INTRODUCTION

The Tropical Pastures Program of CIAT (Centro Internacional de Agricultura Tropical) has worked cooperatively with ICA (Instituto Colombiano Agropecuario) since 1970 at Canaima, a national agricultural research center in the Eastern Plains of Colombia. Canaima is located at 4°37'N Lat 71°36' W Long, at an altitude of 175 m. Average annual rainfall is 2100 mm distributed from April to December. Mean annual temperature is 26°C, mean minimum is 20°C, mean maximum is 33°C. The predominant soils are fine textured Oxisols (Tropical Hapludox, isohyperthermic). The chemical characteristics of a well drained profile from Canaima are shown in Table 1.

The objectives of research conducted at Canaima include the development of low cost, low input technology to increase livestock production on the acid fertile savannas of Tropical America. Since forage quality is recognized as the principal limiting factor in these ecosystems, the program has focused on the collection and testing of legumes and grasses most of which have evolved in similar ecosystems.

Several promising species have been identified since the program was initiated in 1970. Among them are Andropogon gayanus Kunth var. hispaniculatus (CIAT ecotype 621) and Stylosanthes capitata a Vog. (Centro Internacional de Agricultura Tropical 1977).

A. gayanus (Gamba grass) is a large tufted, perennial grass of West African origin. It is widely distributed across a belt of savannas with average annual rainfall ranging from 600 to 1400 mm. It forms dense tussocks up to 1 m in diameter and 2 m in height. Bowden (1964) introduced into the Colombian Llanos from Northern Nigeria in 1974 (Grof 1981). A. gayanus proved to be very well adapted to...
the soil and climate of the ecosystem yield over 17 TDM/ha/year (Centro Internacional de Agricultura Tropical 1978 and Jones 1979).

S. capitata is a perennial self-regenerating legume native to Brazil and Venezuela (Gof et al. 1979). Introduced to Colombia in 1974, it is considered one of the most promising legumes for the Llanos ecosystem. It tolerates tolerance to anthurium and stemboret attack and is very productive on extremely acid and highly Al-saturated soils (Centro Internacional de Agricultura Tropical 1977).

### TABLE 1: Some chemical characteristics of Carimagua-Der soil

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Clay (%)</th>
<th>SiO₂ (%)</th>
<th>OM (%)</th>
<th>pH</th>
<th>P</th>
<th>Ca</th>
<th>K</th>
<th>Mg</th>
<th>EC (dS/m)</th>
<th>Al (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-12</td>
<td>36</td>
<td>12</td>
<td>40</td>
<td>45</td>
<td>1</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>12-22</td>
<td>41</td>
<td>11</td>
<td>20</td>
<td>46</td>
<td>1</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>22-32</td>
<td>43</td>
<td>11</td>
<td>17</td>
<td>46</td>
<td>1</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>32-45</td>
<td>45</td>
<td>12</td>
<td>12</td>
<td>52</td>
<td>2</td>
<td>0.7</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>45-65</td>
<td>45</td>
<td>12</td>
<td>0.8</td>
<td>51</td>
<td>2</td>
<td>0.7</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.4</td>
</tr>
</tbody>
</table>

### TABLE 2: Recommended Fertilizer Rates for A. guayus x S. capitata association (kg/ha)

<table>
<thead>
<tr>
<th>Object</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Mg</th>
<th>S</th>
<th>Ca</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishment</td>
<td>22</td>
<td>48</td>
<td>12</td>
<td>12</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>5</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

From Spann J M (ed.) 1982

### PERFORMANCE AND MANAGEMENT OF THE ASSOCIATION

These two species were planted in association at Carimagua for the first time in 1976, and initial results were very favorable. The high seed production potential of S. capitata was considered a key self-propagation mechanism which would contribute to a stable mixture with A. guayus under grazing (Centro Internacional de Agricultura Tropical 1978). A note of caution was sounded by the report that S. capitata seedlings were often dwarfed and exhibited severe potassium and magnesium deficiency symptoms in the presence of mature A. guayus plants. These observations underscore the importance of competitive interference in grass-legume associations (Centro Internacional de Agricultura Tropical 1978).

By 1981, the association had proven to be highly productive, resulting in live weight gains of up to 200 kg/animal/year and 320 kg/ha/year. However, low vigor of second-generation S. capitata seedlings under grazing was identified as a problem and objective of future research (Centro Internacional de Agricultura Tropical 1981). This problem is still thought to be one of the main causes of limited persistence of legumes in the association under present management conditions.

