6	Sp	Au	Y	Y	Y
Stylosanthes guianensis	Common stylo CPI 18750A	6	Sp	Au	Y	Y	Y
S. guianensis var. *intermedia*	Fine-stemmed stylo cv. Oxley	6	Sp	Au	Y	N	Y
Stylosanthes scabra	Shrubby stylo cv. Seca	6	Sp	Au	Y	Y	N
Trifolium resupinatum	Persian clover	6		Au		N	
Trifolium subterraneum	Subclover cv. Clare	6		Au		Y	
Trifolium subterraneum	Subclover cv. Woogenellup	6		Au		Y	
Trifolium subterraneum	Subclover cv. Nungarin	6		Au		Y	
Trifolium subterraneum	Subclover cv. Geraldton	6		Au		Y	
Trifolium pratense	Red clover cv. Grasslands Hamua	6		Au		Y	
Trifolium pratense	Red clover cv. Redquin	6		Au		Y	
Trifolium repens	White clover cv. Haifa	3	Sp	Au	Y	Y	Y
Trifolium semipilosum	Kenya clover cv. Safari	3	Sp	Au	N	N	N
Vicia villosa ssp. *dasycarpa*	Woolly pod vetch cv. Namoi	9		Au		Y	
Vigna unguiculata	Cowpeas cv. Dalrymple	6	Sp		Y	Y	

[1]Sp = spring; Au = autumn.
[2]N = did not establish; Y = established satisfactorily; T = only trace present.

Table 7. Tropical legume production from spring and autumn sowings on unlimed soil at Lechang Farm (Experiment 2).

	Spring sowing				Autumn sowing	
Date	10.86	4.87	7.87	9.88	3.87	8.87
Parameter measured	Rank	Cover	Yield	Yield	Yield	Yield
		(%)	(kg/ha DM)		(kg/ha DM)	
Cassia cv. Wynn	1	70a[1]	3370a	2280b	260b	1760a
Common stylo CPI 18750A	3	35b	2510b	np[2]	T[3]	840b
Common stylo cv. Cook	2	20bc	2350b	np	T	930b
Fine-stemmed stylo cv. Oxley	6	16c	1120c	2120b	T	180c
Forage peanut cv. Amarillo	4	15c	560d	1610b	T	T
Siratro cv. Siratro	5	13c	260d	310d	140c	355bc
Jointvetch cv. Bargoo	7	14c	T	4240a	T	T
Axillaris cv. Archer	8	11c	T	T	140c	450bc
Lotononis cv. Miles	9	7c	1040c	1360b	110c	940b
Desmodium cv. Greenleaf	10	7c	T	np	375a	T

[1]Means within measurements followed by the same letter are not significantly different (P > 0.05).
[2]np = not present when measured.
[3]T = only trace present at time of measurement (<100 kg/ha DM).

Table 8. Temperate legume production from autumn sowings on unlimed soil at Lechang Farm (Experiment 2).

Species & cultivar	Yield (5.87)
	(kg/ha DM)
Lucerne cv. Hunter River	70i[1]
Lucerne cv. Sequel	80i
Lotus trefoil cv. Maku	1960a
Subclover cv. Clare	650fg
Subclover cv. Woogenellup	560g
Subclover cv. Nungarin	750ef
Subclover cv. Geraldton	510g
Red clover cv. Grasslands Hamua	930d
Red clover cv. Redquin	650fg
White clover cv. Haifa	840de
Kenya clover cv. Safari	370h
Yellow serradella cv. Pitman	1400c
Woolly pod vetch cv. Namoi	1610b

[1]Means followed by the same letter are not significantly different (P > 0.05).

Table 9. Legume and grass production on unlimed and limed soil at Lechang Farm, spring sown, 1987 (Experiment 3).

Species & cultivar	Yield (11.87)		
	No lime	+ lime	
	(kg/ha DM)		
Desmodium cv. Silverleaf	0d[1]	270de	
Desmodium cv. Greenleaf	10d	440de	*[2]
Caribbean stylo cv. Verano	680bc	420de	
Common stylo cv. Cook	14009a	560cd	**
Common stylo CPI 18750A	460cd	290de	
Shrubby stylo cv. Seca	680bc	410de	
Lotononis cv. Miles	740bc	2930a	**
Siratro cv. Siratro	370cd	940c	*
Phasey bean cv. Murray	540c	2220b	**
Cassia cv. Wynn	1070ab	980c	
Axillaris cv. Archer	350cd	360de	
White clover cv. Haifa	0d	70e	
Kenya clover cv. Safari	0d	0e	
Serradella cv. Pitman	290cd	0e	
Mean sown grass (setaria)	2240	3020	
Mean other species	430	310	

[1]Species means within lime treatments followed by the same letter are not significantly different (P > 0.05).
[2]* and ** indicate significant differences between lime treatments within species at P<0.05 and P<0.01, respectively.

