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ESTABLISHMENT AND ADOPTION OF *BRACHIARIA BRIZANTHA/ARACHIS PINTOI* ASSOCIATIONS IN THE ATLANTIC ZONE OF COSTA RICA

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CENTRO AGRONOMICO TROPICAL DE
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GANADERIA DE COSTA RICA - MAG

Location of the study area.

PREFACE

General description of the research programme on sustainable Landuse.

The research programme is based on the document "elaboration of the VF research programme in Costa Rica" prepared by the Working Group Costa Rica (WCR) in 1990. The document can be summarized as follows:
To develop a methodology to analyze ecologicaly sustainable and economically feasible land use, three hierarchical levels of analysis can be distinguished.
1. The Land Use System (LUS) analyses the relations between soil type and crops as well as technology and yield.
2. The Farm System (FS) analyses the decisions made at the farm household regarding the generation of income and on farm activities.
3. The Regional System (RS) analyses the agroecological and socio-economic boundary conditions and the incentives presented by development oriented activities.

Ecological aspects of the analysis comprise comparison of the effects of different crops and production techniques on the soil as ecological resource. For this comparision the chemical and physical qualities of the soil are examined as well as the polution by agrochemicals. Evaluation of the groundwater condition is included in the ecological approach. Criterions for sustainability have a relative character. The question of what is in time a more sustainable land use will be answered on the three different levels for three major soil groups and nine important land use types.

Combinations of crops and soils

	Maiz	Yuca	Platano	Piña	Palmito	Pasto	Forestal I II III
Soil I	x	x	x		x	x	x
Soil II						x	x
Soil III	x			x	x	x	x

As landuse is realized in the socio-economic context of the farm or region, feasibility criterions at corresponding levels are to be taken in consideration. MGP models on farm scale and regional scale are developed to evaluate the different ecological criterions in economical terms or visa-versa.

Different scenarios will be tested in close cooperation with the counter parts.

The Atlantic Zone Programme (CATIE-AUW-MAG) is the result of an agreement for technical cooperation between the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), the Agricultural University Wageningen (AUW). The Netherlands and the Ministerio de Agricultura y Ganadería (MAG) of Costa Rica. The Programme, that was started in April 1986, has a long-term objective multidisciplinary research aimed at rational use of the natural resources in the Atlantic Zone of Costa Rica with emphasis on the small landowner.

PREFACE

This thesis consists of a description of a tropical pasture research as a part of my study Field Crops at the Agricultural University Wageningen. This graduate project has been carried out from January '92 until August '92 as a part of at the Atlantic Zone Programme, a joint research project by MAG, CATIE and the WAU, situated in Guápiles, Costa Rica.

I wish to thank my supervisor and dear friend Muhammad Ibrahim who has given me time and help in doing my research, with a pleasant atmosphere and an unforgettable spirit towards pasture research. Furthermore, I would like to thank prof.dr.ir. L. 't Mannetje for the supervision, the useful comments and the evaluation of this research, and dr. D.A. Pezo and drs. J.H. Neuteboom for the comments and pleasing support. In my research I had the pleasure to work with several farmers, and I would like to thank them for the hospitality and the practical information. The grassland section of the Atlantic Zone Programme, MAG and CATIE I am thankful because of the help during my research. The students, ticos and ticas, staff and employees of the Atlantic Zone Programme I am very grateful for making this stay in Costa Rica an interesting, worthwhile and enjoyable period of my study.

It is obvious that one thesis can not embrace the whole problem of animal production and pasture improvement technologies in the humid tropics, and it requires a lot of labour and energy to obtain structural improvement. I hope that this study can be useful to the introduction of new pasture technologies and further research, and I wish researchers all success in following studies.

André van Schaik

August, 1992

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SUMMARY

The objective of this study was to investigate and evaluate persistence of some grass-legume mixtures, as well as the adoption and production of grass-legume pastures in the Atlantic Zone of Costa Rica. Earlier studies and preliminary results from present studies have indicated the promising qualities of *Arachis pintoi* as a forage legume in humid regions in association with grasses like *Brachiaria brizantha*.

A pot experiment with *B. brizantha* and *A. pintoi*, cultivated in two soil types showed clear results with respect to the growth and development of the species in a juvenile phase. Both species showed a less vigorous germination, growth and development in a less fertile soil.

Persistence of *A. pintoi* in association with *B. brizantha* and *B. humidicola* under grazing was investigated in the PODYNUVA experiment. *B. brizantha* in association with *A. pintoi* showed a well balanced pasture after two years for both high and low stocking rates. *A. pintoi* dominated *B. humidicola*, in particular at a high stocking rate. Sexual reproduction plays a minor role in persistence, for the growth habit is strongly stoloniferous and a low amount of light is available for germination of legume seeds.

A considerable increase of dry matter production of *B. brizantha* in a *B. brizantha/A. pintoi* mixture could be obtained by using a narrow row distance (0.50 m), although it seemed to affect the growth of the accompanied legume. The fast growth of *B. brizantha* not only supressed the growth of *A. pintoi* but the occupation of weeds as well.

Although preliminary results from the PODYNUVA experiment and the introduction at farm level in some areas of the Atlantic Zone show promising results, observations in a region with specialized dairy production made clear that many facets with respect to the establishment of *B. brizantha/A. pintoi* associations and the management following establishment have to be investigated and validated. It is possible to obtain high quality fodder at a high production level when using grass-legume associations such as *B. brizantha* in combination with *A. pintoi*, but the performance of the pasture under less

favourable conditions is not clearly examined. More knowledge is required with regards to phytopathology, environmental stress, sowing methods, time of sowing and pasture grazing management.

1. INTRODUCTION

Animal production in tropical America

Most of the soils in the tropical American lowlands can be characterized as acid and infertile, which is one of the major constraints to agricultural development in these regions. Adaption of commercial cultivars of tropical pastures selected in other continents appears to be a serious problem, while negative biotic factors have been responsible for the failure of many introduced grasses and legumes (Toledo, 1985).

In tropical America the consumption of beef and milk is relatively high in comparison with other tropical regions, and the demand for animal products increases with the growing population. The principal constraint towards expansion of animal production in the marginal regions is the level of animal nutrition. The most efficient and economic way of animal production in these regions is by using pastures, however, both quality and quantity of native pastures are poor. With an increasing demand for animal products the adoption of new pasture technologies will increase and the need for pasture improvement technologies in tropical America seems to be obvious (CIAT, 1990).

Tropical forage production improvement

Forage production is a function of the forage species, the growing conditions and management. Most forage production in the tropics is based on unproductive species, low soil fertility, often low soil moisture and often over-utilization (too frequent cutting, too heavy stocking rates). Tropical forage production improvement is based on the provision of better species, particularly legumes and on the amendment of soil fertility. The practical technologies of this improvement can be carried out (1) by establishing grass pastures with NPK fertilization, (2) by introducing grass-legume mixtures, (3) by oversowing legumes in existing pastures and (4) by establishing monocultures of legumes and (5) fodder crops ('t Mannetje, 1992).

Nitrogen can be regarded as the most critical and important element for the productivity, stability, and persistence of pastures. Fertilization can give considerable increases of pasture yields and persistence, but in many tropical regions this technology is not profitable due to the high cost of fertilizers and the low animal return. Therefore the application of legumes that are adapted under low fertility levels can play an important role in low input forage production systems. The principal role of the legumes in grasslands is twofold: as a source of nitrogen and as high quality fodder. The fixed nitrogen can be transfered to the pasture (1) by dung and urine excreted by grazing animals, (2) by dying and dead plant material, below and above the ground and (3) by direct transfer of the N-fixing nodules. The use of better forage species leads to increased dry matter yields and better quality herbage in terms of digestibility and protein content. The secondary production of improved pasture will be increased because of a higher carrying capacity and is better expressed in higher reproductive rates and higher growth rates ('t Mannetje, 1989).

As forage production improvement implies an intensification of the production system, dairy production systems are more available for the new technologies than beef production systems. Dairy production for the liquid milk market is mostly based on assured incomes with more certain prospects towards future developments of prices and outlets than beef production systems. Uncertainty of prices and income are less favourable conditions to investments into pasture improvement. Therefore, the objective of pasture improvement should be based on newly developed cultivars and management practices that increase production in the most efficient way, at the lowest possible cost, which gives sustainable production, without undue damage to the environment ('t Mannetje, 1989). Only with this *low-input philosophy* new technologies will have a high adoption potential by cattle farmers (Toledo, 1985).

One of the critical factors of the introduction of grass-legume associations is the persistence of the species in the pasture. The combination of growth characteristics of the species and management factors can modify the botanical composition of grass-legume associations. Sustainability of the pasture is related to the species composition and the population dynamics, and depends mostly on the persistence of legumes in the pasture. The maintenance of an adequate density of legumes in grass-legume associations is related to the rates of recruitment of new individuals and to the survival rate of existing individuals (Jones & Carter, 1989; 't Mannetje, 1989). Toledo (1985) emphasizes the importance of the grass-legume balance and cover in the sward towards the persistence and productivity of pastures in humid environments where the leaching potential is high and available nutrients are low and strongly dependent on effective nutrient recycling. In contrast to drier regions, the high content of legumes in established pastured in humid or subhumid tropics could create problems. The lack of a dry period or drought, when legumes are well grazed, could increase the density of the legume which could lead to dominance of the legume and suppression of the associated grass. Adequate grazing management and stocking rates could provide a balance in the grass-legume pasture, animal output, degree of nutrient cycling and persistence of the sward.

Status of animal production in Costa Rica

Costa Rica is one of the few countries of Latin America which is self-sufficient in the production of milk as well as an exporter of milk to neighbouring countries. After 1940 the animal production of Costa Rica increased rapidly, and at this moment the economic value of beef and milk are third on the list of agricultural products, after coffee and bananas (SEPSA, 1991), with the principal production areas in San Carlos in the North Huetar Zone, Cartago, Heredia and San Isidro in the Central Zone of the country. In the Atlantic Zone two farming systems for milk production can be found: (1) specialized milk production systems, concentrated in Rio Frio, and (2) a dual-purpose (beef and milk) farming systems (Aragón, 1992). The low animal production in the Atlantic Zone is mainly caused by poor nutrition derived from grazing native and naturalized grasses and selected grasses without legumes or fertilizers (Ibrahim et al., 1993).

Study objective

Various studies have been published concerning the role of improved pastures in the humid tropics (Villarreal & Chávez, 1991, Lascano & Avila, 1991; Grof, 1985a & 1985b; Rocha et al. 1985) and especially with respect to the Atlantic zone of Costa Rica (Vallejos, 1988; Roig, 1989; CIAT, 1990 & 1991; Giraldo Valderrama, 1991), recommending the use of improved grasses in association with legumes. Since 1989 a study has been carried out to evaluate the performance of legume-grass mixtures under grazing conditions, with emphasis on population dynamics and nutritive value of the pasture. Preliminary results of this study are partly published or are to be published in the near future

(CATIE, 1991; Pezo and Ibrahim, 1992; Ibrahim et al, 1993). Furthermore, field studies have been carried out by CATIE with respect to the development of the dairy production in the parts of the Atlantic Zone including the introduction of improved pastures (CATIE, 1991).

The objective of this study was to investigate and evaluate persistence of some grass-legume mixtures, as well as the adoption and production of grass-legume pastures in the Atlantic Zone of Costa Rica. Earlier studies and preliminary results from present studies have indicated the promising qualities of *Arachis pintoi* as a forage legume in humid regions in association with grasses like *Brachiaria brizantha*. This study will discuss various aspects of growth and development of these species, as well as the establishment, management and future prospects of the grass-legume mixture. The study has been carried out at the Experimental Station "Los Diamantes" in Guápiles and on farm level in Rio Frio, both situated in the Atlantic Zone of Costa Rica, from January until August of 1992.

In Chapter 2 general characteristics of *A. pintoi* and *B. brizantha* are briefly described, followed by investigations of growth and development of both species in two soil types in Chapter 3. Persistence and population dynamics of established grass legume mixtures of *A. pintoi* with *B. brizantha* and *B. humidicola* are discussed in Chapter 4. The following chapter discusses a field experiment concerning pasture production and legume persistence of a *B. brizantha/A. pintoi* association. Chapter 6 covers a description of grass-legume management aspects and problems and limitations for the introduction and adoption of grass-legume associations in the Atlantic Zone.

2. DESCRIPTION OF SPECIES

This chapter describes two promising species for legume based pasture improvement in the humid tropics; the legume *Arachis pintoi* and the grass *Brachiaria brizantha*. Information of the described plant characteristics are obtained by previous research references.

2.1 Arachis pintoi

Arachis pintoi is one of the small genus of *Arachis* L., containing about 22 described species and perhaps more than 40 undescribed species of tropical and subtropical herbs in South America (Norman et al., 1984). *A. pintoi* first was collected and described in 1954 by G.C.P. Pinto in Brazil (Grof, 1985a) and has recently become known for its qualities as a tropical forage legume. Since its collection, it has been distributed to Argentina, Colombia and Australia, and more recently to many countries in South-East Asia, Central America and the Pacific (Cook, 1992). Other forage legumes of the *Arachis* genus are *A. glabrata* and *A. monticola* (Skerman, 1977).

A. pintoi is a perennial, prostrate legume with a stoloniferous growth habit. Leaves are large, quadrifoliate and dark green (Grof, 1985a). The difference between *A. pintoi* and other tropical legumes is the ability to produce a great number of rooting stolons, creating a mattress of stolons and leaves covering the ground. The stolons may reach a length of 1 meter consisting many rooted points which can create new individual plants. For growing points are well protected from grazing, the legume is highly tolerant of defoliation and will stand heavy stocking rates. The plant shows an indeterminate inflorescence, flowering plants can be found throughout the year, and the plant is able to build up a sufficient seed reserve in the ground. These characteristics make *A. pintoi* an ideal type of legume to persist in pastures under grazing. (CIAT, 1990 & 1991; Grof, 1985a & 1985b; Roig, 1989). Its dense structure and high degree of shade tolerance makes *A. pintoi* a suitable legume as a ground cover in orchards and banana plantations (Oram, 1990).

A. pintoi persists well in areas with equally distributed precipitation, with dry periods of no longer than four months. During periods of insufficient precipitation the growth of the plant is retarded. Research of CIAT (1990 & 1991) showed that a reasonable part of the total leaf area of the plants will be decreased under these conditions. However, results from recent investigations of CIAT (1991) with *A. pintoi* in pots showed that the plant maintains a reasonable part of the leaf area during a dry period. In those periods *Rhizoctonia* may affect the stolons, causing weakened or dead plants (CIAT, 1990). During long periods with high precipitation, and in particular during inundations, leaves may turn yellowish (chlorotic), which can be associated with toxic levels of iron in the plant tissues (CIAT, 1990 & 1991).

The establishment of *A. pintoi* appears to be rather difficult, in particulary when using vegetative material as seed material (CIAT, 1991). In general, the first two years show a slow development, with many yellowish and weakened plants (CIAT, 1990). The legume shows a slow nodulation in the first months after establishment (Grof, 1985a & 1985b).

From experiments with *B. brizantha* as a single crop pasture and in association with *A. pintoi* Giraldo Valderrama (1991) determined a significant higher availability of biomass and a higher crude protein content for the associated grass. The increase of animal production was higher for the associated grass. A. pintoi is tolerant of heavy grazing and is not shaded out by taller grasses (Cook, 1992). Preliminary results of recent investigations show a well established balance of *B. brizantha* in association with *A. pintoi* after more than two years (Pezo & Ibrahim, 1992; Ibrahim et al., 1993).

