Section C

Practical and commercial utilisation of *Stylosanthes*

Chapter 22

Stylosanthes: A promising legume for Africa

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Summary

Although a number of pasture legumes have been tried in Africa, these are of minor importance compared with those from the genus *Stylosanthes*. Several species are well adapted to a range of soil and climatic conditions throughout Africa. There is a considerable body of knowledge on its use under various utilisation schemes, although commercial use has been restricted due to problems with seed production and the availability of suitable germplasm for some target environments. In recent years there has been a resurgence of interest in this crop. However, the potential of the genus has not been fully exploited in Africa. This chapter summarises its current usage and highlights the major constraints that have restricted its production and expansion.

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Introduction

To improve livestock productivity in Africa, sustainable solutions to seasonal deficiencies in feed availability and quality are required. Traditionally, livestock rearing has been the specialised vocation of nomadic and transhumance pastoralists; therefore, technological changes in livestock and feed production management strategies have been targeted at this group.

A number of pasture legumes such as *Macroptilium* (Siratro), *Centrosema, Desmodium*, Puero and *Glycine* have been tried in Africa but these are of minor importance compared with those from the genus *Stylosanthes* (stylo). A diversity of species and cultivars of this genus is available in Africa. These include *S. hamata* cv. Verano; *S. guianensis* cvv. Graham, Cook, Endeavour and Schofield; and some cultivars of *S. scabra* and *S. humilis. Stylosanthes* has successfully fitted into the dryland agriculture of Africa, but in the last decade there have been dramatic changes in the areas sown to improved pasture. Reliance on natural pastures that provide the cheapest source of nutrients for ruminants has resulted in failure to meet the nutritional needs of livestock throughout the year. Native pasture is predominantly made up of low quality grasses and the crude protein content of the herbage is only sufficient for three to four months of the year when herbage growth flourishes following rainfall.

Consequently, considerable attention has been focused on the use of high-protein green or dried leaf materials as a feed concentrate. The advantage of using *Stylosanthes* as a protein resource is the high yield of protein per hectare when the crop is harvested several times in one growing season. This offers a tremendous opportunity for the large-scale production of *Stylosanthes* in Africa in conjunction with its existing usage in animal nutrition from pasture-based systems. A previous review by de Leeuw et al (1994) collated information on *Stylosanthes* research and development in West Africa. Focusing largely on recent work in Nigeria, this chapter provides an overview of current *Stylosanthes* usage under different utilisation schemes in Africa, updates information and outlines recent developments.

Adaptation and Cultivars

Stylosanthes species were introduced into Africa between 1949 and 1959 (Lazier 1984), starting with a small number of cultivars from Australia, and many studies on adaptation and utilisation have focused on this limited range of Australian cultivars. *Stylosanthes guianensis* has widely adapted to regions from the north of Senegal (16°N) to Southern Zaire (12°S) (Borget 1969; Risopoulus 1966) and Angola (Sousa Costa, pers. comm.), and from the northern Guinea zone to the humid zone in Nigeria (Adegbola 1964, 1965; Agishi 1971), Ghana (Anon. 1974), Mali, Cote d'Ivoire (Borget 1971), Benin (Borget et al 1969) and Cameroon (Piot 1969). However, it does not survive the seven to eight-month-long dry season of the Sudan zone (Guerin 1977).

Studies on *Stylosanthes* in Nigeria started in 1945 with the introduction of four prominent *S guianensis* cultivars Schofield, Cook, Oxley and Endeavour (Ajileye 2000). Of these, Schofield was the only late maturing and highly productive forage crop to be used in various pasture improvement programs until the appearance of the anthracnose disease. Cook was also late maturing and gave superior performance in areas with frequent bush fires and with low rainfall.

Stylosanthes humilis (Townsville stylo) was another species that became very popular between the late 1960s and mid 1970s. It is a self-regenerating annual imported from Australia and is well adapted to the dry and subhumid areas. Its introduction into the rangelands resulted in a more than ten-fold increase in cattle liveweight gains (Agishi 1982). In Nigeria it is adapted to areas receiving between 700 and 1500 mm annual rainfall. Dry matter yield of *S. humilis* is about half that of Schofield. *Stylosanthes hamata* cv. Verano yields somewhere between Schofield and Townville stylo and behaves both as an annual and a perennial. Its range of climate and soil adaptability in Nigeria is wider than that of Townsville stylo. It was first introduced into Nigeria by the pasture unit of the Federal Livestock Department of Nigeria in 1974 (Agishi 1982; Ajileye 2000; Amodu et al 2002) and over 95% of the seeds in use in Nigeria have come from the original introduction from Australia. Since 1976 intensive studies have been carried out on Verano at the National Animal Production Research Institute, Shika, Nigeria.

The International Livestock Centre for Africa (ILCA) has more recently conducted extensive introduction and evaluation trials with larger numbers of *Stylosanthes* germplasm covering a broad range of species. These have been tested in Nigeria by ILCA programs at Ibadan on the southern edge of the derived savanna, in the northern Guinea savanna at Kaduna, in Cameroon at Bambui and Ngaoundere, in Senegal and in Zaire.

Establishment

Most *Stylosanthes* species can be established with or without land preparation. The most common method of establishment includes broadcasting of seed into natural grassland without any land preparation, although sowing is often carried out after a partial defoliation with herbicide or after burning. Broadcasting seed into fallow land or unprepared soil can similarly establish it. However, stylo often suffers from severe competition from existing vegetation, resulting in poor establishment, slow growth and poor vigour, although in Nigeria some cultivars such as Verano have been found to establish well when sown into burnt ground followed with a superphosphate application at the rate of 100 kg/ha (de Leeuw 1980). The best method for the establishment of Verano and Cook at the National Animal Production Research Institute, Shika, Zaria, has been on cultivated land where competition for nutrients, water and sunlight is minimal. Seed scarification with hot water at 100°C for 1 minute prior to sowing reduces the percentage of hard seeds, resulting in early and uniform establishment. However, seed scarification may prove hazardous in areas with erratic and unreliable rainfall. Sowing onto cultivated strips, cleared following a soil disturbance, gives the best establishment, but this is more expensive than simple broadcasting (de Leeuw et al 1979).

Compatibility with Grasses

In Africa the widest experience with *Stylosanthes* species has been with its use as a component of improved grass–legume pastures. Stylo combines well with molasses grass (*Brachiaria ruziziensis*) in Madagascar (Grainer 1973) and Zaire (Risopoulos 1966), and with *Hyparrhenia rufa, Chloris gayana, Panicum maximum* and *Setaria* at Serere, Uganda (Stobbs 1969). In the northern part of Nigeria Verano is compatible with *Chloris gayana, Cenchrus ciliaris, Andropogon gayanus, Panicum maximum* and *Urochloa mosabicensis* where it has been sown into existing grass swards (de Leeuw & Brickman 1980). In mixed swards under cutting Verano and Townsville stylo persist better than the grasses *C. viliaris* cv. Biloela or *V. maximum* var *trichoglume* (Shehu et al 1980).

Akinola (1991) introduced and screened ten cultivars of *Stylosanthes,* along with chosen indigenous and already adapted forages, as a means of identifying material with potential for combining optimum herbage yield, leaf:stem ratio and crude protein content at the end of the growing season with improved persistence in the dry season. The test sites were in two climatically contrasting environments: Shika in the subhumid zone and Ile-Ife in the humid zone. Investigations at Shika were conducted in 1978 and 1979, while those at the Ile-Ife site were during 1988–89. The performance of *S. guianensis* cv. Cook in the humid zone was good although the yield was 3.2 t dry matter per ha less than that at Shika (Table 22.1). The variation in yield was associated with the slight difference in soil properties and the higher anthracnose disease incidence at Ile-Ife where rainfall was non-limiting to plant growth. All the other cultivars except *S. humilis* cv. Paterson had average dry matter

Table 22.1 Dry matter (DM) and crude protein (CP) yields (t/ha/yr) of indigenous and introduced forages at Shika (1978–79) and Ile-Ife (1988–89).

Forage Species	Shika			Ile-Ife		
	DM		CP	DM		CP
	t/ha/yr	1979 as % of 1978	kg/ha/yr	t/ha/yr (Lcont)*	1979 as % of 1978	kg/ha/yr
Gliricidia sepium				4.7(48.0)	204.2	658
Lablab purpureus						
cv. High-worth	–	–	–	8.4(30.9)	182.0	1234
cv. Rongai	7.4	123.2	1031	6.3(35.5)	157.0	899
cv. White	–	–	–	6.3(34.8)	177.0	851
Leucaena leucocephala						
cv. Hawaii	–	–	–	7.8(31.0)	334.0	807
cv. Peru	2.9	1082.2	421	6.1(33.4)	400.0	618
Macroptilium atropurpureum						
cv. Siratro	4.3	212.4	613	4.8(34.7)	211.0	728
Macroptilium axillare	–	–	–	4.2(32.0)	332.0	513
Macroptilium uniflorum	5.1	57.9	760	–	–	–
Macroptilium wightii						
cv. Clarance	–	–	–	3.9(35.4)	218.0	523
cv. Cooper	–	–	–	3.0(27.6)	208.0	394
Stylosanthes capitata	–	–	–	5.7(3.1)	75.0	688
Stylosanthes guianensis						
cv. Cook	9.7	78.6	1230	6.4(28.5)	91.6	701
cv. Endeavour	5.3	44.9	697	5.2(31.3)	91.5	622
cv. Oxley	3.3	60.0	417	–	–	–
cv. Schofield	5.3	35.1	710	–	–	–
Stylosanthes hamata						
cv. Verano	6.0	63.3	658	7.9(21.3)	67.1	767
Stylosanthes humilis						
cv. Gordon	3.4	77.4	400	–	–	–
cv. Paterson	2.3	80.7	262	–	–	–
Stylosanthes scabra						
cv. Fitzroy	–	–	–	9.6(29.4)	117.9	1113
cv. Seca	–	–	–	7.2(29.2)	132.2	789
Vigna ambicensis				1.7(31.9)	16.6	237

*(Lcont) = Leaf contribution   Source: Akinola (1991)

yields but the herbage was low in crude protein content. Verano had one of the poorest yields due to leaf senescence and defoliation with the onset of the dry season. Rhodes grass and stylo have been sown in Nigeria by broadcasting or drilling (Blair Rains 1963; Haggar 1971; Onifade & Akinola 1986). Schofield stylo was oversown in savanna grassland (Haggar 1971) while Rhode grass (Blair Rains 1963) and Cook stylo (Saleem et al 1986) were mixed in millet and sorghum plantings. Comparable results were obtained for Cook stylo in a mixture with Rhodes grass (Onifade & Akinola 1990) and for Schofield stylo with signal grass (Akinola 1981). Akinola (1977) reported dry matter yields of 13.5 and 14.4 t/ha, respectively, for Schofield stylo grown with signal grass when the legume was broadcast and drilled in rows.

At Serere, Uganda, Stobbs (1969) reported the suppression of the legume Sirato by guinea grass and of stylo by Jaragua grass, both at 1.65 steers/ha, but the legumes became dominant at 2.47 and 4.94 steers/ha, respectively. Shaw (1961) did not detect any dominance of Townsville stylo in native spear grass pastures at 0.33 or 1.10 steers/ha.

Dry Matter Yield

In general, cultivars of perennial species such as Cook, Endeavour, Graham and Schofield yield higher than the mostly annual Verano and Townsville stylo. Verano, in particular, does not accumulate as much dry matter as the perennial stylos. Results from different sowing and cutting dates in trials at Shika in the northern Guinea savanna of Nigeria indicate that Verano can achieve dry matter yields between 3 and 8 t/ha (Table 22.2). Sowing carried out within the months of May, June and July gives similar dry matter yields, as shown in Table 22.2. Broadcasting stylo seed can produce higher dry matter yields than drilling (Onifade & Akinola 1986). A grass:legume seeding ratio of 3:7 gave the highest yield and the proportion of stylo yield in the two years of the trial was 32% (1.64 t/ha)

Table 22.2 The effect of sowing date on dry matter yield in the first year of establishment of *Stylosanthes hamata* cv. Verano.

Sowing date	Yield (t/ha)		
	Verano	Weeds	Total
31 May	3.83	1.89	5.72
6 June	4.44	1.87	6.31
14 June	4.31	1.39	5.70
24 June	3.91	1.56	5.47
19 July	4.89	2.37	7.26

Source: Agishi (1982)

Table 22.3 Crude protein content (CP%), water-soluble carbohydrate (WSC) and in vitro dry matter digestibility (IVDMD) of *Stylosanthes hamata* cv. Verano in Nigeria.

Cutting date	CP%	WSC	IVDMD
16 September	17.4	2.3	63.6
16 October	14.1	3.3	54.6
5 November	7.4	1.2	41.0

Source: Adamu (1977)

and 37% (3.2 t/ha), respectively. Results from the screening of various accessions by the International Livestock Research Institute at Ethiopia have identified several accessions with higher dry matter yields than existing commercial cultivars (Larbi et al 1992).

The dry matter digestibility of Verano hay is high provided the crop is cut early in the dry season when leaf shedding is not excessive. The effect of the time of cutting on crude protein content, water-soluble carbohydrate and in vitro dry matter digestibility is given in Table 22.3 (Adamu 1977). The crude protein content of hay made at Shika from Verano crops in late November was about 7.4% and 17.4% in the middle of September.

Animal Production

Only a handful of controlled grazing studies on pure *Stylosanthes* pastures have been carried out in Africa, although it has been observed that cattle frequently graze *Stylosanthes*. The inclusion of *S. guianensis* and *Centrosema pubescense* into a *Hyparrhenia* grassland at Serere, Uganda, increased animal productivity by 11–49% (Stobbs 1969). Similarly, a *Hyparrhenia*–stylo pasture under low-frequency rotational grazing (ie 7 days grazing and 28 days resting) and high-frequency grazing (3.5 days grazing and 14 days resting) gave equally high liveweight gains of 740 kg/ha/year at Serere (Stobbs 1969). The mixed stylo–grass pasture gave better returns for animal liveweight gains in the dry season than the *Hyparrhenia–Centrosema* pasture, which gave the same yearly liveweight gain.

In Nigeria local cattle herds at Shika in the northern Guinea savanna break fences to graze Verano seed crops, even during the rainy season when range grasses are plentiful and in growth phase, showing the palatability of Verano. While animals grazing on range or sown grasses usually start to lose weight in the dry season, data from cattle grazing trials at Shika have shown that the inclusion of Verano in Buffel grass stands delays the commencement of this weight loss period (de Leeuw et al 1979). Sheep and goats, however, prefer chopped Verano hay to the standing crop. The regrowth after hay harvest forms an excellent feed for sheep and goats in the dry season (Agishi 1980).

Nutritive Value and Palatability

Unlike many legumes that have low nutritive value and palatability in the dry season, *Stylosanthes* is recognised for its retention of nutritive value in the dry season. Both the nutritive values and in vitro digestibility of *S. hamata* and *S. humilis* are similar at similar growth stages (Adamu & Adu 1980). In the semi-arid zone of Zimbabwe fine stem stylo or Verano is the plant of preference; their high feed quality encourages over-grazing as stock graze these in preference to many grasses (Keith 1999).

The palatability of the various stylo cultivars can differ among livestock, cattle finding Verano highly palatable in the rainy season (Agishi 1982) while sheep and goats in the humid zone of Nigeria mainly graze it in the dry season.

Grazed Pastures and Supplementary Protein to Cattle

The potential for increasing the productivity of grazing cattle by introducing *Stylosanthes* species in pastures of the seasonally dry tropics has been thoroughly established in Australia (Shaw 1961) and South America (Alkamper & Schultze-Kraft 1979). Likewise, using *Stylosanthes* to improve the productivity of pastures, animals and crops in Nigeria has been documented over a number of years (Agishi 1971; Mohammed-Saleem & Suleiman 1986; Otchere 1986). Access of Bunaji cattle to *Stylosanthes*-based fodder banks in the dry season produces significant increases in milk (70%), calf growth (40%) and viability (30%), as shown by Otchere (1986), and this can reduce cow liveweight loss by 50% (Bayer 1986). Such protein-rich fodder banks offer the prospect of more intensive utilisation and management of legumes such as *Stylosanthes* species (Schneichel et al 1988), and are therefore recommended as livestock fodder in pronounced dry seasons. At Shika, in northern Nigeria, the least expensive way to provide supplementary protein to grazing cattle is by growing *Stylosanthes*, preferably as a pure crop, and to ration-graze it during the dry season. Promising results have been achieved by penning cattle on pure stands of Verano and Cook stylo at night in the dry season followed by day grazing of native grassland (Haggar 1971). Similar results are at present being achieved by growing annual legumes such as *Lablab purpureus* and *Centrosema* species (Amodu et al, unpublished). However, it has become apparent that herbaceous legumes such as *Stylosanthes* species with multipurpose use and benefits are likely to be more acceptable to farmers as a fodder and a soil fertility enhancer (Tarawali, S.A. & Peters 1996; Weber 1996).

