TROPICAL FORAGE LEGUMES

THE INTERNATIONAL CENTER FOR AGRICULTURAL RESEARCH
IN THE DRY AREAS (ICARDA)

FORAGE TRAINING COURSE 1980

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Index

i. ACKNOWLEDGEMENT

These notes have been prepared with heavy reliance on the data and organization of the volume "Tropical Forage Legumes" by P.J. Skerman, (1977) FAO Plant Protection Series No. 2, Rome. However, many opinions expressed herein are not necessarily those found in that excellent publication.

I Introduction

The objectives of developing tropical livestock production systems are:

1. the production of milk and meat in order to improve nutrition.
2. the saving and earning of foreign exchange by satisfying local demand for these products, and by exporting surpluses of these and other products
3. provision of employment, especially in rural areas.
4. more efficient utilization of land resources particularly in areas unsuitable for cropping due to topography, rainfall or soil nutrients, and land being fallowed in crop rotations.

Grown as crops for a least 6,000 years legumes were recognized as being especially valuable for food and soil improvement as far back as the early Egyptian dynasties. (Whyte *et al* 1953).

The value of legumes lies in their symbiotic relationship with soil bacteria of the genus *Rhizobium* which is able to utilize atmospheric nitrogen. The rhizobia invade the roots of legumes forming swellings called nodules, and through their metabolic activities supply atmospheric nitrogen to the plant in a utilizable form. Legumes as a group then generally have an adequate supply of nitrogen and thus under low soil nitrogen conditions are relatively high in plant protein and their competitive advantage in nitrogen nutrition is undoubtedly the reason for their being an important constituent of the flora of infertile soils. Many species have a weedy character (Baker 1974) which allows rapid colonization of disturbed environments. Decay of leguminous plants releases nitrogen for other plants to utilize (Henzell and Vallis, undated). Both of these features have important implications in their value as pasture fodder plants. It has been noted (Williams _et al_,1976) that there are over 50 leguminous genera of recognized pasture value and over 2000 of their constituent species are as yet unutilized; these species warrant examination as do other genera on which little or no work has been done.

i) History of Research

1.1 Early Work in Tropical Forage Legumes

The unique social, economic and climatic conditions in north-eastern Australia have provided the context for the origin, sustained interest and development of research in tropical forage legumes. Though legumes have been lately tested widely elsewhere in the tropics, Australia remains paramount as the source of experimental philosophies, experimental techniques, and genetic material.

As research into tropical forage legumes was preceeded by the successful development of species for temperate areas, temperate forage legumes were the first species to be tested in the lowland tropics where despite repeated attempts, none have been successful.

The first tropical species recognized to be of potential fodder value was Stylosanthes humilis and the first written reference to it has been quoted as 1904. An annual adapted to lower rainfall areas (650-1300 mm) with long dry seasons, it was an accidental introduction to Australia. Over the next fifty years it became widespread through the tropics by being sown and by natural means. A great deal of research has been done on the plant, peaking in the mid-1960's. Its inability to compete with vigorous grasses and the identification of more valuable legumes for the same climatic zone have prevented its wider acceptance and reduced its popularity.

Following the widespread interest in the use of *S. humilis*, Schofield in 1941 compared the performance of available lines of temperate and tropical forage legumes at South Johnstone in the wet tropics. He concluded that temperate legumes were unsuited for the tropics and that any successful legumes for the Australian tropics would have to come from tropical environments. Among those tested, were many legumes used as cover crops, green manure crops and shade in plantations, particularly in tropical Asia.

Some of these achieved limited success in pastures (Hutton 1970) with increases in dry matter yield, better fodder quality and increased liveweight gains in livestock when grown in mixed swards. *Pueraria phaseoloides* cv. Puero, a vigorous vine suited to the wet tropics has proved to be too palatable to persist except under careful management. *Calopogonium murconoides* cv. Calopo, another vine, is short lived and thus is of limited interest; *Desmodium intortum* cv. Greenleaf (Bryan 1969) and *Centrosema pubescens* cv. Centro (Bryan 1968, Teitzel and Burt 1976) which are adapted to fertile areas of high rainfall have been more successful. Centro has been particularly popular due to its persistence in mixed swards (Humphreys 1974). A more vigorous accession of the species has been recently released as the cultivar Belalto (Harding and Cameron 1972).

Leucaena leucocephala, a small shrubby tree, has received a great deal of attention over the years (Oakes 1968, Gray 1968, Hill 1971) but its toxic properties due to the presence of mimosene (Donaldson et al 1970, Jones et al 1976) has discouraged its wide use despite its high nutritive value, remarkable vigour, and a growing body of published work on its management.

One of the better legumes in Schofield's trial was one of two accessions of Stylosanthes guianensis from Brazil. A high yielding perenniating shrubby plant, it became very popular in wetter areas of Queensland and was eventually released as the cultivar "Schofield" (Gilchrist 1967, Tuley 1968).

The notable success of the two Stylosanthes species, S. humilis and S. guianensis, both presumed to be from Brazil, led Hartley to collect native legumes from homologous climates in that area of South America in 1947-48 (Hartley 1954).

The trip was successful in that two legumes and a grass were released as commercial cultivars, but only after a lapse of 15 to 20 years.

Though most tropical legume cultivars were selected from naturally occuring genotypes some breeding work has been done in an attempt to improve forage character. The notably popular cultivar of Macroptilium atropurpureum, Siratro, was the result of one such program by Hutton (1962), (Shaw and Whiteman 1977). The legume is adapted to the moderate rainfall areas of the tropics; it is resistant to drought for periods up to three months but it is severely affected by diseases under very wet conditions. Further breeding of the species has been done using a somewhat broader genetic base (Hutton and Beall 1977) in an attempt to increase productivity and disease resistance.

By the early 1960's a definite interest had developed in the genus *Stylosanthes*. It was unique in being the source of three successful pasture plants which covered the wet (*S. guianensis* cv. Schofield), dry (*S.humilis* cv. Townsville) and dool (*S.guianensis* cv. Oxley, one of Hartley's accessions) regions of Queensland. Such variability was felt to be worthy of further study. Collection by correspondence which was the source of almost all accessions to date, was realized to be unsatisfactory as many new accessions turned out to be Australian lines, or extremely similar to lines already tested. As a result, many valuable collection trips were made and quite large numbers of accessions were accumulated (Burt and Williams 1975).

The success of the collecting trips produced problems in the assessment of such very large numbers of plants. Previously accessions had been selected for study on a more intuitive basis by scientists who relied heavily their knowledge of the environment of origin, and of the performance of the plant in various Australian conditions. Such methods worked adequately for the small numbers of accessions received by correspondence and on casual collecting trips but were unsuitable for handling large numbers.

Hartley (Hartley and Neal-Smith 1963) suggested that it was unrealistic to test all plants in all places but there must be selectivity in order to reduce the work to manageable proportions. It was of great importance, he noted, that valuable accessions should be developed into commercial lines as rapidly as possible.

Methods of rapidly selecting vigorous plants adapted to a given environment from among large numbers of accessions of diverse species and environments of origin were lacking, until the development of new computer based techniques for handling scientific data.

While statistical methods are most useful for continuous data, the development of computers, and the tendency for scientists to record larger amounts of data and of types other than continuous, created a demand for the development of computer programs designed to deal with heterogeneous data. Such programs have been mainly used by taxonomic workers, their use in agriculture being only relatively recent.

Pattern analysis is one of these programs and it is concerned with the efficient ordering of data. Unlike statistics which aims to demonstrate that discontinuities <u>do</u> exist in a system, pattern analysis demonstrates <u>where</u> the discontinuities lie in data, if they are present. One great value of these programs is their versatility in handling many different types of information (qualitative, quantitative, continuous, ordered) singly or in combination. The subject has been simply and concisely reviewed in relation to agricultural research (Williams 1976).

The reduction of the large numbers of forage legume accessions accumulating in Australia to manageable proportions was one of the first uses of pattern analysis in tropical forage legume research. The programs used data on plant morphology, agronomic performance and climates of origin in order to make groupings. The results have suggested that plants perform best in climates similar to those of their origin. It is throught that climates which are similar but less restrictive in the major factors limiting growth may provide the best conditions for success of introduced plants.

Utilization of legumes has to a large extent been limited by the progress of knowledge on the legumes' requirements for growth, much of which has been done in the last two decades.

The recognition of phosphorus as an essential element for good legume growth was first determined with S. humilis (Shaw 1961) and has greatly increased the area for which legumes are useful pasture plants. Recognition of the need for mineral nutrition to aid legume growth has prompted much research on their requirements in different soils.

Henzell (1962) was among the first to determine the amount ot nitrogen fixed by tropical legumes and work has been done on many legumes since (for example Bruce 1967, Jones et al 1967).

A series of studies was done, mainly by Norris (Andrew and Norris 1961, Norris 1959, 1965, 1966, 1967), on the genus Rhizobium and its relationships to legumes and their environments. The ability of many tropical Rhizobium strains to thrive on acid soils of low fertility was studied and strains which are more effective in nodulation have been isolated for specific plants or groups of plants such as the genus Desmodium, Leucaena and Oxley Stylo. Without specific strains these legumes may not have been considered useful plants. Pelleting of innoculated seed with calcium has done much to help establishment of the calciphile Leucaena on mildly acid soils (Diatloff 1971). Recently pattern analysis has related success of nodulation with the climates of origin of legume and Rhizobium, success being greater when they are similar (Date and Norris, in press). This conclusion supports the hypothesis that legumes do best in homologous climates. The amount of N fixed by legume swards has also been worked on.

Increases in fertilizer prices in recent years have made high fertilizer applications uneconomical in all but the most intensive conditions. This has resulted in a shift in research emphasis from high productivity legumes requiring high fertility conditions to legumes which are persistent and productive under low soil fertility.

A discovery which may help reduce fertilizer costs was the identification of Stylosanthes accessions which do not respond to the addition of phosphorus (Jones 1974). These plants could potentially be grown on land of low fertility with a reduced fertilizer input, the low phosphate content of the plants being offset by the provision of phosphate supplements to the livestock.

1.2 Future Developments

Research is moving towards greater utilization of natural genetic variability and more rapid assessment techniques.

Homogeneity of climate and edaphic characteristics will increasingly determine the collection sites and emphasis will continue to be placed on morphologically and physiologically variable legume taxonomic groups such as the genus *Stylosanthes* which has wide environmental adaptability (Burt and Williams 1975). With increasing interest in tropical legume research on a world-wide basis, it is expected that more attention will be paid to promising genera which have been neglected hithertofore, such as *Desmanthus* and *Zornia*.

Reduction of screening time (Burt and Williams 1975) by including tests while under quarantine and more simplified early field testing under more rigorous conditions will be emphasized, with greater importance being attached to individual trials in actual pasture conditions lasting several years. Major characters examined would include survival, regrowth, propagation, resistance to grazing and productivity under low phosphate conditions (R.L. Burt, pers. comm.).

Very large collections of genetic material will be accumulated at genetic resource centers, and to provide order in these collections pattern analysis and homologous climate techniques will become increasingly important.

II. The Value of Leguminous Crops

2.1. Cropping Systems

The use of leguminous crops in cropping cycles to increase soil fertility has ancient origins. Today legumes are used as green manures, as cover crops, in leys and in permanent mixed pasture swards to increase the organic matter and nitrogen content of soils. They are ploughed under before a crop is planted and may reduce the amount of fertilizer which must be applied. In tropical Australia cowpea (*Vigna sinensis*) velvet bean (*Stizolobium deeringianum*) and other legumes are commonly planted between crops of sugar cane.

Legumes are used as cover crops, to prevent erosion and to enhance soil fertility with crops such as rubber, oil palm, coconut and sisal. It has been demonstrated that higher yield can be obtained when a cover crop is used.

2.2 Ley Pasture Systems

Ley systems of agriculture involve a period of leguminous fodder production in a cropping cycle to improve soil structure and fertility. The fodder is utilized either as pasture or cut and fed. The medic-wheat rotation in Southern Australia is a good example.

2.3 Mixed Sward Pasture Systems

The inclusion of legumes in tropical grass swards has frequently demonstrated to increase the amount of grass produced and also to increase the N content and hence the feed value of the grass. The presence of the legume itself increases the N content of the sward. Increased liveweight gains result.