2.2 Brachiaria brizantha

The species *Brachiaria brizantha*, belonging to the family of Gramineae, has its origin in tropical Africa and is distributed in many tropical countries. The genus *Brachiaria*, with about 80 described species, is well adapted to acid soils with low fertilization and a wide range of different climates. *B. brizantha* is well adapted to tropical regions below an altitude of 1800 m with a precipitation between 1000 and 3500 mm per year. The species is fairly drought tolerant but will not tolerate flooding (Giraldo Valderrama, 1991; Skerman & Riveros, 1990).

In comparison with other *Brachiaria* species, *B. brizantha* grows rather tall, with a relatively low leaf/stem ratio (CIAT, 1990). The growth habit of the species is semi-erect reaching a height of 0.8 to 1.5 m, with few rooted points at the nodes and short horizontal rhizomes (Giraldo Valderrama, 1991).

From cutting experiments in the tropical rain forest climate of Guápiles Vallejos (1988) showed a six months dry matter production of more than 4 ton DM per hectare, while Giraldo Valderrama (1991) showed a production of 4.5 ton DM per hectare of a single *B. brizantha* sward and a significant positive effect of the associated legume Arachis pintoi on dry matter yield. However, cutting experiments may give other results than grazing experiments. The nutritive value of *B. brizantha* can be considered between moderate and high, compared to other species of the genus *Brachiaria* and considering the voluntary intake, palatability, digestibility and chemical composition.

B. brizantha cv. Marandú CIAT 6780 shows a high resistance to spittle bug and other diseases (*Aeneolamia* sp., *Prosapia* sp., *Deois* sp., *Zulia* sp.), which often creates important damage to forage grasses in the humid tropics (Vallejos, 1988). This cultivar was selected as one of the promising cultivars for the humid tropics, in particular the Atlantic Zone. This selection was based on its biomass production, leaf/stem ratio, nutritive value and tolerance to insects and diseases. Important attributes of *B. brizantha* are its productiveness, drought resistence, ability to spread and suppress weeds, and its ability to grow in shade. Its low seed production and the tendency to produce a monospecific sward can be regarded as its main deficiencies (Skerman & Riveros, 1990).

3. GROWTH AND DEVELOPMENT IN A JUVENILE PHASE OF A. PINTOI AND B. BRIZANTHA CULTIVATED IN TWO SOIL TYPES

3.1 Introduction

As grass-legume associations consist of two different types of plants with different growth patterns and habits, the complexity of compounding mixtures for sowing increases, as well as the requirement for accurate management following establishment (Crowder and Chheda, 1982). The first months of establishment seems to be of relevant importance to the occupation and basal cover of the two species, which has an vital influence on the establishment and persistence in the following years. For that reason it is important to obtain and compare basic information of growth and development of the species.

In a small pot experiment, growth and development of *Arachis pintoi* and *Brachiaria brizantha* in the first two months after sowing were investigated.

3.2 Methods and material

The experiment was situated at the Experimental Station of the Ministry of Agriculture of Costa Rica (MAG) in Guápiles. In this experiment two soil types were used: (a) soil of "Los Diamantes", Guápiles, close to the PODYNUVA experimental site and (b) soil of Rio Frio, close to the experiments described in chapter 5. The soils are characterized by a rather high content of organic matter (>10% from 0-10 cm), and a high rate of P fixation. Both the content of organic matter as well as P fixation are expected to be higher in the Los Diamantes soil. The Los Diamantes soil is regarded as a more fertile soil, although clear soil analyses should be made to validate this statement. Values of pH for Rio Frio and Los Diamantes soils are 4.6 and 5.6, respectively. The texture of the Rio Frio soil can be considered as clay loam, for the Los Diamantes soil consist of a more sandy clay texture.

Sexual seeds of *B. brizantha* cv Marandu CIAT 6780 and *A. pintoi* CIAT 17434 were used, with 6 replications per treatment (2*2*6=24 pots). The seeds were planted in plastic pots (10 liters) at three spots per pot (triangular), each spot containing three seeds (9 seeds per pot). Seeds of *B. brizantha* and *A.*

pintoi were planted at about 1 and 2 cm below ground level, respectively. In the first month of the experiment, during a period of minimal precipitation, water was applied daily. No fertilizers nor chemicals were applied.

Regularly (4 - 6 days), seedlings emergence, number of leaves, stolons, tillers and flowering were counted. Random samples of two pots per treatment were taken at 28, 42 and 56 days after sowing. *B. brizantha* was examined by determining the green and dry matter weight of shoots and roots, the number of leaves and tillers, and height. *A. pintoi* was examined by measuring the green and dry matter weight of shoots and roots, the number of leaves and stolons, stolon length, number of (initiated) flowers and pegs, and the number of nodules. Height of *A. pintoi* was not measured because of the prostrate growth habit of the legume with varying leaf positions during the day.

3.3 Results and discussion

3.3.1 Germination

Emergence of the first seedlings were counted and are presented as germination rates in figures 3.1 and 3.2.

In general, *B. brizantha* showed a proper germination after 28 days of 85% and 74% for the Los Diamantes and Rio Frio soils, respectively. The date of 50% seedling germination could be estimated at 6 days after sowing for the Los Diamantes soil, and 12 days for the Rio Frio soil. In contrast with *B. brizantha*, *A. pintoi* showed a slow germination. After one month only 31% and 40% of the seeds germinated for the Rio Frio and Los Diamantes soil respectively. The slower germination of the legume in comparison with the grass may partly be due to the size and hardness of the seeds. For *A. pintoi* has rather big seeds including a nut shell and *B. brizantha* small seeds without shell, seeds of the grass have the advantage to make better contact to soil moisture to initiate germination. The shell of the legume seeds can be regarded as a form of hardseededness, as many legumes have as a natural protection for long term survival of the species in nature (Skerman, 1977; 't Mannetje, 1989). *A. pintoi* has a high level of seed dormancy and some treatment (drying of seed at 35 - 40°C) could be considered to break the dormancy and to increase the percentage of germinable seed (Cook, 1992).

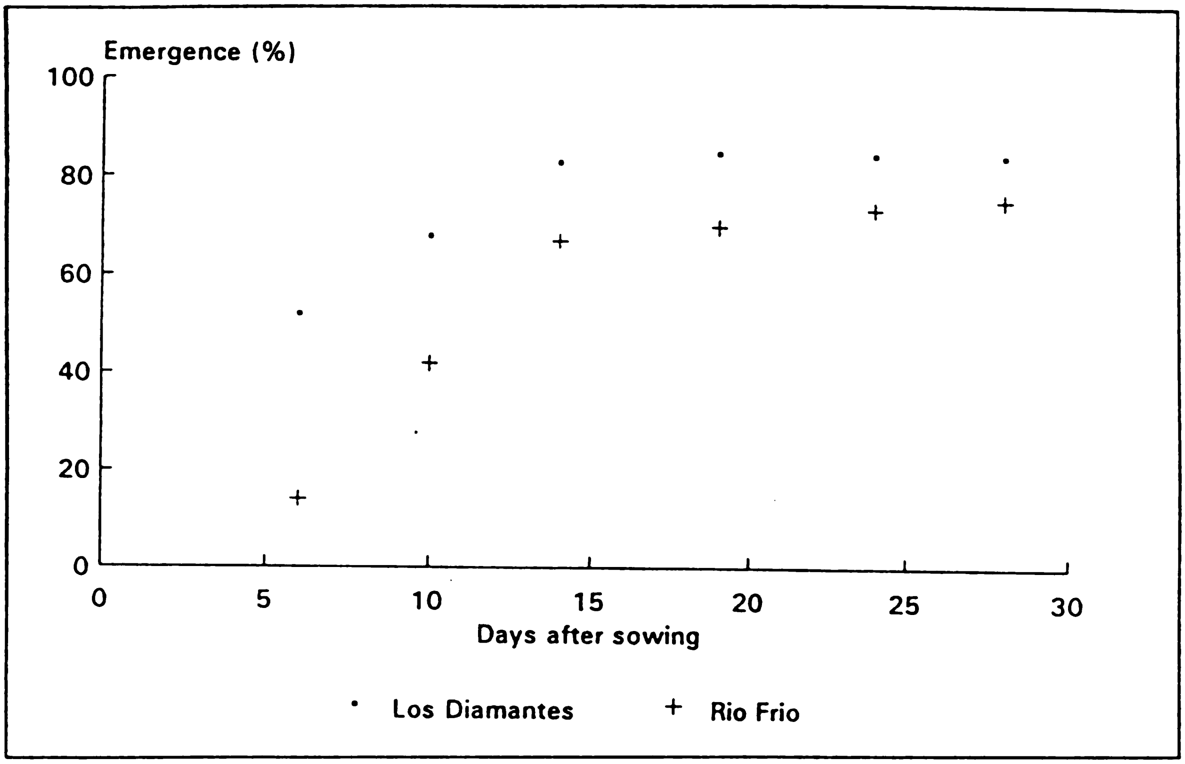

Fig. 3.1: Percentage of germination in time for B. brizantha, cultivated in two soil types.

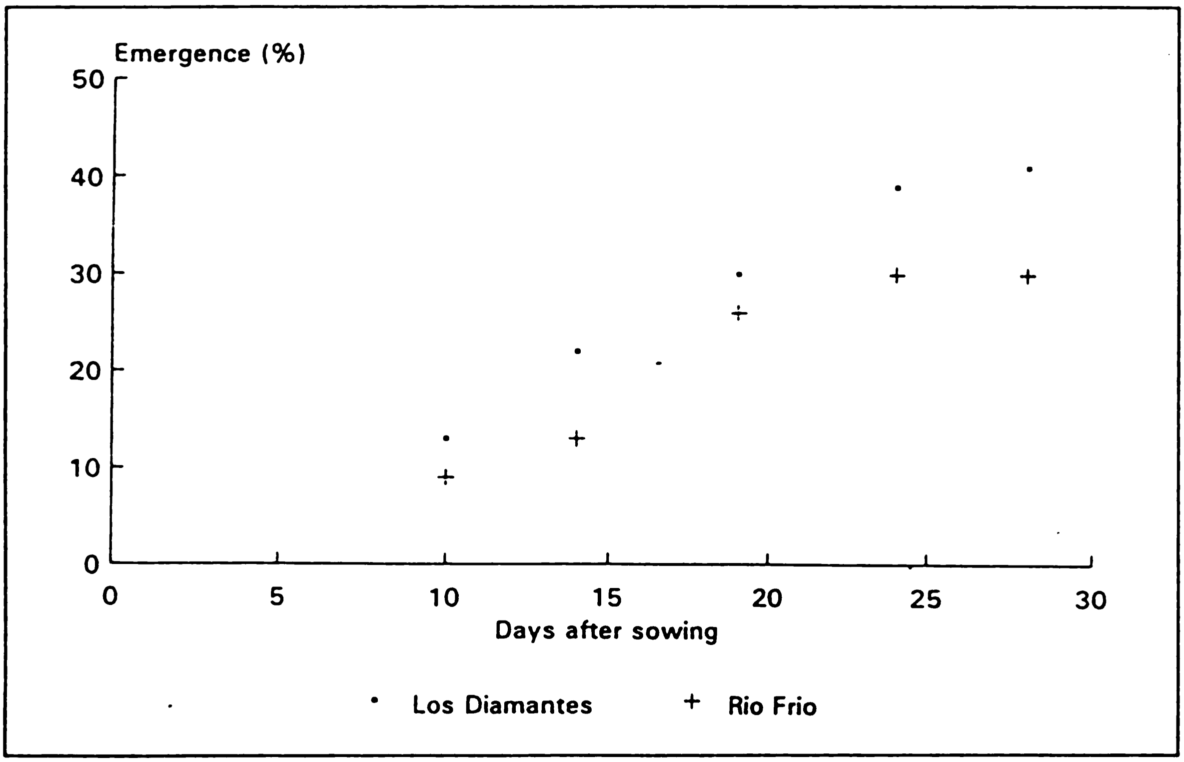

Fig. 3.2: Percentage of germination in time for A. pintoi, cultivated in two soil types.

Crowder and Chheda (1982) emphasize the importance of counting seedling germination as it can contribute to a better understanding of the later development of sward and persistence of the species. A rapid rate of seed germination is often beneficial to field establishment (Humphreys, 1978). From the presented experiment it can be concluded that the seedling emergence of *B. brizantha*, and to a lesser degree *A. pintoi*, can be affected by unfavourable soil conditions or poorer soils.

3.3.2 Dry matter production

Dry matter weights of legume shoots and roots during seedling growth may be used as criteria of legume seedling vigour (Crowder and Chheda, 1982). Comparing the dry matter production in the pot experiment, no significant difference could be determined between the two soil types, nor between legume and grass. Dry matter production of the two species in two soil types are presented in figures 3.3 and 3.4 for areal parts and roots respectively. Eight weeks after sowing, older leaves appeared chlorotic and this presumably was attributed to leaf ageing and senescence.

The shoot-root ratio showed a tendency to decrease in B. *brizantha*. In the first weeks after emergence, the plants produced a greater portion of areal parts to enhance photosynthetic activity, followed by a period of extended root growth to increase water and nutrient uptake and sink activities. A higher soil fertility may have a positive effect on the shoot-root ratio. In general the shoot-root ratio of grasses is higher than for legumes, as grasses show a higher efficiency of N-uptake with higher soil fertility (CIAT, 1991). Shoot-root ratios in this experiment are presented in table 3.1.

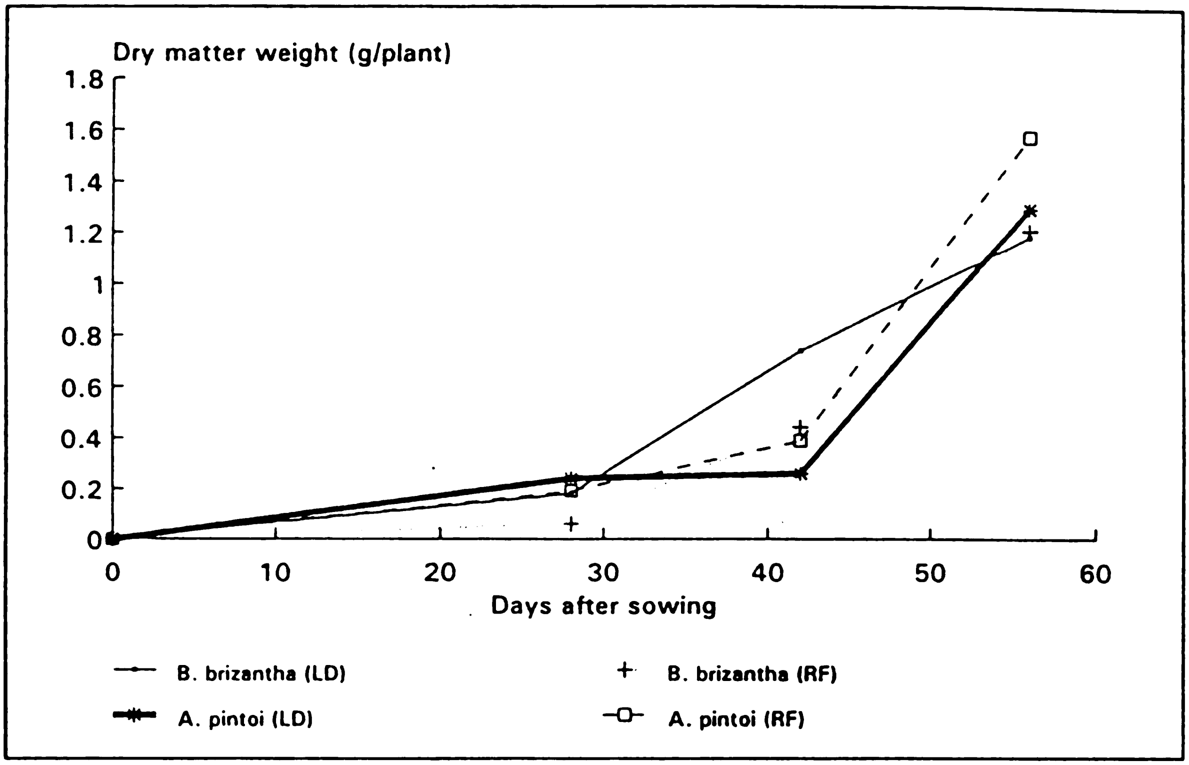

Fig. 3.3: Dry matter production of areal parts of B. brizantha and A. pintoi, cultivated in two soil types.