### Grazing

A. guayus/S. capitata pastures at Carimagua have been grazed continuously with seasonal adjustment of stocking rates (2 animals/ha) during the 8 months rainy season. Grazing usually starts toward the end of the year of establishment.

### Fertilizer

In the CIAT general recommendations (for pasture establishment) published by Spann (1982), fertilizer application rates are separated in two categories: establishment and maintenance. Establishment are selected to provide for the rapid establishment of vigorous stands. Rates are based on results of several years of monoculture small plot experiments under cutting management. Phosphorus and calcium from basic slag or rock phosphate are usually banded with the seed and other nutrients are broadcast to prevent seedling damage from excessive soil concentration. Maintenance rates are estimated from extraction data derived from the same plots and adjusted to allow for recycling by the grazing animals. The recommended fertilizer rates for A. guayus/S. capitata associations are shown in Table 2.

### Developmental stages of the A. guayus x S. capitata association

A. guayus is a rather weak seedling but once established it is a strongly competitive perennial in the Colombian Llanos. In contrast, S. capitata is a strong seedling and rapidly develops into a robust plant. However, it does not behave as a true perennial in the Carimagua ecosystem but more as a biennial depending on seed for self-regeneration. This gives rise to three developmental stages in the life of the association: establishment, post-establishment, and legume stand maintenance (self-regeneration).

### Establishment

Since the two species are established by seed, this stage includes germination and seedling development of both components. It is recommended that the two...
species be planted simultaneously in separate rows 0.50 to 1.000 m apart. At this stage, *S. capituata* is often the dominant species due to greater seed reserves and more vigorous early growth. The legume, however, rapidly develops a strong tap root system which effectively protects the seedling during periods of water stress which often occur early in the rainy season.

Post-establishment

By the end of the first year and through the second, a good balance between the legume and grass components is usually achieved and maintained. These are, however, striking morphological differences between the two species which undoubtedly condition their nutrient needs and uptake and affect their competitive abilities.

The root system of *A. gyanus* has been studied in detail by Bowden (1963) who identified three morphologically distinct types: fibrous roots extending laterally over 1 m from the plant; cord roots extending at a 30 to 40° angle to the soil surface for approximately 50 cm; and vertical roots which penetrate to depths greater than 80 cm. These fractions represented 40% and 10% of the total root weight. One of the authors has repeatedly observed a strong depressing effect of *A. gyanus* plants on the growth of seedlings of the same and other species which comes within the approximately 1 m length of the fibrous root system reported by Bowden (op. cit.). The root system of *S. capituata* has not been studied in such detail but it appears to have a typical tap root penetrating to 1.50 m or more depth, judging from soil moisture extraction studies at Caramuca which show that flowing *S. capituata* ecolyps can extract all of the available water from the profile to a depth of 1 m by the end of the dry season (Centro Internacional de Agricultura Tropical 1979).

Several studies have shown that cation exchange capacity of legume roots is about twice that of grass roots. This may be an explanation for the advantage of grasses in the uptake of K and other mobile cations in competition with legumes (Asher & Ozanne 1961 and Haynes 1980).

*A. gyanus* appears to be particularly responsive to K fertilization. In a field trial Caramuca it did not respond to P application in the absence of K, while significant responses up to 44 kg/ha of K were obtained when 30 and 80 kg/ha K were applied. This trial revealed a higher efficiency of K utilization for *A. gyanus* than for *Brachiaurus decumbens* and *B. humicola* (Centro Internacional de Agricultura Tropical 1980).

Legume stand maintenance (self regeneration)

The two species have very different patterns of persistence. With appropriate management, stand maintenance of *A. gyanus* is no problem, original planting pat

terns can still be observed 5 years after planting. In contrast, *S. capituata* 'mother plants' start degenerating toward the end of the second year or early in the third and the legume fraction of the pasture declines sharply; thus regeneration from seed is a key mechanism for stand maintenance. The legume is a prolific seed; more than 1000 seedlings per m² have been observed in *A. gyanus* associations in Caramuca (M. Sánchez, personal communication) but the number of seedlings decreases rapidly under grazing. The major v. man started at about 3 to 4 cm height with minute chlorotic leaves failing to effectively replace the rapidly declining original stand. Tissue analyses of these plants confirm severe K deficiency status (I. Valencia, unpublished data). Many plants of this type can be found in the older pastures in Caramuca area and it is rather obvious that they do not contribute significantly to forage quality or volume.