Although Wynn cassia was the most productive legume under all the experimental conditions at Lechang, observations of low acceptability of cv. Wynn to Huang Nui cattle is a cause for concern. Cattle grazing pure cassia swards at 3 AU/ha for 75 days lost 0.31 kg/ha/d even though forage on offer exceeded 2600 kg/ha DM over the grazing period (D.L. Michalk and Huang Zhi-Kai, unpublished data). In contrast, setaria pasture (cv. Narok) with an average feed on offer of 1724 kg/ha DM produced 3 kg/ha/d LWG when stocked at 3.5 AU/ha. The reason for this low acceptability of cassia which has also been reported but to a lesser degree by Valdes *et al.* (1987) is not known. Extensive testing by Strickland *et al.* (1987) ruled out toxins as a possible cause and cassia has improved feed intake (Quirk *et al.* 1992) and liveweight gain (Partridge and Wright 1992) in other experiments. Other round-leafed cassias such as the accession CPI 37234, a more robust ecotype presently being seed increased at Lechang, should be tested for acceptability to livestock prior to use for commercial development.

The relative unpalatability of cassia may be advantageous to the initial improvement of the low cation exchange capacity (CEC) soils in north Guangdong as most of the dry matter produced will be added to soil organic matter and thereby increase the CEC. This role of cassia is discussed further by Michalk *et al.* (1994a).

Susceptibility to frost and disease (e.g. anthracnose) makes common stylo, the next most productive tropical legume tested, unsuitable for range improvement in north Guangdong. Oxley, the only other stylo to persist at Lechang, was slow to establish but out-yielded cassia in the third year of production. Lotononis, jointvetch and forage peanut were also slow to establish, but produced acceptable yields with time. Evaluation of the nutritional requirements of these legumes (including cassia) in combination with grasses is required to further determine their value for grassland improvement.

Tropical legumes selected for Australian conditions where Al toxicity is rarely found may not be suitable for Guangdong Province, but a larger selection is available in South America where acid soils are a major problem (Sanchez and Salinas 1981).

Other genera which warrant testing include *Alysicarpus*, *Atylosia*, *Centrosema*, *Clitoria*, *Desmodium*, *Macrotyloma*, *Rhynchosia* and *Vigna*. Some of these are endemic to south China (Groff *et al.* various dates; Merrill 1927; Merrill various dates). Collections made in 1980 (Hwang *et al.* 1986) and 1984 (Schultze-Kraft *et al.* 1984) identified 14 potential forage legumes, some of which are now being evaluated by the Animal Husbandry Research Institute of Guangdong (Hwang *et al.* 1986). Based on Experiment 1, further testing of *Desmodium cuneatum* and *D. heterocarpon* seems warranted.

Temperate legumes

The response of the 13 temperate legumes tested on unlimed soil was consistent with their known tolerance of soil aluminium. Grasslands Maku, which performed best in Experiment 2, has a high Al tolerance (Schachtman and Kelman 1991), and its success suggests that other *Lotus* species may have potential in north Guangdong. For example, *L. purshianus* is also tolerant of Al, but has a deeper tap root system giving it greater ability to survive periodic summer drought (Schachtman and Kelman 1991).

Yellow serradella is also tolerant of high soil Al. Better winter-spring production may be gained by replacing the moderately tolerant cv. Pitman with more tolerant cultivars such as Avila (the most productive serradella in Experiment 2), Tauro, Paros or Eneabba (Scott *et al.* 1991).

Replacing cv. Haifa which is only moderately tolerant of high Al with the Israeli cv. Tamar which is better suited to high Al soils (Schachtman and Kelman 1991), may slightly improve the reliability and yield of white clover on unlimed soil. However, like subterranean clover (Michalk and Huang 1992), satisfactory white clover production will only be obtained on unlimed soil with a heavy application of magnesium fertiliser (Michalk and Huang 1993a). Tolerance of low soil Mg may partly account for the success of Maku lotus and serradella. The Al tolerance of woolly pod vetch is not unknown, but is presently under test (K. Helyar, personal communication).

Effect of companion grass

Setaria proved to be too competitive for most legumes except lotononis. In ungrazed plots it halved the yields of cassia and common stylo (Tables 7 and 9). Setaria also reduced the yield of white clover in ungrazed plots. However, a better grass-white clover balance was achieved in commercial sowings at Lechang where the sward was grazed to a height of about 30 cm. Heavy grazing of white clover-tropical grass pastures improves clover persistence (Jones 1984).

Effects of lime

Lime application had a beneficial effect on production, especially of the twining tropical legumes and white clover, but the residual effect of the 4 t/ha lime used to raise soil pH to 5.9 (Michalk *et al.* 1988) may be less than that expected in temperate regions because of the rainfall and free draining soils (Michalk *et al.* 1994a).

Based on the legume response and the cost of lime ($A23/t), soil amendment may be restricted to establishing small areas of special-purpose pasture (e.g. lotononis, white clover) rather than for use over the whole farm (Michalk *et al.* 1994b). Although white clover failed to establish satisfactorily in Experiment 3, Michalk and Huang (1993a) reported that lime application increased yield from below 800 to over 2600 kg/ha DM in the establishment year.

In addition to reducing the effects of Al on plant growth through pH change in soil, lime also alleviates Ca and Mg deficiencies which limit growth of both tropical and temperate legumes in north Guangdong Province. Lotononis, white clover and subclover all showed symptoms consistent with those reported for magnesium deficiency when grown on unlimed soil, but these disappeared and production increased when Mg fertiliser was applied (Huang Zhi-Kai, unpublished data; Michalk and Huang 1992; Michalk and Huang 1993a). Since local lime contains <0.3% Mg (Michalk and Huang 1993a), there is a need to procure more concentrated Mg fertilisers to sustain production of legume-based pastures in southern China.

An on-going evaluation program is required to select better species to take advantage of the improvements made to soil fertility that will take place when current pasture recommendations are applied.

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