2.3.1 Maintaining soil fertility

In the wet tropics a critical feature of establishing cropping in virgin areas is that of maintaining soil fertility under the intensive leaching and rapid mineralization which occurs under hot wet conditions. Under normal cropping, soil fertility falls to levels where vegetation cover is difficult to maintain. Serious erosion then occurs, compounding the infertility problem. It has been found that grass-legume swards can maintain soil fertility at levels approaching that of the levels found under tropical rainforests.

2.3.2 Increasing soil fertility

The inclusion of legumes on soils of very low fertility has resulted in dramatically increased production. An area of infertile sandy coastal soil in Australia known as the Wallum was unutilized by livestock due to lack of nutritious forage. After defining the nutritional deficiences of the soils, and supplying these, mixed grass-legume swards were established which, with annual fertilizer applications, greatly increased the productivity of the soil.

As noted above, the presence of mixed grass-legume pasture swards can increase soil organic matter content, N levels and maintain and/or increase fertility levels. Many studies have indicated that mixed sward livestock raising can have superior profitability compared to pure grass stands. These studies have indicated greater productivity under high N fertilizer rates in pure grass stands but as the cost ot the fertilizer is high and as returns per kilogram of animal marketed can vary drastically, mixed swards can provide more constant cash returns with lower investment requirements.

Such increased profitability will occur if the mixed sward does not require prohibitively expensive levels of other nutrients such as P or lime for vigorous growth, and the equipment and management required to maintain the sward are not beyond the resources of the enterprise. The assumption is also made that an adapted, vigorous, persistent legume has been identified for the environmental conditions and that seed of both the legume and the grass are readily available at reasonable cost.

III. Environment and Tropical Pastures

It is critical that the legume or grass chosen for a particular location be adapted to the environmental conditions of that site. This is a basic and fundamental concept. The climate and edaphic conditions in which the legume thrives must be known before time, effort and money are invested in the establishment of a trial or pasture. If these conditions do not match or at least are not reasonably similar to the optimal conditions, it is quite likely the legume will fail or will have reduced vigour and be crowded out by a more vigorous grass.

Environmental factors of importance in selecting a legume for a given environment are temperature, precipitation, soils, solar radiation.

3.1 Climate Factors

3.1.1 Solar radiation

3.1.1.1 Amount

Solar radiation is most constant at the equator and varies seasonally more toward the poles. In wetter locations and in rainy seasons reduced radiation due to cloudy conditions can reduce growth markedly. This rarely seems to be an important factor.

Shading by taller plants, on the other hand, is frequently a critical factor in limiting legume growth. Some plants such as *Stylosanthes humilis* are particularly sensitive to shading.

3.1.1.2 Photoperiod

The day length (photoperiod) has a critical effect on the flowering of plants. Some require only small changes to flower, some large changes, while others flower year-round. This produces three generalized groups of plants short day, long day and day neutral respectively. There is usually a critical day length for the short and long day plants, when flowering initiates.

It has been suggested that due to photoperiod requirements the latitudes in which genera will persist can be identified. The potential forage genera can be grouped as follows:

i) Those with a wide range or latitudes *Cassis*, *Desmodium*, *Lupinus*, *Medicago*, *Melapotus*, *Phaseolus*, *Rhynchosia*, *Stylosanthes*, *Trifolium*, *Vicia*.

ii) Those 10° to 20° north or south of the equator, but not in the equatorial zone: *Aeschynomene*, *Astragalus*, *Crotalaria*, *Galactia*, *Indigofera*, *Zornia*.

iii) A group which occurs only in the relatively constant light conditions of the equatorial zone.

Alysicarpus, *Calopogonium*, *Canavalia*, *Centrosema*, *Pueraria*, *Teramnus*.

The list is a rough generalization and many exceptions can be found. The critical daylength of an accession may depend on the latitude at which it was collected. For example, the further north in Australia collections of S.humulis were made the greater the number of days the accessions required for flowering. Changes in photoperiod can also change plant morphology.

3.1.2 Temperature

The terms tropical, sub-tropical and equatorial are frequently used without definition. One must be careful in the interpretations which are given to the terms. If Australia is used an example, Brisbane which has cold winters but no frost is frequently refered to as tropical, and Trifolium repens, white clover, can survive there. Such environments may not even be subtropical by some definitions. It is not the place here to define these terms but it is important to remember that many places may be considered tropical or subtropical which have hot summers and cold winters.

The latitude is not always a satisfactory guide to the climatic type, as other factors besides angle of incidence of the sun's radiation are usually involved. These include movement of air masses from the poles, size of the continent to be heated or cooled, movement of warm or cold ocean currents, and altitude. All of these have a marked effect on temperature.

When chosing a legume to plant the pattern of temperatures in its native environment should approximate as closely as possible that of the environment in which it is being introduced. If the environment is markedly colder the legume will probably show lower vigour than that required.

Generally tropical legumes require temperature conditions ranging from 26.5° to 32.2°C. Growth is slow with cooler temperatures and ceases at about 10°.

Locations closer to the sea and near sea level have lower diurnal temperature variations than those inland or at higher altitudes. These variations affect legume performance. Frosts may occur at higher altitudes. Tropical legumes usually react by defoliating or drying, although some are more tolerant due to physiological adaptation (e.g. Lotononis bainessi) or physical structure, that is growing above the frost level, (e.g. Leucaena) or being sheltered in tall grasses in the case of a short legume.

Cold tolerance may vary markedly among accessions of a species. Previous exposure to low temperatures (hardening) may also increase tolerance.

Temperature is thus a critical factor and it should be a primary consideration in the choice of legumes.

3.1.3 Precipitation

Rainfall is another critical factor in chosing adapted plants for an environment. Rainfall totals give only a general guide to the water available, of greater importance is the rainfall distribution through the year.

The following general rain patterns have been identified.

i. Equatorial : Two heavy rainy seasons with no period really dry. This extends to about 5-6^{o} N & S of the equator.

ii. Tropical : From the equator to the regions of the tropic of Capricorn and Cancer. Most rain occurs when the sun is highest, with a pronounced dry season, frequently in winter or late winter.

a) inner tropical : two rainfall maximum while the sun is overhead and a long dry season. Between the equator and 10^{o}N & S. (Juba in the Sudan).

b) outer tropical : further from the equator. The two wet seasons joined and the dry season is longer. (Khartoum).

iii. Monsoonal : a marked summer maximum and a long dry season.

The pattern of rainfall can be very important as few legumes are vigorous in waterlogged soils which may occur in periods of heavy rain. If the dry season is long enough for soil water reserves to be depleted or if evaporation exceeds precipitation, water will be a limiting factor.

It is important to know the rainfall history of the area. Are there years of high rainfall and years of lower rainfall? What are the extremes and how frequently do they occur? If the rainfall is erratic, and a very dry year may occur one in four years then legumes must be chosen to survive those dry years, or one must be prepared to re-sow.

On the other hand it should be noted that a plant selected to persist in the poorer years, may not be able to compete with the vigour of the companion grasses and weeds in years of high rainfall.

Plant species may adapt to drier environments by having an annual life cycle, defoliating in the dry season, deep root systems and leaf adaptations to reduce transpiration.

3.2 Edaphic Factors

While somewhat less important than precipitation and temperature, edaphic factors too must match the requirements of the plants.

3.2.1 Soil Depth

Shallow soils can limit plant growth during dry periods and necessitate the use of lower yielding, more drought tolerant lines which can survive the stresses of the dry season.

3.2.2 Soil Texture

Legumes generally prefer better drained soils, particularly those with a somewhat sandy texture. Heavy clays may be waterlogged during periods of heavy rains and growth could be inhibited. Vertisols (black, cracking clays) are particularly unsuitable for legumes.

3.2.3 Soil Fertility

With the exception of recent alluvium, fertility is a very important factor in tropical soils. Fertility is generally low as tropical soils are frequently old, and are often from secondarlly deposited parent materials; these soils are usually well leached of nutrients. Iron (Fe) and aluminium (Al) usually remain behind in an acid environment. In Australia where most selection of tropical legumes has been done to date, the soil is generally acid and infertile.

Prior to the early 1970's because of low cost for fertilizers, the modification of the soil fertility by the addition of chemical fertilizers was economical. High rates were used so that the most productive legumes could be grown. As the majority of the initially selected species of tropical forage legumes are common on alluvial soils in their native habitat they often require high fertility to be productive. As a result of the rising prices, fertilizer application to mixed swards ceased on all but the most intensive operations, with the result that the legumes essentially disappear from the swards.

Scientists are now searching for vigorous legumes for soils of low fertility which will require minimal levels of fertilizer input to provide vigorous pastures. Interest is also being shown in the relatively smaller areas of calcareous (high pH) soils in the tropics for which few forage legumes have been selected.

IV. Pasture Establishment

Generally the better the seedbed preparation, the better the establishment. Costs of establishment are a very significant factor in the decision to establish improved pastures; lower establishment costs will likely favour a given legume/grass combination to be sown.

4.1 Methods

4.1.1 Aerial seeding

Where the tree density is not high as in open woodland or savanna Stylosanthes humilis can sown by aerial seeding. Seedbed preparation consists solely of burning or heavy grazing to reduce competition before sowing. On light soils establishment is better and is about half of that seen on well prepared seedbeds. In one instance, the seed (6.6 kg/ha with hooks removed) was sown with 132 kg/ha of single superphosphate. Defoliation of trees by herbicides or ring-barking can also be used in denser stands.

4.1.2 Broadcasting on an undisturbed seedbed.

Annual legumes have been broadcast on burnt native pastures in standing woodlands. The addition of fertilizer aided establishment.

4.1.3 Strip planting in forest or savanna.

Light cultivation has been used on small areas (25%) of rangeland to establish strips of legume with the help of P fertilizer. Grass competition is controlled before planting by grazing or burning and after planting by light grazing. Light intensity can be increased by poisoning, ring-barking or herbicide applications on existing vegetation. Poisoning is done by injection before sowing to avoid possible side effects on the sown legumes.

4.1.4 Animals as seed distributors

Many legume seeds survive passage through an animal's digestive tract and are somewhat scarified in the process. Thus legumes can be established in an unplanted paddock by grazing it at the same time as one planted to a legume. Fertilization of the unplanted paddock may be required in order to achieve significant stands.

4.1.5 Burnt and cleared timber

Commonly used in areas newly opened to cultivation, the timber is cut, burnt, and seed and fertilizer broadcast by hand, machine, or aeroplane, depending in the area and how well the debris has been reduced to ashes. Seeding should take place as soon as the ash has cooled, before the ash is blown or washed away, since it contains much of the nutrients contained in the previous vegetative cover.

Grasses which establish rapidly have been mainly used, for they must compete with weeds (*Chloris gayana*, *Melinis minutiflora*, *Panicum maximum*, *Cenchrus ciliaris* and *Hyperrhenia rufa*)

The few legumes that have been used include Siratro, alfalfa, Schofield stylo and Townsville stylo. Pelleting of the seed is often done to ensure longevity of the inoculant in the ash.

Control of weeds is critical, as their regrowth can be extremely rapid. Safest establishment involves windrowing the fire debris, cultivation and mechanical seeding. Weeds can then be controlled by slashing.

4.1.6 Well prepared seedbeds

As mentioned previously good seedbed preparation is essential for satisfactory establishment. Good cultivation and regular planting assures germination and rapid plot cover and consequently less weed competition. Some legumes are more competitive with weeds and grass than others, hence the amount of preparation actually required varies with the species as well as with the vigour of the competing weeds.

Good mechanical preparation involves the removal of tree stumps by a stump-jump disc plough, disc harrowing to chop any remaining debris such as roots and stems which might interfere with seeding. Several passes will even out the soil surface and will create a finer tilth.

4.1.7 Interplanting

Interplanting maize, sorghum or some other crop is often done after the germination of the crop so the legume and/or grass does not compete with the main crop. Once the main crop is harvested the pasture crop is them maintained.

Combined seed-fertilizer drills are probably the most efficient method of seeding. Rubber trailing wheels should be used to compact the soil about the seed. Broadcasting may be used for smaller seed; larger seed should be harrowed lightly after broadcasting. Compaction after rolling is usually done by a Cambridge roller.