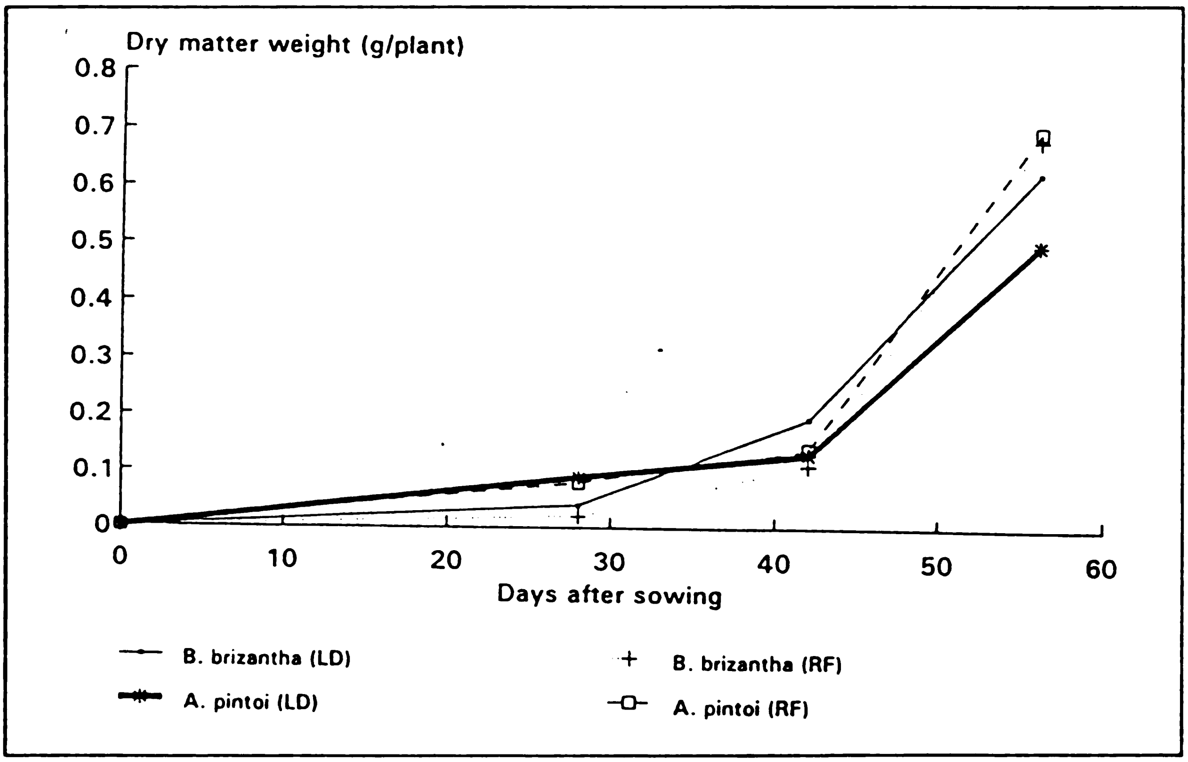

Fig. 3.4: Dry matter production of roots of B. brizantha and A. pintoi, cultivated in two soil types.

Table 3.1: Shoot-root ratio on dry weight basis of *B. brizantha* and *A. pintoi* for two soil types (Rio Frio, Los Diamantes) within two months after sowing.

Days after sowing	Shoot/Root ratio			
	B. brizantha		*A. pintoi*	
	Rio Frio	Los Diamantes	Rio Frio	Los Diamantes
28	2.9	4.3	2.6	3.3
42	3.9	3.9	2.7	2.0
56	1.7	1.9	2.3	2.6

The calculated shoot-root ratios in this experiment do not show significant differences (< 5%) between the two soil types, nor between the species. It has to be mentioned that the data of the first measurement -after 28 days- were less accurate than later measurements, for the weight of the juvenile plants was scant which may cause relatively high deviations.

3.3.3 Height of B. brizantha

Besides the dry matter yield, height of the pasture can be another useful measurement to compare species and treatments (Leach et al., 1976). In figure 3.5 the development of height of *B. brizantha* in time is shown. After one month, a significant difference (<5%) was found between the two soil types: *B. brizantha* in the more fertile Los Diamantes soil grew taller immediately after emergence, but after 42 days there were no differences. The height of the grass may be an important factor with respect to the interception of light and the competition with weeds. The more vigorous growth in the Los Diamantes soil, presumably caused by the higher soil fertility, could offer a significant headstart to the grass. However, the growth and vigour of weeds in the two soil types and the comparison with *B. brizantha* have not been investigated, and weeds as well as *B. brizantha* may take advantage of the better qualities of the Los Diamantes soil. The height of the pasture in the first month is of less importance with respect to the growth of *A. pintoi*. Under field conditions, A.pintoi and *B. brizantha* usually are planted in rows with approximately 40 cm between the two species. Competition usually does not occur in the first month

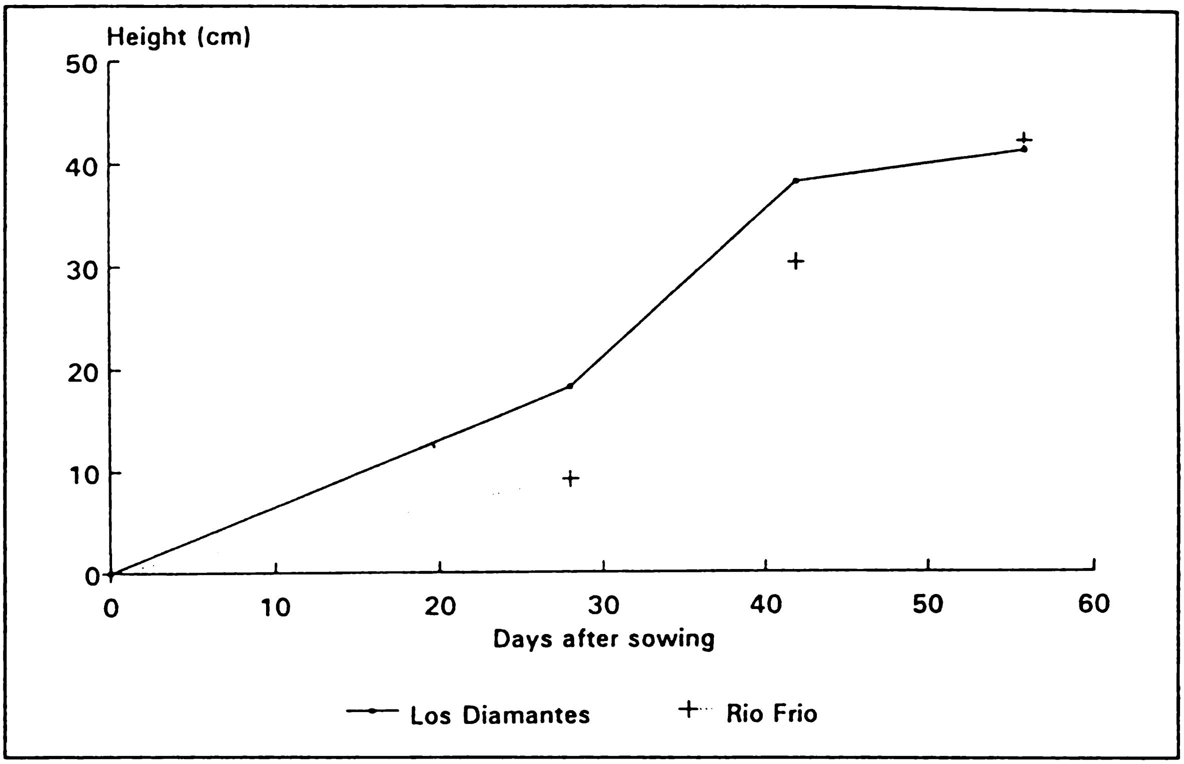

Fig. 3.5: Height of B. brizantha, cultivated in two soil types.

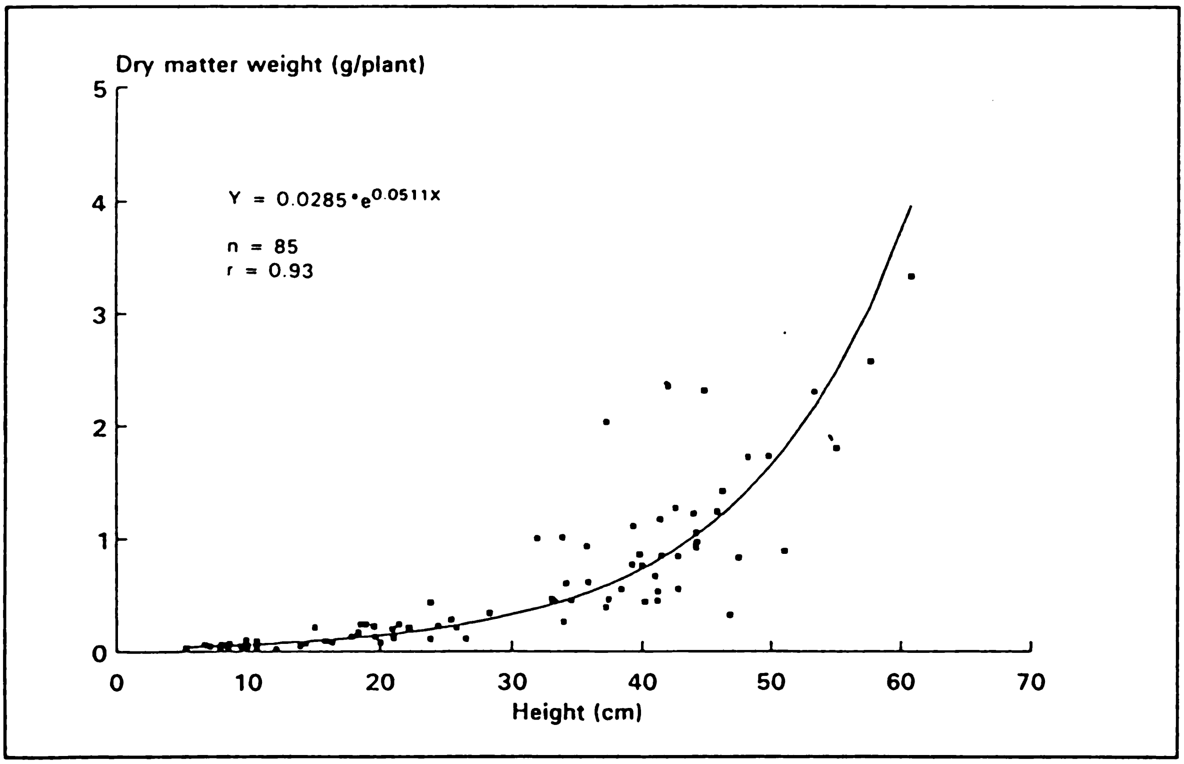

Fig. 3.6: Relation between height and dry matter weight of areal parts of individual plants of B. brizantha.

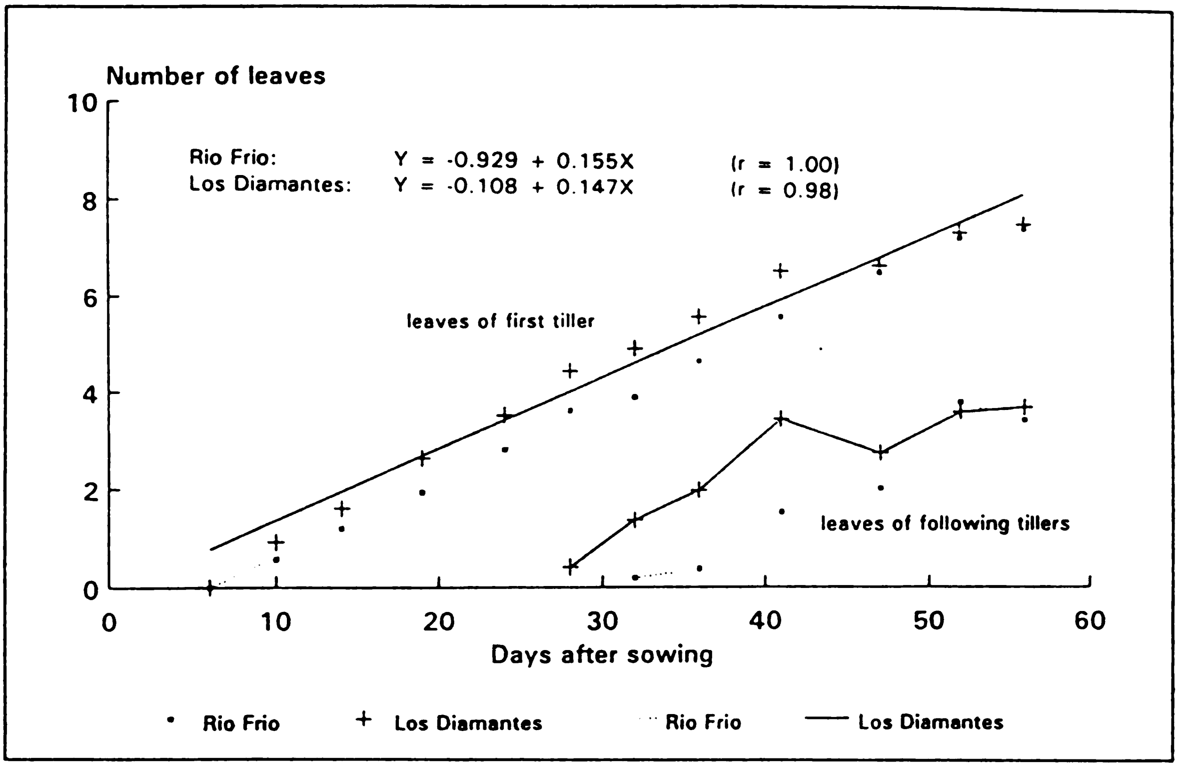

Fig. 3.7: Leaf appearance of B. brizantha, cultivated in two soil types.

