ACIAR Research Front

CSIRO PUBLISHING

*Australian Journal of Experimental Agriculture*, 2007, **47**, 942–948 www.publish.csiro.au/journals/ajea

# Quality and seasonal yields of promising forage species in the red soils region of southern China

*Wen Shilin*[A,C], *R. M. Jones*[B,D], *Xu Minggang*[C] *and Huang Pingna*[C]

[A]Hunan Agricultural University, Changsha, Hunan Province, China.
[B]Formerly: CSIRO Division of Livestock Industry, 306 Carmody Road, St Lucia, Qld 4067, Australia.
[C]CAAS Red Soils Research Station, Qiyang, Hunan Province, China.
[D]Corresponding author. Email: rmdjjones@bigpond.com

**Abstract.** Following increasing interest in the use of special purpose forages to provide quality feed for small holder beef farmers in the red soil region of inland southern China, 14 of the most promising accessions were evaluated over 2 years to measure their seasonal yield of leaf and stem. Seven grasses (six perennials and one annual) and two non-leguminous broadleaf herbs were fertilised with both 200 and 400 kg of nitrogen (N)/ha.year. Two herbs were fertilised with only 200 kg N/ha and three legumes were fertilised with 60 kg of N/ha. The accessions were evaluated under cutting, as cut-and-carry of improved forages is, and is likely to remain, more widely used than grazing in this region.

The highest yielding accessions were an elephant grass hybrid Guimu-1 [(*Pennisetum purpureum* × *P. americanum*) × *P. purpureum* cv. Mott] closely followed by elephant grass (*P. purpureum*) with total annual yields of 18–24 000 kg/ha in 2002, depending on accession and N rate, and 13–22 000 kg/ha in 2003. Their yields of leaf were 9–17 000 kg/ha in both years. Dwarf elephant grass cv. Mott gave similar yields of leaf but only half the yields of stem. Average leaf yields of the three elephant grass accessions were 24% higher at the higher rate of N in the first year and 40% higher in the second year.

With the exception of the herbs *Cichorium intybus* and *Silphium perfoliatum*, there was negligible growth in the cooler months (November–March) and the periods of peak growth were in July and August. *C. intybus* was the most promising of the legumes and herbs, but is damaged by waterlogging and disease.

Averaging over both years and all harvests, there was very little variation in the protein percentage of the different perennial grasses with levels of 12.4% at 200 kg N/ha and 13.7% at 400 kg N/ha. The corresponding protein percentage of the annual Mexican forage corn was higher (13.5 and 15.0%) but the legumes and herbs had a higher protein percentage (16–23%).

The most promising accession was dwarf elephant grass as it gives a high yield of leaf, but a relatively low percentage of stem. As such, it is well suited to a cut-and-carry system of feeding, especially as the time of cutting is less critical than with other forms of elephant grass, which can rapidly develop a high percentage of stem. However, given good management, higher yields of leaf can be obtained from the elephant grass hybrid.

## Introduction

There is an increasing standard of living in China and an increasing demand for beef. Therefore, the Chinese Government is encouraging beef production by smallholder farmers in southern China (Zhang 1991). Although there are some small specialist beef producers, most farmers with beef cattle still rely on rice production as their main enterprise and may have only 1–3 head of cattle (MacLeod *et al*. 2007). Rice straw is the main source of feed during winter and the feed in summer is primarily derived from residues from various crops, such as peanuts, and restricted grazing of low quality native pastures.

In southern China, the 'red soil' region covers some 2.2 million km$^2$ with a population of ~600 million (Xie *et al*. 1991). Rice production is mainly on the alluvial soils although some rice is grown on the better upland red soil areas. Some of the upland red soils are under native grassland, planted forests or orchards yet some large areas are unused. The quality of the native pasture is low, one of the main species being *Imperata cylindrica*. The area has major climatic contrasts between seasons. Winters are wet and cold, with isolated snowfalls, spring is wet and cool, summer is hot and humid and autumn is warm and dry.

To explore the potential to grow forages on these red soils, three Australian Centre for International Agricultural Research projects (UNE 1993; UNE 1998; CSIRO 2000) evaluated several hundred forage accessions. However, most of these failed. This was largely due to a combination of low soil fertility, low winter temperatures, high temperatures in mid summer and dry periods in autumn. The most promising accessions selected from these projects, together with some others selected from other studies, have been planted more widely as part of a follow-up study on beef production in this area (Wen *et al*. 2000). Although other feed sources, such as ammoniated rice straw, are used in the feed year as a result of these studies, fresh material from summer grown forage is a key component.

