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Grassland improvement in subtropical Guangdong Province, China.
2. Evaluation of pasture grasses

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Abstract

During 1986-1989, 3 experiments evaluated the role of tropical and temperate grasses in improving subtropical grassland in China: (1) spring- and autumn-sown tropical and temperate grasses; (2) spring-sown tropical grasses on limed and unlimed Hapludult soils; and (3) response of 2 temperate grasses (perennial ryegrass and cocksfoot) to rates of lime in pots. The tropical grasses were more tolerant of acid soils than temperate species, but only low-quality grasses (e.g. molasses, plicatulum) grew well when fertilised only with superphosphate (300 kg/ha). Applying PK or NPK fertiliser at sowing increased the range of grass species which established successfully and doubled the yield of those grasses which established with P fertiliser only. Molasses grass, setaria, signal grass and guinea grass all produced more than 4800 kg/ha with moderate NPK inputs. Liming (4 t/ha) also increased yield of 9 tropical-subtropical grasses (including rhodes, buffel, signal, guinea and green panic) and perennial ryegrass, but significantly reduced yield of molasses and carpet grasses. Pioneer grasses may be of value for initial soil improvement, but spring- or autumn-sown setaria is recommended as the base grass for improved pastures with and without lime in subtropical Guangdong Province with moderate application of PK fertiliser. Lime application with high fertiliser inputs is essential for the production of temperate grasses and winter forage crops.

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Introduction

There are about 40 M ha of grazable, hill, tussocky pastures in south China, generally with elevation below 500 m and slope between 6–30° (Lai and Lu 1989). Although the climate is suitable, the local low-producing, low-quality grasses limit grazing capacity and animal growth rate. Recent studies have identified legumes suitable for initial improvement of the highly Al-saturated Hapludult soils (Michalk *et al.* 1988: Michalk and Huang 1993a, 1994).

Indigenous grasses such as *Miscanthus floridulus, Digitaria sanguinalis, Sorghum porpingnum, Hemarthria compress* and *Pennisetum polystachyon* have been cultivated and utilised for many years in southern China (Hong 1985; Hwang *et al.* 1986), but perennial grasses with higher productivity and quality are needed for sustained cattle production on Ultisol soils in south China. Introduction of pasture grasses began in the 1920s (Anon. 1924), but little progress was made in identifying species adapted to acid soils in tropical and subtropical China until the 1980s when consultants were invited to initiate pasture testing programs in Hunan (Nan Shan Farm), Guizhou (New Zealand project, farm site unknown), Guangxi (Qian Jian Farm) and Guangdong (Gaopoling Farm).

In this paper, we report results of a 3-year (1986-1989) program which evaluated grasses on infertile, acid soils at Lechang Model Cattle Farm in Shaoguan Prefecture. Aims were: (1) to assess the growth potential of a range of Australian grass cultivars; and (2) to determine the effects of fertilisers and lime on grass productivity.

Materials and methods

The location, climate, soil type and grassland vegetation of Lechang Farm (25°09′N,113°21′E) are described by Michalk and Huang (1993a).

Three experiments were undertaken: Experiment 1 evaluated 33 commercially available tropical and temperate grasses (Table 1) sown on unlimed soil with low fertiliser inputs in spring (June 19) and autumn (October 24) 1986; Experiment 2 evaluated the same grasses sown in spring (April 18) 1987 with moderate inputs of P, K and S fertilisers on both unlimed and limed soil; and Experiment 3 evaluated the response of ryegrass and cocksfoot to increasing rates of lime (0, 1, 2, 4 and 8 t/ha) in a pot study sown on November 10, 1987.

Experiments 1 and 2 were conducted as cutting studies on 4 x 4 m plots replicated 3 times. Grasses were sown at recommended seeding rates (Table 1) into weed-free, cultivated seedbeds and lightly raked after surface broadcasting by hand. Experiment 1, a low-input system, was fertilised only at sowing with 300 kg/ha local Grade 4 superphosphate (18 kg/ha P) at the spring sowing, but at the autumn sowing

Table 1. Name, sowing rate, sowing time and first-year establishment of grass species tested at Lechang Farm in spring and autumn sowings.