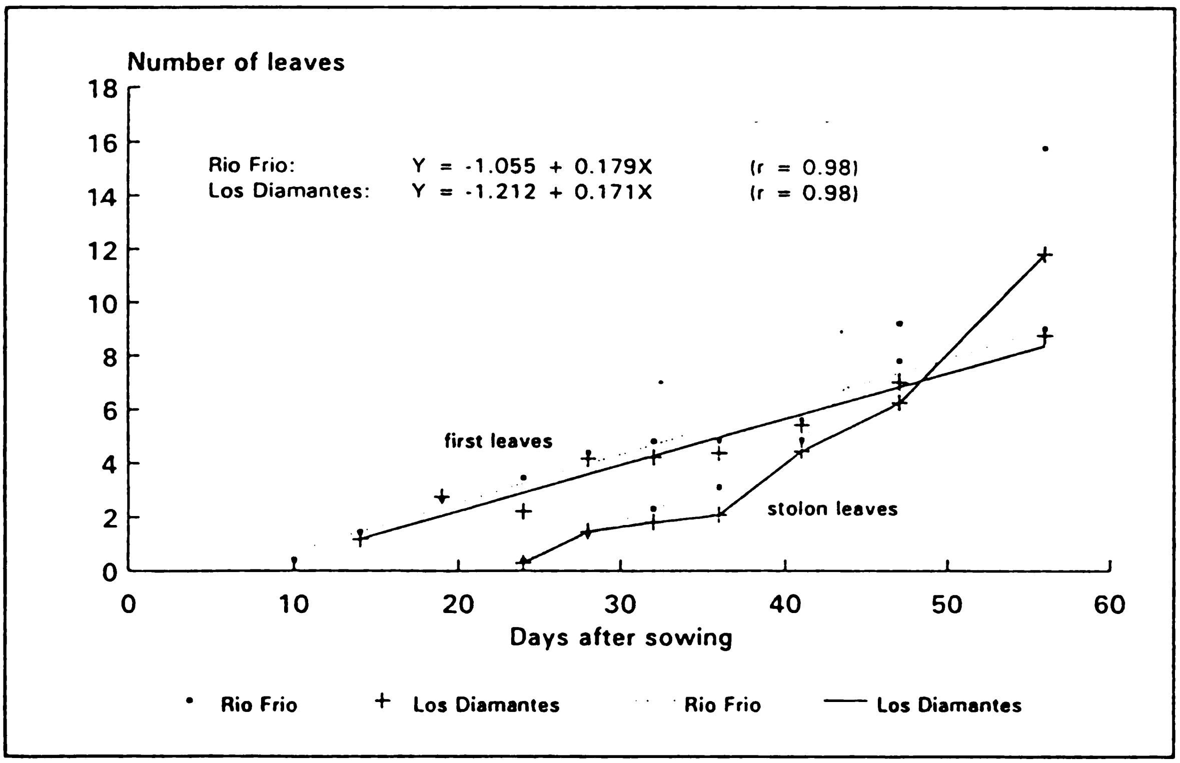

Fig. 3.8: Leaf appearance of A. pintoi, cultivated in two soil types.

after sowing, because the species are not influencing each other.
The weight of areal parts of the grass appeared to be highly correlated ($r = 0.93$) to the height of individual plants (Fig. 3.6). In the calculated equation the correlation between the two variables is shown. This equation can possibly be used in further research to estimate dry matter production. This exponential correlation is expected to change its shape in time; after a certain moment the production of dry matter will decrease and the semi-erect growth habit will reduce the height as the grass will lodge at a certain height. Therefore, the equation should only be used in the exponential stage of growth, within a period of two months after sowing.

3.3.4 Leaf appearance

Leaf appearance is one of the measurements which can be of relevant importance to compare the growth and development of different species under various conditions (Cooper & Tainton, 1968). The number of leaves of the first and following tiller/stolon leaves of individual plants were counted 12 times and presented in figures 3.7 and 3.8.

Leaf appearance rate of *B. brizantha* was linear, as Crowder and Chheda (1982) also described. The comparison between the regression coefficients for the two soil types did not show a significant difference (<5%), which signifies an equal leaf appearance in time for both soil types. From the linear regression equations can be calculated that the first leaf appears at 7.5 and 12.4 days after sowing for the Los Diamantes and Rio Frio soil respectively. These differences are caused by the earlier germination of seeds in the Los Diamantes soil.

The rate of appearance of leaves of *A. pintoi* was also linear (Fig. 3.8). No significant difference was found between the leaf appearance rates in the two soil types. It may be noticed that *A. pintoi* produced more leaves at the stolons than *B. brizantha* at the following tillers.

3.3.5 Tillering of B. brizantha

One of the major characteristics of many grasses to colonize the available ground surface is the ability to extend the number of stems by developing tillers. The tiller is the basic vegetative unit of grasses, and tiller number and

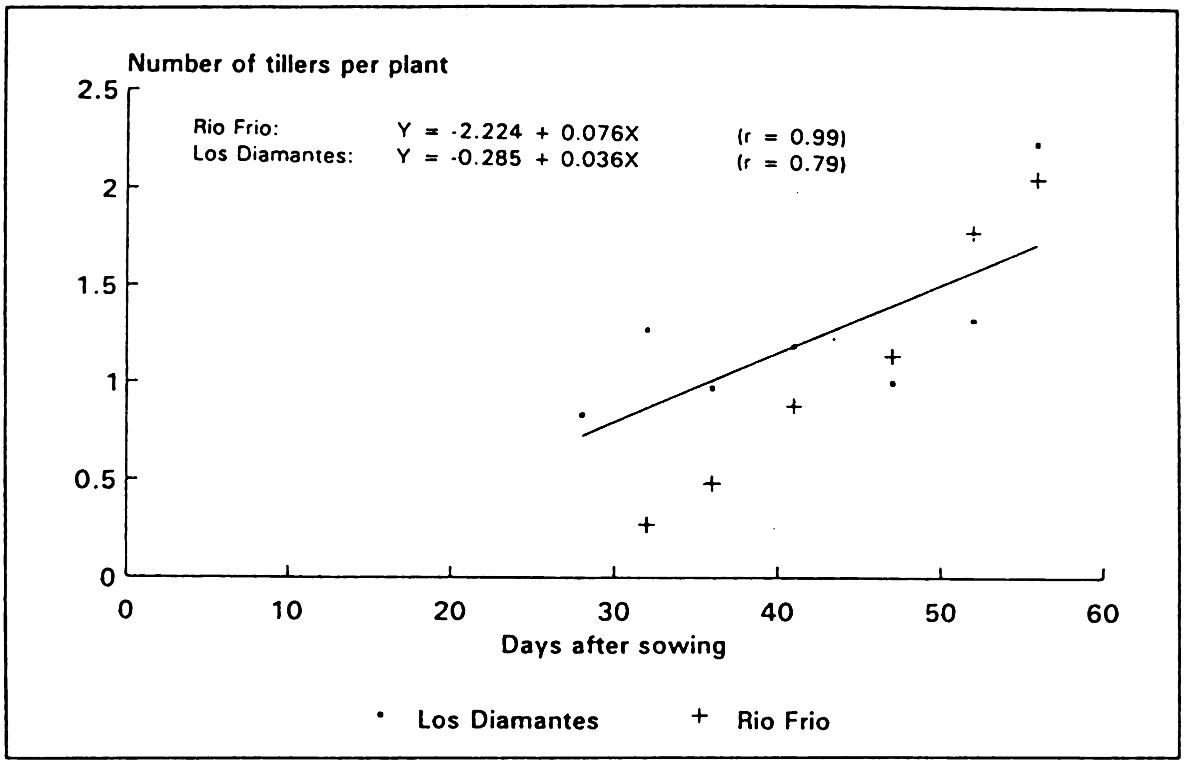

Fig. 3.9: Tillering of B. brizantha, cultivated in two soil types.

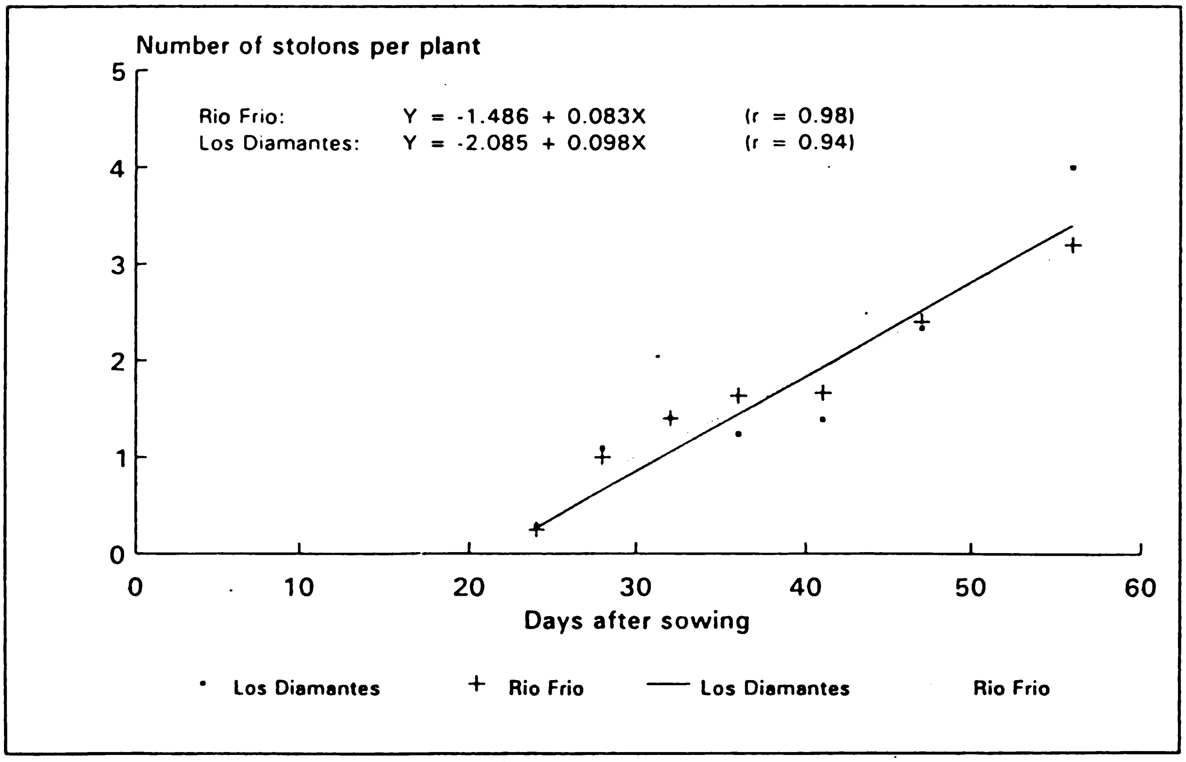

Fig. 3.10: Stolon growth of A. pintoi, cultivated in two soil types.

size can be relevant to analyze grass growth (Ludlow, 1976; Leach et al. 1976). In this experiment, number of tillers per plant was counted and presented in figure 3.9.

In general tillering of *B. brizantha* started with the appearance of the fifth leaf and two tillers are formed within a short time. Data of tillering for the Rio Frio soil indicated a clear linear regression (r = 0.99), with a calculated first date of tillering of 42 days after sowing, 30 days after emergence. Tillering in Los Diamantes soil showed a less clear linear regression (r = 0.85), and a reliable estimation of tillering in time is less secure. Hence, seedlings in Rio Frio soil seemed to show a slower tillering, which may be caused by the slower germination rate. After two months, the number of tillers of *B. brizantha* appeared to be equal for both soil types.

3.3.6 Stolon growth and stolon development of A. pintoi

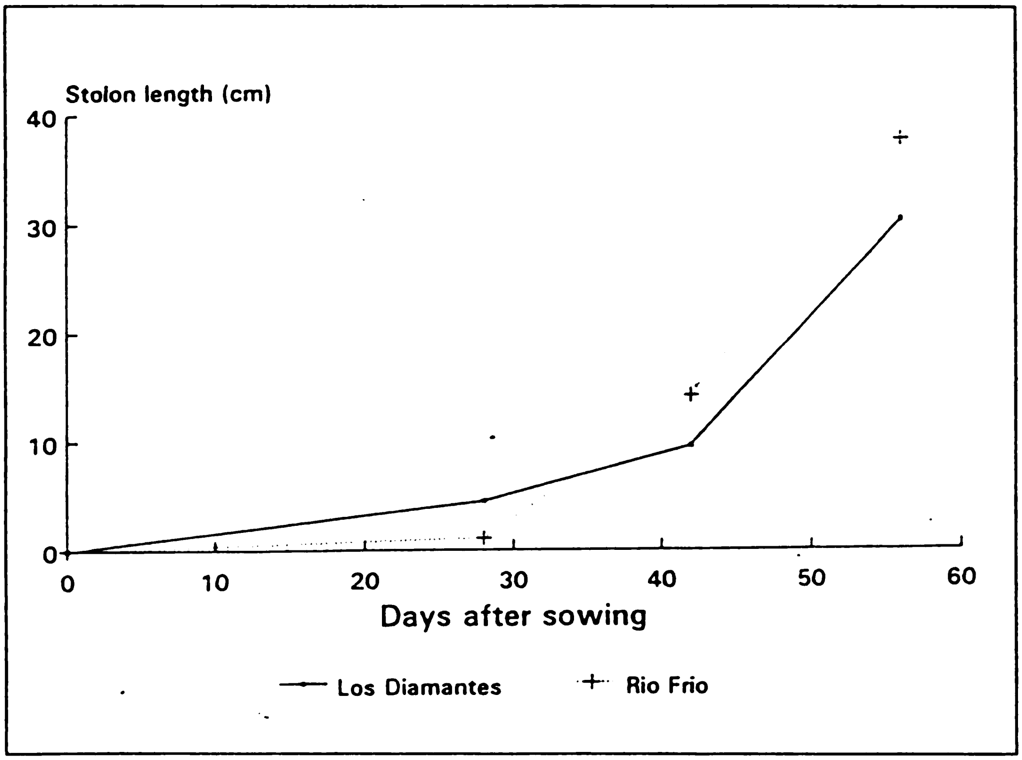

Fig 3.11: Stolon length of A. pintoi, cultivated in two soil types.

The emergence of the first stolons took place with the appearance of the fourth or fifth leaf, and two stolons were formed almost at the same time. The next two stolons were formed with the appearance of the eighth or ninth leaf. Stolon growth is presented in figure 3.10.

The emergence of the first stolons, calculated from the equations, showed 30 days for Rio Frio soil and 31 days for Los Diamantes soil. The total length of the stolons per plant (fig. 3.11) showed a slight difference between the two soil types: plants in Rio Frio soil seemed to have shorter stolons, but showed a faster growth in the next four weeks. Rooted points at the stolons were found sporadically and only after two months. Experiments covering a longer period of time could give more relevant information about the formation of rooted points at stolons.

3.3.7 Nodulation of A. pintoi

Similar to the nodulation of *Arachis hypogaea* (groundnut), *A. pintoi* produces nodules on both tap roots and lateral roots. The nodules are roundish, approximately 2 mm in diameter and can be found individually or clustered in groups. The counted nodules are presented in table 3.2.

Table 3.2: Number of nodules per plant of *A. pintoi* within two months after sowing for two soil types (Rio Frio, Los Diamantes).

Days after sowing	# nodules per plant	
	Rio Frio	Los Diamantes
28	10.0	19.2
42	30.0	26.4
56	111.7	114.5

The absence of significant difference between the number of nodules of the two soil types suggest that soil fertility has a minor effect on the nodulation. Although these measurement were taken in the earliest stages of development and nodulation will expand in time, it appears that the first considerable formation of nodules of *A. pintoi* takes place after about two months.

During the three measurements at 28, 42 and 56 days after sowing, cross sections of about 10 nodules per soil type were made to determine effective nodulation. In the first two measurements an indistinct brownish colour of the substance inside the nodule was observed, but after two months a reddish pink colour was determined. This colouring of the nodules after two months was caused by the presence of legheamoglobin, and characterizes the effectiveness of the nodules to fix nitrogen.

3.3.8 Flowering and seed production of A. pintoi

First flowering of *A. pintoi* was observed at 28 days after sowing, generally after the appearance of the sixth leaf. This date of flowering can be compared to the better known species of the *Arachis* genus *Arachis hypogaea*, which shows an emergence to first flowering between 27 and 37 days after sowing (Norman et al., 1984). An individual flower of the *A. pintoi* shows a longevity of one day.

Similar to the *A. hypogaea*, *A. pintoi* produces a long stalk, called the 'peg', which carries the ovary into the soil to a depth of about 5 cm (Cobley, 1976). Pegging of *A. pintoi* was determined at a few plants at the last measurement, after 56 days. Emergence to the first pegging could roughly be estimated at about 50 days after sowing. This date is comparable to the date of peg emergence of the *A. hypogaea*, which creates pegs between 40 and 60 days after sowing (Norman et al., 1984).