However, there was no information on the seasonal distribution of yield of these forages and such information is required to formulate a feed year and to determine the areas of land that are require to provide forage for a known period of

 10.1071/EA06053 0816-1089/07/080942

**Table 1. Monthly maximum and minimum temperatures at the CAAS Red Soils Research Station, Qiyang County, Hunan Province, China, from January 2002 to February 2004, with corresponding long-term averages (1958–2000)**

| Month | Maximum temperature (°C) | | | | Minimum temperature (°C) | | | |
|---|---|---|---|---|---|---|---|---|
| | Long-term average | 2002 | 2003 | 2004 | Long-term average | 2002 | 2003 | 2004 |
| January | 9.7 | 15.2 | 11.0 | 9.4 | 3.8 | 6.8 | 1.2 | 4.0 |
| February | 12.1 | 15.0 | 12.5 | 16.2 | 6.1 | 8.9 | 5.2 | 4.7 |
| March | 15.1 | 19.1 | 15.5 | – | 8.9 | 11.8 | 7.5 | – |
| April | 23.1 | 24.5 | 22.4 | – | 15.7 | 16.0 | 13.5 | – |
| May | 27.7 | 25.7 | 26.1 | – | 19.9 | 17.6 | 18.2 | – |
| June | 30.4 | 31.7 | 30.8 | – | 23.2 | 23.2 | 21.8 | – |
| July | 33.3 | 32.4 | 36.7 | – | 25.3 | 23.8 | 26.2 | – |
| August | 33.2 | 31.0 | 34.3 | – | 25.2 | 22.7 | 24.6 | – |
| September | 29.4 | 27.3 | 30.9 | – | 21.3 | 19.3 | 20.2 | – |
| October | 23.6 | 23.6 | 24.9 | – | 15.8 | 13.4 | 13.2 | – |
| November | 18.3 | 18.7 | 18.8 | – | 10.5 | 9.4 | 8.8 | – |
| December | 13.3 | 9.3 | 12.2 | – | 6.4 | 3.9 | 1.5 | – |

time for a known number of animals. The present study was undertaken to gather some of this information. In addition, protein and phosphorus (P) percentages, as well as leaf and stem yield, were measured to provide an indication of feed quality.

## Methods

The study was carried out on a terraced soil on the lower hill slopes of the CAAS Red Soil Experiment Station (26.8°N, 111.9°E) in Qiyang County, Hunan Province, China. The site was representative of the upland paddy fields likely to be used for growing forage. The clay soil, of pH 5.1, was well drained and had primarily been used for growing grain crops. Monthly average temperatures and rainfall, as measured on the station, are given in Table 1 and Fig. 1.

Fourteen accessions (six perennial tropical grasses, one annual tropical grass, three tropical legumes, three non-leguminous perennial herbs and one annual herb) were established in March 2002. Most accessions (Table 2) were established vegetatively, whereas Wynn cassia (*Chamaecrista rotundifolia*) and *Chamaecrista nictitans* were seeded at 10 kg/ha. No measures were taken to protect plants over winter and there was considerable death over the first winter. Consequently, many plants of some accessions were reestablished as required after a rating of the percentage survival.

All grasses and two of the herbs were grown with both 200 and 400 kg nitrogen (N)/ha, two herbs were grown with only 200 kg of N due to the limited area of available land, and the three legumes were fertilised with 60 kg N/ha. The N fertiliser, as urea, was evenly applied as a top dressing each month from March to October in both years. All plots received a basal fertiliser with 40 kg P/ha and 50 kg K/ha in March 2002 and again in March 2003.

Plot size was 2 by 3 m with a guard row of 1 m between plots. Plots were hand weeded throughout without any insect control. There were three replicates in a randomised block design.