Botanical name	Common name and cultivar	Sowing rate	Sowing time[1]		Establishment		
					Spring		Autumn
					Exp. 1	Exp. 2	Exp. 1
		(kg/ha)					
Tropical-subtropical grasses							
Axonopus affinis	Narrow leaf carpet grass	6	Sp	Au	N[2]	ns[3]	N
Bothriochloa insculpta	Creeping blue grass cv. Hatch	6	Sp		N	ns	
Brachiaria decumbens	Signal grass cv. Basilisk	6	Sp	Au	Y	Y	Y
B. mutica	Para grass	6	Sp		N	Y	
Cenchrus ciliaris	Buffel grass cv. Molopo	4		Au	N	N	N
C. ciliaris	Buffel grass cv. Gayndah	4	Sp	Au	N	Y	N
C. ciliaris	Buffel grass cv. Biloela	4	Sp	Au	N	Y	N
Chloris gayana	Rhodes grass commercial	6	Sp	Au	N	Y	T
C. gayana	Rhodes grass cv. Callide	6	Sp	Au	N	Y	T
C. gayana	Rhodes grass cv. Katambora	6	Sp	Au	N	Y	T
C. gayana	Rhodes grass cv. Samford	6	Sp	Au	N	Y	T
Cynodon dactylon	Green couch grass	9	Sp	Au	N	Y	N
Dichanthium aristatum	Angleton grass	6	Sp		N	ns	
Digitaria didactyla	Blue couch grass	3	Sp		N	ns	
Melinis minutiflora	Molasses grass	4	Sp	Au	Y	Y	Y
Setaria sphacelata	Setaria cv. Kazungula	6	Sp	Au	Y	Y	Y
S. sphacelata	Setaria cv. Narok	6	Sp	Au	Y	Y	T
S. incrassata	Purple pigeon grass cv. Inverell	6	Sp	Au	T	Y	T
Panicum coloratum	Makarikari grass cv. Bambatsi	6	Sp	Au	T	T	T
P. maximum	Guinea grass cv. Hamil	6	Sp	Au	Y	Y	Y
P. maximum	Guinea grass cv. Gatton	6	Sp	Au	T	Y	T
P. maximum var. *trichoglume*	Green panic cv. Petrie	6	Sp	Au	T	Y	T
Paspalum dilatatum	Dallis grass commercial	9	Sp	Au	Y	Y	Y
P. notatum	Bahia grass cv. Pensacola	6	Sp	Au	Y	Y	Y
P. plicatulum	Plicatulum cv. Rodd's Bay	4	Sp	Au	Y	Y	Y
P. wettsteinii	Broadleaf paspalum	6	Sp	Au	Y	Y	Y
Pennisetum clandestinum	Kikuyu cv. Whittet	2	Sp	Au	N	Y	N
Temperate grasses							
Bromus unioloides	Prairie grass cv. Matua	8	Sp	Au	N	N	N
Dactylis glomerata	Cocksfoot cv. Currie	6	Sp	Au	N	N	N
Festuca arundinacea	Tall fescue cv. Demeter	6	Sp	Au	N	N	N
Lolium perenne	Perennial ryegrass cv. Kangaroo Valley	6	Sp	Au	N	T	Y
L. rigidum	Annual ryegrass cv. Tetila	3	Sp		N	N	T
Phalaris aquatica	Phalaris cv. Sirocco	3	Sp	Au	N	N	T

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

100 kg/ha muriate of potash was also applied. For the moderate-input system of Experiment 2, a basal application of 600 kg/ha superphosphate, 150 kg/ha muriate of potash and 50 kg/ha urea was applied to both unlimed and limed (4 t/ha) sites. Experiment 3 was fertilised with a complete basal dressing including nitrogenous fertiliser equivalent to 100 kg/ha N.

Dry matter production for the spring sowing of Experiment 1 was assessed by ranking yield (0-10 scale) in autumn 1986, and percent ground cover in spring 1987. Production in spring 1987 and 1988 was measured by cutting the entire plot with hand shears to a height of 5 cm. Harvested material was weighed in the field and subsamples taken to determine dry matter content and botanical composition. Harvested material was returned to each plot after weighing and subsampling. Production for the autumn sowing in Experiment 1 and the unlimed-limed comparison in Experiment 2 was assessed by hand-cutting in the establishment year only. In Experiment 3, top growth was harvested at ground level with scissors 35 days after sowing.