4.1.8 Sod seeding into established pastures

Legumes can be introduced into established pastures by using a heavy tine sod seeding implememt which cuts a furrow and introduces seed and fertilizer. This can be done over the entire pasture or in strips depending on the ability of the legume to spread.

Well adapted, vigorously establishing legumes are required. The grass vigour normally needs to be reduced in order to reduce competition so the legumes can become established. Herbicide application, heavy grazings, light disk harrowings are all methods which can be used, singly or in combination.

It must be remembered that the cleaner the soil, and the more debris is removed, the greater are the chances of serious erosion particularly in areas having high rainfall.

4.2 Weeds

The weed problem is a critical one in pasture establishment; especially in areas of higher rainfall, or where N has been applied or N levels in the soil are high. Methods of reducing the effect of weeds are:

1. Good land preparation. Allowing an initial weed germination and then re-harrowing before planting.
2. Pre-emergence herbicides can be used on the initial growth in the rainy season before the seeds are planted. Care must be taken however that the recommended time has elapsed before the seeds are planted in order to avoid residual toxic effects.
3. Sow rapidly establishing species.
4. Slash frequently while the sown plants are still small.
5. Graze lightly during establishment, the weeds are frequently more susceptable to trampling.
6. Avoiding the use of N fertilizer on establishment of legume or legume grass swards, but ensuring that adequate amounts of the other elements are present for vigorous legume growth.
7. Establishment of the legume within another crop such as maize so the costs of weeding are offset by the crop. Oats are often sown with a perennial crop such as alfalfa. The oats provides more feed and reduces weed competition during the establishment of the alfalfa. Such taller

nurse crops can help protect the establishing perennials from the effects of cold night temperatures. Higher economic returns are gained with this system as well. Sorghum interplanted with Stylosanthes guianesis was used as silage for several years until the sorghum disappeared leaving a Stylo sward.

Dolichos lablab has been intersown with maize (2/3 maize, 1/3 Dolichos). The Dolichos which is slow to establish grows over the maize stalk after the maize has been harvested. The two crops are then grazed.

4.3 Feed Planning

The legume and grass chosen for planting should be related to the period of the year when the feed is particularly required.

If the climate at a given location has a cold, a dry and a wet season, paddocks may be planted with a number of grass-legume combinations. Ideally each combination would be particularly productive at a particular time of the year. A sward should be heavily grazed during its season of greatest productivity, and given lighter grazings at other times. Dry matter is often accumulated in a sward before heavy grazing by allowing a rest period. Examples of seasonal productivity are:

1. Siratro - Guinea grass swards which are productive in short dry season.

2. Stylosanthes species which can be left as standing hay in dry season

3. Centro which is particularly vigorous in high rainfall periods.

Temperate legumes (e.g. *Vicia*, *Trifolium* species) may be planted in colder season.

Such combinations may be difficult or impossible to maintain. Usually a farmer is fortunate if one grass-legume combination can be identified which will persist under the management scheme the farmer is economically able to provide.

Most graziers or farmers are simply looking for better feed during the most critical period of feed shortage. One grass-legume combination may fill this need. A short-cut method for establishing which grass-legume combination is adapted and productive is to sow in a mixture, a number of legumes deemed to be adapted for the season required. Within a few years, with proper management, one suitable legume may identified.

It has been suggested that mixtures of legumes selected for their vigour in different seasons of the years can be planted. While theoretically sound, the management difficulties which are already considerable in maintaining one grass-legume combination become insuperable in maintaining a combination of legumes in the same sward; one legume will very likely become dominant.

Mixtures are useful where a colonizing species is required, which because of its low productivity of lack of persistence would be temporary and provide the proper environment for more productive species. Species such as Townsville stylo and molasses grass are used to rapidly cover the ground to prevent erosion and are particularly useful on less fertile soils. As soil fertility increases through the presence of the legume and/or fertilizer application then more productive species (Siratro, Guinea grass) will become dominant.

Pure legume swards are not unknown. These are more effective as short-term pastures as weeds commonly invade the swards taking advantage of the fertile soil conditions. There is no advantage in planting a pure legume sward since the dry matter production is much less than if the legume was planted in mixture with a suitable grass. Usually at least 70% more dry matter is produced by introducing a vigorous grass to legume swards.

4.4 Seeds

Unlike legume seeds the viability of tropical grass seeds usually decreases rapidly with time. Good quality seed free from weed seeds is an excellent investment as it guarantees good germination and good pasture establishment. There are many examples where serious weed seeds were introduced with the seeds of cultivated species which were imported.

4.4.1 Seed dormancy

Seed dormancy is a mechanism to ensure plant survival in unfavourable conditions (e.g. late rains, false starts to the rainy season and years of low rainfall); legumes have a dormancy mechanism which inhibits the development of all seeds at the same time. The dormancy period can vary from a few weeks to several years. Usually a proportion of the seed will germinate annually over a period of several years. Species and varieties can vary in their dormancy periods and in the ease of overcoming it. As dormancy is dependent on the impermeability of the seed coat to water it is overcome by scratching or cracking the impermeable layer. Germination then readily occurs.

Rapid pasture establishment requires a dense stand of the pasture species as soon as possible, thus the seeds are normally scarified to break their dormancy before planting. Where good conditions for establishment are not assured a proportion of the seed (50%) may be left unscarified to germinate later.

4.4.2 Scarification methods

Mechanical scarification is the simplest method. This can be done by using sand paper, small rotating drums with sand-paper liners, concrete mixers with gravel included along with the seed, treading on a concrete floor or hammer milling at harvest.

Sulphuric acid can also be used; however, this proceedure is dangerous, expensive and it is easy to burn the seeds. Alcohol, acetone or warm glycerine treatments work for some seeds. Soaking in hot water, infra-red lamp radiation, very low temperatures (-50^{o} to $-90^{o}C$) and high pressures have also been reported as successful.

Seed can usually be stored for a couple of months after scarification before viability is seriously affected. The period depends of course, on temperature and humidity.

4.4.3 Inoculation

Soils usually have an abundance of native strains of rhizobia which may be quite effective in nodulating and fixing atmospheric nitrogen for a given legume. Effective nodulation may readily occur if the legume has been grown on that site previously, or is found there naturally or has a general rhizobia requirement of the cow pea type. Native rhizobia would be unlikely to be effective for legumes which require a specific strain and which have not been planted and inoculated on that spot before. Native strains may nodulate the legume and fix little or no nitrogen.

A period of time may be required before a population of an effective native <u>Rhizobium</u> can be built up.

As different legume genotypes within a species may differ in their rhizobial requirements they should be tested against a range of rhizobial types in order to ensure effective nodulation before being planted in trials. As can be imagined this is rarely done as the money, staff and facilities are usually lacking.

When agronomists are planting trials they always inoculate with the recommended Rhizobium in order to ensure uniform nodulation throughout the trial site. When a new genotype is being tested whose rhizobial affinities are unknown, the rhizobial strain available commercially is used. When the requirements are unknown the cowpea strain of inoculant is used for lack of anything better. The plants are then carefully watched for signs of poor nodulation which are lack of nodules, poorly developed nodules, nodules without an orange-red centre, yellowish leaves, lack of expected plant vigour. When such symptoms are found it is likely, assuming that viable rhizobia were properly applied, that research is required to find a more effectively nodulating strain, perhaps one more competitive with native strains.

4.4.4 Applying the inoculant

In order to ensure the effective nodulation of the seedling, as many bacteria as possible are affixed to the seed. This is done by applying a bacterial-water or a bacterial 10% sucrose solution to the seed and allowing it to dry on. Alternative stickers are a 15% w/v gum arabic (gum accacia) solution or 1 to 2% commercial methyl cellulose adhesive solution (Methocel from Dow Chemical Co. or

Methofas from ICI). The seed must then be sown as soon as possible, and kept out of direct sunlight which can kill the bacteria. A solution of bacteria can also be applied to the soil when the seed is planted.

Pelleting the rhizobial-coated seed with lime (powdered $CaCo_3$) or rock phosphate is done to protect the rhizobia. This is necessary when seed is sown with acid fertilizers such as superphosphate. It is also useful when a basophyllic Rhizobium is required for a plant which is being sown in an acid soil, for example, leucaena.

When pelleting, very finely powdered coating material (passes through a 300 mm sieve) is mixed with adhesive before applying. Adhesives commonly used are 40% w/v gum arabic (gum accacia), or a 4% methyl cellulose solution. Properly pelleted seed can be stored for a month at room temperature away from sunlight with little loss of bacterial activity. The bacteria must be applied from a peat culture for survival within pellets.

4.4.5 Seed treatment against pests and diseases

Harvesting ants and seed-eating animals can be a major problem with newly sown seeds, especially if sugar is used as a sticker for the inoculant. Pelleting is the simplest method of disguising the seeds. Dieldrin (13 ml of 15% active ingredient/kg of seed) can be applied to seed to prevent bean-fly attack on the seedlings.

4.4.6 Seeding rates

Seeding rates depend on seed costs, seed size, vigour of the plant, rainfall and method of sowing.

Expensive seeds can sometimes be planted in strips (low overall sowing rate) and be allowed to spread to the unsown parts. In low rainfall areas where water is limiting and weed competition is not a serious problem seed should be sown at a lower rate than in areas of high rainfall where weed growth must be suppressed. Broadcast seed requires about twice as much seed as those that are drilled to achieve the same stands. Small seeds are sown at lower rates than large ones, and in sowing are frequently mixed with a dilutant (sand, sawdust, cow manure, fertilizer, rice hulls) to achieve more uniform distribution. Halving the sowing rate, and seeding twice also helps give better distribution.

V. Irrigation

Irrigation of tropical pasture legumes is rarely undertaken as irrigation water could be expensive. If there is a cool season, a temperate species can be grown (alfalfa, white clover, ryegrass); they give higher yields under irrigation and may give sufficiently high returns to be worth while. In warmer periods tropical grasses fertilized with nitrogen give higher yields.

Occasional irrigation is sometimes done to maintain legumes or legume-grass pasture productivity through unusually long dry seasons.

VI. Mineral Nutrition

The legume component of a mixed sward is normally the more difficult to maintain in the pasture, and its nutritional needs must be given priority.

Tropical soils normally have N and P in very low concentrations. As P is essential for legume growth it is usually added and is thus a major expense in the establishment and maintenance of legume swards. Other elements may be limited as well, particularly in soils derived from sands, sandstones, granites, shists and laterites.

6.1 Calcium

Calcium has been frequently added to soils to improve the growth of temperate legumes which prefer alkaline conditions and which require elemental Ca for normal growth.

Most tropical legumes have been collected on low pH, low Ca soils and respond to the addition of Ca although are often quite productive at low Ca levels. They appear to be better than the temperate legumes at extracting Ca from the soils. Some species, such as *Macroptilium* and *Stylosanthes* are more efficient than others e.g. *Desmodium uncinatum* and *Glycine wightii*. It is probably true that legumes found on more fertile, higher pH soils respond more to added Ca in low pH soils. Nodulation is much less in temperature species at low Ca levels than in tropical species.

6.2 Phosphorous

Although P can be high in soils derived from P rich parent materials (such as basalt) and in alluvial soils which accumulate P leached from higher levels, most tropical soils are well leached and have very low P levels. The least soluble materials e.g. Fe and Al, absorb P so it becomes unavailable to the plants.

Increasing P fertilizer levels increases the N content of the herbage . This is probably the result of better root development, better nodulation and improved plant metabolism.

Commercial lines of forage legumes differ markedly in their need for P (table 1). Stylosanthes humilis is a particularly good extractor of P from low P soils. Stylosanthes and similar legumes are reasonably productive in poor soils with a minimum of input. However the P nutrition of the livestock must be maintained in such low P environments by P feed supplements. The critical factor then, in the choice of legumes for a given soil is whether the investment in P required for persistence of given legume is worth making.