There is considerable information on dry matter yields, carrying capacities and cattle liveweight gains, particularly for *S. guianensis* in the northern Guinea savanna zone of Africa. The best utilisation schemes for S. *guianensis* swards in this region are: high grazing pressure (60 beasts/ha) for short periods (3 days) or low pressure (4 beasts/ha) for relatively longer periods (18 days) (Cadot 1971). Maintaining a 25 cm stubble height after grazing and an eight to ten week interval between grazing following an establishment period, and allowing the legume to seed at least once every two years have been recommended (Adegbola 1965), particularly when establishment is poor. Increased grazing pressure (1.3 to 3.3 heifers/ha) increased the Verano content of *Cenchrus ciliaris* swards (Agishi 1982).

Other Usage and Feeding Strategies with *Stylosanthes*

As hay and leaf meal

Stylosanthes makes good hay, containing 14–16% crude protein (Skerman et al 1988). Even crop residue and stubble left over after seed threshing contains 5% crude protein and can be hammer-milled for roughage feeding (Gilchrist 1967). However, when stylo is sun dried for hay production, it loses 15–40% of the dry matter, mostly as leaves. Therefore, improved processing immediately after cutting to reduce dry matter loss, and use of efficient technologies for hay making, including rapid drying (Guodao 2000), can preserve both dry matter and nutrients in stylo hay.

For hay Granier (1973) recommended initial cuttings at three-monthly intervals, progressively raising the cutting height. In the derived savanna zone a 45 cm cutting height in six-month-old stands was the best for hay production (Borget 1971). In Nigeria, Adegbola (1965) has obtained a total yield ranging from 2 to 4 t/ha from three cuts a year. Similarly, Nwosu (1960) also used three cuts a year in Nigeria, taking only the top 45 cm of the crop, dried it in the field for seven days and hammer-milled it into a dry meal that contained 17.17% crude protein at a cost of about US19.8 cents/kg. The use of stylo leaf meal is a highly profitable source of feed concentrate for various livestock in China and is increasingly being tried as poultry feed in India (Guodao et al, this volume). The simple to use technology employed to grow, dry and prepare the leaf meal offers a potentially high monetary return for resource-poor farmers in Africa both to feed their animals and to receive additional income through its sale to other animal-based industries such as dairy and poultry.

As a component of cropping systems

Many forage legumes can be grown in association with crops without lowering grain yields and without additional input. Since the main priority of many smallholder farmers in Africa is the production of grains to feed the family, techniques of incorporating forage legumes such as *Stylosanthes* species into compatible cereal forage crop mixtures can be very suitable in Africa. For instance, undersowing of cereal crops with *Stylosanthes* is suitable, especially for farmers who keep a few animals. Further details on the role of *Stylosanthes* in mixed crop–livestock systems in Africa appear in Whitbread and Pengelly (2000) and Pengelly et al (this volume).

Seed Production

Lack of commercially available seed is one of the major impediments to expansion of planting of *Stylosanthes* in Africa. Labour-intensive and inefficient seed production and harvesting technology has largely contributed to this; in most cases harvesting methods do not involve the use of combine harvesters or pneumatic machines, as in the developed countries. Seed clearing is done manually and the process is slow and expensive. Coupled with these problems is a lack of quality control, resulting in poor quality seeds being sold in the markets, which seriously affects grower perception and the adoption of stylo in Africa.

The most popular method of harvesting *Stylosanthes* in Africa has been manual cutting and sweeping followed by seed threshing and cleaning. This technique is used for Verano, *S. humilis* and *S. guianensis* cultivars. At Shika, *S. humilis* seeds are allowed to drop and accumulate on the ground between late December and January, and are then raked with sticks or metal brooms; the fallen seeds and soil are swept and hand-winnowed repeatedly from metal pans or calabashes. The resulting seed is over 95% pure. With the short-lived perennial Verano, the crop is manually cut with sickles in January and, when dry, the herbage is raked and tied in bundles as hay. The fallen seeds are recovered in the same way as for S. *humilis*.

The method mostly used in harvesting *Stylosanthes* seeds in Africa is the 'harvester ants method', which particularly applies to perennial stylos. The mature seed crop is brush-cut and baled. About a week after baling, seeds are collected from harvest ant (*Messor barbarus*) nests, which form nearby, every three to seven days depending on the size of the field and the labour available. This method has been successfully used for Cook stylo seed production, where seed harvests of 1000–1243 kg/ha have been achieved with 69–83% seed retrieval (Agishi 1980).

Seed yield varies from country to country, depending mostly on the climate. Yields in the central zone of Cote d'Ivoire are in the range 100–120 kg/ha from mechanical production and twice that if harvested by hand (Cadot 1969). Yields for hand-harvested crop seed can range 600–1750 kg/ha. In a study at Bouake in the Cote d'Ivoire (Anon. 1978) cultivars Verano, Cook, *S. humilis,* Endeavour, Schofield and Oxley were ranked in order of declining seed yield.

Baling of hay after the harvest of seeds from a *Stylosanthes hamata* cv. Verano crop.

Manual threshing, sieving and cleaning of seeds following harvest of a *Stylosanthes hamata* cv. Verano crop.

The exotic *Stylosanthes* cultivars widely used in Nigeria are *S. guianensis* Cook and Schofield, *S. hamata* Verano and a selection of *S. humilis*. Over 95% of the Verano stylo grown in Nigeria has come from 1 kg of seed originally introduced from Queensland in 1975. Between 1977 and 1980 the annual Verano seed production was 15 t (Ajileye 2000; Amodu et al 2002). More recently, seed of Cook, Townsville stylo and Verano have been produced on about 160 ha in the northern Guinea zone of Nigeria (Agishi 1992).

Recent Progress on Stylo Research at ILRI

A scan of recent literature on *Stylosanthes* research at the International Livestock Research Institute (ILRI), formerly the International Livestock Centre for Africa (ILCA), shows the continuing interest in this genus for Africa and a strong research and development program at ILRI.

A large number of accessions from many species have been screened for biomass production in the various target environments, such as on acid soils in the medium altitude environment of southern Ethiopia. ILRI research has identified promising accessions including *S. scabra* ILCA12555, ILCA11625, ILCA11599, ILCA11608; *S. guianensis* ILCA11737, ILCA11776; and *S. hamata* ILCA167, which out-yielded existing commercial cultivars and appeared to be adapted to the Nitosols of southern Ethiopia and probably to other similar environments in western and eastern regions of Africa (Larbi et al 1992; Hanson et al 1988).

One major impact of ILRI research and development programs has been the wide adoption of fodder bank technology in West Africa. Following the evaluation of a wide range of species, ILRI recommends *S. guianensis* cv. Cook and *S. hamata* cv. Verano for this technology and strongly promotes their use in West and Central African countries (de Leeuw et al 1994; Tarawali et al 2002). A survey has shown that by the mid 1990s, about 19,000 ha in the subhumid zone of 15 West African countries were using this technology (Elbasha et al 1999; Tarawali et al 2002). Anthracnose susceptibility of the *S. guianensis* component, however, has been the most serious drawback to adoption, and this has driven scientists to experiment with diverse legume–legume mixtures rather than relying on only *Stylosanthes* species (Muhr et al 1999a, b).

In mixed crop–livestock systems producers have been taking advantage of the improved soil fertility in fodder banks to subsequently grow cereal crops (Tarawali et al 1988). However, to maximise the benefits from legumes it is necessary to select the appropriate legume species, follow pasture management practices and optimise the duration of the fallow period. Three-year-old grazed pastures of *Stylosanthes hamata, Chamaecrista rotundifolia* and *Centrosema pascuorum* had a similar ability to contribute to the subsequent maize crop in the subhumid region of Nigeria and all three legumes gave higher grain yields than the native pasture (Tarawali, G. & Peters 1996; Tarawali, S.A. & Peters 1996). Similar benefits of stylo have been demonstrated in cereal crops other than maize. For example, *Stylosanthes* spp. were grown in alternate single and triple rows with a millet (*Pennisetum glaucum*) for one or two years and the millet was grown in rotation following either a one- or two-year intercrop (Kouame et al 1994). The total biomass and crude protein were increased by 45–125% but the millet yield was reduced by 26–83%, although intercropping stylo with millet in alternate single rows did not affect the millet grain yield during the legume seeding year.

Research at ILRI has increasingly expanded the suite of legumes suitable for their target environment and utilisation systems. In an evaluation of the potential of *Centrosema brasilianum, C. pascorum, Chaemaecrista rotundifolia and S. hamata* cv. Verano for use as dry season pasture (ie for fodder banks), Peters et al (1994a) found that all species had good protein values and could be used to improve the quality of fodder, but their ability to compete with native vegetation and consistently produce high yields differed. In a related work, *Aeschynomene histrix, Centrosema acutifolium, C. pascuorum, S. guianensis* and *S. hamata* cv. Verano were evaluated over two years as fodder banks in subhumid Nigeria (Peters et al 1994b). *Aeschynomene histrix* accession ILRI112463 performed the best, with dry matter yields of more than 6 t/ha in the second growing season, good drought tolerance, ability to compete with native vegetation and high nutritive value; but *C. pascorum* cv. Cavalcade and *C. acutifolium* cv. Vichada did not persist in competition with the native vegetation.

Constraints to Stylo Production and Utilisation

Research and development in Africa has strongly emphasised the use of *Stylosanthes* not only as forage but also as a cover crop and green manure (de Leeuw et al 1994). The wide adoption of the fodder bank technology promoted by ILCA in West Africa demonstrates the significant impact that such research and development can have (Elbasha et al 1999; Tarawali et al 2002). Ajileye et al (1992), among others, have summarised the adoption rates by farmers and pastoralists in Nigeria. However, significant constraints to adoption remain; factors limiting the large-scale development of stylo pastures in Africa have been documented earlier (Agishi & de Leeuw 1986; Lazier 1984). The key problems are discussed briefly below.

(1) Seed production is a major constraint and there is a need to improve production, harvesting and processing technologies to produce high quality seeds. Lack of seed harvesting equipment necessary for the large-scale production of seeds of consistent quality has hindered progress on the expansion and diversification of stylo-based fodder development. While both manual harvesting and harvesting through ants can produce high yield, quality is often inconsistent. For instance, delay in collection from harvester ants can lead to low seed recovery, and intrusion of other ants can seriously limit production and quality. In Chad ants removed 90% of grass and legume seeds in an establishment trial and the resulting establishment of *S. humilis* was only 17% (Dulieu 1977). Termite attack is another major problem in seed production; it has seriously affected stands of *S. guianensis* and Townsville stylo in the derived savanna and humid zone in northern Nigeria (Agishi 1982; Akinola 1981).

(2) Anthracnose caused by *Colletotrichum gloeosporioides* is the most serious constraint to *S. guianensis* production. Large stands in Zaire and Cote d'Ivoire have been rapidly destroyed following infection. In Nigeria Verano is more tolerant to anthracnose than several *S. guianensis* cultivars.

(3) The frequent outbreak of fire is a constraint to production of *Stylosanthes* in Africa. Although fire is endemic in the savanna of West Africa, it does pose a serious problem in the persistence of *Stylosanthes* swards.

(4) The lack of a diverse range of species, germplasm and cultivars has significantly affected the use of stylo in Africa, as the potential of the genus has not been fully exploited. Recent work at ILRI may help in providing better germplasm for livestock farmers.

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Chapter 23

Recent trends in *Stylosanthes* seed production by smallholders in India

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Summary

Using results from sample surveys and industry analysis, this chapter captures the development of the *Stylosanthes* (stylo) seed industry in the Ananthapur district of Andhra Pradesh. It outlines the economic, management, marketing and technological issues facing the industry to help identify potential weaknesses and constraints. While the main focus is on the private sector led by smallholder farmers, we briefly discuss the government sector, which also produces small quantities for sale. From a small beginning in 1974 the stylo seed industry in the Hindupur and Pennugonda Divisions of Ananthapur has grown rapidly; in 2002 *S. hamata* and *S. scabra* occupied over 40 ha owned and cultivated by 600 smallholder farm families. The spread of stylo seed production technology from farmer to farmer has occurred because it performs well in low rainfall years, is compatible with the soil and climatic conditions, and offers higher net returns than competing crops. The stylo seed business has changed since the mid 1990s because the main buyers are no longer the sheep unions but private traders/middlemen. The major constraints appear to be increases in wages, lack of formal marketing channels, non-availability of credit from formal channels, and lack of seed processing technology to reduce the drudgery and harmful side effects on health. Currently, the main use of stylo seed is for soil conservation and wasteland development programs by various government departments. Its use as a nutritious fodder crop is increasing to meet feed and fodder shortages. Although the introduction of new varieties with higher yields, minimal seed drop etc is important, current production is more constrained by lack of demand due to a lack of awareness of the multiple uses of stylo.

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Introduction

The livestock sector in India has been growing faster than the crop sector during the last 15 years. It has been driven by an increase in animal numbers with a low to moderate contribution from growth in livestock productivity, except for milk production (Birthal & Parthasarathy Rao 2002). Demand for livestock products results from rising incomes, urbanisation and change in tastes and preferences. Crop residues from coarse and slender cereals form the bulk of the feed for large ruminants, accounting for 50–70% of total feed intake on a dry matter basis. For small ruminants grasses from grazing, fallow and barren lands are the only sources of feed (Parthasarathy Rao & Hall 2003). Owing to competition between food and feed crops, forage crops are grown on only 4–5% of the cropped area, mainly under irrigation (Kelley & Parthasarathy Rao 1996). Over time the quantity and quality of grasses from common lands has reduced due to encroachment, overgrazing and poor maintenance of the commons (Hazra 1997; Jodha 1992), while at the same time there has been large-scale desertification of wastelands from uncontrolled erosion and poor maintenance. Thus, besides implementing strategies to increase feed availability, a number of government organisations are actively involved in the restoration of wastelands by introducing suitable forage species to manage soil erosion and enrich degraded soils (Hazra 1994). These activities have created a strong demand for quality seed of forage grass and legumes, and *Stylosanthes* (stylo), with its high nutritive value and adaptability to varied climatic conditions, has emerged as a multipurpose species for India.

In India the government plays a limited role in forage seed production, while private companies trade only annual forage crops. The seed production activity of the perennial range grasses and legumes is vested more with individual farmers who do not belong to any organised sector. Aided by national and international pilot seed production programs, a viable stylo seed industry led by farmers has emerged in the drier regions of India.

The largest commercial stylo seed production by farmers is in the Ananthapur district of Andhra Pradesh. Based on surveys and experimental evidence at four locations around the country, Singh et al (1995) found the Ananthapur area defined by 13^0–14^0 S and 76^0–77^0E to be the most suitable for economic and efficient production of stylo seeds. Here, stylo offers a lower risk option than the main crop in the region, groundnut, due to its high drought tolerance, suitability to the soil and climatic conditions, and higher net returns.

We have carried out an analysis of the stylo seed industry from regular surveys of the Ananthapur area to outline economic, management, marketing and technological issues facing the industry and to help identify potential weaknesses and constraints. This chapter is a summary of these surveys. It captures the history of stylo seed production in India and its spread to the Ananthapur district of Andhra Pradesh, provides current production statistics for the informal and formal sectors, outlines the management of seed crops at the farm level, and analyses the commercial aspects of seed production including marketing, price and financing of the technology. It briefly highlights the government and semi-government organisations that are party to the seed production chain, and concludes with a discussion on future prospects and constraints to seed production at the farm level.

A Brief History of *Stylosanthes* Seed Production

Stylo seed production started during the late 1970s, when the Government of India controlled it through four main agencies: 1) The Ministry of Rural Reconstruction in association with State Departments of Forest and Agriculture in Andhra Pradesh, Karnataka and Maharashtra through the drought-prone area program; 2) The Animal Husbandry Division, Ministry of Agriculture and Irrigation, as part of a United Nations Development Program on grassland and fodder development, with stylo seed production at Mamidipalli (Andhra Pradesh) and Kalyani (West Bengal); 3) the Indo-Australian seed farm at Hessarghatta, Karnataka, as part of an Australian International Development Agency Bureau project under the Ministry of Agriculture; and 4) The Indian Grassland and Fodder Research Institute (IGFRI), Uttar Pradesh, as part of a national research program of the Indian Council of Agricultural Research.