The whole experiment was harvested whenever any plot was classed as having a complete leaf canopy with full radiation interception. The practical outcome of this was that the greatest number of harvests for any accession was seven in 2002 and eight in 2003. For most accessions, there was enough growth to enable six yield measurements to be made, with the first harvest in May and the last in October. The whole plot was harvested and a subsample of 600 g was taken, separated into leaf and stem and oven-dried at 70°C. The dried leaf and stem were then recombined for measurements of percentage N and P

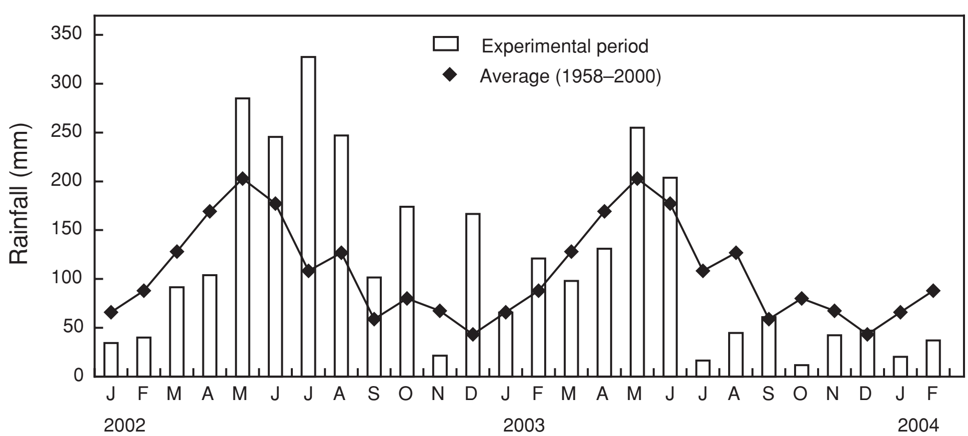


**Fig. 1.** Monthly rainfall in 2002–03 and long-term averages at the CAAS Red Soils Research Station, Qiyang.

**Table 2. The species tested, sowing rate and plant spacing, and species survival over the 2002–03 winter, and the level of nitrogen (N) applied**

| Species | Common name and accession | Sowing rate and plant spacing | Reestablished in 2003 and winter survival (%) | N applied (kg/ha) | |
|---|---|---|---|---|---|
| *Pennisetum purpureum* | Elephant grass | 1500 kg/ha stems (transplant) | Some (70%) | 200 | 400 |
| *Pennisetum purpureum* | Dwarf elephant grass cv. Mott | 1500 kg/ha stems (transplant) | Some (70%) | 200 | 400 |
| (*Pennisetum purpureum* × *P. americanum*) × *P. purpureum* cv. Mott | Dwarf elephant grass hybrid Guimu-1[A] | 1500 kg/ha stems (transplant) | Some (70%) | 200 | 400 |
| *Setaria sphacelata* | cv. Solander | 15 by 25 cm (transplant) | Most (40%) | 200 | 400 |
| *Hemarthria compressa* | cv. Chongqing | 15 by 25 cm (transplant) | None (100%) | 200 | 400 |
| *Digitaria eriantha* | Finger grass cv. Premier | 15 by 25 cm (transplant) | None (100%) | 200 | 400 |
| *Zea mays* | Mexican forage corn | 15 by 25 cm (seedling transplant) | All (0%) | 200 | 400 |
| *Lotononis bainseii* | cv. Miles | 15 by 25 cm (transplant) | All (0%) | 60 | |
| *Chamaecrista rotundifolia* | cv. Wynn | 10 kg/ha | All (0%) | 60 | – |
| *Chamaecrista nictitans* | ATF 2217 | 10 kg/ha | All (0%) | 60 | – |
| *Cichorium intybus* | Chicory cv. Puna | 15 by 25 cm (transplant) | None (100%) | 200 | 400 |
| *Rumex patentia* × *R. tianschanicus* | Rumex K-1 | 15 by 25 cm (transplant) | None (100%) | 200 | 400 |
| *Silphium perfoliatum* | cv. 79–233 | 15 by 25 cm (transplant) | None (100%) | 200 | – |
| *Amaranthus cruentus* | cv. K472 | 15 by 25 cm (seedling transplant) | All (0%) | 200 | – |

[A]The development of this hybrid is described in Liang (1999).

## Results

### Climate

Monthly maximum and minimum temperatures for 2002 and 2003, together with corresponding long-term averages, are given in Table 1. Equivalent rainfall data are given in Fig. 1. The 2002–03 winter was colder than average, with three snowfalls, one with 20 cm of snow. Rainfall conditions ranged from much wetter than average in autumn–summer (May–August) 2002 and much drier than average in late summer–autumn (July–November) 2003.

### Survival over winter

The only grasses with 100% survival of tussocks over the winter were *Hemarthria compressa* and Premier finger grass. No legumes survived the winter, yet there were no deaths in the three perennial herbs (Table 2).