P is available commercially in several forms. Rock phosphate is neutral material of variable P content which dissolves slowly and thus is available to the plant over a period of years. The speed of solution depends on the fineness of the grinding. Single superphosphate is acidic and has about 9.6% P along with 21% Ca and 13% S. It thus normally satisfies the plants'need for all three elements. Basic superphosphate is single superphosphate limed to neutrality. Triple superphosphate has a high concentration of P (44%) but is low in S (1.9%). It is cheap to transport due to its high concentration.

6.3 Potassium

Potassium is essential for good plant growth and is commonly more available in tropical soils than P and N. Commercial cultivars vary in their requirements for this element (table 1).

It has been recently discovered that grass growth is favoured in mixed swards when both P and K soil levels are high Legume growth is favoured under low P, and somewhat less favoured under low P and high K soil conditions. Thus in mixed swards a lower application of P may be necessary in order for the legume to persist in the sward.

6.4 Nitrogen

Nitrogen is not normally added to pure or mixed swards of legumes and grasses as the legume itself fixes N. The application of N increases weed and grass competition relative to the legume which may then disappear.

It has been argued that N will aid establishment of slow establishing lines of legumes. This may be the case in legumes which nodulate slowly, however, the N in high doses could delay nodulation and encourage weed and grass competition which may require expensive weeding operations.

N can be usefully added to mixed swards when the legume becomes dominant, to increase the vigour of the grass.

Table 1

Percentage reduction in yields of some temperate and tropical legumes when grown in soils of low nutrient status compared to those grown in soils of high nutrient status (Published by Andrew and co-workers)

Species	Low nutrient status of			
	P	K	Ca	Mn
Centrosema pubescens	55	51	45	70
Desmodium intortum		30		
Desmodium uncinatum	42	47	60	24
Glycine wightii	53	56		11
Indigofera spicata			21	
Leucaena leucocephala				23
Lotononis bainesii	49	52		42
Macroptilium atropurpureum	64	25		9
Macroptilium lathyroides	82	28	46	29
Medicago sativa	43	34		18
Medicago tribuloides			14	
Medicago truncatula		45		13
Stylosanthes guianensis			7	
Stylosanthes humilis	55	23		50
Trifolium alexandrinum			3	
Trifolium fragiferum		53	31	17
Trifolium repens		38	38	49

6.5 Other Nutrients

Sulphur deficiencies occur commonly in leached sandy soils. The addition of single superphosphates is often sufficient to alleviate any deficiency. The lack of micronutrients such as Co, Mo, Zn, and Mn have all been reported to have marked effects on plant growth. When testing legumes in old, leached soils a complete dressing of plant nutrients should be added to at least one of the treatments and if better growth is obtained than for a complete macronutrient treatment, further research would be necessary to elucidate which micronutrients are lacking.

VII. Chemical Composition and Nutritive Value

The chemical composition of forages is important in computing animal diets, particularly those of high performance animals, battery poultry, dairy cattle fattening operations etcetera where intensive management is practised.

It is also important when legumes are grown under low fertility conditions e.g. old leached soils. Analysis of the fodder should be made to identify any limiting concentrations of nutrients which would have to be given as mineral licks or in concentrate rations.

In the tropics it is very unlikely that the actual feeding value of a legume will be significant as the identification and choice of an economic, productive persistent legume is by itself a difficult task.

The value of a pasture species selected for higher N requirement would rarely outweigh the added expense and extra management, compared to a well adapted line.

With more assured livestock markets, more stable fertilizer and meat prices, better management practices and more productive lines of commercial legumes it is likely that chemical composition and nutritive value could become an important consideration.

VIII. Pasture Management

Appropriate management is essential for the survival of legumes in tropical pastures.

In early pasture establishment it is important that the weeds and grass do not crowd out the legumes. In the first year grasses and weeds are grazed to reduce competition with the legumes. The legumes may be grazed very lightly or not all.

Once the pastures are established careful management is needed to see that the balance of species is well maintained. When weeds and tall grasses start to shade out the legumes these can be slashed or more livestock can be put in.

Management, by changing the stocking rates on pastures is an important and often essential tool in maintaining grass-legume swards.

The movement of animals in the pastures has been much discussed and the advantage of moving them (rotational grazing) compared to retaining them (continuous grazing) must be determined for different type of pastures.

8.1 Rotational Grazing

In a mixed sward, preference in forage palatability could result in the disappearence of the preferred species. This may occur through continuous grazing of the leaves, buds and growing points which will result in exhaustion of plant reserves and death of the plants.

Rotational grazing, that is when the animals are in a paddock for a brief period, perhaps 1 week in 4 or 6 weeks will give plants time to produce new growth and to accumulate energy reserves.

Rotational grazing requires more precise pasture management by the farmer. Good management is essential to maintain a mixed sward. Rotational grazing could be particularly useful in aiding persistence in periods of slow growth and is important in prolonging the productivity of an established pasture.

Alfalfa, for example, requires heavy stocking for short periods, for survival.

In cases where both milk and beef production operations are carried out on the same farm, those animals requiring a higher plane of nutrition are rotated about the paddocks before meat animals. Other advantages of rotational grazing are (1) parasite control (ticks and internal parasites) (2) fodder conservation during periods of low animal productivity, (3) weed control, (4) seeding and rehabilitation of older pastures, (5) segregation of the sexes for controlled breeding.

Rotational grazing has disadvantages in that much more fencing, more water points and more precise management are required than in the case of continuous grazing. This makes management operations much more expensive.

8.2 Continuous Grazing

Animals stocking a paddock continuously select the more nutritious plant parts and thus have a higher plane of nutrition than these on rotational grazing. Continuous grazing is almost always used in areas where pasture productivity is low as it is the only method which is economical in this situation. Hardier pasture species are required which can take occasional over-grazing and which can survive with a minimum of management. The stocking rate is an important consideration for pasture survival.

8.3 "Put-and-Take"Management

In both continuous and rotational grazing it is necessary to remove cattle from the herd at times of low pasture productivity e.g. in the dry or cold seasons, and bring them back during periods of rapid plant growth. Such a "put-and-take" system of management can be used to control the persistence of the entire sward; it also influences the proportion of the constituent species and thus the nutritive value of the fodder.

In extensive or continuous grazing operations it is usually a matter of marketing before or during periods of low productivity. In rotational grazing the "put and take" system is more frequently practised during the year in order to carefully control the species balance and to take advantage of rapid growth after rainy periods.

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IX. Forage Legume Descriptions

Acacia

Acacias are mostly indigenous in tropical and sub-tropical zones especially in Australia, Central Africa and Central America. They are trees, shrubs and less frequently herbs which are well adapted to drought conditions with deep root systems and with horizontal roots in the upper layers of the soil.

Under the natural grazing conditions of the tropics and sub-tropics, grazing animals frequently browse on foliage of *Acacia* species eating twigs, pods and leaves particularly in the dry season when the grass cover is poor and low in protein content, and these browse species are still high in crude protein and other nutrients (Tables 1,2,3 & 4). Camels and goats and many game animals are well adapted to the arid and semi-arid regions because of their browsing habit.

Acacia species are also being used for dune fixation, soil erosion control and shade trees. In the Sudan *Acacia sessegal* is cultivated for gum arabic which is an important cash crop; the pods from *A. arabica* and the twigs and bark from *A. nubica* are used for tannin.

The following is a brief description of some of the important browse species of *Acacia*.

1. **Acacia albida**

Haraz

This one of the largest of the Acacia trees in Africa. Described as having a dull grey bark, fissured and scaly; slash pale brown, fibrous; pinnae in 3 - 10 pairs; leaflets grey-green, 6 - 20. Flowers spikes 7.5 to 10 cm long; pod orange yellow, twisting into strange shapes as it ripens, frequently forming hoops and spirals.

The species is well distributed throughout tropical Africa from Egypt, Sudan, Senegal, Gambia to the Transval and Natal, South Africa, Syria, Palestine and India.

It is abundant on flood plains and on banks of large rivers where it may occur in pure stands. The pods are eaten by cattle, camels and game animals. In western Darfur, Sudan it constitutes a valuable protein supplement for baggara cattle after the rainy season when annual grasses are dry and low in feeding value.

The soil fertility improves significantly as a result of mineralization of dropped leaves as well as from nodulation. It is reported that the yield of millet (Pennisetum typhoides) has increased 2.5 times and protein content by a factor of 3 or 4 when grown near the tree. The trees remain leafless during the rains and produce new foliage and flowers after the rainy season.

Table 1 Chemical analysis of different parts of *Acacia albida*. (FAO Agric. Studies No. 96 Tropical Feeds).

	As % of dry matter						
	CP	CF	Ash	EE	NFE	Ca	P
Fresh flowers. Sudan	19.0	12.5	9.7	1.6	57.2		
Fresh whole leaves. Niger	19.7	19.6	7.2	1.6	51.9	1.00	0.23
Fresh leaflets. Sudan	17.1	12.4	8.4	2.3	59.8		
Pods. Tanzania	8.8	24.4	3.7	1.4	61.7	0.65	0.23
Pods. Niger	14.3	24.7	6.3	1.5	53.2	1.11	0.14

2. *Acacia mellifera*
Kitr

This is a shrub or small tree with ball-shaped crown. The leaves are small with few leaflets.

Branches covered with sharp recurved thorns. Flowers white and gathered in short,dense spikes. Pods thin and flat.

It is widely spread in Africa,commonly found growing on clay soils in Sudan, Egypt, Somalia, Ethiopia, Angola, Kenya, Uganda & Tansania. The leaves which are high in crude protein are browsed by goats (Table 2), but not by cattle as the tree is too spiny and the fallen leaves are too small.

Table 2 Chemical analysis of different parts of *Acicia mellifera*. (FAO Agric. Studies No.96 Tropical Feeds).

	As % of dry matter						
	CP	CF	Ash	EE	NFE	Ca	P
Fresh leaves, very young, Kenya	42.8	16.2	6.2	2.6	32.2	0.51	0.58
Fresh leaves, Sudan	21.3	14.1	8.6	2.6	53.4		

3. *Acacia nilotica*

A tree 8 m or more high with dark bark; spines straight, sharp up to 1.5 cm long in young trees, mature trees commonly without thorns. Pinnae usually in 3 to 12 pairs; leaflets in 10 to 30 pairs. Flowers yellow. Pods grey, with constrictions between the seeds giving a necklace appearance, fleshy when young becoming black and hard at maturity. It is widely distributed in Africa and Asia, and occurs in Australia.

In Kenya it is found at elevation of 900 m to 2000 m while it is more common in areas usually flooded by the Nile in the Sudan. It is also found in Gambia, Togo, Nigeria and in the Himalayan foothills in India.

The leaves and pods are commonly browsed by sheep and goats. The leaves contain 11.9% crude protein and 21.4% crude fibre.

4. *Acacia senegal*

Hashab

Also known as the gum-arabic tree its height ranges between 5 to 10 m. Frequently forming thickets; stem short, usually low-branched; crown eventually flattened; bark pale brown to pale grey, scaly on the other parts; spines up to 0.5 m long, the centre one sharply curved, the other two more or less straight and directed forward. Leaflets grey-green. Flowers creamy white (red in bud), usually appearing before the leaves in spikes 5 to 10 cm long either solitary or 2 or 3 together. Pods brown, flat, papery, oblong, sometimes contricted owing to the abortion of some of the seeds. Seeds greenish-brown 1 to 5 in number.

The tree is deciduous, dropping its leaves after the rainy season. In the Sudan mineralization of leaves was said to improve the fertility of sandy soil enhancing crops of groundnuts, sorghum, millet and seasame. The species is browsed by camels and goats however severe browsing by these animals results in low gum-arabic production.

5. *Acacia seyal*

This is a slender tree of which grows from 6 to 11 m in height, with a flat top, thin crown and rather scarce foliage. Bark smooth and greenish-yellow to orange in colour. Flowers yellow in globose heads; pods sickle-shaped.

The species is widely distributed in northern tropical Africa. It is important fodder for dry periods in the Sudan and Nigeria.

Flowers are highly palatable to sheep and goats while the pods are less nutritious. The greenish-yellow bark is thick and soft and can be used fresh for feeding cattle, goats and sheep. Usually the tree is cut to a height of about 1.5 to 2.5 m or the thick branches are cut and thrown to the ground where these animals browse the bark and eat the leaves. It was estimated that the intake by cattle can be as high as 5 to 6 kg of bark per day per head, an amount sufficient for maintenance and even for some milk production.