Plots in Experiment 1 (autumn-sown) were sown at 6 kg/ha with a mixture of *Trifolium subterraneum* (cv. Nungarin), *Trifolium repens* (cv. Haifa) and *Chamaecrista rotundifolia* (cv. Wynn), and Experiment 2 (spring-sown) with Wynn cassia only. Wynn cassia was chosen on the basis of good performance in subtropical Queensland (Partridge and Wright 1992) and subsequently in legume evaluations also undertaken at Lechang Farm (Michalk and Huang 1994).

Results

Experiment 1

Initial establishment of all grasses was poor and it was not until the second year that even the most acid-tolerant species such as molasses grass and plicatulum produced reasonably dense swards. All species which established in the low-input, spring sowing also established when sown in autumn (Tables 1 and 2). Both setaria cultivars established and yielded better when autumn-sown and fertilised with potassium (Table 2).

Sown legume (mainly cassia) produced more than 500 kg/ha when autumn-sown with all successful grasses except molasses grass, which proved too competitive for cassia and white clover, and Kazungula setaria, which halved legume yield (Table 2). The legume proved to be too competitive for autumn-sown common paspalum, reducing its yield to only 10% of that from the spring-sown plots.

Temperate grasses did not establish when sown in spring, and even with autumn sowing only perennial ryegrass established satisfactorily to produce a yield of 450 kg/ha. Phalaris germinated and produced seedlings when autumn-sown, but the plants subsequently went yellow and died. Cocksfoot failed to establish at either the spring or autumn sowing (Table 1).

Experiment 2

Due to the higher P and K inputs, starter N and earlier sowing, a wider range of tropical and

Table 2. Tropical grass production from spring and autumn sowings on unlimed soil at Lechang Farm (Experiment 1).

	Spring sowing				Autumn sowing	
Date	10.86	4.87	7.87	9.88	8.87	
Parameter measured	Rank	Cover	Yield	Yield	Sown legume	Sown grass
		(%)	(kg/ha DM)		(kg/ha DM)	
Molasses grass	1	87a[1]	3570a	3410a	0c	4510a
Plicatulum cv. Rodd's Bay	2	73a	2250b	1060b	540ab	1700c
Bahia grass cv. Pensacola	3	48b	980c	450de	640ab	570c
Broadleaf paspalum	4	33bc	400c	510cde	860b	780d
Common paspalum	6	17cd	990c	620cd	940a	100e
Signal grass cv. Basilisk	5	12d	860c	740c	720a	420de
Guinea grass cv. Hamil	7	<5d	200c	260e	680ab	170e
Setaria cv. Kazungula	8	<5d	150c	280e	330c	3170b
Setaria cv. Narok	T[2]	T	T	T	750ab	1420c
Perennial ryegrass	—	—	—	—	705ab	450de

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

subtropical grasses established in Experiment 2 on unlimed soil than in Experiment 1 (Tables 2 and 3). Para grass, 3 rhodes grass cultivars, Gatton panic and green panic, all of which failed to establish in Experiment 1, yielded over 1000 kg/ha (Table 3). Creeping blue, couch, purple pigeon grass and kikuyu also established but yielded less than 1000 kg/ha (Table 3).

Table 3. Production of grasses and legume sown in spring 1987 on unlimed and limed soil at Lechang Farm (Experiment 2).

Species and cultivar	Yield (10.87)		
	No lime	+ lime	
	(kg/ha DM)		
Carpet grass	2950d[1]	1010ij	**[2]
Creeping blue grass cv. Hatch	570fgh	1920hi	*
Signal grass cv. Basilisk	6150b	8040a	**
Para grass	2980d	2950g	
Buffel grass cv. Gayndah	50h	420j	
Buffel grass cv. Biloela	590f	2470gh	*
Rhodes grass common	120h	2380gh	**
Rhodes grass cv. Callide	1320ef	5530c	**
Rhodes grass cv. Katambora	2690d	3080fg	
Rhodes grass cv. Samford	1720e	5170cd	**
Green couch grass	910efgh	2910g	*
Molasses grass	7420a	5990bc	*
Setaria cv. Kazungula	6230b	6850b	
Setaria cv. Narok	4170c	3890ef	
Purple pigeon grass cv. Inverell	420fg	830j	
Guinea grass cv. Hamil	4960c	5090cd	
Guinea grass cv. Gatton	1720e	3070fg	*
Green panic cv. Petrie	1620e	2700gh	*
Common paspalum	1080efg	1290ij	
Bahia grass cv. Pensacola	620fgh	840j	
Plicatulum cv. Rodd's Bay	4850c	4450de	
Broadleaf paspalum	1740e	1040ij	
Kikuyu cv. Whittet	340gh	730j	
Mean sown legume (cassia)	220	310	
Mean other species	1420	960	

[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.

