FORAGE LEGUMES IN SANTA CRUZ, BOLIVIA[1]

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Work on forage legumes in Santa Cruz commenced in the period 1964-67 and was continued in 1976-79, in 3 ecological zones - in the central zone an area of transported soils of pH 6.0 - 6.5; in the Yapacani a wetter area of very acid transported soils, and on the oxisols and ultisols of the Precambrian Shield which extend into Brazil. In all the areas, native legumes are common but unproductive due to fires and over grazing.
In the Central area, recommended species are *Glycine wightii*, which, in *Panicum maximum* var. *trichoglume* doubled animal production per ha (181kg), when compared with the, grass alone (90kg), in the 6 months of the dry season. *Lablab purpureus* forms an excellent association with maize and has provided 300 grazing days/ha with the maize straw after harvesting the grain, in the dry season. Complementary grazing of *Leucaena leucocephala* increased growth rates of steers from 0.22kg to 0.70kg per day in the dry season. In Yapacani, promising legume species were *Pueraria phaseoliodes, Macrotyloma axillare* and *Stylosanthes guyanensis* CIAT 136, in that order. In the Precambrian zone *Macrotyloma* and Stylo CIAT 136 increased animal production in the dry season. Less promising species are listed. Some implications of the results for local cattle ranchers are discussed.

Key words: Forage legumes, range legume management, legume species.

The Latin American tropics are known as an important centre of origin for many forage legumes. Collection of some native legumes has been carried out in Bolivia, and Lara and Sauma (1978) state that Herbaria, mostly in the USA, contain the following material from the eastern lowlands:

	No. of Species		No. of Species
Aeschynomene	12	Rhynchosia	8
Calopogonium	2	Stylosanthes	9
Centrosema	7	Tephorosia	3
Desmodium	21	Teramnus	2
Eriosema	7	Vigna	3
Phaseolus	23	Zornia	4

The local flora also includes species of *Acacia, Arachis, Canavalia, Cesalpinia, Cassia, Crotalaria, Galactia, Indigofera, Medicago* and *Psoralea*, and the area is now considered to be the centre of origin of the Genus *Arachis*. There are numerous leguminous trees and shrubs, particularly in the drier areas.

In ungrazed situations as well as on recently disturbed sites, plants of *Desmodium, Stylosanthes, Phaseolus, Rhynchosia, Indigofera* and *Centrosema*, in particular, are very common. In grazed areas however they are much less frequent. It

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seems likely that a number of factors are responsible for this including burning and overgrazing in the dry season. Also many legumes in the area are subject to insect attack at flowering which reduces the amount of viable seed set (eg *Stylosanthes*) , however it has been noted that the quantity of legume herbage can increase enormously in paddocks that are rested for the last 4 months of the wet season.

The experiments reported here are concerned with the performance of cultivated forage legumes most of which are available commercially from Australia and Africa. These were screened and tested in several ecological zones of Santa Cruz. The object was to discover those which are adapted to existing soil fertility levels, rather than those which would require soil amendment or fertilizers, this being considered the most appropriate approach for local conditions. The results therefore refer to trials to which plant nutrients have not been applied.

Materials and Methods

The Department of Santa Cruz was divided into five distinct ecological zones for plant testing purposes. This report concerns trials established in three of them. Rainfall and temperature data for the three areas are given in Table 1, while the soil descriptions given below are summarised from Cochrane (1973).

Table 1:
Rainfall and Mean Daily Temperature

MONTH	Central Santa Cruz (1) Rain (mm)	Temp. (°C)	Yapacani (2) Rain (mm)	Temp. (°C)	Precambrian Shield (3) Rain (mm)	Temp. (°C)
August	36	21.6	85	21.7	34	21.2
September	61	24.3	88	24.2	42	23.3
October	101	25.2	149	25.2	70	24.5
November	125	25.6	156	26.1	104	24.2
December	178	26.1	260	26.2	129	24.6
January	200	25.8	306	26.4	162	24.2
February	141	25.8	243	26.4	141	24.1
March	94	25.1	194	25.9	116	23.8
April	68	23.5	96	24.7	60	22.4
May	63	21.6	99	22.4	51	21.0
June	54	19.9	95	20.8	44	19.9
July	41	19.4	54	20.7	24	20.1
TOTAL	1162		1825		977	
MEAN		23.7		24.2		22.8

Sources:

1. CIMCA (observations at the Estación Experimental Agrícola de Saavedra) 27 year means 1951-1978.
2. Estación Experimental Agrícola de la Colonia San Juan de Yapacaní, 18 year means 1960-1978.
3. AASANA San Javier 28 year means 1950-1977.