Table 3 Chemical analysis for different parts of *Acacia seyal*. (FAO Agric. Studies No.96 Tropical Feeds).

	As % of dry matter						
	CP	CF	Ash	EE	NFE	Ca	P
Bark, dry season. Kenya	4.3	20.7	6.6	0.7	66.7	4.09	0.03
Bark, early wet season. Kenya	10.6	22.2	8.8	0.9	57.5	2.50	0.07
Fresh leaves. Sudan	22.6	8.4	9.0	4.0	56.0	3.83	0.21
Pods, immature. Sudan	21.3	18.6	6.1	1.8	52.2	0.98	0.43
Pods, mature, dry. Sudan	20.9	20.2	9.3	1.9	47.7	1.33	0.37

6. *Acacia tortilis* (*A. spirocarpa*)

A.tortilis occurs in the dry areas of northern Africa, Senegal, Nigeria, Sudan, Kenya and Tanzania. It is a wide-spreading, flat-topped or unbrella-shaped tree, up to 4m high; branchlets pubescent, red brown; spines mixed, some white, straight, slender, and up to 7.5 cm long, others grey with black or tips, sharply curved, very small. Pinnae in 3 to 10 pairs, leaflets in 7 to 15 pairs. Flower heads white to cream. Pod yellow-brown, spirally twisted, slightly constricted between the seeds. Leaves of young tree are browsed by goats and sheep but the pods of this tree are considered more valuable since they are produced in great quantities and they are readily picked up from the ground by livestock.

In Kenya these pods constitute the main source of food for cattle sheep and goats during the dry period January-February.

Livestock feeding on pods also contribute to the regeneration of the species from seeds dropping with the faeces. Seeds collected from fallen pods showed no germination while those collected from faecal pellets have up to 7% germination.

Table 4 Chemical analysis of leaves and pods from *Acacia tortilis*. (FAO Agric. Studies No.96 Tropical Feeds).

	As % of dry matter						
	CP	CF	Ash	EE	NFE	Ca	P
Fresh leaves. Sudan	13.3	9.4	9.6	8.3	59.4	4.00	0.15
Pods. Tanzania	12.3	22.4	5.6	1.8	57.9	0.98	0.24
Pods. Kenya	17.8	17.5	8.4	1.7	54.6	1.34	0.36

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<u>Centrosema</u> <u>pubescens</u>
cv Belalto
centro

<u>Centrosema</u> <u>pubescens</u> (centro) is a very vigorous viney pasture legume suitable for high rainfall and high fertility soils in the lowland tropics. Originating in South and Central America it was a popular ground cover plant for plantation crops and thus is now pan-tropical. Its temperature requirements are lowland tropical for it grows best at an average temperature of about 26° to 30° C. Growth ceases at about 13°C and it is sensitive to frost. The species range is roughly between 22° N and S latitude and below 1000 m/altitude.

Adapted to wet tropical lowlands it grows poorly elsewhere. Its best growth is in areas receiving over 1700 mm rainfall but it will grow in annual rainfalls as low as 750 mm. It can survive droughts of several months (5), remaining green into the dry period due to deep roots but defoliating if the drought persists. It is fairly tolerant of flooding and wet soils.

While growing on a wide range of soils, less droughty and more fertile soils are preferred. It has a wide pH growth range growing most vigorously between pH 4.9 and 5.5. As it prefers fertile conditions extremes in pH can inhibit growth due to lack of available nutrients. A specific <u>Rhizobium</u> is required for best nodulation (strain CB 1103). Nodulation appears best between pH 4.9 and 5.5.

Adapted to fertile soils it responds well to P and less to K. Responses have been recorded to Ca.

Sowing is usually done with scarified seed into a prepared seedbed but over-sowing in pastures can also be done if care is taken to weaken the grass and weeds. Sowing rates are 3.4 to 4.6 kg/ha when drilled, higher when broadcast; sowing depth is 2.5 to 5 cm. Rolling or light harrowing aids germination. Establishment is slow until effective nodulation occurs thus competition from grass and weeds can limit the stand. Growth is often more vigorous in the second year. Diquat (285g/ha) has little effect on centro plants over 5 weeks old and can be used to aid weed control.

Management is important in the establishment and maintenance of Centrosema in mixed swards. Being slow to establish and quite palatable it can be eliminated from pastures quite easily. Once established though it is quite vigorous and its climbing habit allows it to combine well with most vigorous clump grasses. It has been reported as being particularly vigorous in combination with Guinea grass. Care must be taken that the plants are not completely defoliated by grazing, thus high cutting heights and rotational grazing are often recommended. Burning of the pastures can eliminate centro but regeneration from seeds can be good. Swards which have persisted for over 20 years have been reported.

Hay can be made but defoliation on drying may be a problem. Satisfactory silage has also been made. It may have some use as deferred feed in the dry season.

Seed production yields are low due to uneven ripening and shattering of mature pods. Hand and mechanical methods have been used.

Important diseases include *Aschochyta* blight *Cercospora* leaf spot. *Aschochyta* is important in Central America, *Cercospora* in most environments in the wetter periods of the growing season particularly in rainfall over 2500 mm. Pests including *Meloidae* beetles, thrips and red spider (*Tetranchyus* sp.) can be damaging as well.

The cultivar Belalto has recently been released. Native to Costa Rica it has demonstrated higher commercial yields and better cool season growth that common centro. It is reported to be more vigorous and to resist weed invasion, fungal attack and red spider. Most *C. pubescens* planted to date has been the common line.

A vigorous wet climate plant it is competitive, persistent, combines well with grasses and is useful as deferred feed for the early dry season. Its need for high rainfall, fertile soils, consistently warm climate and careful grazing limit its use.

Reference:

Teitzel, J.K. and Burt, R.L. (1976), '*Centrosema pubescens* in Australia'. *Trop. Grassld.* 10, 5-14

Clitoria ternatea
Clitoria or Kordofan pea

A perennial climbing plant which is shrubby at the base, Clitoria is native to the Americas over a latitude range from 20°N to 24°S. Widely planted as an ornamental it has shown promise for pastures particularly in the Sudan. Little work has been done on the plant.

Requiring about 1500 mm rainfall for best growth it can grow in areas with as little as 400 mm as it is drought tolerant. It has been productive under irrigation but is intolerant of flooding. Its soil requiremtns are broad for it grows well on sands and black cracking clays and may have some tolerance to salinity. A warm season plant, it is intolerant of frost. No work has been done to elucidate its temperature requirements.

Establishment is good in well prepared seed beds using scarified seed sown at the rate of 1 to 3 kg/ha and at depths of 1.5 to 4 cm. Where the soil is heavy clay it is grown in ridges 60 to 80 cm apart as the plant cannot take flooding. A specific *Rhizobium* (QA 553) appears to give best yields. Fairly vigorous in establishment it competes with weeds and combines well with tall clump grasses (*Panicum maximum*-Guinea and *Pennisetum purpureum* - Elephant) as well as *Androprogon* species, Sudan grass, sorghum and sunn hemp. Very palatable, it is often grazed out thus careful management usually involving rotational grazing is required. Several cuts or grazings can be made per year as long as moisture is not a limiting factor.

Seed harvesting is usually done by hand.

A number of pests (grass-hoppers, leaf eating caterpillars and nematodes) and diseases (viral and fungal) can effect the plant.

The plant's deep roots are difficult to remove thus it is considered unsuitable for use in rotation with crops in the Sudan. Very palatable, the legume is difficult to maintain in a pasture and though vigorous lines have been identified persistence is still a problem. Much of the interest in the plant is due to it being one of the few vigorous legumes identified which thrive on black cracking clay soils.

<u>Desmodium</u> <u>intortum</u>
cv. Greenleaf
Greenleaf desmodium

Greenleaf desmodium is a vigorous climbing perennial vine which is native to South and Central America. Wide spread through the tropics by its initial use as a plantation cover crop it has been widely tested for use as fodder.

Growing best in warm conditions ($30^{o}/25^{o}$ day/night temperatures) it is more tolerant of high temperatures than <u>D.uncinatum</u>(Silver-leaf desmodium) but is rarely found at low elevations in high temperature zones. Its range extends to 25^{o}N and S and in the tropics it occurs at elevations of 600 m to 2,500 m. Although frost sensitive it retains its leaves fairly well after mild frosts.

Requiring consistently moist conditions for vigorous growth it can grow in a rainfall range of about 900 to 3,500 mm/annum. High rainfall may promote diseases and pests. As it lacks drought tolerance it grows best on soils which retain moisture. Its drought tolerance is higher than that of <u>D.uncinatum</u>.

Successful on a wide range of soil types it requires a pH of greater than 5.0 and good fertility. It has no tolerance for salinity.

Planting is done with scarified seed inoculated with the specific <u>Desmodium</u> inoculant (CB 627) at 1 to 2 kg/ha. Well prepared seedbeds give best establishment. Broadcast seed should be covered with soil but no deeper than 1 cm. Rolling or light harrowing aids germination. Aerial sowing has been used on burnt land. Oversowing pastures is usually unsuccessful due to slow establishment. As the plant roots readily at the nodes, cuttings have been used in establishment.

Some weed control is usually necessary,however it can be relatively easy compared to other legumes as it is tolerant of 2, 4-D herbicide; 1.65 kg/ha can be used on 3.5 week old plants. Diquat at 140 g of cation/ha can be used from 6 weeks and 280 g on established swards.

As good fertility is required for vigorous growth the plant responds to P and K fertilizers though high levels of KCl can cause chlorine toxicity.

Under environmental conditions suitable for vigorous growth the plant can compete and combines well with vigorous grasses of the wet tropics such as Setaria spp., Panicum maximum, Pennisetum purpureum.

For best vigour and persistence the stands should be allowed to become well established before cutting and grazing. As with all viney legumes sufficient leaf and buds should be left after cutting to encourage rapid regrowth. A safe cutting height would be from 10 to 15 cm and a reasonable interval from 3 to 6 weeks, depending on the intensity of grazing and the vigour of the regrowth. Grazing involves the removal of the growing top, then the leaves. More intensive grazing results in the removal of the side buds from which new shoots must come. Burning seriously inhibits the growth of Greenleaf pastures and should be avoided; post-fire regrowth may occur from the roots.

Greenleaf desmodium can be used to make hay and silage. The latter is of better quality when molasses is added. It makes good late season grazing as flowering is relatively late in the year.

Seed production is low due to uneven ripening of the seed. It is usually mowed at 30% to 50% ripe seed and the cut material is windrowed or left in a swath. After 10 to 14 days the material is picked up and threshed. The unripe seed will have matured in the interim. Late seed production extends the grazing period of the crop but early frosts can prevent seed production.

Though there is only one widely used cultivar "Greenleaf" there is much diversity within the species and further useful cultivars should be found.

Greenleaf is attacked by a range of insects and by a variety of fungal diseases. "Little leaf", a virus disease can be damaging. It has low seedling vigour, poor drought tolerance, relatively low digestibility and can be grazed out if not under high fertility. It is however a vigorous legume which combines well with grasses and is persistent under appropriate conditions giving good early season growth and extended growth at the end of the season.

REFERENCE

Bryan, W.W. (1969). '*Desmodium intortum* and *Desmodium uncinatum*'. *Herb. Abstr.* *39*: 187-191

Desmodium uncinatum
cv Silverleaf
Silverleaf desmodium

A trailing, branched perennial plant originating from Dedora, Brazil; it is native to America from 30° S to 19° N.

Optimal temperatures for growth have been found to be 30°/25°C day/night temperature and the minimum temperature for growth is 15°C. More cold tolerant than many tropical legumes it does well at higher altitudes (to 2,400m in Kenya) thus it grows poorly and may wilt under higher temperatures. In areas with a cold season, spring and autumn growth is good. Though frost susceptible it may recover from frost damage. Good yields may be obtained where the rainfall is between 900 and 3000 mm and the soil pH between 5.5 and 6.5. Soils are preferred which are neither droughty nor very heavy for though the plant tolerantes flooding well it has a low tolerance for drought.