3.4 Conclusions

Regarding the results of the various measurements it can be concluded that the less fertile and more acid soil of Rio Frio may cause a less vigorous growth and development of both *B. brizantha* and *A. pintoi* in the juvenile phase in comparison with the Los Diamantes soil. Comparing the performance of *B. brizantha* in the Rio Frio soil with the more fertile soil of Los Diamantes it was noticed that rate of emergence, leaf appearance and tillering were higher in the more fertile soil. *A. pintoi* germinated slower than *B. brizantha* in both soil types. The differences between the two soils did not have a significant effect on the emergence and growth of stolons of *A. pintoi*, nor on the initiation of nodulation. Differences between species or soils with respect to dry matter weight were not significant. Soil fertility may have an important effect on growth and development of a *B. brizantha/A. pintoi* mixture, for different rates of vigour may affect the establishment of the pasture, the balance between the two species, and the competition with volunteer species. Soil acidity could also be an important factor in this experiment, as retarded growth and development in the Rio Frio soil may be related to the more acid soil. More detailed studies with regards to soil fertility, acidity and growth of the plants are required to validate these conclusions.

4. PERSISTENCE OF A. PINTOI IN ASSOCIATION WITH B. BRIZANTHA AND B. HUMIDICOLA UNDER GRAZING

4.1 Introduction

One of the most critical aspects of the introduction of grass-legume associations is the persistence of the species in the pasture. The combination of growth characteristics of the species and management factors can modify the botanical composition of grass-legume associations. Sustainability of the pasture is related to the species composition and the population dynamics, and depends mostly on the persistence of legumes in the sward. The maintenance of an adequate density of legumes in the pasture is related to the rates of recruitment of new individuals and to the survival rate of existing individuals.

In 1989 a joint grassland research project of MAG, CATIE, CIAT and WAU started in the Atlantic Zone of Costa Rica, called the PODYNUVA project (Population Dynamics and Nutritive Value). The main objective of this study was to gain a better understanding of the mechanisms by which legumes survive under grazing in association with grasses. The second objective was to gain information on the yielding ability and the nutritive value of the grasses and legumes in the study. The PODYNUVA study will continue until the end of 1992.

This chapter will discuss a part of the PODYNUVA project, with emphasis on population dynamics and persistence of legumes in grass-legume associations.

4.2 Methods and material

The study took place at the Experimental Station "Los Diamantes" of Guápiles (N10°13', W83°46') at 250 m above sea level on a soil of volcanic origin of medium to high fertility (pH 5.6). The mean annual precipitation is 4435 mm (Appendix I), with relatively dry months from January until March, a mean temperature of 25°C (min. 19.5°C, max. 30.5°C), and a relative air humidity of 87%. The experiment consists of a split-plot design with main factors containing two grasses (*B. brizantha* cv Marandú CIAT 6780 and *B. humidicola* CIAT 6369), three legumes (*A. pintoi* CIAT 17434, *Centrosema macrocarpum*

CIAT 5713 and *Stylosanthes guianensis* CIAT 184) and two stocking rates (1.75 and 3.00 AU/ha, liveweight between 220 and 300 kg) with two replications. A rotational grazing system was used as subfactor with five days grazing followed by 30 days rest on paddocks of 947 m^2 with 1.75 AU/ha and 657 m^2 with 3.00 AU/ha. The species were sown in September, 1989 with the grasses planted vegetatively on a 1.0*0.5 m grid, and the legumes in between. *S. guianensis* and *C. macrocarpum* were sown by using sexual seeds, while *A. pintoi* was sown with fresh stolon material. The study described in this thesis will only discuss some measurements at *A. pintoi* in combination with both *B. brizantha* and *B. humidicola*. Results of grazing cycles before cycle 21 were obtained by analyzing unpublished data of M. Ibrahim.

Botanical composition was estimated before and after each grazing cycle by using the dry-weight-rank method ('t Mannetje & Haydock, 1963). Grids of 0.25 m^2 were used in these measurements, with 50 and 60 samples per small and large plot, respectively.

Stolon length of *A. pintoi* was measured by cutting the areal parts covered by in a cylinder (length 10 cm, diameter 7.5 cm) sampling 8 transect spots per plot, with 5 subsamples. Stolon length, number of rooted points and root size were determined.

Two measurement were taken to determine light penetration in the canopy before and after grazing for *B. brizantha*/*A. pintoi* and *B. humidicola*/*A. pintoi* associations. The percentage of light interception was determined at 0.5 m above ground level and at ground level for *B. brizantha*/*A. pintoi* and only at ground level for *B. humidicola*/*A. pintoi* plots, because of the lower growth habit of the grass. Thirty measurements were taken from the large plots, 20 from the small plots.

4.3 Results and discussion

4.3.1 Botanical composition

The botanical composition, based on dry matter weight of the two *Brachiaria*/*A. pintoi* mixtures with two stocking rates are presented in figures 4.1 - 4.4.

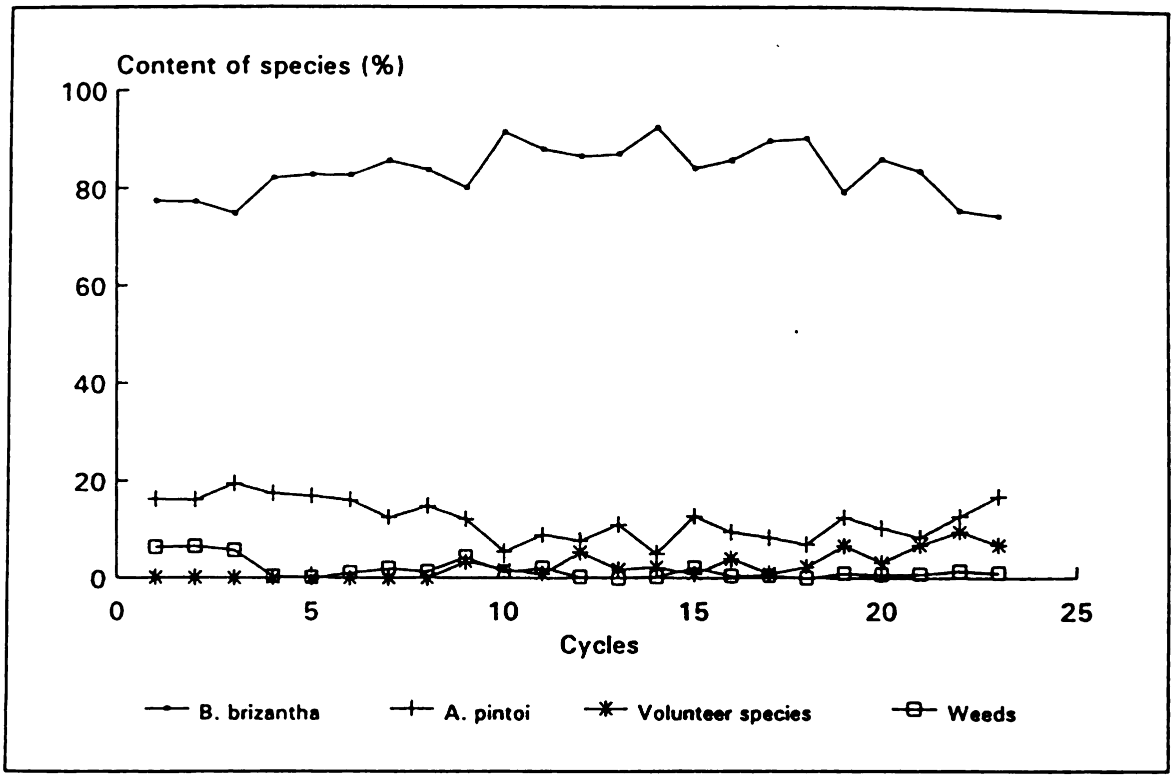

Fig. 4.1: Botanical composition of a B. brizantha/A. pintoi mixture, grazed at a low stocking rate.

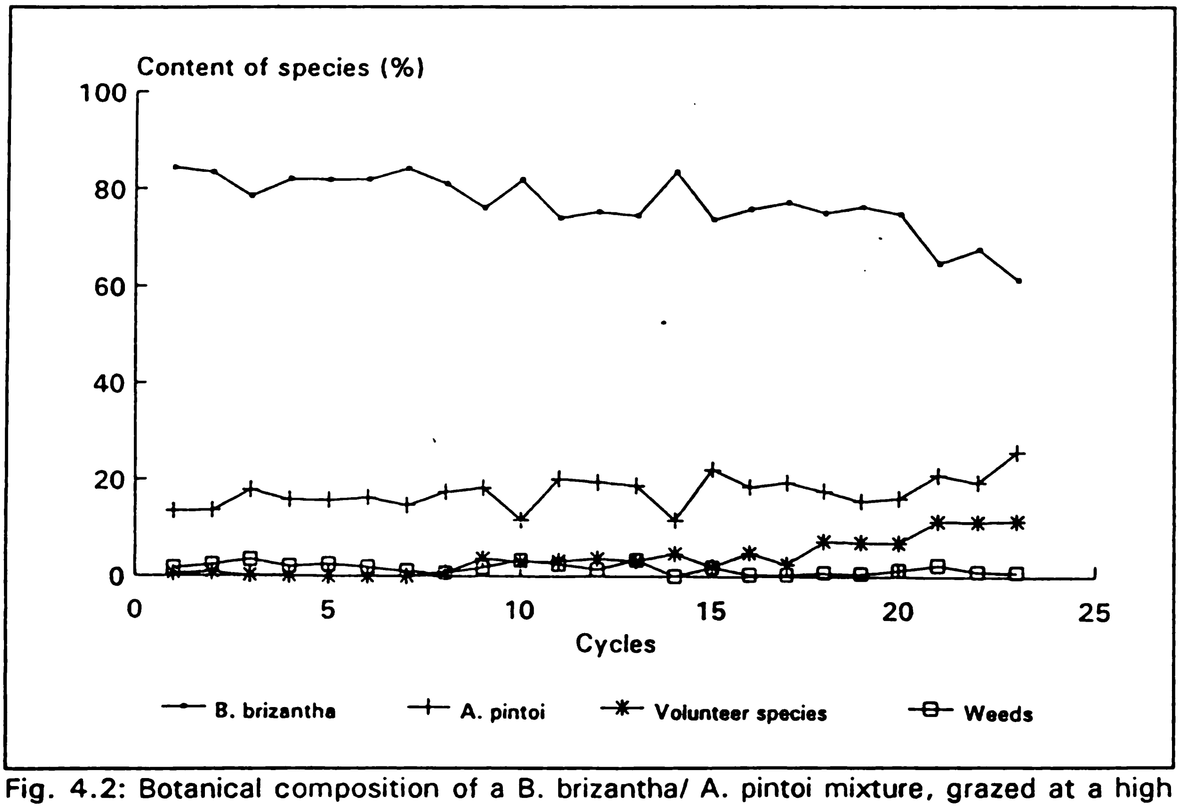

Fig. 4.2: Botanical composition of a B. brizantha/ A. pintoi mixture, grazed at a high stocking rate.

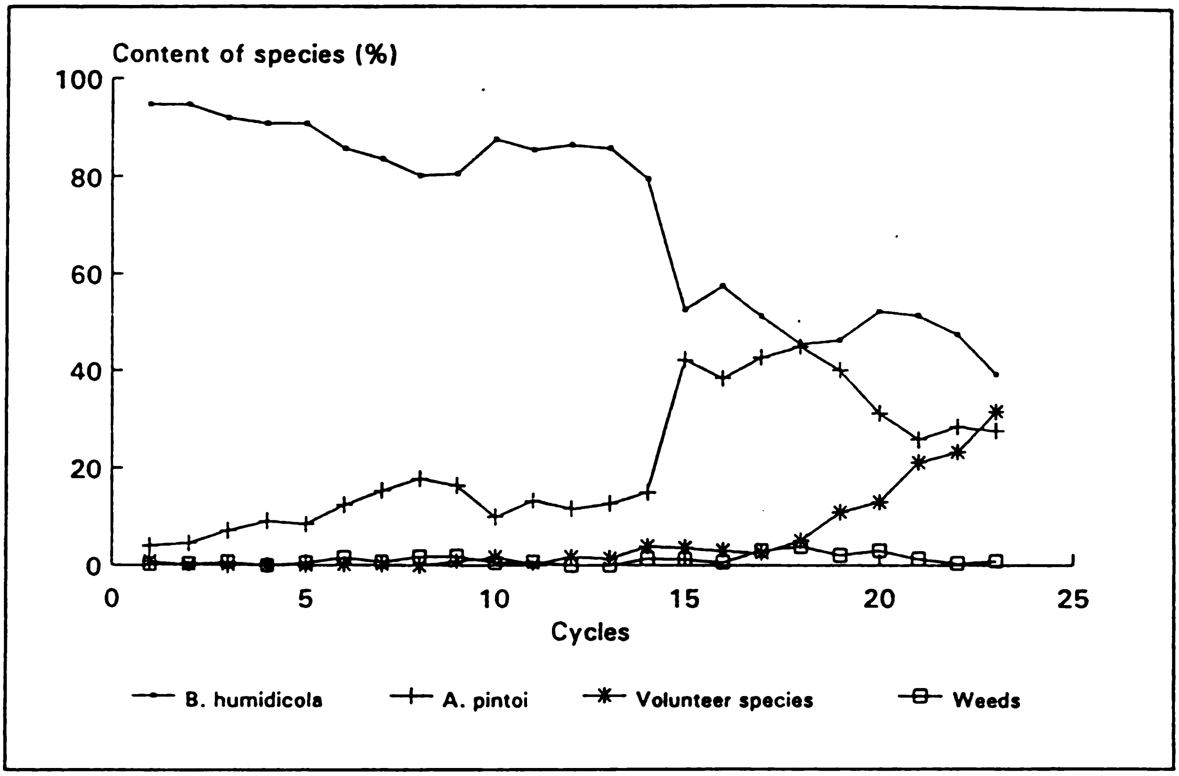

Fig. 4.3: Botanical composition of a B. humidicola/A. pintoi mixture, grazed at a low stocking rate.

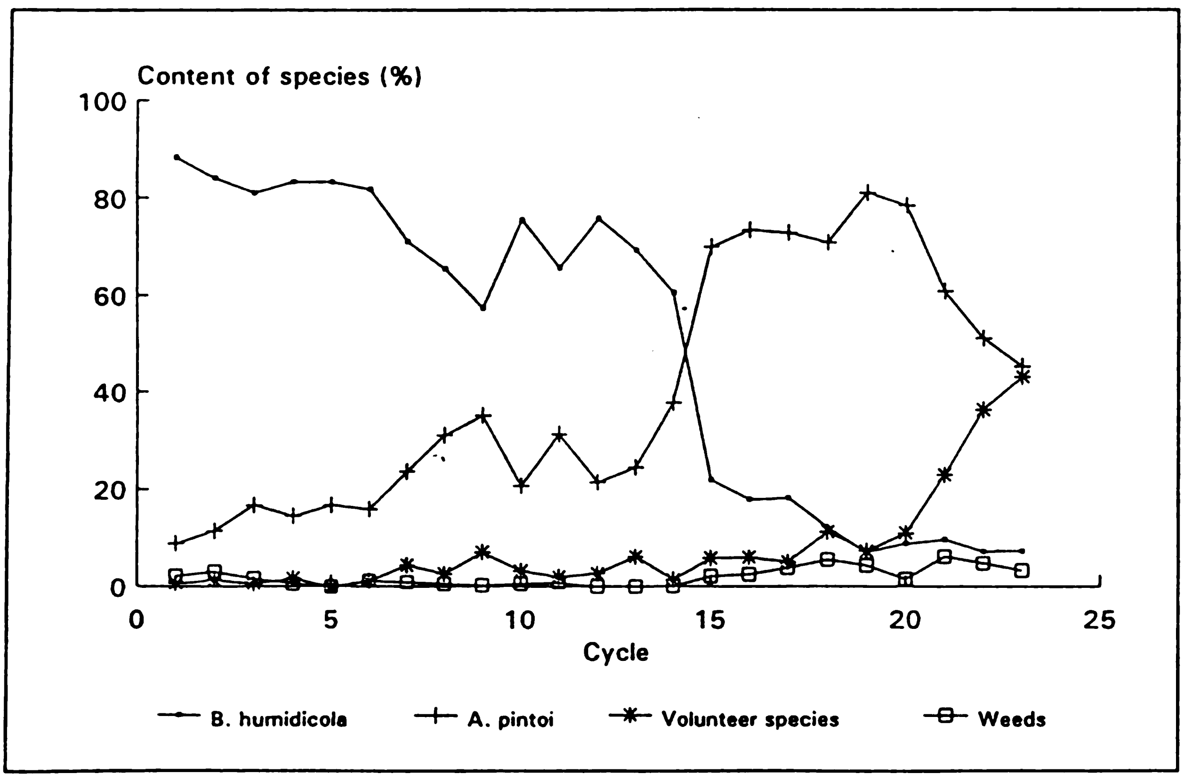

Fig. 4.4: Botanical composition of a B. humidicola/A. pintoi mixture, grazed at a high stocking rate.