In the mid 1980s small farmers in the Rayalseema region, Ananthapur district in Andhra Pradesh, started stylo seed production to meet rising demand from government agencies for their wasteland development programs. Some farmers from the Palasamudram village in Ananthapur were trained in stylo seed production at the Raddipalli state farm of the Department of Animal Husbandry and Veterinary Services. Over the years the improved seed production technology spread to surrounding villages through farmer-to-farmer exchange of seeds and technical knowledge. Stylo seed production today is largely concentrated in three mandals of Hindupur and Penukonda Division of Ananthapur district comprising a network of 40–50 villages. The area has increased from only 4 ha in the late 1970s to an estimated 400–450 ha in 2000–01. Earlier estimates of up to 1000 ha in 1995–96 (Ramesh et al 1997) were due to an erroneous assumption of irrigated land under stylo cultivation. Most of this increase has come from a replacement of cash crops such as groundnut.

Besides the smallholder farmer-led seed production, government agencies (including state farms at Raddipalli and Mamidipalli (both in Andhra Pradesh), Hessarghatta in Karnataka and Almadhi near Chennai; the regional research station of the IGFRI at Dharwad (Karnataka); and the Kerala Livestock Development Board (KLDB) in Dhoni (Kerala)) have taken up seed production in the past 20 years. Other recent entrants include farmers in a cluster of villages around Dharwad in Karnataka, who have been organised through the NGO Bharatiya Agro Industries Foundation; and mostly women self-help groups under an urban afforestation program of the Hyderabad Urban Development Agency in Andhra Pradesh.

Village women produce and sell stylo seeds as a part of a program of the Hyderabad Urban Development Agency.

Most of the commercial stylo seed industry is based on what appears to be naturalised *S. hamata* cv. Verano and *S. scabra* cv. Fitzroy, but small quantities of other species including the recently introduced *S. seabrana; S. guianensis* CIAT 136, Graham and Schofield; *S. humilis;* and *S. viscosa* are grown in some state farms and experimental stations.

Current Status of Stylo Seed Industry

Ananthapur district

Although it does not officially maintain records, estimates from staff of the Department of Agriculture, together with figures from farmers and traders through our 2002–03 surveys, indicate that stylo seed production in this region has expanded steadily over the last 25 years. During 2001–02 some 600 growers from 40 villages in three mandals of this district produced mostly *S. hamata* and some *S. scabra* on around 400 ha (Table 23.1). Of these, the Palasamudram village in Gorantla mandal accounts for 60 ha and most seed traders are concentrated in and around this village. Somalapalli, Devulacheru and Mallepalle in Gorantala mandal, and Edula Ballapuram and Brahmanapalle in Somandapalle mandal are other important villages, with 25–35 ha each under stylo seed production. The area under irrigated stylo is higher in Edula Ballapuram. Brahmanpalli is a small village where the size of land holdings is less than 1 ha, but almost all the farm households have taken up stylo cultivation on at least 5–10% of their land, giving a total of 25–30 ha. The number of farmers involved in stylo seed production in these three mandals has increased between 1986–90 and 1996–2000, with many increasing their area under production and only a few reducing their area due to various constraints discussed later in this chapter. These farmers have realised very high seed yields of 1.6–2.0 t/ha in the first year, rising to 2.2–2.8 t/ha under no irrigation, compared with the 1.7 t/ha achieved at the nearby government research station at Dharwad under similar conditions.

Table 23.1 Seed production of different *Stylosanthes* spp. by growers in the Ananthapur district of Andhra Pradesh during 2001–02.

Mandal	Number of villages	Number of growers	Cropping area (ha)
Gorantla	22	475	320
Somandapalle	8	85	50
Chilamathur	8	42	30
Total	40	602	400

Raddipalli state farm, Andhra Pradesh

Seed production at the Raddipalli state farm was initiated in the mid 1970s through a World Bank Project and it became instrumental in spreading the technology to farmers in the Hindupur area and also to KLDB. During 2001–02 *S. hamata* seed production occupied 23 ha and *S. scabra* about 0.5 ha. Government ownership of the farm and permanent employment of farm labourers means production costs are substantially higher (350 man-days) than on farmers' fields (300 man-days). The seed yields of 700–900 kg/ha (1998 figure) are also lower than in farmers' fields at Hindupur.

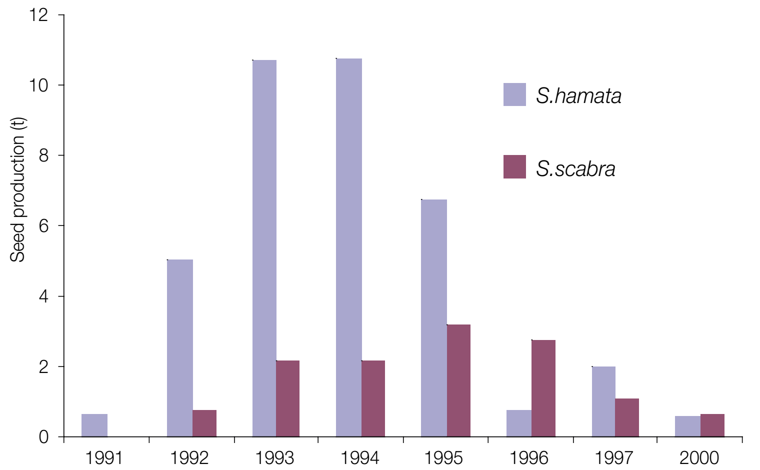


Figure 23.1 **Seed production at the Indian Grassland and Fodder Research Institute regional research station farm at Tegur in Karnataka over a nine-year period.**

Tegur farm, Karnataka

Stylo seed production at Tegur farm started in 1991 with *S. hamata* cv. Verano on 1.1 ha, which yielded 568 kg/ha seeds. By 1993 the area had increased to 8.7 ha with a seed yield of 1229 kg/ha. *Stylosanthes scabra* was sown on 1.45 ha during 1993 and yielded between 1008 and 1608 kg/ha depending on the cultivar. In more recent years there has been a shift in emphasis from seed production to research on the stylo crop and, consequently, seed production has declined at Tegur (Figure 23.1).

Kerala Livestock Development Board, Kerala

KLDB started its pilot seed production program primarily to distribute stylo seeds to dairy farmers. Selected low-income group farmers from dry regions of Chakkupallom, Nirmalacity, Rajakumari and Rajakkad were registered as seed growers under a contract from the KLBD. The seed grower agreed to abide by guidelines for the production and supply of seed to the KLBD, who in turn gave an undertaking to collect all good quality seed produced by the farmer at a predetermined price. Farmers were trained in the production and management of fodder seeds. Total *S. hamata, S. scabra* and *S. guianensis* (CIAT 136) seed procured was as high as 11–15 t/year up to 1995–96, and since then production has reduced due to high labour costs.

Management of Stylo Seed Crops

Management of seed crops differ from one agency to another. As most seed production occurs in the Deccan Plateau, with Ananthapur as its epicentre, we focus our discussion on the management of stylo seed crops practised in this area. Sample surveys by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) during 2002–03 indicate that stylo accounts for about 25% of the total cropped area, and that cultivation practices developed by farmers differ significantly from those used on research stations, where seed is harvested from perennial pastures.

In rainfed farming, farmers sow seeds at a rate of 12–15 kg/ha at the onset of the rains in June. In succeeding years fields are cultivated to reincorporate the previous year's crop along with farmyard manure at the rate of 15–25 bullock carts/ha (1 bullock cart = 350–400 kg manure). Farmers estimate that approximately 20% of the seed from the previous year's crop remains in the field, because either it was missed during sweeping or it was waste left over after cleaning. Seeds from the leftover waste are usually dehulled and sown, and give good germination.

Harrowing follows ploughing. The first weeding happens at the early vegetative growth stage, with a second before the onset of flowering in October/November; sometimes a third weeding is also carried out. Harvesting starts from January, when the crop is cut with a sickle and stacked. Seed collection and processing are staggered over the succeeding months and usually completed by April. The timing of these operations is flexible depending on other demands on labour. The recovery, collection and cleaning of seed is a tedious operation involving sweeping, sieving, winnowing, threshing, winnowing, separation of seed by further sieving, winnowing, and finally bagging.

The fallen seed is swept into piles using a stiff bamboo brush, sieved and winnowed to remove inert material. The manual seed cleaning process is very similar to methods used in Africa (Amodu, this volume). Some farmers lay the cut and dried stylo plants on bitumen road for threshing by passing vehicles and this can save 35–40 labour days/ha.

Under irrigation, seedlings are initially raised in a seedbed and transplanted to the field. Farmyard manure is applied at a rate of 15–25 bullock carts/ha before transplanting, and urea is applied at 125 kg/ha at flowering, much above the recommended dose of 25 kg/ha. The crop needs two to three weedings in a year depending on infestation, and is harvested and processed between February and April.

Cost of Production

One hectare yields 1500–2000 kg seed/ha in good rainfall years but only 800–1200 kg/ha in poor rainfall years, and 1 t of stylo hay. Data from the 2001–02 sample survey in Ananthapur district indicate a per kg cost of production of Rs 7.4 for irrigated stylo, Rs 5.7 for rainfed stylo and Rs 8.8 for a groundnut–pigeon pea intercrop in 2000–01 (Figure 23.2). Based on these figures, the net return for irrigated stylo is Rs 6000/ha, for rainfed stylo Rs 8000/ha, and for groundnut–pigeon pea intercrop Rs 3000/ha. In 2002–03 the net return from rainfed stylo was close to zero and negative for groundnut–pigeon pea intercrop (Rs –4000/ha) due to a severe drought, which reinforces the economic incentives of growing stylo seed crop even in a severe drought year.

Of the total cost of cultivation, the labour cost is the most significant, accounting for 75% of the total for both rainfed and irrigated stylo (Figure 23.3). Operations such as cultivation, fertiliser application, weeding, harvest and post-harvest operations like threshing, sieving, winnowing etc all have high labour requirements. On an average, about 350 labour days/ha are required, of which around 80% is female labour.

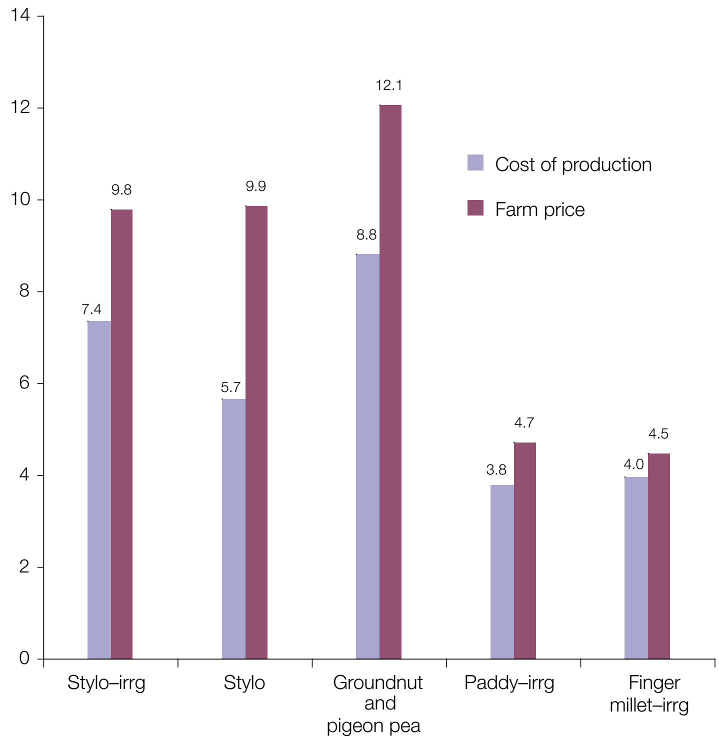


Figure 23.2 Cost of production and farm harvest price of major crops in Ananthapur, Andhra Pradesh, in 2000–01.

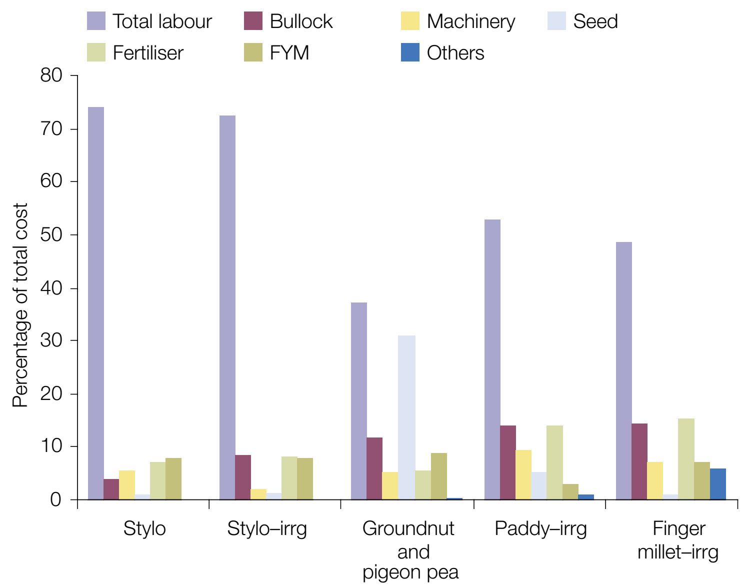
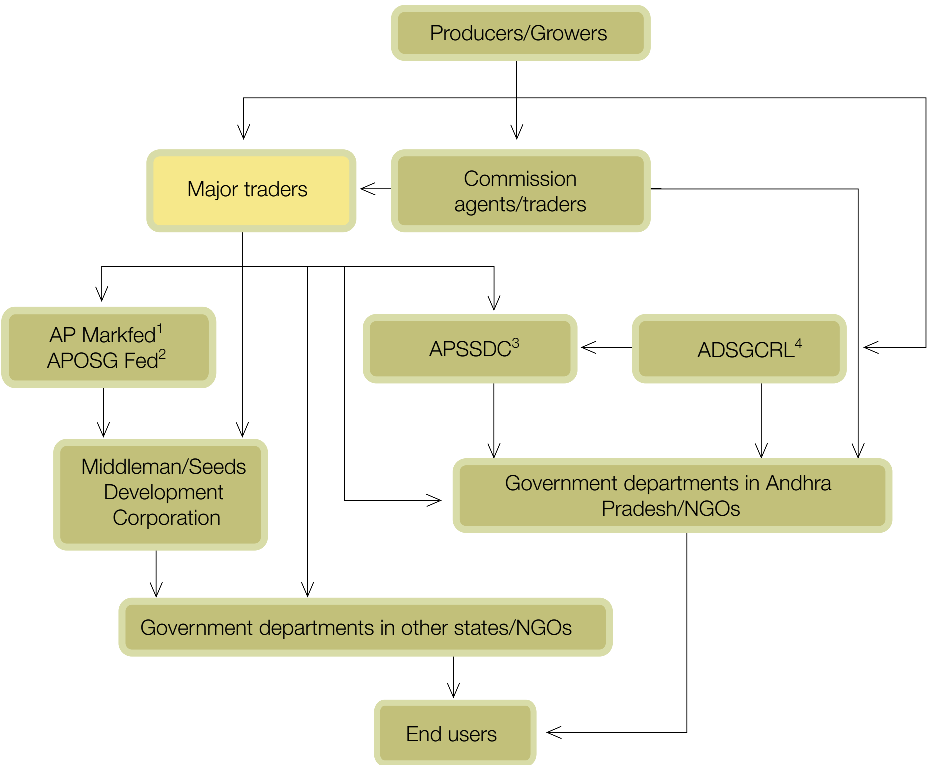


Figure 23.3 Share of major inputs in the total cost of cultivation of stylo seed crop in the Ananthapur area, 2000–01.



1. Andhra Pradesh Marketing Federation
2. Andhra Pradesh Oilseeds Growers Federation
3. Andhra Pradesh State Seeds Development Corporation.
4. Ananthapur District Sheep Growers Co-Federation Ltd.

Figure 23.4. **Market channels for *Stylosanthes* seed in the Ananthapur district of Andhra Pradesh.**

Stylo Seed Marketing System in Ananthapur District

With increasing seed production activity, the number of dealers and agents involved in seed marketing has slowly increased, and the current marketing channels consist of a complex network of interacting agencies and private operators (Figure 23.4).

Seeds are marketed mainly through informal channels. Until the mid 1990s the trade was dominated by agencies like Andhra Pradesh District Sheep Growers Co-Federation (ADSGCRL) and Andhra Pradesh State Seeds Development Corporation (APSSDC). APSSDC procured seed from traders through tenders or directly from ADSGCRL for supply to government departments based on indents at the beginning of the growing season. Andhra Pradesh Marketing Federation and Andhra Pradesh Oilseeds Growers Federation were other formal channels that entered the seed business. ADSGCRL became defunct in the mid 1990s due to management problems and competition from private traders. The other formal channels too have reduced their business due to problems related to seed quality etc.

