There are 12,000 species of Leguminosae in the world, of these 7,000 are tropical and 4,000 species are native to the Americas. Stylosanthes, Desmodium, Centrosema, Macroptilium (syn. Phaseolus) are among principal genera in the Americas. Although these legumes are widely distributed throughout tropical America, only limited exploitation has been made of this germ plasm base in the establishment of legume based pastures. In contrast, Australian workers have tapped this germ plasm, selecting and developing varieties adapted to the Australian environment.

This paper will first discuss productivity of legumes and legume/grass associations, and will be followed by commentary on considerations in developing improved pastures based on tropical legumes. Principal sources of information are from the Centro Internacional de Agricultura Tropical (CIAT) and the Instituto Colombiano Agropecuario (ICA) in Colombia; and the Instituto Veterinario de Investigaciones Tropicales y de Altura in Peru.

Production of Legume and Legume/Grass Based Pastures

Legumes.

Legumes alone would generally be used under two situations, ie as fresh cut forage and as a standing forage for deferred grazing.

Examples of fresh cut forage are Desmodium distortum and Stizolobium deeringianum. These forages are generally used as supplements to low-protein diets during the dry season, and for dairy cattle. These legumes are not suitable components of perennial pasture mixtures, being biennial and annual plants respectively.

Standing legume forage is sometimes used during the dry season as a feed reserve for deferred grazing to provide a high protein forage to supplement low quality-low protein grass pastures. Leucaena leucocephala is an example. It is a browse plant, deep rooted, withstands drouth, and is suitable for medium to higher fertility soils. It is generally not used under continuous grazing. On occasion, Stylosanthes guyanensis might be similarly used.

Legume/Grass Pastures

Although optimal ratios of grasses and legumes will vary widely depending upon species and environment, available information would...
indicate that at least 50%, or even more, of legume is desirable in the tropics and sub-tropics. On the other hand, it is generally felt that if pastures are used all the year around, then some grass mixed with the legume would be preferable to a pure legume pasture. This is in consideration of the generally higher dry matter production of the grasses during the rainy season, their faster growth following early rains, and that they tend to provide more ground cover which controls weeds and minimizes erosion and water runoff.

Legumes contribute in three principal ways in increasing productivity when incorporated in a grass pasture. The legume forage is more nutritious, being especially higher in protein. Secondly, the level of protein is generally sufficiently high that the legume acts as a protein supplement to low protein grass pastures that prevail during the dry season, and also in grass pastures that are marginally deficient in protein in the rainy season. In this instance the supplemental legume increases digestibility and intake of forage. In a series of CIAT investigations, addition of Stylosanthes guyanensis to dry season Melinis minutiflora (3% crude protein) increased total intake, digestibility of consumed dry matter, and increased intake of digestible dry matter from 60 to 100% of maintenance requirements (CIAT, 1973). Thirdly legumes and soil Rhizobia symbiotically fix nitrogen in the soil, improving nitrogen status, providing nitrogen for enhanced growth of both grass and legume.

In the Beef program of CIAT principal emphasis is placed on developing life-cycle beef cattle production systems on pasture; including legume-grass mixtures, pure improved grass pastures, and also on native grass pastures. However particular attention is given to legume/grass improved pastures. Much of the field work in this program is carried out in collaboration with the Instituto Colombiano Agropecuario (ICA) at their Carimagua station in the heart of the Colombian Llanos. Climates and soil type are similar to those found in other savanna grassland areas, i.e., Venezuelan Llanos and Campo Cerrado of Brazil. Average rainfall averages 2000 mm, dry season lasts 4-5 months, mean temperature is 27°C, soils are acid (pH 4.5), phosphorous is low (2 ppm), other bases are low (Ca, Mg, K), and exchangeable aluminum is high (3.5 m.e/100gr) (Spain, 1974).

Predominating native grass genera are Trachypogon, Andropogon, Paspalum and Leptocoryphium. All species present are regarded to be of low nutritive value and slow growth. Principal naturalized grass species include Melinis minutiflora, Hyparrhenia rufa, Brachiaria decumbens. During the rainy season total weight gains are considerably higher on the naturalized grass pastures as compared to the native grass pastures. However, during the dry season severe weight losses are encountered on all grasses. The only exception would be low areas "bajos" that remain moist during the dry season, and where growth of pasture plants continues.