EXPERIMENTAL WORK

It is clear that the stage of legume self-regeneration is of great importance to the survival of the association and although there must be other factors involved in competitive interference between mature *A. gyanus* plants and *S. capituata* seedlings, appears to be a major limitation.

To study the effect of root competition on legumes self-regeneration an experiment was conducted during the rainy season of 1981. In a 3 year old stand of *A. gyanus* at CIAT 621, *S. capituata* at CIAT 019 was seeded in PVC cylinders 15 cm diameter x 30 cm length which were driven into the soil between *A. gyanus* rows to exclude *A. gyanus* roots from the thigmosphere of *S. capituata* seedlings. In another experiment, 3 cm rings of the same pipe were placed on the surface to define the treatment area while continuing to allow root competition. Population density of *S. capituata* was set at 100 seedlings per m². A missing nutrient element series was superseded as split plots on the main treatments root competition and no-root competition. The complete fertilizer treatment consisted of the following rates (kg/ha): 50N 10P 40K 100Ca 20Mg 20S 4Zn 2Cu 1B 0I 0Mo and 0Si. The effect of competition was much greater than that of nutrients the e were ten fold differences in dry matter production between root competition and non root competition treatments. A most interesting result was that the ranking of critical nutrients changed between the root competition and non competition treatments. Although K an important critical factor in both situations nitrogen appeared to improve the competitive ability of *A. gyanus* to the detriment of *S. capituata* seedlings in the root competition treatment as shown in Table 3.

The overriding effect of root competition in this experiment underscores the importance of competitive interference. The results also suggest that the role of N is one of non competitive interference. Harper (1964) defined non competitive
<table>
<thead>
<tr>
<th>Treatment</th>
<th>gDW/10 plants</th>
<th>Maximum yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC</td>
<td>6.80 a</td>
<td>100</td>
</tr>
<tr>
<td>NC minus Ca</td>
<td>6.80 a</td>
<td>99</td>
</tr>
<tr>
<td>NC minus K</td>
<td>6.42 a</td>
<td>93</td>
</tr>
<tr>
<td>NC minus S</td>
<td>6.24 a</td>
<td>88</td>
</tr>
<tr>
<td>NC minus P</td>
<td>6.12 a</td>
<td>88</td>
</tr>
<tr>
<td>NC minus Mg</td>
<td>5.94 a</td>
<td>86</td>
</tr>
<tr>
<td>NC minus K</td>
<td>4.75 b</td>
<td>69</td>
</tr>
<tr>
<td>NC minus N</td>
<td>2.06 c</td>
<td>30</td>
</tr>
<tr>
<td>C minus ed</td>
<td>1.16 ed</td>
<td>17</td>
</tr>
<tr>
<td>C minus Ca</td>
<td>0.80 d</td>
<td>12</td>
</tr>
<tr>
<td>C minus P</td>
<td>0.76 d</td>
<td>11</td>
</tr>
<tr>
<td>C minus S</td>
<td>0.70 d</td>
<td>10</td>
</tr>
<tr>
<td>C minus Mg</td>
<td>0.66 a</td>
<td>10</td>
</tr>
<tr>
<td>C minus K</td>
<td>0.52 d</td>
<td>8</td>
</tr>
<tr>
<td>C minus N</td>
<td>0.36 d</td>
<td>5</td>
</tr>
</tbody>
</table>

1 C = root competition  
2 NC = no root competition

interference as the direct stimulation of one species by another in an association. The positive response of S. capitata to the minus N treatment under root competition suggests that nitrogen is stimulating the competitive ability of A. gayanus. Nitrogen fixed by S. capitata in the association should have the same effect thus explaining the cycle nature of grass and legume vigor observed in the older Carrmagua pastures.

**DISCUSSION**

The present concepts of maintenance fertilization although useful for many tropical forage associations need to be reviewed for cases such as the A. gayanus/S. capitata association where species differ greatly in growth habit and life cycle. The forage problem may arise with any association of strong perennial grasses with biennial or weak perennial legumes. Studies of the ecological interactions among species differing in their life cycles have shown that nutrient competition is always an important factor influencing botanical composition and pasture balance (Torsell 1973 and Smith & Kapoor 1979). Potassium may be the critical nutrient due to its extreme mobility and to the ability and strong tendency of grasses to absorb this nutrient far in excess of their needs.