To fill the void, several big traders have entered the seed business in a significant way and they sell stylo along with seeds of other crop, horticultural and forestry species. The turnover of dealers ranges from 10 to 100 t of stylo seed. Dealers buy from a number of agents/middlemen as well as directly from growers to match the demand from the various public and private sources, which include the Ministry of Agriculture, and watershed and wasteland development agencies working all over India. The price depends on demand and is often inversely related to the level of production. Thus, growers have the option of selling seeds immediately or waiting for a better price, since no specialised storage is required to preserve stylo seeds. Most growers sell a certain portion of their seeds immediately to cover the investment cost and the remainder is sold when the price improves. The formal sector, which had been operating on a small margin, has not been able to compete with the traders, who now directly supply the various government departments in Andhra Pradesh and elsewhere via commission agents/traders. According to sales figures from the traders, Andhra Pradesh is the largest buyer of stylo seed in India (Table 23.2).

The major problem in the current marketing network relates to the role of the middlemen. At present, they are taking the bulk of the profit, with the farmer receiving a smaller share. Further, in the intervening stages between grower and end user, the seed is often adulterated, leading to quality concerns among end users. The longer the length of the chain the poorer the quality of the seed is likely to be. Organising producers and giving them the responsibility of selling the seeds directly could curtail such problems. Recently, the IGFRI Regional Research Station, Dharwad, has mobilised farmers to form cooperatives to market their seed to ensure a fair price for the growers. The society has been active since 2000 with a membership of 100 growers. More than one-third of the members are women and they are adequately represented in the management of the cooperative.

Table 23.2 A statewide breakdown of buyers of *Stylosanthes* seed in India.

State	Share of total sales (%)
Andhra Pradesh	25
Karnataka	15
Maharashtra	10
Madhya Pradesh	10
Rajasthan	15
Gujarat	5
Orissa, Himachal Pradesh, Bihar, West Bengal and Tamil Nadu	10
Others	10
Total	100

Demand for Stylo Seed

Data on the actual quantities purchased by various users of stylo seed are not available. There is also no consistent pattern of demand since many government departments postpone purchase due to budgetary constraints. According to government officials, traders and middlemen, government departments (notably the soil conservation and forest departments), watershed committees, NGOs and Sheep Growers' Federations are the main buyers of stylo seed for various purposes (Table 23.3). Often, government departments distribute the seed to farmers. The main uses of stylo seed are for strengthening of bunds and check dams in watershed programs, reducing soil erosion in forests and hillocks, and wasteland development. Grazing or cut-and-carry use as a forage crop for ruminants is often a secondary objective. Using stylo as a supplementary nutritious forage is gaining in importance due to demands from dairy and breeding farms, military farms, sheep growers associations etc; however, the quantities purchased are relatively small. There is a need to obtain more systematic information on the demand for stylo seed.

Although direct information on demand is not available from formal channels, traders estimate demand based on purchases in previous years, and the price is determined based on orders received from different agencies for the forthcoming season. Estimates of stylo seed production vary between 650 and 300 t depending on rainfall and other weather induced factors. In 2002–03, a drought year, stylo production was estimated to be only 300 t, and consequently the farm harvest prices rose to Rs 15/kg compared to Rs 10/kg in the previous year

Table 23.3 Major buyers of Stylosanthes seed and the intended uses.

Main buyers of stylo seed	Uses of stylo seed
Soil conservation / agriculture Forest department Animal husbandry Drought-prone area program Watershed committees Wasteland development board Joint forest management / social forestry Horticulture department National highways / urban forestry NGOs / rural development agencies Dairy federations/unions Military farms Sheep growers federation Railways River valley projects	Watershed programs: • strengthening of bunds / check dams • reducing soil erosion • supplementing fodder Reserve forest and hillocks: • reducing soil erosion • grazing ruminants Wasteland development / Common property resources (CPRs) Supplementary feed (dairy, breeding farms etc) Pastures for sheep Urban forestry Cover crop in horticulture and agroforestry River valley project bunds

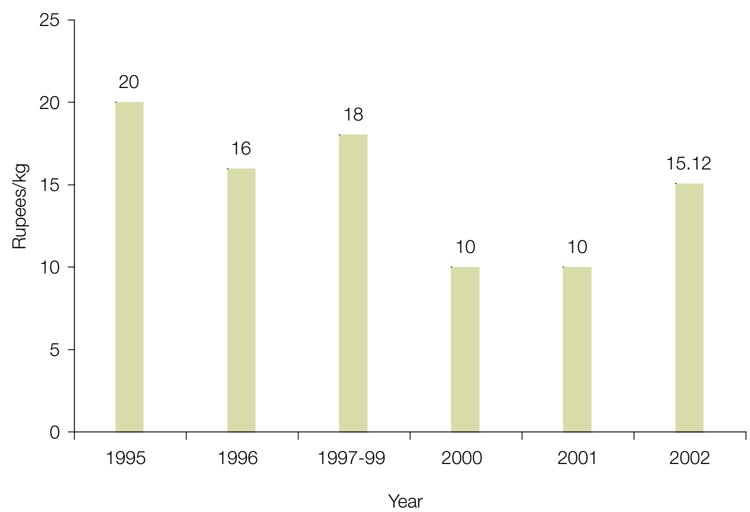


Figure 23.5. **Farm price of *Stylosanthes* seed in the Ananthapur district of Andhra Pradesh during 1995–2002.**

(Figure 23.5). In subsequent months the prices rose further to Rs 18–20/kg, indicating a strong demand for the seed.

With over 1.5 million ha of wasteland and another 60 million ha of climatically marginal area in India, the potential demand for stylo seed is very large (Ramesh et al 1997). In addition, there is a tremendous potential for the use of stylo as a forage crop, either freshly cut or as a component of processed feed, for poultry and dairy cattle (Guodao et al, this volume). There is a need for increased awareness among growers and the relevant key industries to facilitate this growth.

Financing Stylo Seed Production

The major sources of credit for stylo growers are seed traders/dealers. The majority of the large seed dealers provide this credit facility by pre-financing seed growers; they are then repaid an adjusted amount at the end of the season, depending on the sale price of the seeds. Credit is only given to those farmers who have sold seeds to these traders over the years, and hence is based on trust.

Smaller growers often receive a large share of the credit due to their weak financial condition. The length of the credit period varies in the range 3–6 months as the majority of growers borrow at crop harvesting time when the labour requirement is very high. The cost of production of stylo seed is around Rs 12,000/ha compared to Rs 6000/ha for groundnut. The interest rate on credit varies between 2% and 3% per month, which is higher than bank rates, but farmers have no alternative as the crop is not a notified/scheduled crop and hence is not eligible for credit from other sources.

An analysis of the strengths, weaknesses, opportunities and threats to the stylo seed industry in Ananthapur district

A focus group consisting of seed growers in the Ananthapur area have identified nine strengths, seven weaknesses, six opportunities and one threat to the stylo seed production industry (Table 23.4). Two of these opportunities in particular offer significant growth potential for the seed industry in the region. These are:

Stylo leaf meal preparation

Recent research on the use of stylo leaf meal as a component of commercial poultry feed has been carried out at IGFRI-RRS, with coordinating centres at ICRISAT, Acharya NG Ranga Agricultural University (ANGRAU) and Tamil Nadu Agricultural University (TNAU) (Guodao et al, this volume). This work has followed a coalition approach involving national and international institutes, State Agriculture Universities, private poultry integrators and farmers. It has unequivocally shown that most stylo cultivars and species can be used for leaf meal production, and that the meal has acceptable nutrition, achieves industry-standard liveweight gain in broilers and layers, and offers additional quality advantages to both meat and egg yolk colour. A benefit–cost analysis also shows a reduced feed cost from the use of stylo leaf meal. Growing stylo for leaf meal production should fit in well with the crop husbandry practices of a seed production farming system where stylo is grown as a crop. Farmers should be encouraged to grow suitable cultivars and trained to take two cuttings for leaf meal preparation and leave the third cutting for seed.

Table 23.4 Strengths, weaknesses, opportunities and threats to the stylo seed industry in Ananthapur district.

Strengths	Weaknesses	Opportunities	Threats
• A seed yield which is less subject to erratic rainfall • Profitably grown in poor soils • Long storage & low incidence of rodents and pests • Low incidence of pests and diseases in comparison to groundnut • Harvesting and processing occurs in lean season, so labour is available at relatively cheaper rate • Profitable crop for marginal and poor farmers who generally own marginal lands • Employment opportunity for landless and poor farmers in off-season, thus reducing migration • Can be grown in saline soils with average yield 1000 kg/ha	• Seed cleaning is cumbersome, a labour-intensive crop • Peak demand for seed is May–September only, unlike groundnut which exists almost throughout the year • Higher cost of cultivation compared to groundnut • Non-scheduled crop, so credit from formal channels not available; dependence on middlemen for loans • Loss of fertile topsoil during post-harvest processing • Lack of knowledge of new stylo cultivars as S. hamata is predominantly cultivated • Fodder is wasted if drenched in rain	• Exploiting rich experience of farmers in producing seeds of new stylo cultivars • Clipping seed crops one to two times to meet fodder requirements and leaving the third crop for seed • Educating farmers on optimum utilisation of fertiliser • Introducing stylo leaf meal preparation • Marketing dried stylo hay to areas with fodder shortages • Encouraging farmers to raise sheep, goats and lambs as a complementary enterprise	• Dust inhalation while processing of stylo seeds has negative effect on health of farmers/ farmwomen

Expanding the range of stylo cultivars

The current narrow range of cultivars used for seed production has its obvious drawbacks, including the threat from anthracnose. The recently selected new high-yielding and anthracnose-resistant materials need to be made available to replace existing cultivars. Cultivars have been identified in the erect *S. seabrana* with high biomass and seeds that don't shatter as much.

Conclusions and Policy Implications

Stylo seed production has become well established in the relatively drier and drought-prone area of Ananthapur district of Andhra Pradesh as it compares favourably with other crops in terms of the inputs required and the economic returns possible under marginal cropping conditions. This is despite excessive profit margins taken by the middlemen who finance production and buy much of the seed produced.

The area under stylo seed production has increased consistently during the last two decades from less than 10 ha to 400–450 ha, mainly to meet the growing demand for seed. This has enabled farmers to diversify cropping patterns and income streams. Currently the crop is not recognised as a notified crop; hence, statistics on area and production are not recorded and there is no policy support relating to marketing or credit etc.

The seed production technology has spread from farmer to farmer with little assistance from government agencies, and now there is a need to introduce new cultivars that have higher seed and fodder yields. Cultivars that demand less labour at different stages of crop growth, particularly for harvesting and post-harvest operations, would go a long way in securing the future of the crop. Experimentation with low-cost machinery to reduce labour demand needs to be examined as a matter of priority. Since marketing of the seed is a monopoly of private traders/middlemen, establishment of farmers' cooperatives and associations should be facilitated to increase the producer's share in the final price. Cooperatives can also play a role in providing credit at low interest rates to its members, in purchasing and renting out stylo seed processing machinery, and in taking up stylo leaf meal preparation and marketing. Maintaining a consistently high quality through seed certification systems will help maintain credibility in the seed industry.

On the demand side, government departments are currently the major buyers; they use stylo mainly for soil conservation and wasteland development activities, and are driven more by budgetary considerations than by need. There is less emphasis on the use of stylo as a nutritious livestock fodder for large and small ruminants, and a need to increase awareness of this application through demonstrations and appropriate extension activities. The potential of stylo leaf meal for poultry feed also needs to be exploited.

Information on the demand for seed from different locations and agencies will help in better planning of production by farmers. There are no established ways to share information on future demand. Presently, stylo seed production is more constrained by a lack of sufficient demand, despite its huge potential in various utilisation schemes.

Acknowledgments

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Chapter 24

Stylosanthes leaf meal for animal industries in China and India

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Summary

The use of *Stylosanthes* leaf meal in China was started by a group of farmers in Hainan who realised its value as a feed concentrate for pigs, poultry, cattle etc to save on valuable feed grain. Commercial production of leaf meal has since become a reality, with two commercial meal production facilities. This paper reports results of feeding trials using *Stylosanthes* leaf meal in the rations of ruminants and monogastrics. These trials have confirmed the encouraging weight and quality gains noted by farmers and have determined the optimum levels of *Stylosanthes* leaf meal in different animal rations. Following its success in China, we have recently evaluated the role of *Stylosanthes* leaf meal in poultry nutrition in India, where *Stylosanthes* in the past has been mainly used as a green forage crop for large and small ruminants. The poultry industry is among the fastest growing sector in India and is always interested in cheaper sources of feed. Here we report significant gains in live weight and the cost of production in broiler chickens using *Stylosanthes* leaf meal at varying levels in the ration. The findings indicate that *Stylosanthes* meal can replace more expensive ingredients in the ration by up to 6% without any adverse effects on the final product. Skin and shank color of the broilers are more appealing on rations containing leaf meal. Encouraged by these findings, a coalition of stakeholders involving farmers, researchers, veterinary institutions, large-scale private sector feed manufacturers and poultry producers is exploring the prospects of commercialisation of leaf meal production by linking *Stylosanthes* producers the feed industry and poultry producers.

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Introduction

China accounts for 22% of the world's population but only 7% of the land area, thus putting immense pressure on land resources to meet the food requirements of the growing human population. Due to population and income growth, the demand for livestock products is rapidly increasing at 28% per annum, creating additional demand for fodder and feed. Feed production, however, is increasing at less than 10%, and hence shortage of feed is a major concern which needs to be addressed urgently. According to available statistics, the shortage of feed at present is about 50 million t/year. The deficiency in protein feed alone is estimated at 15 million t/year. Decreasing crop area and declining yields have further compounded the problem. Southern China, the drier region of the country, is no exception in this regard; declining water availability and increasing soil erosion are threatening sustainable agriculture. This scenario is changing as a result of China's entry to the World Trade Organisation. Changes include increasing the ratio in livestock breeding, returning hilly cropland and wasteland to forest and pastures, and improving the rate of feed grain to 40% of whole crops, among others. Under this scenario, production of types of forage, particularly legumes, and their processing for feed will be a meaningful strategy to solve the problem of feed shortages and at the same time enrich the soil.

The situation in India is not very different from that in China. Due to population and income growth, urbanisation, and change in tastes and preferences, the demand for livestock products is increasing rapidly, which in turn generates derived demand for feed and fodder resources. In a study on the livestock sector in India, The World Bank (1996) estimated the feed deficit for all categories of animals to be 251 million t of roughage (dry and green fodder) and 2.6 million t of concentrate feed, ie grains, oilcakes etc. Several other studies have also alluded to the growing feed shortage in the country for green and dry fodder and concentrates (Hazra & Rekib 1991; Phansalkar & Pandey 1991; Singh & Majumdar 1992). The productivity of small ruminants is stagnant due to a decline in the area under common property resources (CPRs) and pastures, and a consequent decline in quality of grasses available from these lands. Recent studies by Deaoghare (2003) have found that semi-intensive systems of feeding goats are more profitable than systems relying solely on grazing. For large ruminants, cereal residues, which account for the bulk of the feed, are generally low in nutrients, particularly protein. Within the animal sector poultry is growing the fastest, followed by dairy. Based on recent projections, in the medium to long term egg production will grow by 9% per annum and broiler production by 12%, implying growth in feed demand of 10–12% per annum for the poultry sector alone (McKinsey 1997; Kleih et al 2000).

This paper reports the work carried out on promoting *Stylosanthes* (stylo) as a nutrient-rich source of feed, particularly a dry leaf meal (SLM) for ruminants and monogastrics in Southern China and the semi-arid regions of India, under the marketing and commercialisation component of a project funded by the Australian Centre for International Agricultural Research (ACIAR). The first section documents ongoing research and use of SLM in China, while the second section highlights the recent studies on SLM in India for the poultry industry. Prospects for commercialisation of SLM in India are discussed in the concluding section.

SLM in Southern China

Southern China consists of 10% of the total land area of China (96 million km^2) and accounts for 11% of the total population (1300 million people). Ruminants (cattle, buffaloes, goats) are raised on state and smallholder farms, but state farms account for only 2–3% of the total livestock numbers. State farms raise 200–3000 head of animals on farms of 200–2000 ha, where animals are grazed on natural rangeland or occasionally feed on improved rangeland (<1%). Smallholders raise 2–10 cattle, 1–5 buffalo or 5–20 goats, which graze along the side of cultivated land and natural rangeland.

The main tropical part of southern China includes Hainan, the southern part of Guangdong, Guangxi, Yunnan and Fujian provinces. The mean annual temperature range is 20–26°C, annual precipitation is in excess of 1500 mm, and soils are generally acidic with a pH range of 4.5 –5.5. The area under grasslands and its share in the total land area in the provinces of southern China are shown in Table 24.1. Besides large ruminants, pigs and poultry are the most important livestock species.

Stylosanthes is a very important forage legume and feed source in tropical and subtropical regions in the world and southern China is no exception. Among the many utilisation schemes for *Stylosanthes* in southern China (Phaikaeuw et al, this volume), a dried SLM offers the most versatility as an animal feed since it is rich in protein, vitamins and other nutrients, including an ‘unknown nutrient / growth factor’ which can promote livestock growth.