The results from the estimations of botanical composition showed clear differences between the *B. brizantha* mixture and the *B. humidicola* mixture. *B. brizantha* in association with *A. pintoi* showed a more constant amount of *B. brizantha*, although the high stocking rate tended to decrease the content of *B. brizantha* in the last five months. The legume content in this mixture was low (5% - 16%) but stable with the low stocking rate and tended to increase up to more than 25% with the high stocking rate. These results contrast sharply with the tendency of decrease of grass content in the *B. humidicola* mixtures. The pasture was established with a *B. humidicola* content of more than 90%, but showed a drastic decrease with time. After 23 cycles the content of *B. humidicola* was less than 40% with the low stocking rate and 7% with the high stocking rate. Notable is the relatively high decrease after cycle 14. The decrease of *B. humidicola* in the sward was accompanied by a considerable increase of legume content for both stocking rates. The legume content with the low stocking rate increased from 4% to 28%, with a maximum of 40% in cycle 18. The legume content with the high stocking rate showed even a more drastic tendency with an increase from 9% in cycle 1 to 81% after 19 cycles. The next cycles showed an decrease of legume content to 45% in cycle 23.

Remarkable is the increase of volunteer species in *B. humidicola* mixtures, whilst the content of volunteer species in *B. brizantha* mixtures stayed rather low (< 10%). The unpallatable *Paspalum fasiculatum* was determined as the dominant volunteer species in *B. humidicola/A. pintoi* mixtures with a content of 32% and 43% for low and high stocking rate respectively, mainly increased in the last five cycles. The weed population hardy exceeded 5% for both *B. brizantha* and *B. humidicola* mixtures.

In general it can be noted that a well balanced grass-legume mixture can be obtained with *B. brizantha/A. pintoi* associations under grazing for both low and high stocking rates, with a low amount of volunteer species and weeds. High stocking rates even favour the content of the legume, which can increase to 25%. The aggressive growth habit of *A. pintoi* may dominate *B. humidicola* and allows volunteer species to extend in the sward, in particularly under heavy grazing.

4.3.2 Stolon length and root characteristics

Stolon length and the number of rooted points can be regarded as important indications of legume occupation and persistence in a legume based pasture. Vegetative reproduction is an important mechanism of persistence, especially in humid regions, where flowering and seed banks probably play a minor role. Under favourable conditions, grazing can promote stolon rooting, and seasonal grazing pressure can influence stolon growth and rooting (Humphreys, 1991). Table 4.1 shows the length of stolons, as well as the number of rooted points in three classes of diameter. Analyses of variance are presented in Appendix II.

Table 4.1: Stolon length and root characteristics of *A. pintoi* cultivated with *B. brizantha* and *B. humidicola* at two stocking rates (1.75 and 3.00 AU/ha)[a].

	B. brizantha		*B. humidicola*	
	1.75 AU/ha	3.00 AU/ha	1.75 AU/ha	3.00 AU/ha
Stolon length (m/m^2)	105	162	146	189
Rooted points (m^{-1})	29.6	32.4	36.8	38.2
Root size:				
< 4 mm	26.2	28.6	33.3	35.3
4 - 12 mm	3.2	3.7	3.2	3.4
> 12 mm	0.2	0.1	0.1	0.1

[a]Average of two replications.

Table 4.1 presents clear results with respect to the differences between the growth of stolons under high and low stocking rates ($P<0.01$). *A. pintoi* showed a higher stolon density under high stocking rate, probably due to the less denser sward which could have favoured the growth of *A. pintoi*. The higher number of rooted points ($P<0.05$) and length of stolons ($P< 0.05$) in *B. humidicola* swards may be related to the structure of the pasture, which permitted a more prostrate growth habit of *A. pintoi* than the growth habit of the legume in a *B. brizantha* sward. In the relatively higher canopy of *B. brizantha*, *A. pintoi* tended to raise its stolons up to approximately 40 cm. It is obvious that these stolons will produce less rooting points than stolons close to the soil. Apart from the difference with the small roots (< 4 mm), no differences of root sizes were encountered with *A. pintoi* in the two grasses. The results from table 4.1 may be regarded as an indication for the aggressiveness of *A. pintoi* in the legume based pasture, which is of relevant importance for legume persistence. The aggressiveness of *A. pintoi* contrast sharply with growth habit of a number of legumes, in particularly the trailing and erect types like *Centrosema macrocarpum, Centrosema pubescens, Pueraria phaseloides* and *Stylosanthes* sp., which tend to disappear in pastures especially under heavy grazing (Crowder & Chheda, 1982). The excellent persistence of *A. pintoi* under grazing conditions was also documented in experiments in Carimagua, Colombia (CIAT, 1990). Grof (1985a) found increased dry matter production with associations of *A. pintoi* in *B. humidicola* and *B. dictyoneura*, and the composition of the legume was greater than 20% in the two associations.

4.3.3 Light interception

Radiation is an important factor with respect to the growth and development of plants. In a mixture of two different species, one species can reduce growth of the accompanied species by overshadowing it. Particularly in the first stage of establishment this could be an important factor for limiting growth and reduced occupation of the soil of the legume in the sward. Reduction of available light may also be significant to the germination rate of legume seeds, which is an important factor for persistence of legumes in a sward (Humphreys, 1991). Considering the differences between the prostrate growth habit of *A. pintoi* and the erect growth of *B. brizantha*, light extinction in the sward could be of relevant importance to the establishment of the pasture. Dense sown swards of *B. brizantha* can reduce the light interception for *A. pintoi* and disfavour the occupation of the legume. *B. humidicola* shows a less erect growth habit and a higher leaf/stem ratio compared to *B. brizantha*, and might permit a different growth of *A. pintoi*. Table 4.2 presents the results of light penetration measurements in the swards. Appendix II shows the results of analyses of variance of these measurements.

Table 4.2: Light penetration at two heights of an *A. pintoi* pasture in association with *B. brizantha* and *B. humidicola* with two stocking rates, before and after grazing[a].

	Stocking rate (AU/ha)	Light penetration (%)		
		B. brizantha		*B. humidicola*
		0.5 m	ground level	ground level
Before grazing	1.75	72.7	2.0	1.5
	3.00	87.5	1.2	1.3
After grazing	1.75	80.2	5.7	5.3
	3.00	92.7	6.6	11.9

[a]Average of two replications.

With regards to the *B. brizantha/A. pintoi* mixtures, no significant (P>0.05) differences could be determined between stocking rates nor after or before grazing. Strict conclusions with respect to light penetration at ground level may not be drawn because of the high coefficients of variation. However, the tendency seems to be clear that after grazing, the light penetration was higher, especially with higher stocking rates. In general it can be mentioned that the interception of light in a *A. pintoi* mixture was relatively high, for less than two percent of the light was still available at ground level. After grazing, the amount of light at ground level tended to increase, which may be important for light interception by soil seeds. Although *B. brizantha* has a higher and more erect growth habit and plots with *B. humidicola* showed many spots with only *A. pintoi*, it did not show clear differences in light penetration in the sward. This may be due to the dense strata of *B. humidicola* tussocks and mats of *A. pintoi*. The two species of the *B. humidicola/A. pintoi* mixture were more separately located in the sward, whilst *A. pintoi* was rather well mixed with *B. brizantha* in the sward.

The low amount of available light for germination may imply a miner role of sexual regeneration in the pathways of persistence in *A. pintoi* associations. Vegetative regeneration will dominate the sexual regeneration considering the strongly stoloniferous growth habit of the legume.

4.4 Conclusions

This experiment shows a well balanced grass-legume mixture of *B. brizantha* in association with *A. pintoi*, in particularly under heavy grazing where the legume content could increase up to 25%. The ability to produce a large number of stolons with many rooted points allows *A. pintoi* to tolerate high stocking rates. Sexual reproduction plays a minor role in persistence, which is underlined by the low amount of available light for seedling germination in the dense swards. This growth characteristic also prevents weed populations to increase. The aggressive and strongly stoloniferous *A. pintoi* dominated *B. humidicola* under both low and heavy grazing, accompanied by a considerable occupation of volunteer species.

5. ESTABLISHMENT OF A B. BRIZANTHA/A. PINTOI ASSOCIATION CULTIVATED AT THREE ROW DISTANCES

5.1 Introduction

A few years ago CATIE started to encourage beef cattle and dairy farmers to adopt improved pastures in their farming systems. Considering the low economic value of the animal production, it was the objective to introduce a pasture with low inputs and high sustainability. The results of the PODYNUVA experiment and earlier investigations showed that a mixture of *B. brizantha* and the legume *A. pintoi* can give good results on poor soils with low fertilizer inputs. At this moment, several farmers in the Atlantic Zone have sown this grass-legume association with technical and financial support of CATIE. However, a large-scale adoption of the improved pasture is restricted by several limiting factors. This includes establishment, management (e.g. stocking rate and grazing frequency, plant density, seed distribution) and financial aspects (e.g. financial risks, investment restrictions and extension service).

During several observations in the Rio Frio region it appeared that various row distances are being used to sow the pasture, with often different periods of time between the sowing of the legume and the grass. As the pasture consists of two different types of plants with different growth habits, growth and botanical composition of the pasture may vary in time when using different ways of sowing and management. The establishment of the pasture in the first months after sowing can affect the growth and development of both grass and legume. To achieve a well balanced and well established pasture, the distances between the rows and the management following establishment are of important relevance to the success of the pasture in the next years.

An experiment has been carried out to investigate the introduction and adoption of improved pastures at farm level, with emphasis on the first stage of growth; the earliest months of establishment. In this experiment the effect of row distances on yield and botanical composition of the pasture will be discussed.

5.2 Methods and material

The experiment was situated at Rio Frio, a region between N10°20'and N10°22', W83°53' and W83°55' at an elevation between 100 m and 150 m above sea level. The average daily temperature is 25.4°C (min.: 21.0°C, max.: 29.7°C) and an average air humidity of 88%. Annual precipitation is about 4000 mm with February and March as relative dry months. The monthly precipitation in the Rio Frio region of the first four months of 1992 is presented in Appendix I. Generally, the region can be characterized as plain land, consisting the two soil types Utisoles and Inceptisoles, with a pH of 4.6, a high capacity of P fixation and a clay-loam texture.

A. pintoi CIAT 17434 was established in association with *B. brizantha* cv Marandú CIAT 6780. The grass was sown at three distances: 0.50 m, 0.75 m and 1.0 m. Between the rows the legume was sown by planting vegetative bundles of *A. pintoi* at distances in the rows of about 0.6 m. Each treatment was established in 56 m^2 plots and arranged in a completely randomized block design with two repetitions. No fertilizers nor chemicals were applied during the time of experiment.

Samples of the pasture were taken 4, 8 and 12 weeks after emergence (10 days after sowing). Yield samples were taken by cutting $3*1m^2$ per plot, randomly chosen, at 3 cm above ground level. The first sample contained $4*1m^2$ per plot. Immediately after cutting the samples were separated into *B. brizantha*, *A. pintoi* and weeds, and weighed. Subsamples were taken to determine the dry matter content and dry matter production (70°C, 48 hours).

Two months after sowing, light measurements were taken to investigate the light penetration in the swards. Eight samples per plot were taken, at two heights in the sward (0.50 m and at ground level).

5.3 Results and discussion

5.3.1 Dry matter production

Dry matter production of *B. brizantha*, *A. pintoi* and weeds are presented in figures 5.1, 5.2 and 5.3. Dry matter contents of *B. brizantha*, *A. pintoi* and

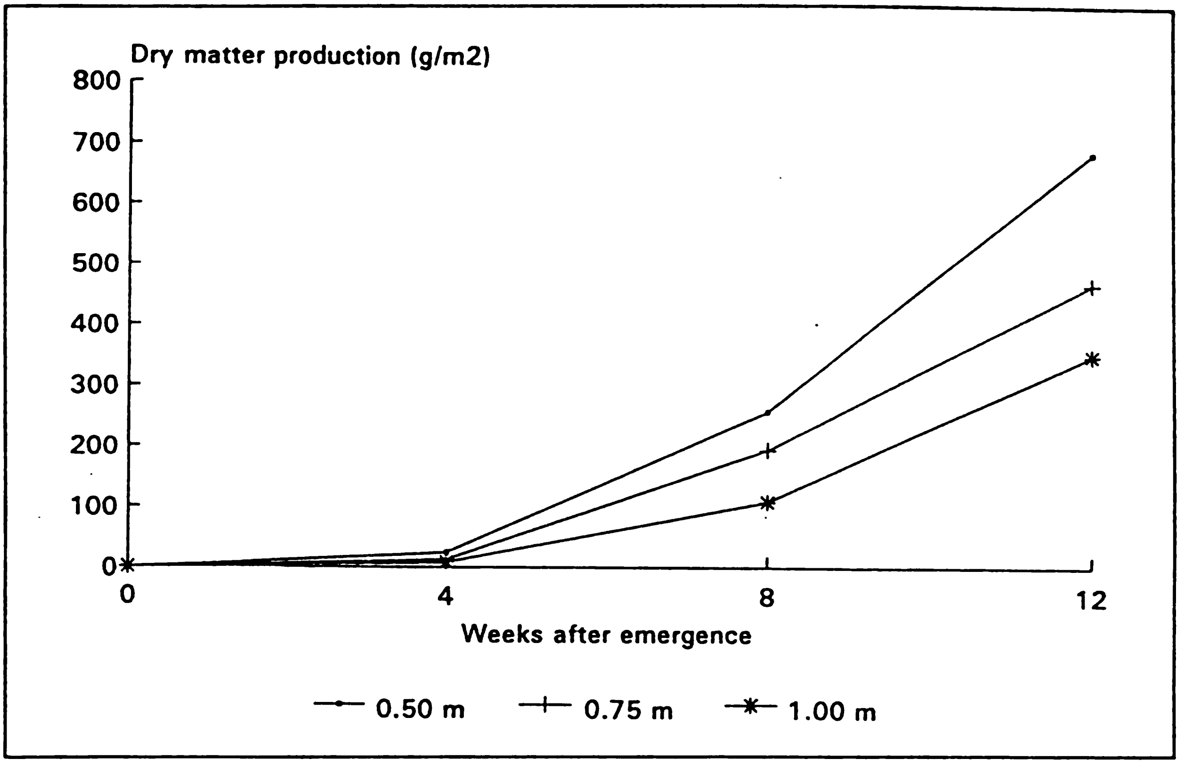

Fig. 5.1: Dry matter production of B. brizantha in a B. brizantha/A. pintoi mixture, cultivated at three row distances.