Adapted improved "naturalized" grasses are available, and establishment methods and management systems are reasonably well defined. However, this is not true with legumes. In many instances, adapted varieties that will persist, that are insect and disease resistant are either not available or are just being identified. Further definition is needed on phosphorous fertilizer requirements, establishment methods,
required pasture management and seed production systems. Serious errors have been made in assuming that "overseas" selected varieties and technology would be directly usable in the Latin American tropics.

Annual liveweight gains of animals grazing native grass pastures in the Colombian llanos have been low, i.e. 8-21 kg/ha/yr with stocking rates ranging from .2-.5 animal units/ha (Table 1). Whereas nominal weight gains were made in the rainy season, severe weight losses resulted in the dry season (CIAT, 1974).

Table 1. Productivity of native savanna and Melinis minutiflora pastures at the ICA Carimaguá station, Colombia.

<table>
<thead>
<tr>
<th>Pasture</th>
<th>Stocking rate steers/ha</th>
<th>Weight change/animal</th>
<th>Weight gain/ha/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native</td>
<td>0.20</td>
<td>6</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>0.35</td>
<td>-14</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>-27</td>
<td>43</td>
</tr>
<tr>
<td>Melinis</td>
<td>0.44</td>
<td>-54</td>
<td>170</td>
</tr>
<tr>
<td>minutiflora</td>
<td>0.88</td>
<td>-56</td>
<td>68</td>
</tr>
<tr>
<td>all year 1/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melinis</td>
<td>0.44</td>
<td>-</td>
<td>143</td>
</tr>
<tr>
<td>minutiflora</td>
<td>0.88</td>
<td>-</td>
<td>102</td>
</tr>
<tr>
<td>rainy season 2/</td>
<td>1.30</td>
<td>-</td>
<td>67</td>
</tr>
</tbody>
</table>

1/ 335 days
2/ Rainy season only (241 days); dry season (124 days) not included.

In comparison, weight gains on Melinis minutiflora pastures have been considerably higher during the rainy season, i.e. 63-90 kg/ha/yr with stocking rates ranging from .44 to 1.30 animal units/ha (Table 1). However as with the native grass pastures, severe weight losses were incurred during the dry season, actually more severe than on the native pastures. Although quite acceptable gains were achieved during the rainy season, a large portion of these gains were wiped out by dry season losses (CIAT, 1974).

Although preliminary, results to date indicate that annual weight gains can be sharply increased through use of tropical forage legumes (Paladines et al., 1974). Good weight gains were obtained during the dry season on Stylo-grass pastures (Table 2) whereas cattle on native and improved grass pastures suffered severe weight losses. Performance on the legume-grass pastures has been superior to that of animals on improved grass pastures in the rainy season, both in stocking rate and live weight gain. Stocking rates ranged from .90 - 1.70 animals/ha with weight gains of 611-800 gm/head/day.

These results are highly encouraging, but it must be emphasized that all currently available commercial Stylo varieties, i.e. TRI 1022, Endeavour, Schofield and Cook, are very susceptible to anthracnose, a fungus disease caused by Colletotrichum sp. (Grof, personal communication). This disease results in reduced plant vigor, defoliation, often death
of susceptible ecotypes, and subsequent reduction in stand. Also some cultivars are susceptible to attack by an unidentified stem borer insect which killed a large number of plants. This emphasizes the importance of identifying adapted varieties of *Stylosanthes guyanensis* that are resistant to disease and insect attack.

Table 2. Weight gain of steers grazing mixed pastures containing *Stylosanthes guyanensis* at the ICA Carimagua station, Colombia.