### Yields

Yields in 2002 tended to be higher than in 2003 (Tables 3 and 4), the range for perennial grasses being 11–24 000 kg/ha in 2002 and 6–22 000 kg/ha in 2003. In particular, yields of Premier finger grass, Solander setaria, Mexican forage corn, all

**Table 3. Leaf, stem and total (leaf + stem) dry matter yields (kg/ha) in 2002**

The l.s.d. values are for any accession × nitrogen (N) rate comparison. n.a., not applicable

| | Leaf yield | | Stem yield | | Total yield | |
|---|---|---|---|---|---|---|
| | 200 kg N/ha | 400 kg N/ha | 200 kg N/ha | 400 kg N/ha | 200 kg N/ha | 400 kg N/ha |
| *Grasses* | | | | | | |
| Elephant grass | 10 850 | 12 380 | 7200 | 8290 | 18 070 | 20 660 |
| Dwarf elephant grass | 9220 | 12 190 | 2360 | 3230 | 11 580 | 15 420 |
| Elephant grass hybrid | 13 140 | 16 550 | 4940 | 7950 | 18 080 | 24 490 |
| Solander setaria | 7740 | 9340 | 5270 | 7830 | 13 010 | 17 170 |
| *Hemarthria compressa* | 4790 | 5910 | 8550 | 8860 | 13 300 | 14 770 |
| Premier finger grass | 6920 | 7220 | 3920 | 4670 | 10 830 | 11 890 |
| Mexican forage corn | 7570 | 7530 | 5030 | 5600 | 12 600 | 13 120 |
| l.s.d. ($P = 0.05$) | 1120 | | 710 | | 1340 | |
| *Herbs* | | | | | | |
| *Cichorium intybus* | 6050 | 7480 | 0 | 0 | 6050 | 7480 |
| Rumex K-1 | 4030 | 4630 | 0 | 0 | 4030 | 4630 |
| *Silphium perfoliatum* L. | 3440 | – | 0 | – | 3440 | – |
| *Amaranthus cruentus* L. | 3420 | – | 1520 | – | 4940 | – |
| l.s.d. ($P = 0.05$) | 730 | | n.a. | | 740 | |
| *Legumes (60 kg N/ha only)* | | | | | | |
| *Chamaecrista rotundifolia* | 5170 | – | 3280 | – | 8450 | – |
| *Chamaecrista nictitans* | 4120 | – | 2130 | – | 6240 | – |
| *Lotononis bainseii* | 4770 | – | 0 | – | 4770 | – |
| l.s.d. ($P = 0.05$) | n.a. | | 450 | | 1290 | |

**Table 4. Leaf, stem and total (leaf + stem) dry matter yields (kg/ha) in 2003**
The l.s.d. values are for any accession × nitrogen (N) rate comparison. n.a., not applicable

| | Leaf yield | | Stem yield | | Total yield | |
|---|---|---|---|---|---|---|
| | 200 kg N/ha | 400 kg N/ha | 200 kg N/ha | 400 kg N/ha | 200 kg N/ha | 400 kg N/ha |
| *Grasses* | | | | | | |
| Elephant grass | 8550 | 8630 | 4580 | 4770 | 13130 | 13400 |
| Dwarf elephant grass | 8530 | 14380 | 2300 | 3450 | 10420 | 17830 |
| Elephant grass hybrid | 11470 | 16880 | 3850 | 5420 | 15320 | 22300 |
| Solander setaria | 4120 | 5930 | 2300 | 3080 | 6420 | 9020 |
| *Hemarthria compressa* | 5180 | 6530 | 6630 | 8100 | 11820 | 14630 |
| Premier finger grass | 6450 | 6200 | 2050 | 2750 | 8500 | 8950 |
| Mexican forage corn | 4280 | 4370 | 2030 | 2030 | 6320 | 6400 |
| l.s.d. (*P* = 0.05) | 970 | | 670 | | 1130 | |
| *Herbs* | | | | | | |
| *Cichorium intybus* | 6950 | 7380 | 0 | 0 | 6950 | 7380 |
| Rumex K-1 | 967 | 617 | 0 | 0 | 970 | 620 |
| *Silphium perfoliatum* | 6430 | – | 0 | – | 6430 | – |
| *Amaranthus cruentus* | 1220 | – | 580 | – | 1800 | – |
| l.s.d. (*P* = 0.05) | 870 | | n.a. | | 870 | |
| *Legumes (with 60 kg N/ha only)* | | | | | | |
| *Chamaecrista rotundifolia* | 2780 | – | 1480 | – | 4270 | – |
| *Chamaecrista nictitans* | 2750 | – | 1400 | – | 4150 | – |
| Lotononis | 1620 | – | 0 | – | 1620 | – |
| l.s.d. (*P* = 0.05) | 440 | | 260 | | 580 | |