Freshly cut *Stylosanthes*, mixed with wheat or rice bran and other feed, has been used by farmers to raise pigs for a long time, thus reducing the cost by replacing part of the grain component. In the mid 1990s smallholders, especially in the Ledong and Wenchang counties of Hainan province, began to harvest *Stylosanthes*, sun-dry it and grind it into a powder using small grinders. The crude meal was used for feeding chickens, pigs, geese and other animals. It was found that chickens and geese grew fast and healthy and the incidence of ‘plume pecking’ was greatly reduced, thereby improving the feather quality and commercial value. Motivated by the encouraging results, some farmers began to buy SLM from smallholder farmers who grew *Stylosanthes*, although the quality of the sun-dried SLM was not high. With increasing demand a few small state farms began to plant and harvest *Stylosanthes* to produce SLM using commercially available feed grinders. Soon SLM became a

Table 24.1 Land resource and animal numbers (million head) of southern China (2000 data).

	Hainan	Guangdong	Guangxi	Fujian	Yunnan	Southern China
Area						
Land area (million km2)	0.03	0.22	0.23	0.12	0.38	0.99
Cultivated land (million ha)	0.4	2.5	2.6	1.2	2.8	9.6
Grassland (million ha)	0.6	3.0	8.7	0.5	18.9	32.0
Cultivated land (ha/person)	0.07	0.04	0.06	0.43	0.77	0.06
Grassland per farm (ha/farm)	0.13	0.07	0.24	0.02	0.59	0.24
Animals						
Beef cattle	3.4	2.5	2.0	3.6	5.0	16.4
Dairy cows	–	0.02	–	0.02	0.07	0.12
Buffaloes	0.8	2.7	4.0	0.5	2.8	10.8
Pigs	2.9	21.2	19.0	10.0	21.1	74.3
Goats	0.1	0.1	0.9	0.6	5.1	7.3
Poultry	32.0	513.0	151.0	101.0	33.0	830.0

commercial commodity and was sold at prices reaching 1.6 yuan/kg (1 USD = 8.27 yuan), higher than the price of rice, cassava or corn. In more recent years private companies have started SLM production from over 200 ha of plantings in Linshui county, and have introduced high-temperature quick-drying machines to produce SLM using the latest technology.

Utilisation of SLM in China

Several studies have now been conducted to demonstrate the usefulness of SLM as a component of feed rations of many farm animals. Pigs can be fed a feed ration containing 10–15% SLM or green *Stylosanthes* cut into 2–4 cm pieces and cooked with other food wastes. Poultry are fed a ration containing 3–5% SLM and for ducks it is included in a swill. For ponded fish, green material can be thrown directly into the pond as with grasses, or 1% SLM can be added to the compound feed. The following paragraphs outline some of the key studies on animal performance from feeding SLM.

Comparing SLM and green *Stylosanthes* fodder for rabbits

The performance of SLM compared with freshly cut *Stylosanthes* as components of a balanced feed for young rabbits (45 days old) was studied in Hainan. Three different types of feed were mixed in different proportions to feed 60 rabbits separated into three groups and raised in five cages. The SLM had 11.6% water and 16.8% crude protein (CP); the mixture containing green *Stylosanthes* had 67% water and 6.8% CP; and a feed concentrate formulation contained 43% corn meal, 22% bean cake, 2% fishbone dust, 2% bone dust, 30% wheat bran and 1% other materials. Fresh green *Stylosanthes* material was cut into 2–4 cm pieces. Rabbits in group I were fed 1/2 SLM feed + 1/2 feed concentrate; group II received 1/3 SLM + 1/3 green material + 1/3 feed concentrate; group III had 1/2 green material + 1/2 feed concentrate. The average feed ration was 110 g/head, which was fed at a fixed interval. The preliminary results showed that daily gain was significantly different for the three groups. Group I had the highest daily gain, which was more than 28% higher than that of group II and more than 98% higher than that of group III (Table 24.2). This trial clearly indicates that SLM can be used to partly replace feed concentrates in rabbit diets.

SLM as a component of pig and chicken diets

For this work SLM was prepared by mixing meals to contain 45% *S. guianensis*, 45% *S. hamata* and 10% *S. scabra* cv. Seca. The composite SLM contained 13% CP, 2.7% crude fat, 32% crude fibre, 37.4% non-N extract, 4.1% ash, 1.13% Ca and 0.11% P in dry matter, with a gross energy of about 4089 kcal/kg. Two treatments were used in the chicken feeding trial: group I was initially given a ration containing 6% SLM until they were four weeks old, and after five weeks of age SLM in the ration was increased to 12%; group II received 4% SLM in the ration until four weeks of age and 8% SLM afterwards; the control group did not receive any SLM in their ration. For pigs, group I received 30% SLM in their ration, group II received 20% SLM, and the control group had no SLM.

The preliminary results showed that, with chickens, there were no major differences in daily weight gain or final yield between the three treatment groups during the 56-day experimental period (Table 24.3). This indicates that SLM can be easily used to replace some of the feed concentrates in formulations for chickens. Similar results were observed for pigs, with similar gains for SLM and concentrates, although the overall growth with 30% SLM was lower than with 20% SLM. Thus, for pigs SLM can easily replace 20–30% of the ration, to minimise feed concentrates.

Several other studies have been made on aspects of feeding SLM to chickens. In one study 25-day-old birds of the Shaihuang breed were raised on five different feed formulations containing different levels of SLM made from *S. guianensis* cv. Reyan 5. Each of the five formulations contained similar amounts of maize (542 g), cassava (100 g), bean cake (185 g), fish bone meal (34 g), bone dust (15 g), shell dust (2.5 g), salt (1 g) and metamino (0.5 g) per kg of feed; but the total amount of wheat bran (120 g/kg) was replaced completely or partially by 90, 60 or 30 g SLM in the five treatments. Results show that substituting wheat bran with 30 or 60 g/kg SLM does not change the weight gain or feed conversion ratio. However, increasing the SLM content over 60 g/kg to replace wheat bran reduces the weight gain despite similar amounts of feed intake; this in turn reduces the feed conversion ratio (Figure 24.1). Dissection of chickens at the end of the experiment showed a darker, yellow skin and flesh, a larger gall bladder and spleen, and a harder liver in chickens fed with SLM.

Table 24.2 Growth of young rabbits fed on a *Stylosanthes* leaf meal diet for 60 days.

Group	Number of rabbits	Average weight at beginning (g)	Average weight at end (g)	Total increase (g)	Daily weight gain (g)
I	20	701.1±35.5	2230±111	1528.9±26	25.48±2.1
II	18	709.2±36.1	1895±49.6	1185.8±78	19.76±3.8
III	15	702.2±36.6	1474±72.1	771.8±24	12.86±5.5

Table 24.3 Performance of pigs and chickens fed on a daily allowance of *Stylosanthes* leaf meal (SLM)

Group	SLM in feed (%) First 4 wks	SLM in feed (%) After 4 wks	Feeding period (days)	Average final weight (kg)	Daily Weight gain (g/head)	Ratio of feed to meat
Chickens						
I	6	12	56	2.17	38	2.24
II	4	8	56	2.11	37	2.11
Control	0	0	56	2.13	37	2.23
I	6	12	49	2.11	42	2.17
II	4	8	49	2.08	42	2.12
Control	0	0	49	2.22	44	1.95
Group	**SLM in feed (%)**		**Feeding period (days)**	**Average final weight (kg)**	**Daily Weight gain (g/head)**	**Ratio of feed to meat**
Pigs						
I	30 whole		112	78.29	526	4.18
	30 early		36	38.50	531	3.14
	30 middle		35	62.63	689	3.49
	30 end		41	78.29	382	6.49
II	20 whole		112	84.17	587	3.78
	20 early		36	38.38	556	2.90
	20 middle		35	65.08	763	3.20
	20 end		41	84.17	466	5.52
Control	0 whole		112	88.08	616	3.62
	0 early		36	39.40	554	2.70
	0 middle		35	66.96	798	3.21
	0 end		41	88.08	515	5.05

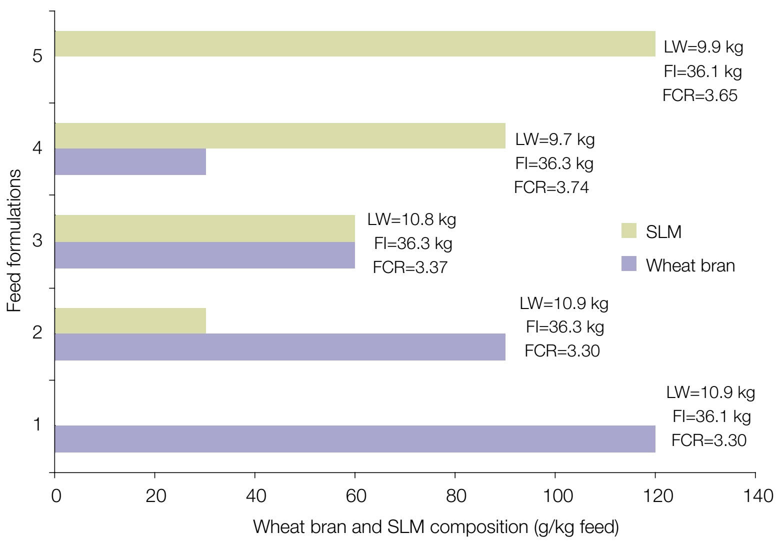

Figure 24.1 Live weight (LW), feed intake (FI) and feed conversion ration (FCR) in chickens using five feed formulations containing similar amounts of all ingredients except the wheat bran component of 120 g/kg being completely or partially replaced by *Stylosanthes* leaf meal (SLM).

Consumers in China prefer a yellow colouring of the chicken meat and shank and producers often use artificial colouring agents in feed formulations to cater for this demand. This trait in the chicken meat increases its market price. SLM contains about 700–1000 mg/kg of β-carotene, which transforms into vitamin A and precipitates under the skin to give it a yellow colour. A chicken feeding experiment examined whether SLM could replace the need to add staining agents in feed to improve colour. Two different levels of SLM were used, in combination with partial or complete elimination of the staining agent, in the feed formulations for 25-day-old birds of the 882 Shaihuang breed. The results show no significant difference between treatments in either weight gain or feed

Table 24.4 Weight gain, feed conversion ratio (FCR) and yellow colouration of meat in chickens fed with two different levels of *Stylosanthes* leaf meal (SLM) and a staining agent.

Treatment	Weight gain (g)	FCR	Degree of yellowing
Control (with staining agent)	45.0	2.57	8.71
2% SLM + 50% staining agent	43.1	2.65	8.54
2% SLM + staining agent	43.1	2.67	7.67
3% SLM + 50% staining agent	44.1	2.65	8.94
3% SLM + staining agent	44.1	2.63	8.19

conversion ratio (Table 24.4). There was no major change in meat colour with 3% SLM completely or partially replacing the artificial staining agent, and the best staining was with a 50% dose of the colouring agent with 3% SLM; a comparable yellow colour with 2% SLM was only obtained by retaining a 50% dose of the staining agent (Table 24.4).

Goose feeding trials

The Sichuan White breed of goose was used in a feeding trial of 7-day-old birds with different amounts of SLM replacing a standard feed formulation. A total of 160 birds were randomly separated into four groups and fed one of the following formulations: group I, 20% SLM + 80% concentrate, group II, 30% SLM + 70% concentrate, group III, 40% SLM + 60% concentrate, group IV, mixed green materials (free intake) + concentrate. Green *Stylosanthes* material was cut into 2–4 cm pieces before feeding. Although there were no significant differences in daily weight gain between treatments, group IV, fed on concentrates and green *Stylosanthes* fodder, had the highest daily gain (data not shown).

The use of SLM in livestock feeding is already widespread in the drier regions of southern China. These studies have tried to indicate experimentally the potential contribution of SLM to animal production and market quality. Findings show that although SLM can partly replace concentrates in livestock rations, the amount will vary in different animals. The maximum usable SLM levels for the various animals are; pig 5–10%, broiler 2–5%, duck 8–12%, goose 15–20%, rabbit 30-40%, and cattle, goat and other ruminants about 40–60%.

SLM in India

Stylosanthes is grown extensively in India, with a thriving smallholder-led seed industry producing and selling about 500–750 t of *Stylosanthes* seed every year. Government farms, including the Indian Grassland and Fodder Research Institute and the Kerala Livestock Development Board, and a few NGOs also produce seed. Presently, the use of *Stylosanthes* is mainly restricted to soil conservation and wasteland development activities. Its use in pastures for grazing small ruminants and its role as a cut-and -carry fodder for domestic and farm animals have been growing in recent years (Phaikaeuw et al, this volume; Ramesh et al 1997). The use of SLM is relatively new and yet to take off on a commercial scale. However, the biggest commercial use of *Stylosanthes* in India could be from its use as a dried SLM; examples of its successful use in southern China are detailed above. One of the aims of research funded by the Australian Centre for International Agricultural Research in India was to examine the feasibility of using SLM in commercial poultry feed. Pioneering baseline studies have been made on fine-tuning the production technology for SLM and on the nutrition and economics of incorporating SLM as a component of poultry feed in India. Two detailed poultry feeding studies were carried out, one at the Acharya NG Ranga Agricultural University (ANGRAU) at Hyderabad, and one at the Tamil Nadu Agricultural University (TNAU) at Coimbatore. Significant findings from these studies are outlined below.

Broiler feeding trials at ANGRAU

There is scant literature on the use of *Stylosanthes* in poultry and particularly in broiler rations. An initial study was therefore designed to evaluate the nutrient profile of SLM from three species of *Stylosanthes*, followed by a biological trial in a randomised block design to determine the feasibility of SLM utilisation in broiler rations.

The initial experiment compared SLM from *S. scabra, S. guianensis* and *S. seabrana*, each at three incremental levels (3, 6 and 9%), with a maize–soybean meal based control diet. Each of the ten dietary treatments had four replicates with seven broilers/replicate, housed in battery brooders which provided a floor space of 205 cm^2/bird. The feed and water were offered *ad lib*. All the dietary treatments were iso-caloric and iso-nitrogenous, formulated by adjusting the levels of vegetable oil and inert material (saw dust).

Nutrient composition For the nutrient profile, the proximate principals were determined at the Poultry Experiment Station (AOAC 1990) and the amino acid profile at the Degusa laboratory, West Germany, while anti-nutritional factors like tannins and phenolic compounds were analysed at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The metabolisable energy contents were evaluated by a metabolic trial at the All India Coordinated Research Project on Poultry Breeding facilities at ANGRAU.

Table 24.5 Nutritional composition of dry leaf meal produced from three *Stylosanthes* species expressed on a percentage dry matter basis.

	Stylosanthes scabra	***Stylosanthes guianensis***	***Stylosanthes seabrana***
Dry matter (%)	89.4	89.4	88.2
Crude protein	14.2	16.4	13.7
Crude fat	2.4	1.9	1.8
Crude fibre	35.1	26.3	31.1
Non-N extract	42.3	48.6	45.3
Total ash	6.0	6.8	8.2
Calcium	0.57	0.68	0.51
Total phosphorus	0.01	0.02	0.01
Polyphenols	8.07	5.77	6.63
Tannins	4.75	0.76	2.35
Lysine	0.74	0.8	0.71
Methionine	0.21	0.22	0.2
Cystine	0.18	0.16	0.19
TSAA (methionine + cystine)	0.39	0.38	0.39
Arginine	0.81	0.93	0.8
Threonine	0.64	0.69	0.61
Leucine	1.06	1.16	1.04
Isoleucine	0.56	0.64	0.58
Valine	0.73	0.81	0.72
Histidine	0.31	0.35	0.31

The nutrient composition of SLM was medium (13.7–16.4 %) for crude protein and good for amino acids lysine (4.3–4.7 %), methionine (1.2–1.34 %), cystine + methionine (2.1–2.56 %) and arginine (5.1–5.25 %) on a percentage crude protein basis (Table 24.5). The crude protein values for both *S. guianensis* and *S. scabra* were higher than the 13.31–13.41 range for *S. hamata* (Rai & Patil 1986). The amino acid profile is in close agreement with the values reported by Gupta et al (1992).

The SLMs were high in crude fibre (26.30–35.10 %) and contained tannins as catachin equivalents (0.76–4.75 %) and polyphenolic compounds as tannic acid (5.77–8.07%). Mishra et al (1997) had found up to 39.12% crude fibre in *S. hamata*.

The metabolisable energy (ME) contents were lower for SLM, between 1730 and 1815 kcal/kg, compared to 3638–3777 kcal/kg for a standard broiler ration of maize and soybean meal (SCB). On average, the ME in maize is around 3706 kcal/kg, and 2230 kcal/kg in SCB. Protein in SLMs, however, was higher than in maize but lower than in SCB. Generally the mineral content, including calcium, and amino acid contents of SLMs are superior to those of maize and SCB rations. On the negative side, the SLMs had higher fibre content, which could lead to an increase in feed consumption, and higher tannin content, which may affect growth.