Zone 1. Central (altitude 300-500 m above sea level). This lies between the Rio Pirai and Rio Grande and is composed of transported soils which range from light windblown sands to clay-loams, are generally of medium surface texture, often with an impermeable horizon at varying depths which creates localised waterlogging in the wet season. They are of medium fertility with pH generally above 6.0. They are usually sown to pastures after years of cropping with sugar cane, and/or cotton has reduced their native fertility. Rainfall averages 1150 mm per year, with a dry season of 4-5 months in the period May to October. The natural vegetation is of relatively tall forest.

Zone 2. Yapacani (altitude 300-500 m above sea level). This area to the west of zone 1 has a higher rainfall due to its nearness to the foothills of the Andes. Rainfall increases in a westerly direction from about 1400 mm at Portachuelo to 2800 mm at the Yapacani River, to 3,200 mm at the border between Santa Cruz and Cochabamba Departments. The soils are alluvial highly leached, with pH values in the range 4.2-5.0. They are frequently medium textured at the surface, with an impermeable clay horizon at depth producing localised waterlogging. Due to leaching, nutrient cations are often in short supply; phosphate is also low. The natural vegetation is tall rainforest with an understory of vines and shrubs. The area was colonised in the last 20 years so large tracts of forest have been felled by hand. The colonists practise a shifting cultivation within their farm boundaries cultivating a given area for only 2 or 3 years in 10. Thus much land is in varying stages of forest regeneration. It is hoped that pastures will be widely established in the zone in order to prevent the regrowth of the forest after the cropping phase, and so lead to a more stabilised pattern of land use.

Zone 3. Precambrian Shield (altitude 500-1000 m above sea level). This is a large area of soils formed over metamorphic rock. The landscape is undulating, with granitic outcrops on many ridges, Soils are frequently red and well drained with pH of between 5.0 and 6.0. They are very deficient in phosphorous and possibly less deficient in potassium. Several minor elements may be in short supply and aluminium toxicity may occur in some parts of the zone. Annual rainfall is 1000-1100 mm with a well defined 3-5 months dry season. Natural vegetation consists of relatively tall forest on the better soils tending to tree savannah and poor quality natural grassland on the shallower and lower fertility soils. Forest is hand-felled and burned with maize being sown into the ash to offset some of the clearing costs. In the western part of the area seed of *Hyparrhenia rufa* (Nees) , Stapf. (Jaragua), is hand broadcast into the maize, while in the east, *Panicum maximum* Jacq. (guinea grass) is planted as vegetative material between the rows so that after the maize harvest grazing-may commence. Bush regrowth in pasture is controlled by occasional hand-slashing.

Results and Discussion

In the central zone, among a number of legumes introduced by Horrell in the period 1964-67, the most extensive have been *Glycine wightii* (R. Grah ex Wight and Arn.) Verde cv Tinaroo and *Lablab purpureus* (L) Sweet cv Rongai, both of which are of African origin.

Glycine has proved to be persistent and productive on the nearly neutral soils of the zone, and shows a high degree of resistance to pests and diseases. At the Estacion Experimental Agricola de Saavedra (EEAS), two paddocks of *Glycine* associated with *Panicum maximum* cv Petrie (Green Panic) which were sown in 1970 are still very productive, and contain about 40% by weight of the legume.

Paterson et al (1979) described a grazing trial in which stabilised Brahman-Angus (Brangus) weaner bulls (8-10 months of age) were set-stocked at 3 animals/ha (1.3 LU/ha) for the dry season on either green panic alone associated with *Glycine*. The results are given in Table 2 and show that given comparable performance in a second dry season of grazing, animals could reach slaughter weight at 28-30 months of age from Glycine based pastures compared with traditional 4-5 years from natural pastures.