the legumes and *Amaranthus cruentus* were appreciably lower in 2003 than in 2002. The three accessions of elephant grass gave the highest yield of leaf at both rates of N in both years. Their yields of leaf were 9–17000 kg/ha, depending on accession and N rate, in both 2002 and 2003. The only grass with a higher stem yield than leaf yield was *H. compressa*.

Average leaf yields of the three elephant grass accessions were 24% higher at the higher rate of N in 2002 and 40% higher in 2003. The response to the higher rate of N was greater for dwarf elephant and elephant grass hybrid than for standard elephant grass, especially in 2003.

*Cichorium intybus* and *Silphium perfoliatum* were the highest yielding herbs and all the harvested material was leaf. *Rumex* gave similar yields to these in 2002 but yielded much less in 2003 and *A. cruentus* had the lowest leaf yield in both years. The three legumes gave similar leaf yields to *C. intybus* and *S. perfoliatum* in 2002 but had much lower leaf yields in 2003.

Seasonal yields of the grasses was similar, so they are presented for only one accession, the elephant grass hybrid, in Fig. 2. Typically, there was no grass growth from winter to early spring (December–March) and grass yields were still low in late spring (May). The cool season yields of the three legumes were equally poor. There was some growth of *C. intybus* and *S. perfoliatum* in the cooler months, as shown for *C. intybus* in Fig. 2.

## *Protein and P percentage*

There was little variation between the protein concentration of the grasses, although *H. compressa* had the lowest at both rates of applied N (Table 5). The protein percentage was 1–2% higher with the 400 kg N/ha compared with 200 kg N/ha. All herbs had an appreciably higher protein percentage than the grasses. *C. rotundifolia* had the lowest protein concentration of all the herbs and legumes.

The P concentration of both herbs and legumes (0.48–0.54% at 200 kg N/ha) were higher than those of the grasses (0.33–0.41%) at 200 kg N/ha. P percentage was always lower at the higher N rate.

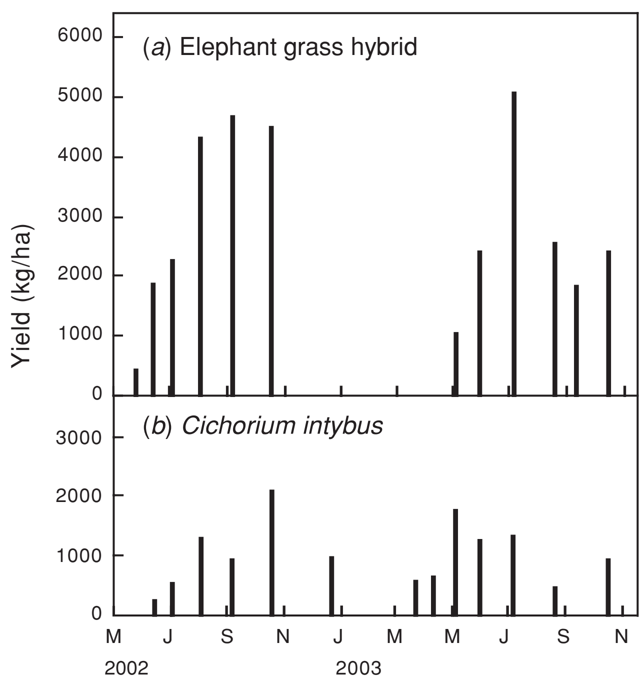


**Fig. 2.** The seasonal yield of elephant grass hybrid and of *Cichorium intybus* from May 2002 to October 2003.

**Table 5. Percentage crude protein and phosphorus of fourteen forages, averaged over all harvests**
The l.s.d. values are for any accession × nitrogen (N) rate comparison