<table>
<thead>
<tr>
<th>Pasture</th>
<th>Stocking rate steers/ha</th>
<th>Dry season g/head/day</th>
<th>Rainy season g/head/day</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Stylosanthes guyanensis</em></td>
<td>0.50</td>
<td>532</td>
<td>-</td>
</tr>
<tr>
<td>+ <em>Melinis minutiflora</em></td>
<td>0.90</td>
<td>-</td>
<td>714</td>
</tr>
<tr>
<td></td>
<td>1.30</td>
<td>-</td>
<td>713</td>
</tr>
<tr>
<td></td>
<td>1.70</td>
<td>-</td>
<td>611</td>
</tr>
<tr>
<td><em>Stylosanthes guyanensis</em></td>
<td>0.50</td>
<td>446</td>
<td>-</td>
</tr>
<tr>
<td>+ spontaneous graminae</td>
<td>0.90</td>
<td>-</td>
<td>773</td>
</tr>
<tr>
<td></td>
<td>1.30</td>
<td>-</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>1.70</td>
<td>-</td>
<td>703</td>
</tr>
</tbody>
</table>

These results indicate that incorporation of the tropical forage legume *Stylosanthes guyanensis* in the swards improved forage quality, especially protein content, which in turn increased consumption of total forage, resulting in increased TDN production/ha/yr as indicated by increased weight gains and carrying capacities of legume-grass swards.

Similar results have been obtained by researchers in the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA) at their tropical station in Pucallpa, Peru. This station is located in the Amazon basin. Terrain is undulating, vegetation is of the high rain forest type. Annual rainfall is 1600 mm and is fairly well distributed, with June, July and August being relatively dry. Mean temperature is 30.8°C. Soils are lateritic clay loams, acidic (pH 3.8 - 5.3), low in phosphorus (1.5 - 4.5 ppm), low in Ca, Mg, and K, and high in exchangeable Al (0.20 - 7.60 m.e/100 gm). Several legume species (*Macroptilium atropurpureum*, *Glycine wightii*, *Lotononis bainsii*, *Desmodium intortum*, *Stylosanthes humilis*, *Stylosanthes guyanensis*, *Pueraria phaseoloides*, *Centrosema pubescens*) were observed with associated grass species at Pucallpa. Of these, *Stylosanthes guyanensis*, *Pueraria phaseoloides* and *Centrosema pubescens* appeared to be suitable legumes to develop grass/legume mixtures in that region (Santhirasegaram et al., 1972). Productivity of the legume/grass association was markedly higher than that of the pure grass pastures. Santhirasegaram (1974) obtained liveweight gains of 352.4 kg/ha/yr with two yearling Nellore heifers per hectare on *Pueraria phaseoloides*/grass pastures. They observed that at this stocking rate, only about two-thirds of the available forage was utilized, and that potential production was estimated to be 581.7 kg/ha/yr.

Santhirasegaram (1974) also observed that direct phosphorous supplementation is necessary for animals grazing legume/grass associations. Although the legumes have a higher phosphorous content than
the grasses, they are still deficient in phosphorus. Spain (1974) observes that although phosphorous fertilization level will influence the phosphorus content of tropical forage legumes, it generally will not be economical to fertilize to the level necessary to make the legume forage nutritionally adequate in phosphorus. Fertilization level should be adjusted to achieve optimum dry matter productivity, which for Stylosanthes guaynensis in Carimagua, Colombia would generally be no more than 40-50 kg P/ha at time of establishment and with maintenance levels of no more than 10-20 kg P/ha/yr thereafter. Deficiency of phosphorous in the forage can be corrected by ad lib feeding of a mineral supplement.

Thus far, only live weight gain comparisons have been made between pure grass and legume/grass pastures, with no reference to effect on reproductive performance. Calving percentages are low in most lateritic soil areas, averaging probably no more than 45-50% with cows calving every two years (Stonaker, 1974). Inadequate nutrient intake is the principal cause of low reproductive performance, and often is accentuated during the dry season, when forage protein content declines sharply, often to as low as 2 to 3%. In these situations, the legume could be invaluable in correcting the marked protein deficiency of dry season pasture grasses, acting as a supplement in increasing forage digestibility and intake, and raising nutritional plane sufficiently to enable the lactating cow to rebreed.