Table 2:
Mean liveweight gains (kg) of 4 Brahman-Angus (Brangus) bulls

Period	Parameter	Green Panic Alone	Green Panic and Glycine	Standard Error of Means (±)	Significance
May 1977	Initial Weight	185.8	189.5	11.24	ns
1) May - October Dry season 180 days	LWG/head	29.3	71.8	5.56	P <0.01
	LWG/head/day	0.16	0.40	0.031	P <0.01
	LWG/ha	89.5	180.8		
	Grazing days/ha	535	546		
2) Nov-April Wet season 186 days	LWG/head	75.0	84.5	4.03	P <0.05
	LWG/head/day	0.40	0.45	0.022	P <0.05
May 1978	LWG/head in 12 months	104.3	156.3	7.40	P <0.01
	LWG/head/day	0.29	0.43	0.041	P <0.01
	Final Weight	290.0	345.8	12.85	

[1] Period when animals grazed on separate experimental treatments
[2] Period when all experimental animals grazed together on common pasture

In Santa Cruz, Lablab has been grown in association with maize to provide grazing in the dry season after the harvest of the maize grain. Samur (1978) reported yields as follows:

Maize with Lablab: Yields (kg/ha)

	Maize alone	Maize/Lablab	SE (±)
Maize grain	1588	3325	336.8
Maize stover (DM)	1637	3156	372.3
Lablab forage (DM)	-	1730	
Lablab seed	-	535	
CP for grazing after Maize grain harvest	43.2	303.7	28.61

Samur (1978) also reports a commercial sowing of maize with Lablab where the yield of maize grain was 2115 kg/ha and of Lablab seed, 1150 kg/ha. After harvest of both grains the area provide 300 cow grazing days per hectare in the latter part of the dry season from July to October. Although an increase in maize yield as a result of association with Lablab is not always obtained, no decrease in yield as a result of competition has yet been observed. Lablab is attacked by leaf eating insects but these do not seriously reduce production. Disease problems have been limited to one case of isolated plant deaths, the causal agent being identified as the fungus *Macrophomina phaseolina* (Tassi) Goid; and to an isolated problem of flower abortion which was tentatively attributed to an unidentified microplasm. The agressive growth habit of Lablab makes it a very useful forage legume.

Leucaena leucocephala (Lam.) de Wit is a native of Central America (NAS 1977) which has become naturalised in Santa Cruz where it is used mainly for windbreaks in crop lands and as an ornamental tree in the city. There exist large areas of pasture land which were sown to *Hyparrhenia rufa* and which have degenerated to unproductive pastures dominated by *Paspalum notatum*, Flugge (*Grama negra*) and shrubby weeds. Paterson et al (1978) reported preliminary results which showed that *Leucaena* could be used to complement the poor grazing value of these pastures in the dry season. A control paddock with no *Leucaena* produced 0.23 kg/head|day liveweight gain in 2 year old steers whilst a similar paddock in which 30% of the area had been sown to Leucaena produced 0.70 kg/ head/day (means of 9 animals, SE means - 0.052 kg). Paddocks with 10% and 20% of their area sown to *Leucaena* produced gains of 0.42 and 0.50 kg/head/day respectively.

In the Yapacani zone, in simple ungrazed plots observed over a period of two years the best legumes were noted as follows:

Macrotyloma axillare (E Mey) Verde cv Archer, has shown excellent productivity and resistance to diseases and freedom from insect pests. It combines well with tall grasses.

Pueraria phaseoloides (Roxb) Benth. (Tropical Kudzu) has grown very strongly at most sites smothering weed growth.

Desmodium intortum cv Greenleaf also grows well but is often attacked by Little Leaf Virus and by leaf eating insects.

Stylosanthes guyanensis (Aubl.) Sw CIAT 136 is attacked occasionally by Anthracnosis (caused by Colletotricum gloeosportioides) shows much better recuperation than Schofield Stylo.

Under grazing management, Kudzu was more persistent than Archer, and has spread into adjacent pilots. Desmodium was eliminated by heavy grazing pressure so the order that is emerging in this area is Tropical Kudzu then Archer and Stylo.

In the Precambrian zone trials have shown good results from *Stylosanthes guyanensis* CIAT 136, *Macrotyloma axillare* cv Archer and *Desmodium intortum* cv Greenleaf. For one trial on a deep, red friable soil at San Ignacio, DM yields for these three legumes (averaged over 4 replications of each of the 3 companion grasses Jaragua, Green Panic and Coloniao), are shown in Table 3.

The yields refer to the period Jan 1977-Teb 1978 which was the establishment year.