| | Protein (%) | | Phosphorus (%) | |
|---|---|---|---|---|
| | 200 kg N/ha | 400 kg N/ha | 200 kg N/ha | 400 kg N/ha |
| | *Grasses* | | | |
| Elephant grass | 12.4 | 14.0 | 0.38 | 0.32 |
| Dwarf elephant grass | 12.9 | 14.6 | 0.41 | 0.31 |
| Elephant grass hybrid | 13.1 | 13.9 | 0.35 | 0.30 |
| Solander setaria | 12.1 | 13.8 | 0.40 | 0.38 |
| *Hemarthria compressa* | 11.7 | 12.5 | 0.36 | 0.33 |
| Premier finger grass | 11.9 | 13.5 | 0.39 | 0.37 |
| Mexican forage corn | 13.5 | 15.0 | 0.33 | 0.32 |
| l.s.d. ($P = 0.05$) | 1.0 | | 0.04 | |
| | *Herbs* | | | |
| *Cichorium intybus* | 18.8 | 19.7 | 0.50 | 0.45 |
| Rumex K-1 | 22.8 | 23.0 | 0.53 | 0.46 |
| *Silphium perfoliatum* | 18.8 | – | 0.48 | – |
| *Amaranthus cruentus* | 20.1 | – | 0.54 | – |
| l.s.d. ($P = 0.05$) | 0.9 | | 0.04 | |
| | *Legumes (with 60 kg N/ha only)* | | | |
| *Chamaecrista rotundifolia* | 15.7 | – | 0.52 | – |
| *Chamaecrista nictitans* | 17.4 | – | 0.48 | – |
| *Lotononis bainseii* | 20.6 | – | 0.48 | – |
| l.s.d. ($P = 0.05$) | 1.1 | | n.s. | |

## Discussion

The three accessions of elephant grass gave the highest leaf yields in both years at both rates of N and they must be considered as the most promising forage grasses for incorporation into the feed year for beef cattle in this region. The fact that they must be established vegetatively rather than by seed is an advantage rather than a disadvantage for farmers. Adequate sources of vegetative material are being made available. Although our experience suggests that it takes some 30 man days per hectare to establish elephant grass, this is not a serious problem as we estimate that only small areas would be needed for elephant grass to fulfil its role in a feed year. Vegetative propagation is well accepted by smallholder farmers. In contrast, there have been many more problems in establishing small seeded grasses such as Solander setaria and Premier finger grass.

One disadvantage of elephant grasses in this trial is that ~30% of the tussocks died over winter and plants had to be reestablished the following spring. This is not surprising as elephant grass is regarded as a species suited to the humid tropics, although it has been noted as being able to survive light frost (‘t Mannetje 1992). However, other studies at a nearby site have shown that survival over a severe winter was increased from 10 to 85% by protecting tussocks with a 5-cm layer of straw and to 95% by covering tussocks with a 5-cm layer of soil (W. Shilin, unpubl. data). Both these options are considered to be practical on smallholder farms. Furthermore, survival of elephant grass varies between sites and years and in some plantings, there has been negligible death. Thus we believe that winter survival will not be a major limiting factor to the use of elephant grasses in this area.

As recorded in other studies (i.e. Van de Wouw *et al.* 1999), standard elephant grass gave higher total yields than dwarf elephant grass. However, there are sound reasons for suggesting that it would be best to use the dwarf strain as its leaf yield was similar to that of normal elephant grass. The higher quality of leaf (Laredo and Minson 1975; ‘t Mannetje 1992) means that leaf yield is the key attribute when selecting the preferred accessions. This is particularly so in a cut-and-carry system. Delays in cutting time of the dwarf type will be less critical than in the normal strain, which can rapidly elongate during peak growth periods. Furthermore, there is little point in farmers having to cut and carry large amount of stem, which is of lower quality and, in our experience, is largely uneaten by cattle (W. Shilin, unpubl. data). Nevertheless, the hybrid elephant grass gave the highest yields of leaf in both years and could be preferred by some smallholders. The hybrid also appreciably outyielded cv. Mott dwarf elephant grass in trials carried out during its development (Liang 1999). However, time of cutting is much more critical for the hybrid than it is for dwarf elephant grass. Also, the visual attractiveness of high total yields may lead to delayed cutting and hence to increased levels of stem. Nevertheless, both the hybrid and dwarf forms are being given out to farmers for on-farm testing.