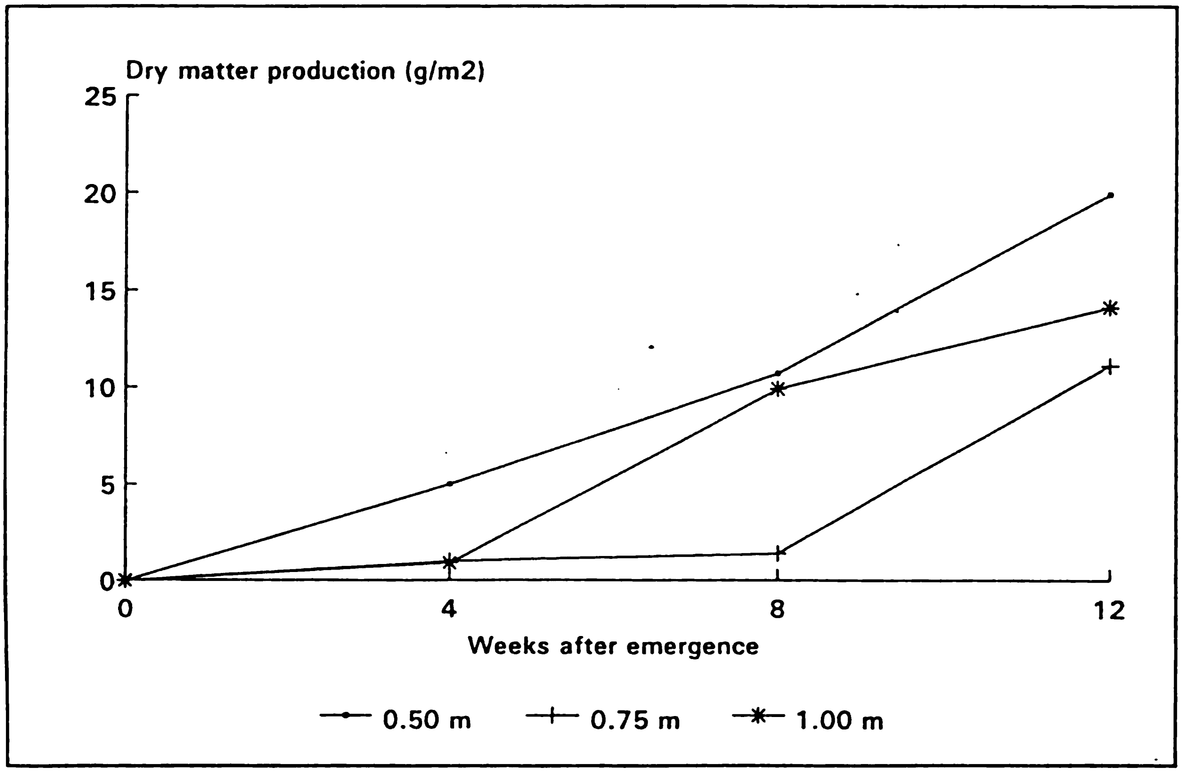

Fig. 5.2: Dry matter production of A. pintoi in a B. brizantha/A. pintoi mixture, cultivated at three row distances.

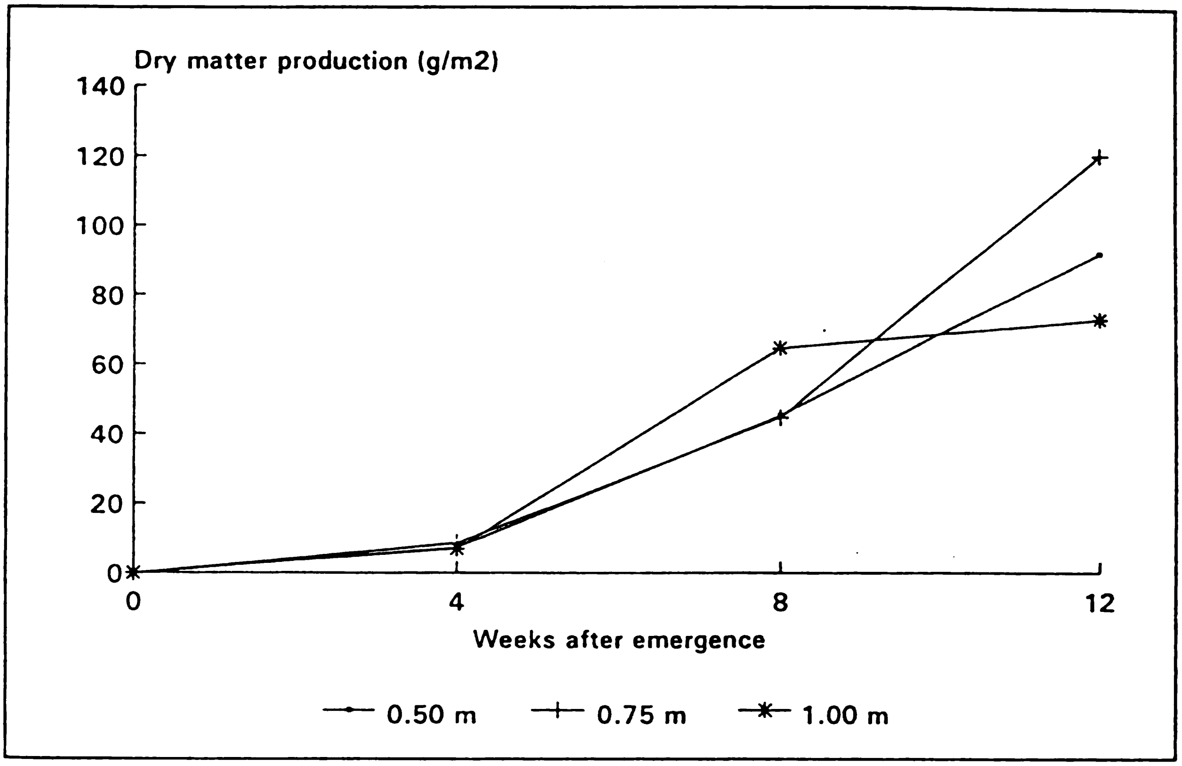

Fig. 5.3: Dry matter production of weeds in a B. brizantha/A. pintoi mixture, cultivated at three row distances.

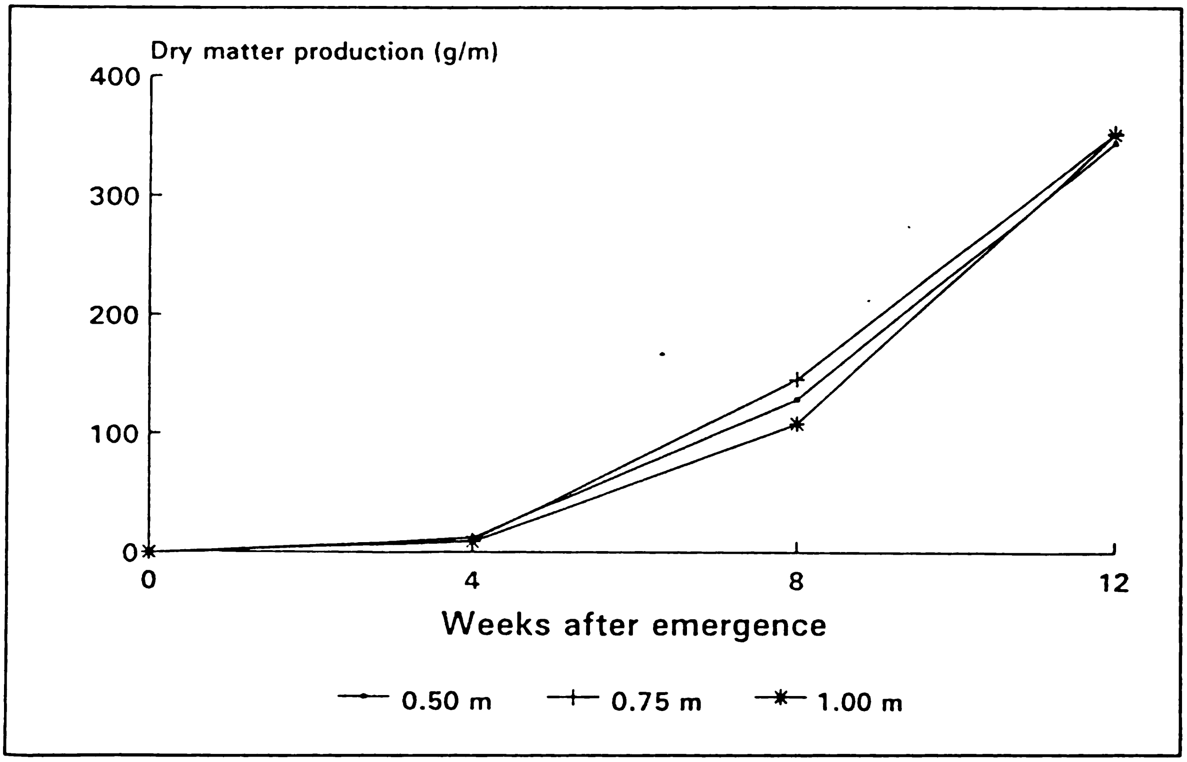

Fig. 5.4: Dry matter production per row of B. brizantha in a B. brizantha/A. pintoi mixture, cultivated at three row distances.

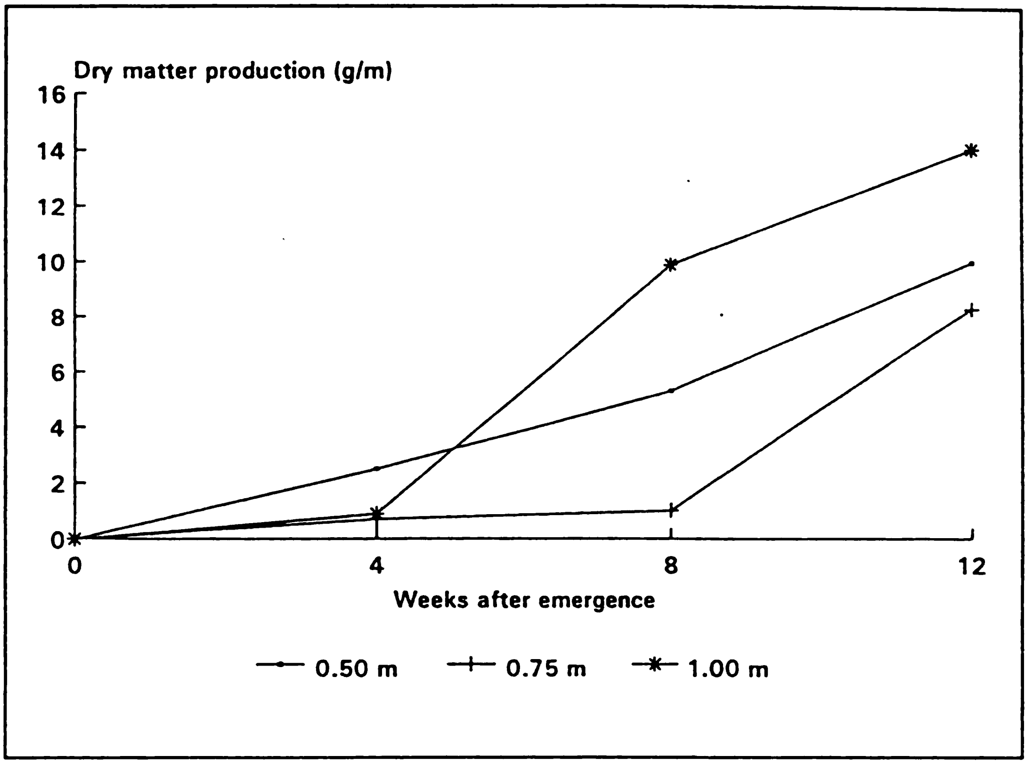

Fig. 5.5: Dry matter production per row of A. pintoi in a B. brizantha/A. pintoi mixture, cultivated at three row distances.

weeds after 12 weeks were 22.6%, 16.3% and 23.0% respectively. Appendix III shows the dry matter contents of the species after 4, 8 and 12 weeks.

A reliable analysis of variance of dry matter production can hardly be made because of the high variability of the data and the following coefficients of variation. However, figures 5.1, 5.2 and 5.3 present clear results with respect to the growth of the grass, legume and weeds. Generally it can be concluded that the growth of the legume was rather slow in comparison with the grass and weeds.

The figures 5.1, 5.2 and 5.3 show the total dry matter production per area, but also the dry matter production per row can be calculated. With this information it was possible to discount the row distance and determine the effect of row distance in individual rows. Data of dry matter production in a row is presented in figures 5.4 and 5.5.

After a analysis of variance most of the coefficients of variation appeared to be too high (> 20 %). Nevertheless, it would appear that there is hardly any difference between the production of grass per row with different row distances. Thus, the production of biomass was not affected by the growth of *A. pintoi* nor the production of weed biomass. Differences in dry matter production of *B. brizantha* with the three row distances were mainly caused by the increase of rows per area; production of dry matter per row remained the same.

A. pintoi showed a slight tendency in favour of the wide row distance, although trustworthy analyses of variance could not be made. This tendency could imply a better growth of the legume with a larger row distance because of the ability to intercept more light.

5.3.2 Botanical composition

From the data of dry matter production, the botanical composition on dry matter basis was calculated, as presented in table 5.1. Analyses of variance of these calculations are shown in Appendix III.

Table 5.1: Botanical composition of a *B. brizantha*/*A. pintoi* mixture for three row distances of the grass over three months.

Row distance (m)	Specie	Botanical composition (%)[a]		
		4 weeks	8 weeks	12 weeks
0.50	*B. brizantha*	67.0	82.2	86.0
	A. pintoi	13.5	3.4	2.5
	Weeds	19.6	14.4	11.6
0.75	*B. brizantha*	57.8	80.9	78.1
	A. pintoi	4.3	0.6	1.8
	Weeds	38.0	18.6	20.1
1.00	*B. brizantha*	52.1	59.2	80.1
	A. pintoi	5.7	5.4	3.2
	Weeds	42.3	35.4	16.7

[a]Average of two replications.

The slow growth of the legume in comparison with the grass and weeds (fig. 5.1 - 5.3) is underlined by the data of botanical composition, presented in table 5.1. In general it must be stated that the legume content in the sward after 12 weeks seemed to be too low to create a well established grass/legume association. The low content may partly be due to climatic conditions. As can be noticed in Appendix I, the precipitation in Rio Frio in the period of the experiments (February - April) was relatively low.

All three of the row distances showed a significant increase of grass content in time. Row distance 1.00 m seemed to show a slower pasture occupation. Differences between row distances were found after four weeks (a higher content of pasture in 0.50 m in comparison with 1.00 m) and after 8 weeks (a lower content of pasture of 1.00 m in comparison with 0.50 m and 0.75 m). A significant interaction between row distance and time could not be demonstrated.

Conclusions of analyses of variance of *A. pintoi* and weeds content are hardly useful, due to the high coefficients of variation (47.8% and 41.6%, respectively). Though, observing table 5.1, it can be concluded cautiously that the increase of grass content reduces both legume content and weed content. The relatively low content of grass at 1.00 m after 8 weeks was accompanied by a relatively high content of *A. pintoi* as well as weeds. This should imply a direct negative effect of grass occupation on the establishment of the legume in the sward. A close row distance, like 0.50 m, may rapidly create a dense sward with the advantage to suppress the occupation of weeds, but also an repression of growth and establishment of the legume. A remarkable aspect is the low content of legume in the row distance of 0.75 m, for a tendency should be expected from 0.50 m until 1.00 m in legume content. For all three measurements, the legume content at row distance 0.75 m appeared to be lower, which may be due to planting errors. It should be noted that the method of planting (bundles of vegetative material) may cause a high variation in growth. Sexual seeds may give a more equal occupation of the legume and more accurate results. Therefore it might be recommended to use sexual seeds of *A. pintoi* in these experiments.

5.3.3 Light interception

Radiation is an important factor with respect to the growth and development of plants, as has been mentioned in chapter 4. Results of light interception measurements at three row distances are presented in figure 5.6.