In a farm level grazing trial at San Javier, also on red soil, legumes were established in strips of about 1.4 m wide in an old paddock of *Hyparrhenia* with the strips making up a total of 25% of the paddock. They were sown to the legume mixtures St *Stylosanthes guyanensis* CIAT 136 + *Macrotyloma axillare* cv Archer, or *Stylosanthes guyanensis* CIAT 136 + *Glycine wightii* cv Tinaroo or *Stylosanthes guyanensis* CIAT 136 + *Centrosema pubescens*. In a 31 day period in July-August (dry season) 10 yearling steers grazing the 4 ha area gained an average of 9.8 kg each while 10 similar animals in an adjacent control area with no legumes gained 6.0 kg (SE of the means ± 1.06). An unseasonable frost caused the legumes to shed their leaves in mid August preventing the continuation of the trial (Burgess 1979).

Table 3:
Yields in grass legume associations at San Ignacio (kg DM/ha) (after Paterson 1979)

Period		Legume species		
		Stylo CIAT 136 Stylosanthes guyanensis	Archer Macrotyloma **axillare**	Greenleaf Desmodium **intortum**
Jan-Apr 1977	legume	1283	858	458
wet season	grass	2767	4333	4400
May-Oct 1977	legume	1370	413	340
dry season	grass	1309	2526	2433
Nov. 77-Jan 78	legume	2742	1017	343
wet season	grass	4827	6145	6024
13 months	legume	5395	2288	1141
total	grass	8903	13004	12857
% legume overall		37.7	15.0	8.2

It was observed that *Macrotyloma axillare* spread from the sown strips into the undisturbed areas between them. *Stylosanthes gayanensis* was growing well in the strips but did not invade the unsown area. Glycine and Centrosema contributed little to available grazing.

It is found at San Javier that Glycine, although unproductive on the red soils, is adapted to the rather limited areas of brown forest soils in the zone. The latter are probably alfisols whereas the acid red soils where Glycine does not perform well are oxisols.

Promising legume introductions which are still under observation in the three zones are listed in Table 4.

Table 4:
Recent introductions of promise (+)

	Central	Yapacani	Precambrian
Desmodium ovalifolium syn, D heterocarpon	+	+	+
Glycine wightii cv cooper	+		
Leucaena leucocephala various selections	+		
Mucuna pruriens		+	
Stylosanthes capitata	+		+
Stylosanthes hamata CIAT 114, 118, 147	+		
Stylosanthes guyanensis CIAT 136		+	
Stylosanthes scabra	+		
Zornia latifolia			+

Legume cultivars which have been found to be less satisfactory in these investigations are noted in Table 5.

Table 5:
Legumes considered less satisfactory

	Central	Yapacaní	Precambrian
Centrosema pubescens, common	xy	xy	xyz
Desmodium uncinatum, silverleaf	z	z	z
Glycine wightii cv Tinaroo	(good)	z	z
Lablab purpureus cv Highworth	z	-	-
Macroptilium atropurpureus cv Siratro	x	x	x
Pueraria phaseoloides	z	(good)	z
Stylosanthes hamata cv Verano	z	z	z
Stylosanthes humilis	z	z	z
Stylosanthes guyanensis cv Schofield	x	x	x

x = disease susceptible
y = susceptible to insect attack
z = poor productivity

The most serious diseases noted have been Rhizoctonia, which causes severe leaf-fall in Siratro, and Anthracnosis which very strongly attacks Schofield and most other Stylosanthes cultivars and also affects common Centrosema.

The investigations reviewed here were focussed primarily on providing quality grazing in the period of the dry season. We consider this to be crucial in areas of extensive or semi-extensive cattle production in the Tropics. The critical period, in Santa Cruz lies between April and October.

The legumes that were studied grow best at the end of the rains and into the dry season provided that soil moisture can be reached by their deep tap-root systems. They are more competitive with associated grasses at this time when soil nitrogen levels are low.

Legumes retain their nutritive value for up to 3-4 months under deferred grazing management and can be used to create reserves of good quality forage for grazing in the most critical period.

Cattle with access to legumes in this period can adequately utilize reserves of low grade grass, or roughage from crop residues, on which they might otherwise starve. These were factors in providing the rationale for the approach adopted.