Fertilizer rates needed to ensure vigorous development of seedlings in grazed pastures may well be much higher than those required for initial establishment in this case it may be useful to think in terms of banding maintenance fertilizers to selectively favor a few seedlings instead of broadcasting over the entire area. Since there are many more seedlings in second and third year stands than needed for stand maintenance it would suffice to provide favorable growth conditions for a small percentage of the total population.

For this to be effective planting pattern concepts also need to be reviewed. It seems logical to try to avoid the zone of maximum competition of a vigorous species like A. gayanus by increasing row spacing thus creating a more favorable environment for seedling survival. It may be possible to maintain the initial planting pattern over time by selective fertilization. These and other alternatives are presently under study at Carrmagua.

Improved pastures are by definition not equilibrium systems (Todhill 1978). There are two types of nutrient effects which may determine the failure of a species in an association. One is a direct negative effect resulting in deficiencies toxicities or the alteration of the relationship between nutrient uptake and/or translocation. The other is an indirect negative effect resulting from a positive effect on the associated species through modification of its morphology or chemistry. This in providing its competitive ability. A very delicate balance between these dynamic effects which are in turn affected by a diverse set of biotic and abiotic factors and by management determines the life span of an improved pasture association.

The problem of second generation seedling establishment in grazed pastures is of special importance in highly weathered soils of the humid tropics which are characterized by low cation exchange capacity almost complete lack of primary minerals as nutrients replacement sources and marginal to sub-marginal fertility status for most of the essential elements. Such soils are well adapted strongly per nitral species could accumulate most of the essential nutrients available in the soil in its biomass thus greatly inhibiting the establishment of seedlings which have very low competitive ability during a period of high nutrient requirements.

**REFERENCES**


PRODUCTIVIDAD ANIMAL Y MANEJO DE BRACHARIAR HUMIDICOLA (RENDEL) SCHWEICKT EN LA ALTILLANURA PLANA DE LOS LLANOS ORIENTALES DE COLOMBIA

Luis E. Tergas
Osvaldo Paladines
Ingo Kleinheesterkamp

INTRODUCCION

Brachiaria humidicola (Rendel) Schweickt es una especie de gramínea prometedora que ha inspirado a algunos investigadores y productores sobre todo en las regiones de suelos arenosos e inferiores tanto en las sabanas como en regiones de bosques. Sin embargo, no existen datos confiables acerca de su productividad animal. El objetivo de este trabajo es mostrar las limitaciones de B. humidicola en cultivo puro en cuanto a ganancias de peso logradas en condiciones de sabanas bien drenadas en la altillanura de los Llanos Orientales de Colombia (Salinas y Guadron 1982).

EVALUACIONES DE GANANCIAS DE PESO

En un experimento que se estableció en Camaguey, Llanos Orientales de Colombia en 1978 con Panicum maximum Andropogon gayanus Brachiaria decumbens y Brachiaria humidicola con una fertilización con 50 kg de P2O5, 50 kg de K2O 18 kg de MgO y 22 kg de S por hectárea, respectivamente, se logró un crecimiento de 100 kg de P2O5 se evaluó durante 2 años el comportamiento de novillos mestizos criollos Cebu de un peso promedio de 150 kg en pastoreo continuo con cargas variables de 1 y 2 novillos por hectárea para las estaciones seca y lluviosa respectivamente. Los promedios de ganancias de peso diario (Tabla 1) muestran que el comportamiento animal en B. humidicola fue inferior al de las demás gramíneas sobre todo durante la estación lluviosa. La cantidad de materia seca de hoja y tallo disponible se determinó en una muestra de forraje recolectada por 10 submuestras por hectárea de 1 m² cada una tomadas al azar cortadas a 10 cm de altura, seco al horno a 60°C por 24 h y separadas manualmente. El forraje ofrecido durante la estación lluviosa de 1979 (Tabla 2) fue más alto en B. humidicola que el de las otras gramíneas lo que no explica el comportamiento tan pobre de los novillos en pastoreo durante la mejor época de crecimiento del forraje. Asimismo, la baja producción animal en esta gramínea es inconsistente con los valores de digestibilidad encontrados.