Weight gain, feed consumption and feed efficiency Although an analysis of variance did not show significant ($P>0.05$) difference between dietary treatments at six weeks, there was a clear weight gain benefit from feeding 3% SLM of all three *Stylosanthes* species compared with the control, and the overall weight gain at 3% SLM for all three species was significantly higher than for 6 or 9% SLM (Table 24.6). The cumulative feed consumption was significantly influenced by the dietary treatments and intake was lowest for both 6% *S. guianensis* and the control. Despite this, the feed conversion ratio (FCR) was not significantly ($P>0.05$) influenced by dietary treatments; only minor differences in FCR were evident. Overall, there was no significant difference in weight gain, feed consumption or FCR between the three *Stylosanthes* species, but feed consumption was higher than control at all levels.

Carcass parameters and skin and shank pigmentation None of the parameters like dressed, eviscerated and ready-to-cook yields were significantly ($P>0.05$) altered by the dietary treatments (Table 24.7). This bodes well for SLM, since the percentage of ready-to-cook yield is a commercially important parameter. As seen earlier with feed intake and weight gain, neither the species of *Stylosanthes* nor the level of SLM in the ration significantly influenced any of the carcass parameters. Although the intestinal length was lowest for the control diet, the species of *Stylosanthes* did not influence either the intestinal or the caecal lengths as a percentage of body weight, but the level of SLM in the diet significantly ($P<0.05$) influenced both parameters. Intestinal and caecal lengths were significantly less at 3% SLM compared with the 6 and 9% levels.

Poultry feeding trial using stylo leaf meal at the Acharya NG Ranga Agricultural University, Hyderabad.

Table 24.6 Weight gain, feed consumption and feed conversion ratio in broilers raised for 42 days on diets containing three different levels of *Stylosanthes* leaf meal (SLM).

Poultry ration	SLM Levels[a] (%)	Weight gain (g)	Feed consumption (g)	Feed conversion ratio (FCR)
Control[b]		1563 ± 51	2924 ± 82	1.87 ± 0.06
Stylosanthes scabra	3	1682 ± 49	3163 ± 32	1.88 ± 0.04
	6	1615 ± 42	3037 ± 66	1.88 ± 0.01
	9	1527 ± 41	3097 ± 34	2.02 ± 0.04
Stylosanthes guianensis	3	1608 ± 61	3012 ± 78	1.87 ± 0.05
	6	1510 ± 35	2924 ± 53	1.93 ± 0.01
	9	1606 ± 35	3115 ± 89	1.94 ± 0.02
Stylosanthes seabrana	3	1646 ± 13	3175 ± 30	1.92 ± 0.004
	6	1571 ± 29	3046 ± 38	1.93 ± 0.02
	9	1546 ± 41	3099 ± 23	2.00 ± 0.04
Means				
S. scabra		1608 ± 30	3099 ± 29	1.92 ± 0.02
S. guianensis		1575 ± 27	3017 ± 46	1.91 ± 0.02
S. seabrana		1588 ± 20	3106 ± 23	1.95 ± 0.02
3% SLM		1645 ± 26	3117 ± 35	1.89 ± 0.02
6% SLM		1566 ± 23	3002 ± 33	1.91 ± 0.03
9% SLM		1559 ± 23	3104 ± 30	1.99 ± 0.02

[a] *Stylosanthes* leaf meal included at three levels by replacing maize and soybean meal. Ration is balanced for nutrients by adding oil/filler material

[b] Control diet includes maize and sorghum meal and additives

Table 24.7 Carcass parameters, visceral organ weights and skin and shank colour in chickens as influenced by species and levels of *Stylosanthes* leaf meal fed to broilers.

Species/ levels	Dressed weight (%)	Eviscerated weight (%)	Giblet weight (%)	Ready-to-cook yield (%)	Liver weight (g)	Intestinal length[a]	Caecal length[b]	Skin colour[c]	Shank colour[c]
Control	87.5	67.5	4.8	72.3	1.9	10.9b	1.2	1.0b	2.0b
Stylosanthes scabra	87.6	65.8	4.9	70.7	2.0	11.3a	1.2	1.8a	3.3a
Stylosanthes guianensis	87.5	66.0	4.6	70.7	1.9	11.3a	1.1	1.9a	3.5a
Stylosanthes seabrana	88.8	66.6	4.8	71.4	1.9	11.0a	1.2	1.7a	3.3a
Level SLM 3%	88.0	66.8	4.7	71.5	1.9	10.9m	1.1m	1.4n	3.1n
6%	88.4	66.2	5.0	71.1	2.0	11.0mn	1.2mn	1.8mn	3.3mn
9%	87.5	65.5	4.6	70.1	1.9	11.7n	1.3n	2.1m	3.8m

Means bearing at least one common letter in a column do not differ significantly (P>0.05).

[a]Intestinal length: cm/100 g of body weight [b]Caecal length: cm/100 g of body weight [c]Skin and shank color: Roche Fan Color Score

The dietary treatments had significant ($P<0.05$) effects on both skin and shank pigmentation measured as Roche Fan Color Scores (North 1984). Roche Fan Color Scores are measured on a 1–10 scale in ascending order for grading the colour of egg yolk. SLM levels in the diet significantly ($P<0.05$) influenced skin and shank pigmentation but *Stylosanthes* species did not have a significant ($P>0.05$) influence on either (Table 24.7). Shank pigmentation was more intense with SLM than in the control, as was skin pigmentation. As the SLM level increased from 3 to 9% in the diet, the intensity of shank and skin pigmentation also increased.

There were no deleterious or toxic effects due to the addition of SLM to the diet and mortality on SLM diets was less than that with the control diet.

Economic returns The returns for six of the nine SLM diets were positive over the control diet (Table 24.8) and all *Stylosanthes* species gave a positive return when SLM was used at the 3% level. At the 9% level both *S. seabrana* and *S. scabra* gave a small negative return, while *S. guianensis* gave a negative return at the 6% level but not at 9%. However, there were positive returns over the control diet for each of the three species at 3 and 6% levels of SLM in the diet (Figure 24.2). *Stylosanthes scabra* produced the maximum gain, followed by *S. guianensis* and *S. seabrana*. The returns decreased linearly from the 3% to the 9% level, with higher returns at 3% than at 6%, but both gave higher returns than that obtained with the control diet. Only the 9% level of SLM in the diet gave a marginal loss over the control diet.

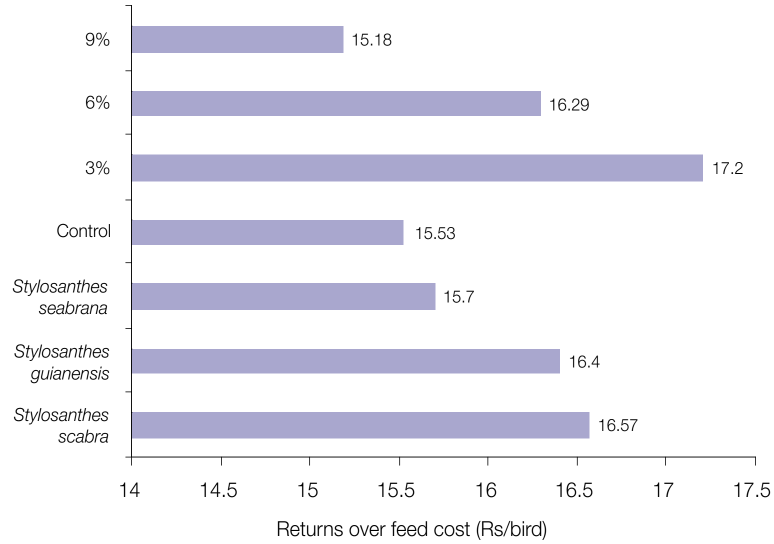

Figure 24.2 Returns over feed cost (Rupees/bird) from feeding diets containing leaf meal made from three ***Stylosanthes*** species at three different levels in comparison with a control diet.

Broiler feed trials at TNAU

A preliminary feeding trail at the Department of Animal Husbandry in association with the Department of Forage Crops, TNAU, has explored the potential of SLM from sun-dried *S. seabrana* as a broiler feed substitute. Three iso-caloric and iso-nitrogenous diets were formulated by replacing a control diet of maize and soybean meal with 2.5%, 5% and 7.5% SLM, oil and other filler material, as required. Day-old chicks of the breed Ven cobb-100 broiler were allocated to the four diets with five birds per diet. Feed and water were supplied *ad lib* during the six-week experiment, with a starter mash until day 21 and a finisher mash after

Enhanced yellow pigmentation of the shank in 42-day-old broiler chickens (right) fed with a diet containing 6% *Stylosanthes* leaf meal compared to a control diet.

Table 24.8 Influence of leaf meal made from three different *Stylosanthes* species and fed to broilers for 42 days at three different levels in the diet on the cost of feeding, returns over feed cost and profit/loss over control diet at market age.

Diet	Body weight (kg/bird)[a]	Total feed consumption (kg/bird)	Total feed cost (Rs)	Sale amount (Rs/bird)[b]	Returns over feed cost (Rs bird)	Gain/loss over control (Rs/bird)
Control	1.60	2.92	32.56	48.09	15.53	–
3% *Stylosanthes scabra*	1.72	3.16	33.62	51.66	18.04	2.51
6% *Stylosanthes scabra*	1.65	3.04	31.96	49.65	17.69	2.16
9% *Stylosanthes scabra*	1.57	3.09	33.02	47.01	13.99	–1.54
3% *Stylosanthes guianensis*	1.65	3.01	32.46	49.44	16.98	1.45
6% *Stylosanthes guianensis*	1.55	2.92	31.26	46.50	15.24	–0.29
9% *Stylosanthes guianensis*	1.65	3.11	32.41	49.38	16.97	1.44
3% *Stylosanthes seabrana*	1.69	3.17	33.99	50.58	16.59	1.06
6% *Stylosanthes seabrana*	1.61	3.05	32.38	48.33	15.95	1.42
9% *Stylosanthes seabrana*	1.59	3.09	33.01	47.58	14.57	–0.96

[a] Cumulative weight gains + weight of day-old chick (40 g)
[b] The sale price of broilers was taken as Rs 30 per kg live weight

that. Feed consumption was calculated from the weekly leftover feed and body weight was recorded once a week.

In common with the ANGRAU trial, the average weight gain at the end of the experiment was significantly higher for 2.5% (1988 g) and 5% SLM (1969 g) than the control (1783 g), but lower at the 7.5% level (1710 g). Compared to the control, the average feed intake was marginally higher at the 2.5% and 5% SLM levels, but similar at the 7.5% level. FCRs of 1.84 and 1.85, over 1.9 for the control diet, indicate that 2.5% and 5% SLM save, respectively, 60 and 50 g of commercial feed concentrate to produce a 1 kg live broiler.

Industry trial with SLM

Both ANGRAU and TNAU trials have produced highly encouraging results. A large-scale private sector poultry feed industry in Andhra Pradesh is carrying out experiments at ANGRAU using sorghum-based rations in broilers and layers. SLM is included in one of the treatments at a 3% level. To meet industry requirements this experiment is being carried out on a part-by-part replacement of ingredients in the ration as opposed to iso-caloric and iso-nitrogenous feeds. The treatments include feed in mash as well as pelleted forms. Preliminary findings confirm the promise seen in more controlled trials.

Inclusion of SLM at 3% in broiler diets comprising sorghum and soybean improved both shank and skin colours of the carcass. Diets containing pelletised SLM improved the FCR and thereby lowered the feed cost/kg of broiler weight gain. For mash feed, however, the FCR for the stylo diet was higher and hence not economical.

SLM Farmers' Forum

Kamplikopa village in the Dharwad district of Karnataka has been a staging post for many new and emerging forage technologies. *Stylosanthes* has played a major role in the economic recovery of this village and several farmers here have readily taken up *S. seabrana* as a fodder and seed crop. Many villagers are active members of the newly formed Nandini Stylo Leaf Meal Producers Association. The Bharatiya Agro Industries Foundation, an NGO, is setting up a SLM facility in collaboration with the farmers' forum to link the farmers to the poultry feed industry. A large-scale poultry producer in the nearby Narendra village has used SLM to feed broilers at a commercial farm. Impressed with the performance of SLM, the farmer has planned to set up local farmer groups who can grow and supply *Stylosanthes* to meet his SLM requirements.

Future Prospects for SLM

Research and development work in collaboration with the industry has conclusively shown a tremendous potential for SLM in poultry rations in both China and India. The economic benefits by themselves should make SLM a significant component of the feed if regular supplies can be assured through fine-tuning the technology and quality assurance. In addition, SLMs are a good source of β-carotene and are also known to contain some unidentified growth factors, both of which lead to improved quality and greater consumer acceptance of the meat, shank and egg yolk. With two major commercial SLM production facilities, the industry in China is up and running.

With a production of >1.4 billion broilers each year, the Indian poultry industry is growing at 10–15% per year. It is the fourth largest egg producer and the eighth largest broiler meat producer in the world and contributes 3% to India's GDP. Similarly, the dairy industry is growing at 4–5% each year. As a component of poultry and dairy rations, SLM can potentially generate income for smallholder farmers and address the significant shortages in green and dry fodder that exist in India. SLM technology and knowledge on poultry feeding has created a sound platform to build a commercial success for *Stylosanthes* in India, and industry and farmer groups are well aware of this tremendous potential. Prospects for commercial use will grow exponentially if similar information also comes from dairy feeding trials. Schemes to produce SLM for commercial poultry feed are starting to emerge through partnerships between government, NGOs, industry and farmer groups. Three such partnerships were forged at the final meeting of the ACIAR project: the first involves a feed manufacturer, local farmers and ANGRAU at Hyderabad; the second involves the Tamil Nadu state Department of Animal Husbandry and local farmers in the Palladam area near Coimbatore; the third involves the NGO Watershed Organization Trust, farmers around Ahmednagar and the Mahatma Phule Krish Vidyapeeth Department of Animal and Dairy Science.

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Chapter 25

Leaf meal production from *Stylosanthes* in China and India

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Summary

The technology for large-scale commercial production of *Stylosanthes* leaf meal has been standardised in China over a period of several years and both the private and public sectors are involved in its production. Most of the materials presented in this paper are based on the Chinese experience. In India, although *Stylosanthes* leaf meal production is in its infancy, production on a small-scale is spreading fast among farmers and various government and non-government organisations. The package of technology given here is still undergoing fine-tuning in both countries.

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History and Background

Farmers in the Ledong and Wenchang counties of Hainan province in China are credited as being the first to use a sun-dried powder of *Stylosanthes* to feed chickens, pigs, geese and other animals in the mid 1990s. Chickens and geese, in particular, grew fast and healthy, with reduced 'plume pecking', which improved their feather quality and commercial value. Soon this sun-dried *Stylosanthes* leaf meal (SLM) became a saleable commodity as encouraging results motivated farmers, but the quality of the SLM was highly variable. Increasing demand gradually led state and private farms to plant and harvest *Stylosanthes* to produce SLM using commercially available drying and grinding machines. There are now 200 ha of plantings of *Stylosanthes* in the Linshui County dedicated to producing SLM.

In India production and feeding studies involving SLM started in 2000, and so far the regional research station of the Indian Grassland and Fodder Research Institute at Dharwad has produced most of the SLM. As yet there are no privately-owned commercial production facilities in India.

Research in China and more recently in India (Ghangjun et al, this volume) has compared nutrients in SLM with other ingredients commonly used as feed concentrates in the poultry industry. Protein and fat contents (Table 25.1) and essential amino acids (Figure 25.1) of SLM are similar to those in most other ingredients except soybean and wheat. However, SLM provides β-carotene not available through the other ingredients and this adds to meat, egg yolk and shank quality. Recent comparisons between SLM and alfalfa show that P and Ca content of SLM is less than half that in alfalfa.

Table 25.1 Comparison of dry matter (DM), crude protein (CP), crude fat (CE), Ca, P, Fe, digestible energy (DE) and animal metabolisable energy (AME) content of selected crops used as ingredients in feed concentrates in China (adapted from 'Chinese Feed', April 1999).