Forage legume recommendations are now available for the central region of Bolivia, either as perennial legume/grass pastures (with Glycine) as complementary grazing of high nutritive value (with the perennial Leucaena), and as annual high protein grazing reserves in maize stovers (with Lablab). There are promising alternative species for the different soils of the Precambrian Shield and the wetter climate of Yapacani. Animal growth rates have been greatly improved by the use' of legume based pastures, principally in the dry season.

Nores and Estrada (1979) examined the economics of using cultivated pastures, among the other techniques, in place of or in association with, native pasture, in the Colombian Llanos. Their article indicates the multi-factor nature of the economic analysis required, and the need to consider the effect of cultivated pastures in terms of their strategic value in the ranch production system rather than*per se.*

The present experiment showed that cattle slaughter weights can be reached at 30 months of age on pasture alone, by animals that are weaned at 7-8 months at the beginning of the dry season, if they are grazed on legume based pastures for two successive dry season periods of 6 months each. Calculations of the effect of reducing the slaughter age to 30 months instead of the normal 4 years on traditional ranches, show that this enables the number of brood cows kept to be increased by 19%; with a resulting increase in annual "off take" of 25%. (Table 6).

Table 6:

Calculated effect of reducing slaughter age to 30 months on ranch production

Assumptions:				
Calving rate			60 %	
Calf mortality			5 %	
Subsequent mortality per year			3 %	
Cow replacement rate			12 %	
Slaughter weight			400 kg	
		Traditional System Slaughter at 4 years	"Improved System" Slaughter at 30 months	
Weights of Young Cattle (kg) assumed:				
At 1 year		150	200	
2 years		200	300	
2.5 years		280	400	
4 years		400		
Herd Structure (normal):			Herd Structure (becomes):	
	Animals		Animals	
Cows	100		119	
bulls	6		7	
calves	57	Total Animal	68	Total Animal
1 - 2 years	55	Units = 227	66	Units = 226
2 - 3 years	53		65	
3 - 4 years	51		-	
Animals sold per year:				
Steers	26		32	
Surplus heifers	10		14	
Old cows	12		14	
Total offtake	48		60	

Our model (Table 6) assumes a mandatory "package" of recommendations consisting of a controlled breeding season with calving in August and weaning in April, the weaned calves remaining on legume-based pastures for 6 months until the end of the dry season (October) and returning to these pastures again for their second dry season. In practice there may be additional benefits to those shown in the table notably an improvement in calving rate and reduction in mortality.

There are alternatives to legume based pastures to achieve the same end of earlier slaughter, namely, heavy feeding of concentrate supplements at pasture or in yards. These are less attractive, if not impracticable, in areas of extensive cattle production, where land is remote and of low value. We consider the system proposed to be more appropriate for local conditions at the present time,although,like any alternative, it demands more management skill than traditional methods and some extra capital investment.

Paterson et al (1979) calculated the costs of establishment of legume based pastures at US$160 per hectare (no fertiliser used) with annual costs amortising the capital loan over 10 years and including annual maintenance of the pasture at $62/ha per year. The area of such pasture required in the model given, for 70 animal units (68 calves + 66 young stock) would be 46 ha according to local experience which rates the pastures capable of carrying 1.5 LU per ha in the dry season on a sustained basis.

Many practical problems to the widespread adoption of such pastures in Santa Cruz remain, principal amongst which are:

i) the high degree of risk involved in successfully establishing pastures with present methods.
ii) the frequently encountered lack of persistence of the legumes under present grazing management practices.

Concerning establishment, good land preparation is often not possible with the machinery available to cattle farmers. Germinating pasture seeds are vulnerable to conditions which are typical at the soil surface on tropical farms and include poor contact of seed and soil, inadequate planting depth, rapid surface drying, soil movement under rain-storms, leaching of nutrients and waterlogging. Young pasture plants-are vulnerable to leaf cutting ants and other pests including uncontrolled grazing animals. The degree of skill required for successful establishment is high and there have been many failures. Better methods to ensure establishment are therefore required.

The frequent failure of legumes to persist in pastures in practical farm trials is noteworthy. This may be due to non-use of fertilisers, including for example Molybdenum (Roberts 1979). It has been frequently caused by overstocking in our experiences, particularly where grazing management has been learned on traditional pastures of Jaragua or Grama Negra. Local cattlemen are notoriously careless of their pastures and the traditional outlook is difficult to change.

More effort is required to find solutions to these problems before widespread farmer-adoption of legume-based pastures can be expected in this region, despite recent progress.

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