Scarified or machine harvested seed should be inoculated with the specific Desmodium Rhizobium (CB 627) before planting at about 2.2 kg/ha. Establishment is best when the seed is drilled into a well prepared seedbed but good results have been obtained with rough seedbeds as long as the seeds are covered with soil. Oversowing of pastures is usually not very successful. Good levels of Pand K in the soil are required for vigorous growth.

Seedling growth is slow initially but its tolerance to 2-4 D aids management of weeds during establishment. From 3½ weeks of age 1.65 kg of acid equivalent per hectare can be used. It is less resistant to diquat at early stages but 0.275 kg of cation/ha is safe to spray. Weed control is usually necessary for about 4 months.

Grazing should not be commenced until the sward is well established and should not be too heavy or close to the ground. Ten to 15 cm is usually the minimum height. Rotational grazing is commonly practiced with 4 to 8 weeks rest periods. Combining well with grasses vigorous under its optimal climatic conditions (such as _Setaria_, _Panicum_ and _Paspalum_ spp.) its persistence is aided by somewhat low palatability. The plant has only moderate fire resistance.

Little work has been done on hay production, and none reported on silage. It is not well suited for use as deferred feed. Seed harvesting is similar to that of _D.intortum_. Pest damage due to a wide range of insects can be severe; the little leaf virus and _Colletortichum_ fungal diseases can be serious.

The plant generally then is difficult to establish, has low drought tolerance and is susceptible to pests and diseases. It is however a vigorous legume for fertile, cool, consistently moist conditions.

R E F E R E N C E

Bryan, W.W.(1969). '_Desmodium intortum_ and _Desmodium uncinatum_'. _Herb. Abstr._ _29_: 187-191.

<u>Glycine</u> <u>wightii</u>
glycine
previously <u>G</u>.<u>javanica</u>
cvs. Clarence, Tinaroo and Cooper

Glycine is a twining vine which bears white or violet flowers. Branches arise from a crown which may be below ground. Native to Africa it is adapted to cooler weather than many tropicals thus it continues to grows in the cool season as far south as 17° in Australia.

Optimum temperatures are fairly low (27°/22°C day/night) with higher temperatures inhibiting growth. Growth slows below 16°C and ceases at 13°C while leaves are shed near 0°C. It can survive frosts, the Tinaroo line being more cold tolerant. A higher altitude plant, it grows at up to 2450 m at the equator and 1800 m in Colombia.

Adapted to rainfall in the 500-1500 mm range it does poorly under higher levels of precipitation. Optimal yields lie in the 1000-1200 mm zone Productivity is low in warmer areas and at low altitudes.

Fertile, freely draining soils with a pH above 6.0 or 6.5 are required. Intolerant of salinity it can survive salinity and some degree of drought. Careful seedbed preparation is required as the plant is quite slow establishing and sensitive to competition. Generally scarified and drilled it has been recorded as being sod seeded into a pasture whose growth was checked by herbicide. As high temperatures can inhibit germination 1 to 2cm of soil cover is necessary during germination. Weeding is usually required during establishment.

Rates of herbicide application (2, 4 D and 2, 4 DB and diquat) have been determined for weed control.

Once established it becomes fairly vigorous and can crowd out weeds and Imperata cylindrica. It combines well with a range of tall and short tropical grasses, from Pennisetum purpureum to Melinis minutiflora.

A suggested regime of grazing management is as follows: In the first year weeds should be slashed and only light grazing done so that only the grass is grazed.

Guinea glycine pastures should be ready to graze 7 or 8 weeds after sowing. Once established the grass will tend to dominate if left ungrazed in the warm season, while if left ungrazed in the winter the legume dominates. In the second season, winter and spring grazing should be followed by a rest period in the wet to allow the plants to build up leaf area. Generally rotational grazing is best in the summer (warm and wet) and continuous stocking in the winter (cool and dry). If the pasture is to be saved for any particular season it should rested in the previous season to build up green forage. Low, frost prone areas should be grazed before the slopes. Frosted pasture if grazed immediately will still be palatable, and retain the leaves briefly.

Pure glycine stands should be grazed no lower than 30 cm, mixed swards no lower than 10 cm.

Glycine regrows well after fires. It makes good hay and silage in mixed swards and it can be used as standing hay, with the limitation that its leaves fall after frost.

Seed harvest is difficult due to the large amount of vegetative material and uneven ripening. The first year the plants are slashed high and the seed is not collected as the crop is usually weedy. In the second year the crop is harvested and dried in the field for a couple of days before threshing.

Several cultivars have been selected. The first three of these are the most widely known.

1) Tinaroo	-	late maturing
2) Cooper	-	matures 4 to 6 weeks ahead of Tinaroo. It is more drought resistant and thus grows later than Clarance into the autumn. More tolerant of excess moisture than Tinaroo or Clarance, it also is more productive in year 1.
3) Clarence	-	A little earlier flowering than Cooper. This cultivar is the best for cooler areas, (planted between 27^{o} & 29^{o} S in Australia). It starts spring growth earliest of the 3 Australian cultivars.
4) Kenyan	-	white glycine (white flowered) performs better than other varieties in Kenya.
5) Kenyan	-	violet glycine (violet flowered) performs well in Kenya.
6) Brazilian		IRI No. 1 - higher yielding in soils high in Mn.
7) Tanzanian		cv M 218 does best in rainfalls of 700-800 mm.
8) Tanzanian		cv Moshi-best in about 600 mm rainfall.
9) Malawi	-	similar to Tinaroo but is productive in acid soils (pH 6).

other cultivars are being tested.

Problems with glycine as a crop include its slow establishment and nodulation, high percentage of hard seed and susceptability to pest attack on its roots.

In the climates and soils to which it is adapted it is productive, persistent and combines well with adapted grasses.

REFERENCE

Gartner, J.A. and Fisher, A.E.(1966). 'Improving pastures on the Atherton Tableland', Qld. Agric, J. 92: 356-361

Lablab purpureus

Dolichos lablab, Dolichos

A vigorously growing, twining annual or short-lived perennial it is widespread in the tropics as far as 30° from the equator.

Growth is most rapid at temperatures above 29° though some growth may occur as low as 3°C. Though tolerant of low temperatures, it is affected by frosts. Its rainfall preference is between 750 and 2500 mm and it is fairly drought tolerant. Requiring well drained soils good fertility and a pH range of 5 to 7, it is intolerant of wet soils and salinity. A large seeded plant, the seedlings are slow growing but easily established in well prepared seed beds. Some soil cover is required for the seed to germinate successfully, usually 2.5 to 5 cm. Inoculation with the cowpea strain of *Rhizobium* is recommended.

Sowing rates vary from a low of 5 kg/ha drilled, to 10 kg/ha broadcast. Scarification is usually not required. Its slow early growth and short life usually result in its being sown between widely spaced rows of maize and sorghum for grazing or silage. It is grown alone as well. Once established it can compete with weeds.

Its season of growth is longer than other important annual legumes for it starts growth a little later in the season than cowpea (*Vicia sinensis*) and continues much later into the winter. Compared to velvet bean (*Stizolobium deeringianum*) which germinates slightly later, it also has a longer growing season. The lower leaves of the plant are usually shed and add considerable quantities of organic matter to the soil. Early season plantings will provide up to 3 grazings a year, later plantings as few as one. The plants are grazed to remove the leaves only, the stems being left to regenerate leaves; the first grazings can be done about 10 weeks from planting. Cutting should not be done below 25 cm or recovery will take 4 to 5 months. It can be used as a poineer crop when establishing pastures and for silage and as hay if care is taken to retain the leaves and if the stems are conditioned for more rapid drying. The haying sequence is cutting, conditioning, windrowing, drying and bailing. Sorghum is a common companion crop when silage is made. Planted with maize it is grazed as standing hay after the maize harvest. Its feed value even after frosts make it a useful late season fodder.

Animals may take a few days to adjust to eating the plant. Diets should not be pure legume but with grass as well as bloat has been reported. It can flavour milk.

Seed collection is simple as the pods are large and do not dehisce. Two cultivars are available cv. Rongai and the earlier flowering cv. Highworth.

Numberous pests, diseases and nematodes can damage the plant. Other defiencies include its short life, low stem palatability and susceptability to frost. It requires fairly fertile soil conditions.

Good for cool season growth it is early and easy of establishment. High yielding and drought tolerant it is a good pioneer species when pastures are being established.

R E F E R E N C E

Luck, P.E.(1965). 'Dolichos lab-lab - a valuable grazing crop'. Qld. Agric. J., 91: 308-309.

<u>Leucaena</u> <u>leucocephala</u> (formerly <u>Leucaena</u> <u>glauca</u>).
Leucaena
cvs Peru, Cunninghum,
Hawaii, El Salvador, Guatemala

Leucaena, a shrub or small tree is native to Central America but has become wide spread in the tropics due to its use as shade for plantation crops. There has been increasing interest in it as a forage legume in recent years.

A warm season plant, it grows best im temperatures from 22°C to 30°C and poorly in temperatures are below 15.5°C. I has persisted in temperatures down to -10°C and as high as 42.5°C. Leaves are retained in winter and spring growth has been reported as being good. Frost sensitive, it may escape by growing above the frosts. Its latitudinal range is roughly 30°N and S.

Productivity generally increases with increasing rainfall, being most vigorous in areas with over 1000 mm rainfall. It will persist though, in areas with rainfall as low as 600 mm and dry seasons of up to 6 months due at least in part to its deep root system. Prolonged droughts may result in defoliation.

Tolerant of quite acid and basic soils (pH5 to 8) it is most productive on calcareous well drained soils remaining small and shrubby on very acid soils. A water table within reach of the roots can result in very vigorous growth.

The plant has specific rhizobial requirements (strain NGR81 and CB81) for best growth thus the seed should be inoculated before sowing. As the <u>Rhizobium</u> is basophillic, lime pelleting is required when leucaena is planted in acid soils.

Scarified seed is usually planted at 2 to 5 kg/ha, in rows 1m to 3m apart. Row planting greatly simplifies the weeding which must be done to aid establishment. Planting depth is 2.5 to 5 cm. Pieces of main stem up to 10cm in diameter and 4m long can be rooted in nurseries and transplanted. Oversowing is difficult due to its slow establishment, though if sown in rows designed for mechanical or hand cultivation and slashing of the companion grass, it can be done. Phosphorous, even in small amounts usually greatly increases growth on most tropical soils.

Though the plant has been commonly planted as hedges, it is more productive as rows in pastures. It is particularly successful in combining with vigorous grasses such as Pangola (*Digitaria decumbens*), Guinea(*Panicum maximum*) and Napier (*Pennisetum purpureum*) for which sufficiently vigorous legumes are difficult to find. The plants will recover after fire, if it is not too frequent. It is susceptible to most herbicides but monuron appears to be an exception.

Management depends very much on the vigour of the plant in a given environment. The plant should be allowed to become well established and develop a deep root system before grazing. Allowing them to reach a height 1 to 1.5 m is usually sufficient. Once established the plants can persist under very heavy grazing; stems as thick as 0.5 cm are often grazed. Growth is usually vigorous enough in the wetter periods to require cutting back of the plants which can be done severely in the wet season without reducing the vigour of the plants.

Excellent live-weight gains have been reported for cattle fed on it. Seed production is abundant and is usually done by hand.

It is generally little affected by pests and diseases though the seeds can be badly infested with insects in its native environment.

There are a range of ecotypes of leucaena. Five cultivars have been selected.

1. cv. Guatemala	tall & sparsely branched.
2. cv. Hawaii	small bushy type
3. cv. El Salvador	tall, few low branches
4. cv. Peru	an intermediate height plant which branches well at the base giving a symmetrical tree of 2m height and 2m width in one season.
5. cv. Cunningham	derived from a cross between a Hawaiian line and cv. Peru it is slightly taller than Peru and slower establishing but higher yielding.