Applying the higher rate of N to elephant grass produced an extra 13 kg of dry matter (DM) per kg of N in 2002 and 19 kg DM in 2003. The current price of one kg of N, as urea, is ~3.5 yuan. This extra amount of leaf produced per kg of N above 200 kg N/ha should produce at least one kg of beef (W. Shilin, unpubl. data), which is worth ~6 yuan. Local farmers are used to applying N to rice and that the concept of N fertilisation is widely used and supplies are adequate and reliable. However, from early on-farm testing of elephant grass, it appears that many farmers may give priority use to the manure that they remove from stalls. Preliminary economic assessments of the role of elephant grass as part of a feed year for smallholder beef producers in the red soils area are promising (MacLeod *et al*. 2007).

Using the yield data provided, it is possible to make an estimation of the area of elephant grass required to produce feed for a given number of months. For example, a 200 kg animal needs 200 kg of DM per month (allowing 5 kg per day and 50 kg for wastage) for good growth. Therefore, during the main growth period (June–November), when elephant grass could produce 2000 kg/ha, primarily of leaf, per month, 0.1 ha could provide adequate feed for one animal.

There were no reasons to suggest that any of the other grasses should be used in preference to elephant grass. The smaller seeded grasses such as setaria and finger grass have not established reliably and many sowings have failed. Seed has to be imported and is expensive. *H. compressa* can be established vegetatively, gives better early spring growth than elephant grass, survives cold winters without any protection and tolerates waterlogged conditions. However, it has the highest stem percentage of all the grasses and the lowest protein concentration. The superiority of the elephant grass accessions was confirmed in other concurrent trials at the CAAS Red Soils Station and also at Jianxi Agricultural University, Jianxi Province (Wen *et al*. 2004).

The protein percentages of the bulked samples of leaf and stem of elephant grass, even given only 200 kg N/ha, would be more than adequate for beef production. The protein percentages at both 200 and 400 kg N/ha were ~2 percentage units higher than obtained at the same fertiliser rates in South Africa (Pieterse and Rethman 2002). It is reasonable to assume that the N percentages of leaf would be even higher than that of the bulked leaf and stem samples analysed in the present study. Tudsri *et al*. (2002) found that N% in leaves of elephant grass was usually 50% or more higher than that in stems, whereas there was little difference in the P% of leaf and stem, the P levels in stem usually being marginally higher. As would be expected from the basal fertilisation, P concentrations were much more than adequate although being slightly lower in the higher yielding material grown at the higher N rate.

All three legumes tested show less promise of being commercially used in beef production systems. Both *Chamaecrista* accessions have at times not been readily accepted by cattle although *C. nictitans* has been well eaten by goats (W. Shilin, unpubl. data). A low preference for Wynn cassia, especially during periods of peak growth, has been noted in other studies under grazing (e.g. Clements *et al*. 1996; Jones *et al*. 2000). *C. nictitans* has an upright growth habit, in contrast to Wynn, and would be easier to harvest in a cut-and-carry system. If *Chamaecrista* accessions are to find a place on farms, it will be as pure swards on soils with a low N status as neither species can persist in legume-grass swards in this environment (W. Shilin, unpubl. data). *Lotononis bainseii* has a prostrate growth habit and, although it shows promise as a monospecific ground cover in orchards in this environment (Wen 2003), it is not suitable as a reliable component in a feed year.

*C. intybus* was the most promising herb, although it is usually regarded as a species grown in mild temperate environments such as parts of Europe, the United States and New Zealand, where cv. Grassland Puna was released. It grew during the cooler months and its yields of leaf in 2003 were higher than all the grasses except the three elephant grass accessions. Unfortunately, *C. intybus* has been severely damaged by unknown disease problems, especially under waterlogged conditions. Furthermore, although *C. intybus* does grow slowly during winter and early spring, its growth may not always be sufficient to warrant the labour involved in cutting and carrying the forage to penned animals. However, further studies of a wider range of *C. intybus* accessions may be warranted. The *Rumex* hybrid was severely damaged by insects during summer. *A. cruentus* showed no promise as it grew poorly and acted as an annual in southern China. *S. perfoliatum* had a similar yield and growth period to *C. intybus,* and no disease or insect problems. However, it has, at times, not been readily accepted by cattle.