In Pucallpa, preliminary results indicate sharply higher pregnancy rates for cows grazing legume/grass pastures as compared to grass pastures (Santhirasegaram, 1974). Although no data are yet available in CIAT, growth data indicate that the Stylosanthes guaynensis/grass pastures would provide a plane of nutrition adequate for lactating cows to rebreed. Nutrient requirements established by the National Research Council indicate that a ration that would support live weight gains of 500 g/day in yearling steers would also provide nutrient intake adequate to enable the lactating cow to rebreed. Current live weight gains in Carimagua on the Stylo/grass pastures are well above this amount on a year around basis.

Developing Pasture Improvement Programs Based on Tropical Legumes

These results and others obtained in the Latin American tropics, when reinforced by the Australian experience, are highly encouraging and illustrate the tremendous potential to increase beef cattle production through use of tropical forage legumes. But there are still some gaps in workable, legume based pasture systems at the field level. Some of the gaps are technological, some are socioeconomic, some relate to availability of inputs. These problems are not only critical, but must be resolved before the legume package will be saleable and workable. Principal constraints are 1) adapted varieties 2) availability of phosphorus fertilizers and 3) availability of seed.

Adapted Varieties.

Native tropical forage legumes abound in the Americas. Of these, the Australians have collected ecotypes and developed varieties that will perform under their conditions, which are generally more acid and less tropical than in much of the Latin American tropics. With the
success obtained in Australia with these varieties, many organizations were prompted to directly use these varieties in the Americas. Results have been disappointing. The Australian commercial varieties have often not been adapted to the tropical conditions in the Americas.

Susceptibility to disease, insect attack and inability to compete with other species have been common problems. This perhaps seems strange since these varieties were developed from ecotypes collected in the Americas. However the American ecotypes were selected for Australia, and not Latin America.

But little has been done in the Americas to understand and exploit this germ plasm. There's a job to be done in adequately sampling and evaluating native species. Whereas variability within grass species would appear to be fairly low, natural variability within legume species appears to be quite high. Consequently the probability for identification of adapted, and superior, ecotypes from the native germ plasm pool must be fairly high.

Identification of adapted varieties that will persist in association with grasses using simple management practices is an absolute requirement. CIAT, in collaboration with national agencies, is now systematically collecting and evaluating selected genera (Stylosanthes, Centrosema, Desmodium, Macroptilium) of tropical forage legumes with the goal of identifying ecotypes that will be adapted to the major tropical ecosystems in the Americas.

Phosphorous Fertilizer

Establishment of legume based pastures in most humid tropical areas will require the application of some phosphorous fertilizer. Although amounts required for establishment and maintenance are nominal, sizeable quantities of phosphorous fertilizer will be required in a pasture improvement program of any significant dimension.

It is encouraging that in many legume species, maximum response to phosphorous fertilization is obtained at fairly low fertilization levels (no more than 40-50 kg/P/ha, and maintenance requirements are low).

Seed Production

Once adapted varieties are identified, seed production will first be limited by the initial quantity of seed, which is generally only a few grams; secondly time to produce a seed crop which often is as much as a year; thirdly by multiplication rate which is about 50-100 kg harvested for every kilo of seed planted in the case of S. guianensis; and fourthly by economic feasibility of commercial seed production. Although recommended seeding rates are only 2-3 kg/ha, total area required annually in seed production would be 2-6% of the area to be seeded. These combined considerations all emphasize the importance of developing comprehensive seed production packages that are efficient, economically feasible and attractive to commercial seed producers. Any large scale pasture improvement program based on tropical legumes will require sizeable quantities of commercially produced seed.
Apart from commercial seed production, sizeable quantities can, and should be produced in "on farm" seed production plots. For instance, one kg of Stylomasantes guyanensis will seed one hectare, which in 12 months will produce 50-100 kg of seed, which if seeded in 50 cm rows would seed as much as 50-100 ha. If every livestock farm could seed such an area annually, with an adapted variety that would persist, the beef cattle industry would be revolutionized, and beef production increases would be phenomenal.

Conclusion

Tropical forage legumes aren't new. But even so, we haven't yet exploited this resource nor do we yet have the comprehensive legume package, ie the varieties, fertilizer and seed production systems to enable us to put tropical legumes to work at the field level. A concentrated and systematic effort will be required to close these gaps.

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