Crops	DM (%)	CP (%)	CE (%)	Ca (%)	P (%)	Fe (mg/kg)	DE (%)	AME (%)
Corn (grain)	86	8.7	3.6	0.02	0.27	36	3.41	3.24
Sorghum (grain)	86	9.0	3.4	0.13	0.36	87	3.15	2.94
Wheat (grain)	87	13.9	1.7	0.17	0.31	88	3.39	3.04
Paddy (grain)	86	7.8	1.6	0.03	0.36	40	2.89	2.63
Cassava (tuber flake)	87	2.5	0.7	0.27	0.09	150	3.13	2.96
Soybeans (grain)	87	35.5	17.3	0.27	0.48	111	3.97	3.24
Alfalfa (meal)	87	14.3	2.1	1.34	0.19	437	1.49	0.84
Stylosanthes (meal)	27.5	15.6	2.5	1.18	0.19	960	5.37	5.31

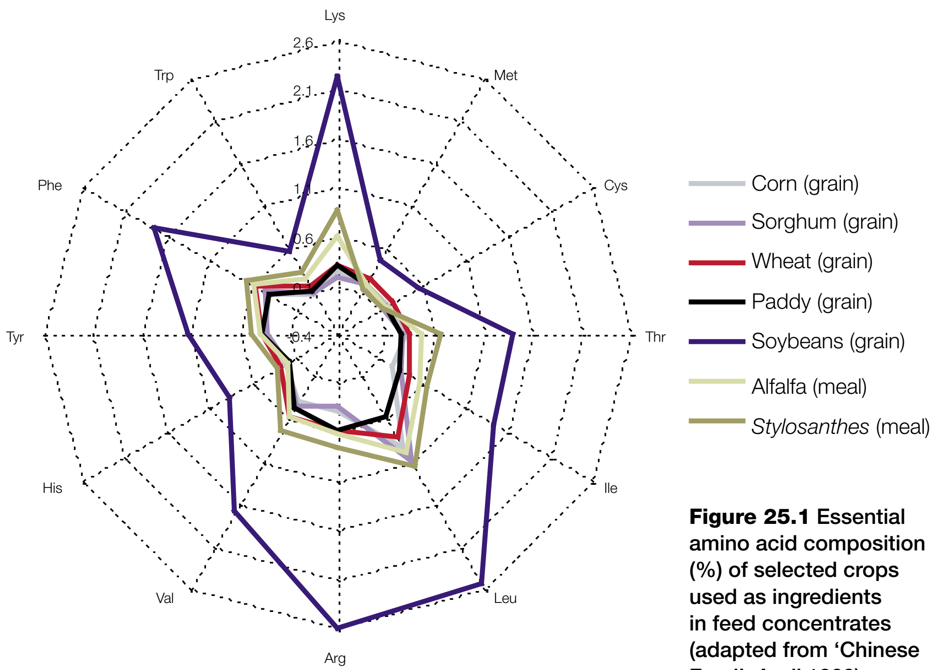


Figure 25.1 Essential amino acid composition (%) of selected crops used as ingredients in feed concentrates (adapted from 'Chinese Feed', April 1999).

Leaf Meal Production Technology

Selection of *Stylosanthes* spp. and cultivation

Recent comparisons in India show that the recovery of SLM is lowest for *S. guianensis* despite it having the highest green fodder yield; *S. scabra* and *S. seabrana* have similar green fodder yields but *S. seabrana* has a higher SLM recovery (Table 25.2). SLMs made from the three species are similar in most nutrients, although *S. guianensis* has comparatively higher crude protein and lower crude fibre and tannin than the other two species (Changjun et al, this volume). *Stylosanthes seabrana* has the advantage of early growth compared with *S. scabra* and *S. guianensis*. For SLM production, stylo is grown as a crop in well-tilled and labeled land with fertiliser and herbicide applications. Up to four cuttings can be taken each year with one or two irrigations to combat critical water shortages. Multi-purpose *Stylosanthes* plantings, such as cover crops in plantation horticulture, can be easily used to make SLM.

Stylosanthes **grown under young (top) and mature (above) coconut groves as a pure stand in southern India.**

Table 25.2 Green fodder yield and leaf meal recovery for selected *Stylosanthes* species in India.

Species	Yield (t /ha)	Recovery of leaf meal (%)
Stylosanthes seabrana	83–85	40
Stylosanthes scabra	80–86	32
Stylosanthes guianensis	90–95	28

Harvesting

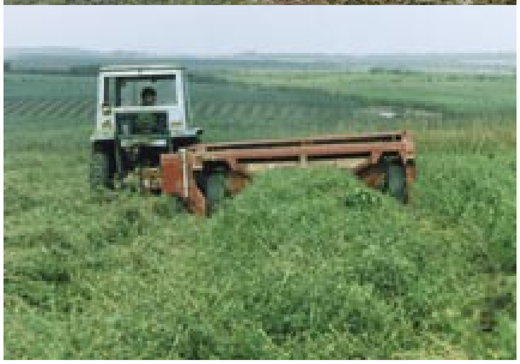
Cutting can be done manually, especially the first cut if the crop is not uniform, or by using a machine. The time of cutting influences the dry matter yield and quality and needs to be carefully selected to optimise productivity and SLM quality. Cutting too early will give high quality SLM but low yields; and cutting too late will decrease nutrient content and increase fibre content, but give high dry matter yield. The recommended cutting height in China is when the crop is 60–80 cm high, which translates to every two months during the rainy season and every three months during dry and cold seasons. Under Indian conditions, the first cut can be taken after 55 days for *S. seabrana*, 60 days for *S. scabra* and 80 days for *S. guianensis,* but this depends on soil fertility and water availability. A top dressing of fertiliser after each cutting can help boost production and quality.

Drying

In areas with good sunshine cut materials can be sun dried in the open. Materials should be spread in a thin layer on a clean hard surface, preferably concrete, and dried for two days, then turned over and dried for another day. In general field drying will result in a poor quality end product with often 10–30% lower yield and about 10% less crude protein. However, this is easy to use and can serve as a source of hay at the local level. Alternatively, drying racks can be built using local materials such as bamboo to dry the materials above the soil surface and avoid spoilage. This can help hasten the drying process and improve quality through increased protein and β-carotene content.

For large-scale SLM production materials are machine dried after transporting from the field. Two different types are in use. Slow drying at low temperatures (50–60°C) over two to three hours in dehydrators reduces the loss of dry matter, protein and β-carotene and produces a good quality product. In the quick drying method materials are dried very quickly (10–20 seconds) in kilns at temperatures well above 60°C. These kilns are usually used in making hay and can serve a dual purpose. The quality of SLM is very high, with less than 3% loss in dry matter and 1–4% loss of crude protein and β-carotene. Although this method requires machinery that makes it more expensive, often the additional cost of kiln drying is compensated for by the high price of the quality product. Sometimes materials are sun dried for a short period after cutting and at

(A)



(B)

Cutting *Stylosanthes guianensis* for leaf meal production in China. Herbage can be manually cut (A) or machine harvested (B) and gathered for collection and transportation.

45–60% water content the half-dried material is finally dried using a set of artificial quick-drying ovens at high temperature for three to five minutes to achieve a final water content of 9–12%.

Grinding

A hammer-mill type grinder is used, the material passing through a 1–1.5 mm sieve after grinding. The local brands in China include Shenxing 9FQ-5, made in Jiangxi, and Huada 9FQ-5, made in Guangdong.
A simple grinding and sieving facility can be set up in the field or can be part of an entire drying, grinding and packing facility 8. In India a beater type pulveriser with blower is used at the Indian Grassland and Fodder Research Institute (IGFRI) farm in Dharwad. It runs on a 5-HP, 1440-rpm motor and is connected to a cyclone dust collector fitted with a 3-mm and a 5 mm screen.

(A)

(B)

Grinding of dried *Stylosanthes* cuttings to produce leaf meal in the field (A) and in a factory which dries, grinds and bags the leaf meal (B).

Grading, packaging and storage

Grading is done for quality assurance and pricing. In China SLM is graded in one of three grades according to its nutrient content (Table 25.3) and packaged in 50 kg parcels in hessian bags with a waterproof lining. Under Indian conditions, crude protein content varies in the range 14–16% depending on the species and weather conditions during sun drying. Grading and quality control of SLM require further standardisation.

In combination with other ingredients, SLM is incorporated into feed formulations targeting different feed rations, either as a powder or in pellets.

The quality of SLM can rapidly deteriorate if stored under high temperature and humidity conditions. There can be significant loss in β-carotene content in as little as 30 days storage under normal temperature conditions. Other nutrients including crude protein, vitamins D, B1 and B2 can also decrease under these conditions. The preferred option for long-term storage is at 3–9°C.

(A)

(B)

Stylo leaf meal is used in feed rations as powder (A) or pellet (B) formulations.

Table 25.3 Standards for three grades of commercial *Stylosanthes* leaf meal in China.

Item	Grade		
	I	II	III
Colour and odour	Dark green or green, no mould or unusual odour		
Meal water content (%)	9–12	9–12	9–12
Meal granule and cake water content (%)	9–14	9–14	9–14
Crude protein content (%) of dry matter	>19	>16	>13
Crude fibre content (%) of dry matter	<23	<26	<30
β-carotene concentration (mg) per kg dry matter	>210	>160	>100
Poisonous materials	None		
Coarse materials >2 mm (mg) per kg meal	<50	<50	<50
Sand/soil content (%)	<0.7	<0.7	<0.7
Percentage of materials retained on 3 mm sieve	<5	<5	<5
Metal and other inert materials	None		

International standards on meal quality

Nutrient grade	I	II	III	IV	V
Maximum β-Carotene (mg/kg)	230	190	150	120	80
Lowest percentage of crude protein	20	16	15	14	12
Maximum percentage of crude protein	22	24	27	30	45

Chapter 26

Stylosanthes seed production technology in India

C.R. Ramesh[1] and P.S. Pathak[2]

Summary

Seed production is the most economically viable part of any stylo-based industry in India. Both production and the number of growers have steadily increased in the last decade or so mainly through informal links between producers. This is also true for the seed production technology used by the growers. This paper outlines the key steps in commercial seed production and identifies opportunities to improve yield and quality following improved production practices identified through on-farm research.

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Introduction

India produces by far the largest quantity of *Stylosanthes* (stylo) seeds in the world, with recent annual production exceeding 300 t from nearly 400 ha, with an annual turnover of more than Rs 30 million. Stylo seed production is a commercially viable sector which sustains over 600 growers with small land holdings in peninsular India. A detailed analysis of the Indian stylo seed industry appears elsewhere (Rao et al, this volume). Most of the stylo seed is utilised in government-sponsored programs for the development and rehabilitation of wastelands and in the stabilisation of watersheds around the country. Only relatively small quantities are used by the private sector as a cover crop in plantation horticulture and forestry, as a soil conditioner to enrich fertility, as a cut-and-carry fodder and as a ley crop in cropping systems. The recent demonstration of the usefulness of dried stylo leaf meal as a component of commercial poultry feed (Changjun et al, this volume) has the potential to further extend the commercial use of this crop in the poultry industry, which is growing at 10–15% a year. Growing stylo for leaf meal production should fit in well with the crop husbandry practices of a seed production farming system where stylo is grown as a crop.

Commercial stylo seed production by farmer groups is largely centred on the Ananthapur district of Andhra Pradesh where the seed crop competes favourably with other crops such as groundnut and cotton, especially in drought years. In addition, government organisations including the Indian Grassland and Fodder Research Institute (IGFRI) and the Kerala Livestock Development Board (KLDB), among others, and farmer groups organised through non-government organisations also produce and sell stylo seeds.

The identification of new promising germplasm for India in the last five to six years, including the recently described *S. seabrana*, has even further expanded the scope of using this versatile legume in a wide range of target environments and production systems (Ramesh et al, this volume). In the absence of any standards, the quality of seed produced is often poor and the purity of the cultivar is generally not maintained. Most commercial seed production is focused on derivatives of *S. hamata* cv. Verano and what appears to be *S. scabra* cv. Fitzroy, although small quantities of *S. guianensis* and other accessions and cultivars of *S. scabra* are also produced in some areas.

Following a brief summary of the various seed production schemes in India, this chapter outlines the current best practice for stylo seed production based on studies made at the IGFRI regional research station in Dharwad in Karnataka.

Commercial Seed Production

Commercial quantities of stylo seed are produced by the private sector, which includes farmer groups in the Ananthapur area and farmers around Dhoni in Kerala; and public sector institutes such as the IGFRI, several state departments of animal husbandry, state-run forage production and demonstration farms and agricultural universities. In the private sector, where individual farmers or farmer groups are involved, seed production contracting and often financing may be done through seed traders/dealers. A joint public and private sector compact operates under the KLDB, where farmers from low-income groups are trained in seed production technology, provided with quality seed, contracted to produce seed following specified guidelines; at the end of the process the seed is purchased by the KLDB at a predetermined price. The marketing of the seed is done by the KLDB (Rao et al, this volume). This scheme has produced significant quantities of stylo seed since its inception in 1983 (Figure 26.1). Another developing private–public sector partnership is between women self-help groups and the Hyderabad Urban Development Agency in Andhra Pradesh, where stylo seed is produced under an urban afforestation program covering degraded land and wastelands. Non-government organisations such as the Bharatiya Agro Industries Foundation also help organise farmer groups for stylo seed production at semi-commercial levels.

Most of these production schemes involve a large component of manual labour for sowing, crop husbandry, hand harvesting, and seed cleaning and processing from sown seed crops, roadside plantings and crops under plantations. Stylo is hand stripped into containers, but commonly the flowering heads are harvested with a sickle and dried before threshing. Often, farmers also sweep or rake seeds from the ground, a method that leads to a poor quality product with high inert matter

Steps in commercial seed production; from top to bottom, harvesting, sweeping seeds off the ground, threshing, sieving, and winnowing to produce clean seeds.

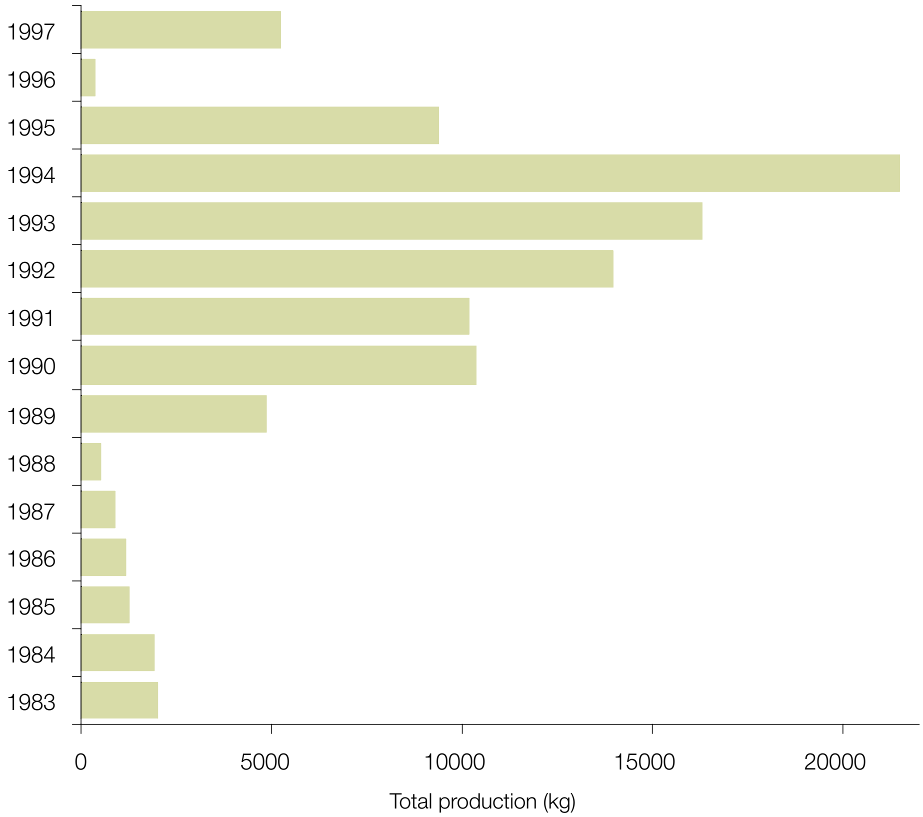

Figure 26.1 **Seed production by smallholder farmers under contract from the Kerala Livestock Development Board.**

content. Traders and their agents procure seed from the farmers and seed merchants generally package, promote and handle sales.

Seed Production Research at Dharwad

In 1991 the IGFRI regional research station at Dharwad (15°28'N, 75° E), Karnataka, was selected as the site for stylo seed production research due to its proximity to the commercial seed production areas and its suitable climate for seed production. The temperature and rainfall is suitable for vegetative growth; a favourable photoperiod and high temperature allows floral induction; and calm, dry weather during maturation and harvest leads to high seed yield. The centre has worked on several species, although the major focus has been on *S. hamata* cv. Verano and *S. scabra* cv. Seca, and interest has shifted somewhat to the highly productive accessions of *S. seabrana* in recent years. Seed production in *S. seabrana* offers particular advantages. With flowering commencing in May, the first lot of seeds are ready for harvesting around the end of August. Under good management, the rejuvenated crop can flower six weeks after the first harvest and can be ready for a second harvest in another 16 weeks. In *S. hamata* and *S. scabra,* as flowering commences in June/July and continues through the rest of the season, harvesting after 50% flowering can occur in October/November, allowing only one harvest.