Except for common paspalum, the yield of species which established and formed dense swards in Experiment 1 more than doubled under the higher fertiliser regime of Experiment 2 (Tables 2 and 3). Molasses grass was the highest yielding grass followed by Kazungula setaria, signal grass and guinea grass.

The response of tropical grasses to liming is also shown in Table 3. Of the 23 cultivars sown, there were significant increases in 9 grasses, a significant decrease in 2 (molasses grass and carpet grass) and no effect on 12.

Some native grasses and forbs responded to the PK fertiliser applied to unamended soil, with yield exceeding 2500 kg/ha in plots where production of sown grass was poor. However, where the yield of sown grasses exceeded 4000 kg/ha, production of volunteer species was less than 500 kg/ha. On limed plots, the overall yield of native grasses and forbs was reduced by 30% due to better performance of most sown grasses (Table 3).

Overall, legume content (mainly cassia) was low on both unlimed and limed plots (Table 3). Even where the yield of sown grasses was less than 500 kg/ha, legume yield rarely exceeded 600 kg/ha because of the competition from volunteer grasses and forbs.

Experiment 3

Lime application improved the performance of perennial ryegrass, but did not affect cocksfoot production (Table 4). The results suggest that a rate of 1–4 t/ha lime is required for optimal growth of perennial ryegrass.

Table 4. Relative yield (RY) response of ryegrass and cocksfoot to lime (Experiment 3).

Species	Lime rate (t/ha)				
	0	1	2	4	8
Perennial ryegrass	82bc[1]	91ab	100a	94ab	73c
Cocksfoot	100a	73a	86a	82a	92a

100% RY for ryegrass = 7.7 g DM/pot
100% RY for cocksfoot = 6.2 g DM/pot

[1]Within species, means followed by the same letter are not significantly different ($P > 0.05$).

Discussion

Tropical-subtropical grasses

In general, C_4 grasses were more tolerant of infertile acid soils than C_3 grasses. Of the 33 grasses tested, only C_4 grasses produced yields above 2000 and 3000 kg/ha on low- and moderate-input systems, respectively. Fertiliser improved the survival of tropical grasses, with better persistence being recorded in the moderate-input systems which included potassium.

Pioneer grasses such as molasses grass and plicatulum, which are very tolerant of acid soil conditions (Spain 1975) and low available soil P (Andrew and Robins 1971), were the only specie to produce more than 1000 kg/ha DM when fertilised with superphosphate only, and more than 4800 kg/ha when fertilised with both P and K. However, while these grasses may be of value for soil improvement (Michalk *et al.* 1994a), their low quality may restrict livestock performance. Molasses grass does not have the nutritional quality to match moderately fertilised setaria on either unlimed or limed soil.

The yield of setaria cultivars was not increased by application of lime, but quality was improved, with higher levels of phosphorus, calcium and magnesium in forage grown on limed soil (Huang Zhi-Kai, unpublished data). In commercial pastures, setaria sown on unlimed soil exhibited some symptoms typical of phosphorus deficiency (i.e. purple older leaves, stunted and spindly growth) unless fertilised with moderate levels of phosphorus and potassium (Michalk and Huang 1993b), the latter being particularly important for setaria establishment and yield (Table 2). This was not evident in paddocks treated with lime. In addition to improving grass quality, lime application will also increase the range and production of companion legumes (Michalk and Huang 1994).

Setaria (cv. Kazungula) has also performed well in Fujian Province (a subtropical province to the north-east of Guangdong), where yields of more than 90 t/ha fresh weight have been measured when cut 4–7 times per year (Hong 1985; Wu *et al.* 1986). It is now recommended for improvement of all red soil upland areas below 1000 m in Fujian, Guangxi, Yunnan, Guangdong and Hainan Provinces (Wu *et al.* 1986). Setaria will establish when sown in either spring or autumn which gives it an advantage over alternative grasses such as guinea grass or signal grass.