There are major problems with the plant however: (1) It is difficult to establish as it grows slowly after germination. Weeding may be required for as long as three months. (2) It requires inoculation with a specific rhizobial strain in order to give best production. (3) The Rhizobium prefers alkaline soils thus the seed should be pelleted before planting in acid soils. (4) Rapid growth once the plant is established may crowd out the companion grass. Thus it must be cut back regularly. (5) Imparts a flavour to milk. (6) The mimosene content of the plant is a major factor inhibiting its wider use. This toxic compound affects all animals, particularly non-ruminants with depiliation, loss of weight or low weight gains and general ill-health. Control of the amount of leucaena consumed can prevent deleterious effects. One rule is that it should not constitute more than 1/3 of the diet or animals should not eat a leucaena diet for a longer period than three months. They should then be on a non-leucaena diet for an equivalent period.

Leucaena is an outstandingly vigorous plant of high palatability, persistence and seed and dry matter productivity.

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Lotononis bainesii
cv Miles
Lotononis or Miles Lotononis

Lotononis is a short perennial with slender stems up to 1.5m long which form dense swards as high as 60 cm.

Native to southern Africa (23° to 33°S) it is a cool climate plant with reduced growth above and below its 13.5°-21.0°C optimal range. The most tolerant tropical legume to low temperatures it continues growing in air temperatures as low as 7.5°C and has remained green down to -6.5°C. Rainfall for best growth is 1125-1675 mm and it is quite tolerant of drought, water-logging and flooding.

Though it will grow on clay soils it grows best on free draining soils and is tolerant of soils as acid as pH 4.0. Growth is possible on soils of low fertility (especially P) but generous fertilizer applications are usually recommended.

Specific in *Rhizobium* requirements (Australian strain CB376) it must be scarified and inoculated before planting. The very fine seed need a well prepared, compact, fine seed bed and a weed-free environment. It is usually planted by being broadcast and rolled for it should not be planted deeper than 6 mm. Some success has been reported on oversowing burnt *Imperata cylindrica* pastures.

Slow to establish it requires weed control and sunny days. Growth can cease in overcast periods.

It combines well with cool season grasses: *Paspalum commersonii*, *P.plicatum* and *P.dilatatum* *Digitaria decumbens*(Pangola grass) can sometimes form a good mixed sward as both can take heavy grazing. It can grow with tall grasses i.e. *Setaria anceps* if it is defoliated frequently. As it is prone to failure it is often sown with another legume such as *Macroptilium atropurpureum*, *Trifolium repens* or *Centrosema pubescens*.

The most palatable of the tropical legumes it should be kept grazed low to encourage stolon development and to reduce disease. It recovers readily from fire. Silage has been made from it but there is no record of hay making. Low yielding in winters it is still of good fodder value as it retains its greenness. Milk from cattle grazing it may be tainted.

Seed harvesting is done when about 80% of the seed is purple (mature). The cut material is allowed to dry 3 to 4 days before threshing in a high speed drum without an air blast. The threshed seed should be dried immediately to prevent fermentation.

The plant is susceptable to root nematodes, the "little leaf" virus and *Rhizoctonia* fungal disease. Heavy grazing can help control the latter two.

Lotononis is a valuable legume which can grow well in poor soils, remain green in winters, take high grazing pressure and drought and is relatively pest free. It is best suited for the cooler parts of the sub-tropics.

Problems of the plant include unpredictable growth, low dry matter yields, low seedling vigour and low seed yields(thus the seed is expensive).

R E F E R E N C E

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Macroptilium atropurpureum
cv Siratro
Siratro

Siratro, a twining perennial legume native to Central and South America, was selected as a promising legume due to its persistence under pasture conditions in a wide range of climates.

A bred cultivar, Siratro originated from two lines of *M. atropurpureum* which were selected from a small number of accessions of that species. They had high dry matter productivity, compatability with grass and persistence under grazing. From the F4 generation of crosses of these two lines, three lines producing significantly more dry matter and with more stolons than their parents were chosen. The selected cultivar produced by crossing the three superior lines was called Siratro and was released in 1960. Recent research has attempted to breed more productive and disease, pest and frost tolerant lines that are productive in acid, low phosphate soils.

Probably the most widely planted tropical legume in Australia, over 21,000 ha/year have been sown, totaling over 100,000 ha since 1969 in areas having rainfall between 750 mm and 1800 mm. It has been widely tested throughout the tropics.

A very vigorous plant, its twining habit permits it to climb to reach light in pastures where grass competition is strong. The crown of the plant is well below the soil surface and if not defoliated too frequently readily regrows after burning or severe grazing. Spread in wet conditions is aided by rooting at the nodes by stolons.

Broadly tolerant of soil types it grows well under alkaline and acid conditions (pH 4.5 to 8.0) but it does not persist in heavy cracking clays or poorly drained soils. Best growth is obtained about pH 6.

Siratro flowers in response to short daylength in autumn (mainly) and spring. Temperature and growth responses were found to be similar to those of other tropical legumes. Growth is reduced below $32^{o}/24^{o}$ day/night temperatures and with shorter days, and ceases at $14^{o}C$. Despite defoliation its persistence under frost is the greatest of all the tropical legumes. Survival has been recorded at temperatures as low as $-8^{o}C$. Its range may be summarized as being roughly between the latitudes $30^{o}N$ and S.

Responding strongly to fertilizer, particularly P and K, Siratro is most productive and persistent under fertile conditions. The balance between these two elements can be important in maintaining the sward for it has been found that high P low K encourages the grass and high P - high K, and high K - low P encourages the legume.

A popular legume, much work has been done on its management. A vigorous grass is required as a companion species as the legume is very vigorous and may shade out the grass. Greater grass palatability may also result in legume dominance. Siratro combines well with most vigorous tropical grasses including *Panicum maximum*, *Pennisetum purpureum* and *Cenchrus* spp.

Though establishment is better in well prepared seedbeds Siratro has formed successful swards after sod-seeding or oversowing of established pastures or native vegetation. Seedling vigour is high and it competes well with weeds. Scarified seed is usually sown between 2 and 8 kg/ha, and at a depth of 1.5 to 2cm. Nodulation is achieved with the cowpea (CB 756) strain of Rhizobium.

Persistence is excellent under cutting and grazing as long as some leaf is left. Generally 15 cm is the lowest recommended grazing and cutting level. Seasonal differences in palatability may explain its persistence under very heavy grazing. A Rhodes grass-Siratro pasture has been reported as having persisted for over 14 years. Rotational grazing is frequently used to encourage persistence. Thinned stands may be rejuvenated by allowing a rest period and by allowing the plants to seed. Its resistence to drought due to deep rooting extends the productive period of pastures in the dry season and is a major reason for improved productivity.

Hay production is difficult as it sheds its leaves when dry. Successful silage has been reported when molasses was added.

Seed production is difficult and yields are low due to shattering of ripe pods. Best seeding is achieved in a rain free season and not under best climatic conditions for pasture (vegetative growth).

Two main fungal leaf diseases affect the plant: leaf blight (Rhizoctonia solani) and downy mildew. The former disease can be severe especially in wet cool periods and complete defoliation can result. Productivity is low in cool periods; higher levels of productivity are achieved only with higher levels of fertility.

A palatable, productive legume it is easy to establish, competitive, adapted to a range of soils and drought resistant.

REFERENCE

Various authors in Tropical Grasslands(1977) Volume 1

Stylosanthes

The genus Stylosanthes has received much research attention due to its hardiness,and variability. An early colonizer of disturbed soils it has many of the characteristics of a successful weed.

Some 25 mainly American species have been tested for forage potential however the plasticity of the species is such that genotypes of one species may be found in a wide range of climatic and edaphic environments. Thus much work is needed to explore the limits of the gene pool of even the best known species.

1) Stylosanthes humilis

cv Townsville, cv Lawson, cv Gordon, cv Paterson. Townsville stylo, Townsville lucerne.

A persistant annual legume for drier areas it forms a small branched plant which is erect (up to 0.7m) or prostrate. Native to the American tropics, it was first recongnized as a legune with potential as a forage species in Australia in 1914, where it was an accidental introduction. It was developed rapidly and within two decades seeds were available commercially and much basic research had been done on its climatic, agronomic and mangement requirements. Spreading naturally, or by enthusiasitic proponents of the plant it was soon found through even the most remote regions of northern tropical Australia. It is now spread throughout the tropics.

Its native range is from the southern United States and 23^{o}N in Mexico, through Central America and the Caribbean islands to 14°S in Brazil. Rainfall in its native range is from 400 mm in areas with longer rainy seasons to 1300-1500 mm where the rainy seasons are shorter.

In Australia the plant grows in low rainfall areas but rarely when the rainfall is under 560 mm. It has been recorded as growing in rainfalls of up to 2500mm, but secondary fungal infections reduce the hay quality of the standing dead plant material.

A large body of literature has accumulated on the plant, but only the most pertinent data will be simply presented here.

Although a self pollinating plant it is variable both in flowering time and morphology. Three cultivars have been selected on the basis of flowering time: Paterson(early), Lawson(mid), Gordon(late).

Generally a warm temperature plant (optimal temperatues are about 33/28°C day/night) it is affected by frost and thus will not persist in the subtropics. It requires a 3 to 4 months growing season in order to set seed. In Queensland it is recommended for the 640-1300 mm rainfall zones, in the warmer areas.

Intolerant of shading and waterlogging it does not grow well in soils with saline or vertisol characters, but will grow under low fertility conditions. It prefers free draining slightly acid soils but can tolerate very acidic, very low phosphate conditions perhaps due to a vescicular - arbuscular mycorrhizal association. The cowpea strain of Rhizobium will effectively nodulate the plant.

The presence of the plant in pastures increases live weight gains and this effect is enhanced by the addition of P. Rates of phosphate recommended for the Northern Territory in Australia were 100 kg/ha P initially, with 50 kg/ha in in alternate years. However, increased soil phosphate levels commonly caused a decline in sward legume content. Initially trials were rarely carried on beyond three years thus long term competetion effects were lacking. It was noted in 1977 that despite 50 years of research very few improved pastures existed which contained Townsville stylo. The problem was that the presence of the plant in a pasture rapidly raised the N level of the soil increasing the grass competition. The legume was then rapidly eliminated. This effect was enhanced by the addition of P. Researchers attempted to reduce the grass competition so as to allow the legume to persist by testing less vigorous perennial grasses. Such mixtures were not popular as total dry matter production yields were low.

Despite the appearance of occasional scientific papers on Townsville stylo it is essentially no longer planted in Australia. Only a small amount of seed is produced annually by one grower for the overseas market. The benefit of planting Townsville stylo would then appear to be the up grading of native pastures where native legumes are not abundant. It may be used in the establishment of temporary swards with improved perennial grass species to raise the level of soil fertility on impoverished soils.

Establishment is best on well prepared seedbeds but aerial sowing on closely grazed or burnt pastures has been successful as has oversowing in established pastures. Sowing is normally done just before the rainy season at 4 to 6 kg/ha. Strips (about 25% of the area) can be planted to save money and the plant will soon colonize the unsown areas.

The seed is normally scarified before sowing but hardseededness declines to about 50% six months after harvesting. The hooked poods are normally mixed with sand to allow even seed application.

Poorly adapted to persisting in mixed swards with tall grasses it has been reported as combining well with *Cenchrus ciliaris* (Buffel grass), *C.biflorus*, *Urochloa bulbodes* and *U.mosambicensis*, *Digitaria decumbens* (Pangola) among others.

Light seedings are given to keep costs to a minimum and grazing management is used to encourage heavier stands in future seasons. Early season grazing should be heavy and late season grazing should be light to encourage seeding. It survives burning as seeds, whose germination is thus stimulated. Burning can be a regular feature of sward management. Less palatable when young its acceptability increases with age. It makes a reasonable hay either cut or left standing in the field when seeds improve its nutritional value.

Generally the value of the plant as a forage crop depends on the fertilizer history of the site. Once the fertility of site has been increased by the legume, invasion of native grasses occurs and the legume is crowded out.

A valuable forage legume in that it will colonize and persist on infertile soils in low rainfall areas, its palatability increases with age and it is a heavy seed producer.

Unfortunately its yields of dry matter are low as is its N fixing ability. It is intolerant of shade and thus readily disappears when there is vigorous competition. Its hooked seed is difficult to handle and sow uniformly.