Various management options have been tested to increase seed yield, improve seed quality and reduce the cost of production. In one study aimed at reducing the labour cost, the seed crop was either weeded twice a year before seed harvesting, cut or control-grazed by goats or heifers, or maintained without weeding. Comparable seed yields were obtained from grazing and manual weeding but the crop without any weeding was overrun with weeds. Hence, seed production can easily be combined with fodder production, either in a cut-and-carry or a controlled grazing system.

Other seed production related research has included the comparison of *S. hamata* ecotypes from Venezuela and Florida for seed production and ecoclimatic adaptation, a comparison of bred lines of *S. scabra* from Australia, and the seed production potential of selections of *S. seabrana* and *S. guianensis*. However, a large part of activities at Dharwad consists of the production and sale of quality stylo seed. From a mere 1.1 ha area under *S. hamata* cv. Verano, which yielded 568 kg/ha in 1991–92, the average yield has increased to around 1.1 t/ha in recent years, with substantial increases in areas under seed production. Similar high yields of 1.6 t/ha have been achieved for *S. scabra* cv. Seca.

The threat of severe anthracnose damage has been a constant factor in seed production at Dharwad. Under favorable weather conditions the pathogen can reduce Verano seed yield by 60% while loss to Seca is just over 21% (Ramesh & Gangaiah, this volume). With most accessions already suffering low to moderate level of damage, this situation is not expected to improve with the newly introduced *S. seabrana.*

Package of Practices

In addition to being grown as a pure seed crop, seed is often harvested from a stylo crop grown in different production schemes. Hence, a range of production schemes is targeted in this package of practices. Overall, light textured soils are preferred for persistence and vigour; heavy, poorly drained soils do not encourage productivity of most stylo species except some accessions of *S. seabrana*. Application of 120 kg/ha superphosphate maximises yield. Nitrogen is often added in seed crops for rapid establishment and 20 kg/ha N, 80 kg/ha P_2O_5 and 30 kg/ha K_2O may be applied to both annual and perennial stylo pastures. For perennial crops 80-kg/ha phosphorus and 30-kg/ha potash may be applied in subsequent years. A 2.0–3.5 kg/ha seed rate can be used when stylo is grown as an intercrop in plantation horticulture; a rate of 1.5 kg/ha may be sufficient for grass legume mixtures and 5 kg/ha is recommended when raising a crop primarily for seed production. A fine seedbed preparation or soil disturbance is necessary in most cases. Seeds can be broadcast and covered with a thin layer of soil or sown in rows 30 cm apart, at a 5–10 mm sowing depth. If irrigation is available, best results are obtained with 33 mm of water once every nine days during summer months from January to March. The first weeding is usually necessary 45 days after sowing, with a second weeding and hoeing after the first fodder harvest. The first fodder harvest is taken three to four months after sowing, with subsequent harvests at 45-day intervals or according to the growth of the crop. A maximum of four or five harvests can be taken in a year for a perennial crop lasting for three years. Stylo seed crops need a minimum of four to five months of wet period for profuse flowering and seeding, and any shortening of this period is likely to prejudice seed production. Verano is treated as an annual for seed production. *Stylosanthes scabra* and *S. seabrana* have an effective life of about four years and the management of their seed crop generally aims to retain established stands. However, renovation is necessary to maintain stands of all species.

Deciding when to harvest seeds can be tricky as seeds must be mature before harvesting can start. The crop must also have passed the 50% flowering mark to ensure adequate seed production. Manual harvesting is the main method, unless machine harvesting with appropriate cutting and vacuum attachments are available. Seed heads can be cut with a sickle or other implements and stacked on a dry clean floor. Sweeping of the ground to recover some of the fallen seeds often follows harvesting. Threshing can be done manually by beating with a heavy baton, followed by winnowing and sieving to clean the seeds. Seeds can be further dried in the sun before storage in a cool environment in bags that allow gas exchange.

Currently, no quality standards apply to commercial stylo seeds for physical, physiological or genetic purity and a seed certification scheme is urgently needed for quality assurance. The physical quality of stylo seed is usually poor due to contamination with weed seeds and inert materials, largely as a result of the manual harvesting methods. The physiological quality, in contrast, is usually good and, as the seed is not usually stored for long periods of time, germination percentages in most commercial seed lots are high to very high. Assuring genetic purity is far more difficult because most stylo seed growers maintain their own supply and the operation and enforcement of any licensing scheme for new varieties with or without plant breeders' rights is onerous.

Acknowledgments

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Chapter 27

Evaluation of imported *Stylosanthes* germplasm in Australia

Bill Messer[1]

Summary

For 17 years the author was a technical officer working on *Stylosanthes* with Mr L.A. Edye, who has been responsible for the release of *Stylosanthes* varieties Seca, Verano and Amiga and more recently Primar and Unica. The release of these cultivars has had a major impact on increased beef production in northern Australia. This paper discusses the techniques used and developed to evaluate collections of introduced *Stylosanthes* accessions into Australia over this period. While many of these techniques may be well known and currently utilised, the stepwise and systematic arrangement of the exact procedures followed in CSIRO may prove useful to some readers. These techniques mark the beginning of all plant evaluation trials that have led to the release of several very important *Stylosanthes* cultivars.

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Plant Introduction and Quarantine

Upon receipt at the CSIRO Samford seed store near Brisbane, Queensland, collections of *Stylosanthes* accessions are fumigated with carbon tetrachloride (25 mL poured on an absorbent foam rubber and placed with the seed in a 200 L drum fitted with an airtight lid. Seeds are fumigated for 24 hours, then the lid is opened and the drum allowed to stand for a further 24 hours in a well-ventilated area. It is essential for staff to wear protective clothing, gloves and face mask during this treatment to destroy any insect pests. The accessions then undergo a preliminary processing and recording before being forwarded to the Davies Laboratory in Townsville. Here the seed is processed under quarantine before field evaluation. The processing steps are provided below:

Seed Preparation

In a dedicated insect-proof laboratory, with plenty of clean secure bench space and washing facilities, each seed is dehusked via a small hand operated dehusker and by rubbing the seed on a corrugated rubber board. The seed is then put through a series of small hand sieves until almost pure seed is separated, and an aspirator is used for the final cleaning process. The clean seed is then placed into a sterile/clean labelled seed packet, along with a fungicide such as Bayleton or Thiram for protection against fungal infestation.

Throughout this entire process, hygiene is most important. All equipment must be sterilised with 70% alcohol before use and between seed samples. A small vacuum cleaner is useful to allow rapid cleaning between samples. All extraneous matter removed from the seed must be collected and destroyed in an autoclave or incinerator. An effective

An aspirator used for cleaning seeds. Air is gently blown from a small fan in the base housing through the column, where dehusked seeds are collected in a sieve, while dust and husks accumulate in the top container.

insecticide such as pyrethrum is required to quickly destroy any insects that may have escaped previous fumigation. Insect eggs and pupae may also survive initial fumigation and emerge later.

Seed Germination

Stylosanthes seed can be germinated in 90 mm Petri dishes on three or four filter papers soaked with sterile distilled water or 2% water agar. Whilst filter papers are relatively inexpensive, there are some drawbacks to their use, eg the need to regularly replenish the water to prevent drying up, and the possibility of damaging young seedlings when transferring from the Petri dish.

A 2% weight by volume agar offers a superior alternative (2 g powdered agar to 100 mL distilled water). Nutrient agar should not be used, as it will allow moulds to grow and destroy the seed. If 500 mL of agar is needed, measure out 250 mL of distilled water and bring to the boil in a beaker on a heating plate equipped with magnetic stirring. Weigh out 10 g of agar powder and pour quickly into the beaker. Stir until all agar is dissolved and the solution is a rich honey colour before adding the remaining 250 mL of distilled water. This will reduce the temperature, but not enough to solidify the agar, and will reduce the cooling time considerably. Only sterile Petri dishes should be used, labelled on both the top and bottom with the accession number. Approximately 40 mL of the molten and sterilised agar is poured in each Petri dish, immediately closing the lid to reduce contamination. Condensation will occur on the inside of the lid. This is beneficial as a high humidity environment aids germination. Allow the gel to cool and solidify before placing any seeds in the dish. One to several hundred seeds can be germinated in a single dish.

Seed Scarification, Surface Sterilisation and Germination

Germination of *Stylosanthes* seed can be slow for two reasons. Firstly, the seeds have a hard coat that prevents or slows down moisture uptake. This can be overcome by treating the seed coat to make it more absorbent. The best method is to gently rub the seed between two sheets of sand paper. This process of scarification etches small cracks into the seed coat and enhances moisture uptake. Acid and heat treatments can also be used. This scarified seed is then placed in a fine mesh sieve or strainer and dipped into a 50:50 solution of household bleach and water for 30 seconds to kill any surface contaminants. The seeds are then washed with distilled water.

The second reason for slow germination is naturally occurring germination inhibitors. These inhibitors can be degraded in most cases by soaking the seed in a 0.1% thiourea solution. A few drops of a wetting agent, such as Tween20 or Agral, in the thiourea solution will improve the uptake of the solution. Enough thiourea solution should be pipetted to cover the seeds placed in a Petri dish lid and then the seeds should be allowed to imbibe (swell) for three to four hours. Some seeds will not imbibe due to poor scarification and these can be removed and scarified again.

The swollen seeds are placed on the agar surface and spread around the Petri dish using sterilised tweezers and the dish is placed in a germination cabinet at around 25°C for about 12 hours. Germination can be aided if lights are switched on. Sprouts can usually be transplanted after around 48 hours. Those accessions that do not germinate can be assisted by manually removing the seed coat with a sterile, sharp implement. This is particularly important when working with small numbers of seeds. It is advisable that only small lots of accessions be germinated at one time to ensure these can be handled effectively.

Transplanting to Seedling Trays

Germinated seedlings are grown in a quarantined glasshouse which is maintained clean, regularly fumigated for spider mite and other insect pests, and has to be approved by a quarantine inspector. For watering, a timer-controlled fine spray irrigation system will save time; however, hand watering, although time consuming, does allow for constant inspection and monitoring of the germinated seedling and is very beneficial for a short period after transplanting. At CSIRO we have used PYCO polythene trays with 30 or 42 cells/tray (available at nursery supply outlets) as these were strong and easily cut into sections if required. Trays are filled with sand sterilised using steam or fumigated with methyl bromide. Sterilisation reduces the chance of fungal diseases, especially damping off by *Pythium* and *Rhizoctonia* spp.

The trays are thoroughly watered just before planting the sprouted seed. A small hole is pushed into each cell with the back of tweezers deep enough to take the radicle. The sprout is gently lifted from the agar using the thumb and forefinger and first placed on the inverted Petri dish lid, from where it is gently lifted by grasping the tip of the radicle with fine tweezers and placed into a hole. Never grasp the seedling below the cotyledons, as this will damage the radicle. Leaving about 3 mm between the cotyledons and the sand, lightly press the sand over the radicle. Sprinkle the seedlings, first with a wash bottle to gently settle the soil and then by using a hand-held hose with a fine sprinkler nozzle.

Seedlings will grow and establish over the next week. Once established, a half-strength liquid fertiliser can be applied every two weeks; most commercial nursery brands are suitable. Two weeks after planting, the appropriate *Rhizobium* inoculant, if necessary, needs to be applied. Peat culture of the *Rhizobium* is mixed with water in a watering can and gently watered on the seedling trays. It is very important at this stage to regularly check for disease, and a qualified plant pathologist should inspect the germinated seeds in the quarantine facility on a fortnightly basis. Any infected seedlings and soil must be removed and destroyed by autoclaving or incineration.

Transplanting Seedlings to Pots and Seed Collection

At about 12 weeks of age, the seedlings can be transplanted from the trays into correctly labelled 200 mm pots. Soil used in these pots should be sterilised or fumigated as previously. Continue fertiliser application on a fortnightly basis and regular inspections by a pathologist as often as necessary. A drip irrigation system is the best method for watering pots.

After flowering the seedpods quickly develop in the inflorescence. When ripe, the seedpod dries out and becomes grey in colour. Seed can then be carefully removed with sharp sterile tweezers as soon as ripe. Collected seeds can be placed into labelled envelopes or jars and kept with the plant, but well out of the watering area, by attaching them to the dowels used to support the plants. This practice is designed to reduce errors, but some may prefer to remove the packets or jars to a seed storage cabinet within the quarantine facility, if concerned about high humidity causing seed deterioration. However, no seed should leave the quarantine glasshouse until cleared by a plant pathologist. Recording of flowering dates is very important as early flowering is a valuable and desirable attribute. Morphological characterisation is also useful for later identification of the accession.

After clearance by a pathologist, collected seeds are removed and stored at 10°C and 30% humidity for long- or short-term preservation. It is important to send some seeds of each accession to another storage facility to ensure that valuable materials are not lost due to accidents such as fire or the failure of cold storage at any one location. All plant material and soil are incinerated and pots sterilised after the collection of seed.

Nursery Field Evaluation

Nursery observation plots are the next stage in appraising each of the introduced accessions. At CSIRO this is done in plots at the field experiment research station at Lansdown near Townsville, using the seed previously gathered from the quarantine facility. The seed is germinated using the same techniques and grown in PYCO seedling trays in a glasshouse until 12 weeks of age, and then transplanted into a field nursery at Lansdown. Weeds are controlled by using weed mat (woven polythene fabric) laid prior to planting of the seedlings. Weed mat allows water to penetrate and excess soil water to escape while providing an impenetrable barrier for germinating and established weeds. The matting is rolled out over the cultivated soil surface and held in place by ‘U’-shaped pins (10 cm wide and 20 cm long, made from 8-gauge galvanised wire) placed around the edge of the matting and through the middle. The mat pieces should overlap with one other by about 10 cm to ensure no weeds can emerge between them. It is also important to ensure that the mat edge nearest the direction of the prevailing wind is on the underside of the overlap to prevent the wind getting under the matting and lifting it, which can cause problems.

Holes for seedlings are marked on top of the weed mat in rows, with an intra-plant spacing of 1 m and an inter-row spacing of 2 m. This provides sufficient space for each plant to grow and allows easy access to each plant for subsequent observation. The holes are burnt into the weed mat with heated pieces of 75 mm diameter pipe 100 mm long with a 1 m-long steel rod welded to it as a handle. Several of these pipes can be simultaneously heated in a fire or a portable furnace to provide a continuous supply. A hole is then dug in the soil using a crowbar with a moulded tip to accommodate a single cell from a seedling tray. The holes are dug just prior to transplanting and are immediately filled with water using a watering can. Filling the holes with water reduces the number of transplanting mortalities. Seedlings are hand-watered immediately after transplanting. A reliable irrigation system is necessary to ensure adequate establishment. We generally use 10 to 14 plants in each row for an accession and each accession is replicated three times.

Observations

Observations, including the incidence and severity of anthracnose, are recorded on individual seedlings within each accession often three times per week from the time of transplanting. A numerical rating system from 0–6 is used, with a rating of 0 indicating complete disease resistance and 6 representing death of the plant. Other observations include the recording of morphological and agronomic traits. As the plants approach maturity, observations on flowering are made. A specimen of each accession is preserved by mounting between two sheets of blotting paper as a herbarium record for later identification.

Stylo accessions under evaluation on weed mat in north Queensland (Photo: Bill Messer).

Seed Harvest from Nursery Plots

After all observations are completed on each accession for each replication, seed from all accessions is collected for use in future evaluation trials. Obviously those accessions with desirable attributes are dealt with first. Seed yield measurements are obtained by hand-harvesting and threshing of three plants from each row of each replication and weighing the cleaned seed. Bulk seed is collected by vacuum suctioning using commercially available cleaners designed to pick up leaves and rubbish from garden lawns and powered by a petrol motor (Victa Lawnmowers, PO Box 60, Campsie, NSW 2194). Uncleaned seed is collected in a bag attached to the machine. Contents from the bag are cleaned using a 'Clipper' seed cleaner (Clipper Seed and Grain Conditioning, 785 South Decker Drive Bluffton, IN 46714, USA) to separate out the seed from all other material. Seed going through this process usually maintain a high germination rate, as little damage to the seed occurs. Suitable personal protective clothing and equipment should be worn during seed harvest and cleaning as prolonged exposure to dust and noise can be a health hazard.

Data collected from nursery plots trials are used to select *Stylosanthes* accessions for regional evaluation trials. The approach, strategy and selection criteria for regional evaluation trials and cultivar development have been previously documented by Edye (1997).

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Reference

Edye, L.A. 1997. Commercial development of *Stylosanthes* pastures in northern Australia. I. Cultivar development within *Stylosanthes* in Australia. Tropical Grasslands 31, 503–508.