Other tropical grasses such as signal grass, rhodes grass and guinea grass produced more than 5 t/ha with moderate fertiliser inputs and/or lime. However, the poor frost tolerance of signal grass and guinea grass limits their potential in north Guangdong Province where winter temperatures may reach –4°C and 14 frosts are experienced each year (Michalk and Huang 1994). The good performance of these grasses in our studies reflects the mild winter experienced in 1986-1987.

Lime application increased production of a number of grasses including couch grass, creeping blue grass, rhodes grass, signal grass, buffel grass, guinea grass (cv. Gatton) and green panic. However, of these only green panic has sufficient cold tolerance and superior quality to setaria to be potentially useful for grassland improvement in subtropical China.

Production of kikuyu and common paspalum was poor in all sowings. Both are subtropical grasses which are well adapted to climatic conditions similar to that of Lechang, and have the ability to extend production into the winter months, but need higher fertility conditions for good growth. If paddock fertility can be improved (Michalk *et al.* 1994a), these species may replace setaria as the grass component in improved pasture on at least part of the area available for grassland improvement to provide greater flexibility for livestock management.

Temperate grasses

Lime had a beneficial effect on ryegrass, with application of 2 t/ha increasing yield by about 20%. However, high fertiliser inputs (especially P, K and N) are needed to ensure good growth of temperate grasses even when lime is applied. Although these temperate grasses flowered, low boron levels in the soil (Michalk *et al.* 1988) prevented seed set and led to a failure to re-establish in the following autumn. In commercial sowings at Lechang Farm, ryegrass did re-establish from existing plants, but plant development was slow due to low soil fertility. Competition from faster growing tropical grasses is also a problem in the management of temperate pastures in subtropical areas. Invasion of white clover-ryegrass pastures by indigenous and introduced (e.g. setaria) grasses, which are better adapted to low fertility soils, has occurred at Lechang Farm.

The failure of phalaris to establish in any experiment, and variable production of cocksfoot indicate that further studies are needed to examine the fertiliser requirements and amendment strategies for the production and persistence of temperate grasses. The high aluminium saturation of the Lechang Hapludults explains the poor performance of phalaris which is known to be susceptible to aluminium toxicity (Helyar and Anderson 1971), but there is no apparent reason for the poor performance of cocksfoot in field trials. However, commercial observation at

Lechang Farm suggests that high production from pastures based on temperate species will be achieved only when soil fertility problems have been corrected (Michalk *et al.* 1994a).

Companion legumes

In evaluation studies conducted in north Guangdong Province, Wynn cassia performed most consistently and is recommended as a pioneer legume because it can establish quickly with low fertiliser inputs (Michalk and Huang 1994). In the present study, fertilised sown grasses and volunteer native species proved too aggressive and reduced cassia production to less than 5% of the sward with moderate fertiliser inputs. However, this may not reflect the situation under grazing where strategic management can be employed to maintain a more desirable grass-legume balance.

Lotononis, jointvetch and forage peanuts are alternative legumes which should be evaluated for compatibility with setaria (Michalk and Huang 1994). White clover is also a useful legume under rainfed conditions in regions like Lechang which receive moderate spring and autumn rainfall. However, additional magnesium fertiliser above that supplied by lime is needed for satisfactory white clover production on Hapludult soils in south China (Michalk and Huang 1993a).

The results obtained were used in conjunction with legume evaluations also undertaken at Lechang Farm (Michalk and Huang 1994) to formulate grass-legume mixtures which would improve soil (Michalk *et al.* 1994a) and beef cattle production systems (Michalk *et al.* 1994b) for use in north Guangdong Province.

Recommendation

Setaria is recommended as the main summer growing species for north Guangdong Province although molasses grass may be used as a pioneer grass in the initial stages of improvement. Perennial ryegrass is presently the only temperate grass able to provide quality winter feed but needs moderate to high fertiliser inputs. Further studies are required to select better companion legumes and to formulate better fertiliser strategies for setaria-based pastures in north Guangdong Province.

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