REFERENCE

Humpheries, L.R.(1967). 'Townsville lucerne - history and prospect' J. Aust. Inst. Agric. Sci. 33: 3-13

Stylosanthes guianensis
cv Schofield
Schofield stylo
(also cvs. Cook and Endeavour)

An erect, warm season perennial it may grow up to 1 m or be prostrate under grazing. Native to America it occurs from Northern Brazil to Mexico, about 23°C N and S of the equator. It thus requires warm weather for growth (above 15°C). Not found above an altitude of 2,000 m it requires at least 500mm rainfall but best growth occurs with 900 or 1000 mm/annum.

Preferring better drained soils it does poorly on heavy clays, vertisols or saline soils but is tolerant of pH levels as low as 4.0. Nodulation is effective with the cowpea strain of *Rhizobium*. Able to grow satisfactorily on soils containing low levels of P, it generally does better when fertilizer is added.

Establishment is best in a well prepared seed bed with scarified seed planted no deeper than 1.5 cm and compacted with a Cambridge roller. It may also be oversown in closely grazed or burnt pastures or established by stem cuttings. It has been oversown in burnt *Hyparrhenia rufa* and *Imperata cylindrica* pastures and in hill rice in the first 35 days after sowing the rice.

Slow to establish and only moderately tolerant of shading, competition from grass and weeds must be controlled. Establishment under grazing is aided by its low early palatability. Light early grazing in the first 6 to 8 weeks is recommended to reduce competition and promote tillering. It will persist with most grasses as long as it is not shaded.

Later grazings are best done on a rotational basis (1 week in 6 or 8) to ensure plant survival. Plants are usually killed by fires though there may be good regeneration from seeds.

Hay has been successfully made but leaf loss may be a problem. A stylo-sorghum mixture has been used for hay for several years until it became a pure stylo sward at which point it was used for grazing. It is also useful when left as a standing hay in the dry season. Its resistance to 2-4 D after 6 weeks of age is useful in controlling weed competition.

Adverse effects on the yields of crops have been noted in cotton (Uganda and Zambia) and sisal (Tanzania).

Seed is harvested using a crop harvester with a peg drum and a high cylinder speed. The first harvest is done with the comb set at 20 to 25 cm below the top of the sward. A lower comb height a few days later will harvest more seed. Seed yields are heavy but maturing takes place over a period of time and ripe pods are shed so only a fraction of the seed crop is actually harvested.

Generally disease-free it can under some circumstances be severely affected by a Colletotrichum fungal disease, particularly in the Americas. Seed from Australia may be infected with the organism which can defoliate the plants and severely restrict its growth. Seed yields may be reduced by insect attack.

The main defiencies of the plant are that it is frost susceptible, cannot take heavy grazing, may reduce the yields of subsequent crops, has a relatively low protein content, tends to become woody and it is susceptable to severe insect attack, particularly in the Americas.

Its low P requirement, ability to grow on infertile soils and its persistence into the dry season are all useful attributes in a plant which is relatively vigorous and has increasing palatability with age. It thus offers an excellent method of raising the productivity of natural pastures.

Schofield as a cultivar has been partly replaced by the new stylo cultivars Cook and Endeavour. Cook is earlier flowering and adapted to cooler environments giving better early season yields than Schofield; Endeavour performs better under higher rainfall.

Other cultivars have been developed: in Brazil, Deodoro I and II and FAO 13821; Senegal N-6399; Colombia (CIAT) Libertad.No data is available on these.

Stylosanthes guianensis
cv Oxley Fine Stem
Oxley fine-stem stylo

This semi-prostrate perennial cultivar is native to Paraguay, Argentina, Northern Uraguay and southern Brazil as far as 33°S. It is more cold tolerant than most Stylosanthes cultivars for it grows through frost-free winters and survives temperature of 10°C. Early spring growth is thus a feature. It yields well in warmer weather growing optimally at 27°to 29°C. It is grown in Australia in the cooler parts of the tropics (24° to 30°S), lower altitudes, and where rainfall ranges from 625 to 875 mm.

Preferring better drained soils it is drought tolerant but is intolerant of flooding and does poorly in vertisols. Its range of adaptability is wider than that of Schofield or Townsville stylos. It prefers a very slightly acid pH and is tolerant of low fertility levels including P and Ca. A specific Rhizobium (CB 1552) is required for effective nodulation.

Establishment is relatively easy as it is often established by broadcasting scarified seed after burning and a light cultivation. It can be oversown in established pastures as well if the grasses are kept grazed to reduce the competition. Its somewhat lower palatability when young is an advantage in establishment. The plant can take heavy grazing due to a low crown and is fire resistant . It can spread readily.

A compatable grass is not too dense or too tall in order that light may reach the plant. It grows well in Australia with Spear(Heteropogon contortus), buffel(Cenchrus ciliaris) and

Rhodes(Chloris gayana) grasses.

As it is prostrate it is not cut for hay and silage but a lawn mower with a grass catcher can be used to harvest seed. The cut vegetative material is then dried and threshed. As the seed is shed on ripening harvesting is difficult. Fallen seed can be vacuumed up or collected from rows of the crop by plastic sheets in the ground.

The main problems with Oxley stylo are its specific Rhizobium requirement and low dry matter and seed yields.

Its ability to survive cold, heavy grazing, fire, low fertility soils and its compatability with grasses have made it a very useful plant.

R E F E R E N C E

Stonard, P.(1968). 'Fine-stem stylo, a legume of promise'. Qld. Agric. J. 94: 478-484

Other Stylosanthes Species

Stylosanthes fruticosa

Originating in tropical Africa, Arabia and India it is a perennial which acts as an annual in the subtropics. Adapted to low P status sandy soils and very low rainfall, as low as 248 mm over 4 months, it can also grow in higher rainfall zones, up to 1000 mm. It has promise as a low input legume adapted to very poor soils.

A day neutral flowering plant it tends to flower more rapidly in shorter days. Rapid maturity occurs at $30^{o}/25^{o}C$ day/night temperatures and temperatures of $35^{o}/30^{o}C$ inhibited flowering. It is somewhat frost tolerant. Nodulated by a wide spectrum of *Rhizobia* some specificity may occur.

In the Sudan it combines well with tall growing grasses such as *Andropogon guyanensis* and in Tanzania with *Hyparrhenia* species and *Heteropogon contortus*. It has good palatability and has shown promise in well drained soils in Queensland.

A major problem is that its dry matter yields are low.

Stylosanthes hamata
Caribbean stylo
cv Verano

Originating in north Venezuela at sea level in a rainfall of 563 mm occurring from May to November it is a vigorous herbaceous semi-erect plant which is tolerant of drought. Perennial under heavy grazing and in swards, it acts as an annual when a spaced plant. Suited to regions with 500 to 1300 mm rainfall and a short growing season it responds well to brief showers.

Establishing readily from seed, it nodulates well with the cowpea strain of *Rhizobium* and forms vigorous swards with the grass *Urochloa mosambicensis* on a wide range of soils and environments. It is palatable, digestible and has a high nutrient content. It is higher yielding than any of the cultivars of *Stylosanthes humilis* and will persist in a mixed sward.

Originating in an area of generally calcareous soils and with a wide range of genotypes available, selection within the species may provide valuable forage plants for dry soils of low pH.

REFERENCE

Mackay, J.H.E.(1975). '*Stylosanthes hamata* (L) Taub (Caribbean stylo) cv. Verano'. *J. Aust. Inst. Agric. Sci.* *41*: 271-272

Appendix 1

Major References in order of importance.

1. Skerman, P.J.(1977) Tropical Forage Legumes FAO Plant Production and Protection Series No. 2, FAO. Rome, 609 pp.

2. Anon. (1975). Better Pastures for the Tropics. Arthur Yates and Co. Pty. Ltd., P.O. Box 117, Rockhampton, Qld. Australia 4700, 60pp.

3. Bogdan, A.V.(1977). Tropical Pasture and Fodder Plants. Longmans, London. 475 pp.

YATES SOWING GUIDE FOR TROPICAL AND SUBTROPICAL LEGUMES

Common Name	Annual Rainfall		Tolerance to:			
LEGUMES	Range inches	Millimeters	Drought	Water logging	Frost	Low fertility soils
Archer Dolichos	40+	1015+	G	P	F	F
Calopo	60+	1525+	F	F	P	F
Centro	60+	1525+	F	G	F	F
Dalrymple Vigna	60+	1525+	P	VG	P	F
Desmodium Greenleaf	35-50	890-1270	G	G	F	F
Desmodium Silverleaf	35-50	890-1270	F	F	F	F
Dolichos	20-60	510-1525	G	F	F	G
Glycine	30-60	760-1525	G	P	F	P
Leichhardt Dolichos	25-45	635-1140	G	P	F	F
Lespedeza Japanese	35-50	890-1270	F	F	F	G
Leuceana	30+	760+	G	P	F	F
Lotononis	35-60	890-1525	F	G	VG	G
Lucerne	20+	510+	VG	P	G	P
Phasey Bean	30-80	760-2030	G	G	F	G
Puero	60+	1525+	P	G	P	F
Siratro	30-70	760-1780	VG	F	F	G
Stylo (1)	60+	1525+	G	F	F	G
Townsville Stylo	20-50	510-1270	VG	P	P	G
White Clover	30-60	760-1525	F	P	VG	G

(1) cv. Oxley is suited to an annual rainfall of 25-35 inches (635-890 mm).

VG very good, G good, F fair, P poor.

YATES SOWING GUIDE FOR TROPICAL AND SUBTROPICAL LEGUMES (continued)

Common Name	Average Seed Count('000)		Seed Analysis		Sowing Rate	
LEGUMES	per lb.	per kg.	Minimum purity%	Maximum germn.%(1)	lb./acre	Kg/ha
Archer Dolichos	40	88	97.5	60(10)	2-3	2.2-3.3
Calopo	33	73	93.5	50	1-3	1.1-3.3
Centro	18	40	93.8	50	1-2	1.1-2.2
Dalrymple Vigna	17	37	97.5	70	1-2	1.1-2.2
Desmodium Greenleaf	340	755	94.5	70	1-2	1.1-2.2
Desmodium Silverleaf	100	220	945	70	2-3	2.2-3.3
Dolichos	1.8	4.0	97.5	75(10)	4-5	4.5-5.6
Glycine	70	154	97.5	60	3-4	3.3-4.5
Leichhardt Dolichos	15	33	97.5	60	5-8	5.6-8.9
Lespedeza Japanese	300	660	93.5	40(10)	3-4	3.3-4.5
Leucaena	11	24	97.5	60	2-4	2.2-4.5
Lotononis	1500	3300	93.0	50(45)	½-1	0.6-1.1
Lucerne	200	440	98.0	80(30)	1-5	1.1-5.6
Phasey Bean	54	119	98.0	70	2-3	2.2-3.3
Puero	37	81	93.5	50	1-3	1.1-3.3
Siratro	34	75	97.5	70	2-3	2.2-3.3
Stylo	120	264	96.5	40(20)	2-3	2.2-3.3
Townsville Stylo	200	440	90.0	40(20)	2-3	2.2-3.3
White Clover	700	1700	93.5	75(20)	2-3	2.2-3.3

(1) Figure in brackets indicates maximum percentage hard seeds.

Notes for Sowing Guide

Archer Dolichos[1]	: Macrotyloma axillare(Dolichos axillaris)
Calopo[1]	: Calopogonium mucunoides
Centro	: Centrosema pubescens
Dalrymple vigna[1]	: Vigna luteola (V.marina)
Desmodium greenleaf	: Desmodium intortum
Desmodium silverleaf	: Desmodium unicinatum
Dolichos	: Lablab purpureus (Dolichos lablab)
Glycine	: Glycine wightii (G.javanica)
Leichhardt dolichos[1]	: Macrotyloma uniflorum(Dolichos uniflorus)
Lespedeza, Japanese[1]	: Lespedeza striata
Leucaena	: Leucaena leucocephala
Lotononis	: Lotononis bainesii
Lucerne[2]	: Medicago sativa
Phasey bean[1]	: Macroptilium lathyroides
Puero[1]	: Pueraria phaseoloides
Siratro	: Macroptilium atropurpureum
Stylo	: Stulosanthes guianensis cv. Schofield
Townsville stylo	: Stylosanthes humilis cv. Townsville
White clover[2]	: Trifolium repens.

1 of minor importance, not described in notes.

2 major legume not described in notes.