In conclusion, this study has shown that elephant grass, preferably the dwarf form or else the taller and more productive hybrid, warrants wider testing in on-farm situations to see if it can meet the needs of smallholder beef producers in the red soils region of southern China. Care will need to be taken to ensure that it is cut regularly enough to maintain a high leaf : stem ratio, especially so if non-dwarf accessions are grown, and that it is adequately fertilised with N and basal nutrients as inorganic fertiliser or manure to maintain high productivity (‘t Mannetje 1992). Using straw or mulch to protect tussocks over winter may be required in some areas. It can be the main source of quality green feed for some 6 months and experience has shown that dwarf elephant grass can make good quality leafy hay. The other main feed source, apart from purchased concentrates, will be ammoniated rice straw used in the cooler months. Many farmers use other crop residues and some are using N fertilised annual rye grass to provide feed in late winter–early spring.

## Acknowledgements

We thank Ms Shen Huaping for helping with analysis of plant samples. The work was carried out as part of ACIAR project AS2/98/35 and Chinese state brainstorm project 2001BA508B-14.

## References

Clements RJ, Jones RM, Valdes LR, Bunch GA (1996) Selection of *Chamaecrista rotundifolia* by cattle. *Tropical Grasslands* **30**, 389–394.

CSIRO (2000) Selecting *Chaemacrista rotundifolia* for soil stabilisation and forage. Report to ACIAR on Project LWR1/96/172. CSIRO Livestock Industries, Brisbane.

Jones RM, McDonald CK, Clements RJ, Bunch GA (2000) Sown pastures in subcoastal south-eastern Queensland: pasture composition, legume persistence and cattle liveweight gain over 10 years. *Tropical Grasslands* **34**, 21–37.

Laredo MA, Minson DJ (1975) The voluntary intake and digestibility by sheep of leaf and stem fractions of *Lolium perenne. Journal of the British Grassland Society* **30**, 73–77.

Liang Y (1999) Studies on selection and cultivation of Guimu-1 hybrid *Pennisetum purpureum. Grasslands of China* **1**, 19–22.

MacLeod N, Wen S, Hu M (2007) An economic assessment of forage systems to improve the profitability of smallholder beef cattle enterprises in the Red Soils region of China. *Australian Journal of Experimental Agriculture* **47**, in press.

Pieterse PA, Rethman NFG (2002) The influence of nitrogen fertilization and soil pH on the dry matter yield and forage quality of *Pennisetum purpureum* and *P. purpureum* × *P. glaucum* hybrids. *Tropical Grasslands* **36**, 83–89.

'‘t Mannetje L (1992) *Pennisetum purpureum* Schumach. In ‘Plant resources of South-East Asia. No. 4. Forages’. (Eds L ‘t Mannetje, RM Jones) pp. 191–192. (Pudoc: Wageningen)

Tudsri S, Jorgensen ST, Riddach P, Pookpakdi A (2002) Effect of cutting height and dry season closing date on yield and quality of five napier grass cultivars in Thailand. *Tropical Grasslands* **36**, 248–252.

UNE (1993) Forage development of the red soils of south central China. Report to ACIAR on Project LWR 89/25.University of New England, Armidale.

UNE (1998) Forage management for the red soils of south central China. Report to ACIAR on Project LWR1/93/03. University of New England, Armidale.

Van de Wouw M, Hanson J, Luethi S (1999) Morphological and agronomic characterization of a collection of napier grass (*Pennisetum purpureum*) and *P. purpureum* × *P. glaucum. Tropical Grasslands* **33**, 150–158.

Wen S (2003) Ground cover in southern China orchards. *Tropical Grassland Society of Australia News & Views* **19**(4), 7.

Wen S, Macleod D, Scott J, Xu M, Huang P (2000) Forage research on red soils of southern China. In ‘Working with farmers: the key to adoption of forage technologies’. ACIAR Proceedings No. 95. (Eds WW Stur, PM Horne, JB Hacker, PC Kerridge) p. 177. (ACIAR: Canberra)

Wen S, Xie G, Jones D (2004) Forage Production. Report to ACIAR on Project AS2/98/35. Ruminant production in the red-soils region of southern China and in northern Australia. CSIRO Livestock Industries, Rockhampton. Review 3, pp. 1–16.

Xie K, Zhang J, Horne P (1991) Potential and problems for forage development and animal production in the red soils region of southern China. In ‘Forages on red soils in China’. ACIAR Proceedings No. 38. (Eds PM Horne, DM Macleod, JM Scott) p. 11. (ACIAR: Canberra)

Zhang S (1991) Keynote Address. In ‘Forages on red soils in China’. ACIAR Proceedings No. 38. (Eds PM Horne, DM Macleod, JM Scott) p. 1. (ACIAR: Canberra)

Manuscript received 6 February 2006, accepted 7 February 2007