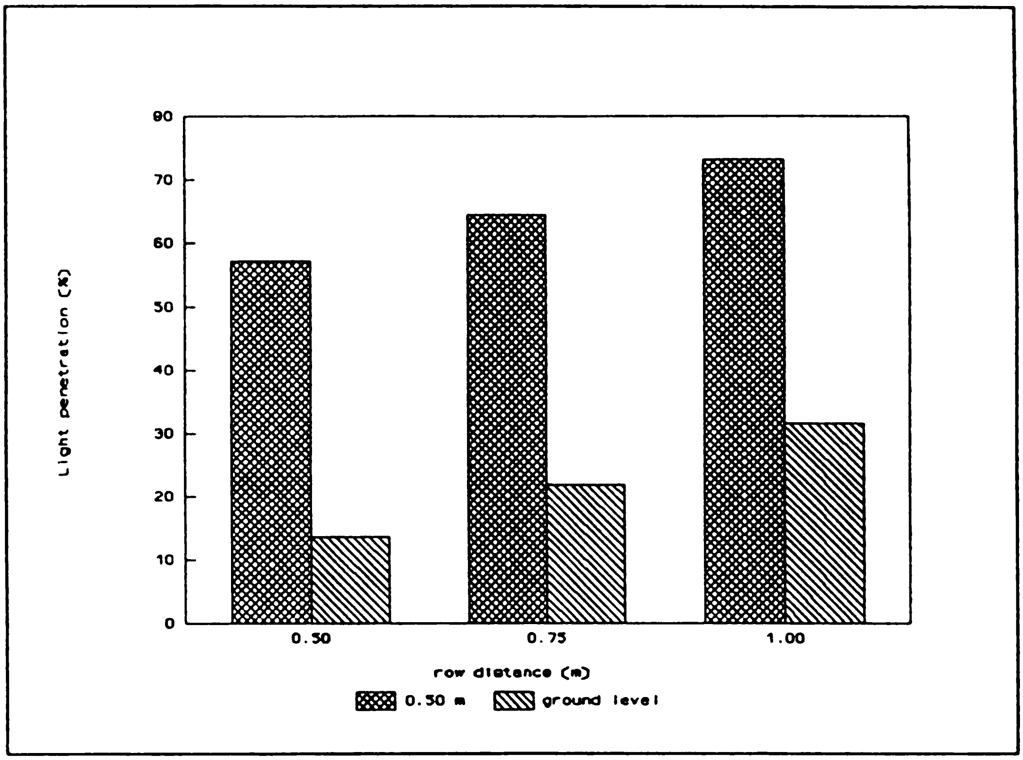

Fig. 5.6: Light penetration at two levels in a B. brizantha/A. pintoi sward, cultivated at three row distances.

The slight tendency of increased light penetration with a broader row distance could be expected, for less light can be intercepted in a denser sward. However, differences of light penetration between row distances were not significant at both levels (Appendix III). As concluded from results of dry matter production, row distance had an insignificant effect on the growth of *A. pintoi*. This should imply that light reduction caused by a denser sown sward does not have a significant effect on the growth of *A. pintoi*. Earlier investigations also show the high degree of shade tolerance (Cook, 1992). The legume showed an adaptability to the reduction of available light by raising its growth habit, and climbing into the sward until a height of approximately 40 cm. This change of growth habit was observed especially in swards with *A. pintoi* CIAT 17434, while it was hardly found in *A. pintoi* CIAT 18744 swards. The climbing growth habit will increase the interception of light available for *A. pintoi*, but may also have less favourable side effects. Stolons will climb into areal parts of the sward, which could lead to less rooted points and a higher susceptibility to grazing. This effect was also observed in the PODYNUVA experiment and described in chapter 4. More detailed studies are required to investigate the changes of growth habit and the effects on legume persistence in the pasture.

Athough this experiment and earlier investigations showed the capability of A. pintoi to grow under shaded conditions, it is likely that an early grazing benefits the growth of the legume by increasing the amount of available light in the sward. This may lead to a higher content of legume in the sward and an improvement of the grass-legume balance of the pasture. Chapter 6 will discuss this aspect of grazing management.

5.4 Conclusions

A considerable increase of dry matter production of *B. brizantha* could be obtained by sowing at narrow row distances (0.50 m), and the denser sward did not seem to affect the growth of individual plants in the first months. The narrow row distance seemed to affect the dry matter production of *A. pintoi*, and the legume content in the sward remained low at every distance in this experiment. The fast growth and occupation of *B. brizantha* not only suppressed the growth of the legume but the occupation of weeds as well. All row distances showed a low content of *A. pintoi*, which may be due to the low amount of light available for the legume.

6. INTRODUCTION OF B. BRIZANTHA AND A. PINTOI ASSOCIATIONS IN THE ATLANTIC ZONE

6.1 Introduction

Commercial use is the final step in pasture improvement technology to make an evaluation of the pasture at farm level. In practice the farmer is responsible for the grazing management, and dependent on other environmental and economic conditions ('t Mannetje, 1989). This chapter consist of a description of the introduction of improved pastures in the Atlantic Zone, with emphasis on the specialized dairy production systems in Rio Frio.

6.2 Animal production in the Atlantic Zone

The development of the Atlantic Zone of Costa Rica has been taking place during 80 years, with animal production as a major activity. In the early years of the eighties, the exportation of beef to the United States of America decreased due to low prices, and producers were obliged to obtain extra income by selling milk. Many of these producers changed their production system into specialized dairy production systems or systems with dual purpose cattle. A better access to markets was possible after the construction of the Guápiles-Siquírres highway in 1983 and the introduction in 1985 of a milk factory in Guápiles. In 1988 the principal activities of animal production in the Atlantic Zone were beef production (68%), dual purpose production (19%) and milk production (13%). The latter is mainly concentrated in region of Rio Frio (Aragón, 1992).

6.3 Animal production in the Rio Frio region

Rio Frio is one of the latest colonized regions in the tropical rain forests of Costa Rica. The main purposes for the cultivation of this area is the agricultural development, in particularly the exploitation of bananas. Besides the cultivation of bananas, the principal activities in the region are agriculture and specialized dairy production. Table 6.1 presents the size of dairy farms in Rio Frio and the neighbouring region El Indio.

Table 6.1: Total pasture area of dairy farms in the Rio Frio/ El Indio region (Anon. 1988).

Total area (ha)	Farms (%)
0 - 5	3.3
5 - 8	3.3
8 - 10	56.7
10 - 15	20.0
15 - 20	6.7
> 20	10.0

The major part of the dairy farms consists of 8 -10 ha (Table 6.1), with ratana (*Ischaemum ciliare*) as the most dominant grass. Other pastures in this region of minor importance are Estrella africana (*Cynodon nlemfluencis*) and pasto natural (*Axonopus compresus*). Most of the farmers (73%) do not apply fertilizers, mainly due to the high costs.

Concentrates are used on 70% of the farms, of which 57% apply 2 kg per cow per day or less. The use of concentrates is mainly restricted by the costs and transport facilities. More than 80% of the farmers use mineral supplements, less than 20% use bananas. The use of bananas as supplements increased over the last four years, caused by a considerable increase of banana plantations in the Rio Frio area, and the improvement of transport facilities (Piedra, pers. comm.).

The principal characterization of the dairy production in the Rio Frio/El Indio region is the low amount of productive cows per farm. About 90% of the farmers own less than 20 productive cows. About 87% of the farmers have access to credit in the system of Bancario Nacional. The credit was principally invested in the purchase of cattle (52%), pastures and fences (20%), equipment (15%), construction (15%), and land (2%). In contrast to other producers, most of the dairy farmers are organized to establish marketing channels for milk outlet to the two most important companies: Cooperativa de Productores de Leche Dos Pinos and Lactaria Costarricense Borden (Anon. 1987, Anon. 1988).

6.4 The use of native and improved pastures

Detailed studies on milk production in the Atlantic Zone from legume based pastures, like *B. brizantha/A. pintoi* mixtures, have not been documented. However, preliminary results from dual purpose production systems in Guácimo show that significant increases in milk production can be achieved from *B. brizantha/A. pintoi* mixtures (Table 6.2).

Table 6.2: Milk production from native grasses and *B. brizantha/A. pintoi* mixtures in dual production systems in the Atlantic Zone of Costa Rica (CATIE, unpublished data).

Pasture	Stocking rate (AU/ha)	Production per cow per day (kg)	Production per hectare per year (kg)
Native species[a]	1.2	4	1839
B. brizantha/A. pintoi	2.5	6.5	5931

[a]*Axonopus compresus* and *Paspalum notatum*

The results presented in Table 6.2 show that milk production per hectare represent an increase of more than 300% with the use of the legume based pasture. Improvement in milk production was not only a function of higher animal productivity, but also of increased carrying capacities, which resulted in higher production per hectare. From the results, it may be anticipated that higher milk yields are attainable with some genetic improvement.

The increase of milk production from legume based pasture may be associated with the high dry matter production, as can be observed in Table 6.3.

Table 6.3: Dry matter production and quality of native grasses and *B. brizantha/A. pintoi* mixtures measured in two dual production farms (CATIE, unpublished data).

Pasture	Dry matter production (tons/ha)	Quality	
		IVDMD (%)	CP (%)
Native species[a]	2.1	52	7.5
B. brizantha/A. pintoi	5.2	64	12.2

[a]*Axonopus compresus* and *Paspalum notatum*.

Results presented in Table 6.3 show a superior quality of the improved pasture, and as a result of this, animals grazing the legume based mixtures were able to select a higher quality of forage compared to native grasses.

The development of specialized dairy production in the Rio Frio region was initiated and encouraged in 1978 by CATIE and ITCO. Due to economic restrictions in the eighties, producers had to discontinue the application of fertilizers, followed by a reduction of the amount of cattle per hectare. In the first years of the development programme, *B. ruziziensis* showed promising results, but a degradation of the pasture was observed after the reduction of fertilizer application. Consequently, the improved grass *B. ruziziensis* was displaced by unproductive natural and naturalized grasses, such as *Axonopus compresus* and *Ischaemum ciliare*. This was concomitant with lower milk production, as a result of depressed carrying capacities and animal productivity. From 1988 onward an increase in dairy production occurred, caused by an increase of the number of cows and an increase of the milk production per cow. Producers were stimulated to rent other paddocks to put on the young and unproductive cattle, while the farm area could be kept for the productive milk cows. In the last four years the total area of pastures increased constantly, as well as the amount of cattle per farm (>60%). This increase of cattle was needed to increase the milk production per farm, which should make the farm more profitable (Piedra et al. 1992, Argüello et al. 1990, Anon. 1987).

6.5 Pasture grazing management

The main tools that the farmer can use to establish a well balanced grass-legume pasture are seed size, rate and timing of sowing, fertilizer level and placement, previous land treatment, and grazing or cutting management (Humphreys, 1978).In the first year after sowing a tall grass-legume mixture the grass is usually more vigorous, and at this stage the pasture may be ready for grazing before the legume is well established. If the grass is shading the legume too much, light grazing should be applied to increase light penetration in the lower strata so that the prostrate *A. pintoi* will have sufficient light for growth (Skerman et al. 1977).

Observations at farmers level in Rio Frio showed clearly that the timing of the first grazing is of relevant importance to the success of establishment and persistence of the legume in the sward. In the first week of January 1992, *B. brizantha* was sown in a small plot (0.7 ha) with row distances of about 40 cm. In the next three weeks *A. pintoi* was sown by planting vegetative material at distances in the row of about 1.5 m. In the next few months the grass showed a vigorous growth, particularly in comparison with the growth of the legume. After nearly five months the grass had attained a dense stand with a maximum height of approximately 1.8 m, and an estimated dry matter production of 7 tons/ha. In this period the farmer decided to apply light grazing. As the pasture was established in the dry season with minimal precipitation in March and April, both species may have suffered from drought, but there was more limitation on the growth of the legume than the grass. Furthermore it seemed obvious that the growth of *A. pintoi* suffered from competition for light in the dense sward. This effect may have been accentuated by the lodging of the grass, which occurred especially in areas where growth of *B. brizantha* was above 1.0 m. This growth habit of the semi-erect *B. brizantha* may affect the growth of the legume for the lodged stems and leaves will cover the entire ground, reducing the light interception of the legume and creating physical suppression. Moreover, as has been observed in the plot, the lodged grass could die creating a dense structure of dead material on the ground surface. The result of these limiting factors was an insignificant content of *A. pintoi* in the sward and unfavourable future prospects for a well-balanced grass-legume mixture.

One of the major motives of this problem was the moment of grazing; adequate grazing management may give the legume more opportunities to proper establishment in the sward and equal competition with the rapidly growing grass. Hence, it is recommended to apply a light grazing at an early stage. Particularly in the first months of establishment the pasture management and moment of grazing should be based on the legume content instead of grass yield. In the case as described above a light grazing at an earlier stage should be applied, for example after 3 months when the grass reached a height of about 1.0 m. Crowder and Chheda (1982) even recommend to practice a light grazing when the pasture reaches a height of 40 - 60 cm, especially when using legumes in the pasture since they grow slower than the grasses. This, however, depends on the growth habit and structure of the pasture. Adequate grazing management to suppress the grass should be aimed at encouraging the stoloniferous growth of the legume (Skerman, 1977).

6.6 Timing of sowing

The competition between grasses and legumes in the first stage of establishment can be modified by using different dates of sowing. As *B. brizantha* shows a more vigorous and aggressive growth in the first months of establishment, legumes could be sown first to give an advantaged growth, as Crowder and Chheda (1982) suggest. Problems with this procedure can be expected with respect to weed control, unfavourable weather conditions and labour demands. In general *B. brizantha* is planted in rows, with *A. pintoi* in between, and it would be a difficult and laborious method to separate the planting of the species. However, this method was used for establishment of *B.brizantha/A. pintoi* mixtures at some farms in Rio Frio (CATIE, 1991), but an evaluation has not been made yet. Another strategy is to sow the mixtures during periods of lower but adequate precipitation. This usually slows the growth of the grasses and permit establishment of the legumes, but may increase weed pressure as well.

6.7 Insects and diseases

Vallejos (1988) described the relatively high resistance to spittle bug and other diseases of *B. brizantha* cv Marandú CIAT 6780 (Chapter 2), which makes the species one of the most suitable improved grasses in the humid tropics.

However, this species is not free from other attacks, as could be concluded in areas with poorly drained soils in the Atlantic Zone. In these regions the grass was affected by a root born fungal disease of the genus *Phytium*, which caused chlorosis of leaves, followed by necrotic lesions and finally death of the plants (M. Ibrahim[1], pers. comm.). In the Rio Frio region *B. brizantha* affected by *Fusarium* sp. was found (CATIE, 1991), which could cause losses of more than 15% of the grass production in paddocks. Therefore, attention should be paid to these attacks, and probably action should be taken by using fungicides on affected locations, depending on economic use and management. Experiences of Rio Frio showed that diseases can lead to considerable losses and an expectable reduction of establishment success. More detailed studies are required to investigate and validate these conclusions, and to evaluate the performance of *B. brizantha* in the Atlantic Zone with emphasis on phytopathology.

6.8 Tolerance to water flooding

In contrast with other species of *Brachiaria* like *B. mutica* and to a lesser degree *B. humidicola*, *B. brizantha* will not tolerate flooding (Skerman & Riveros, 1990). This negative aspect of the promising species for the humid tropics also became clear at observations at a farm in Rio Frio, where *B. brizantha* was sown in combination with *A. pintoi*. During a period of heavy rainfall most parts of the paddocks were temporarily inundated, mainly caused by insufficient drainage. A week after this period of high precipitation more than half of the pasture wilted, creating a dense mat of dead material on the ground. It seems to be obvious that this phenomenon will affect the establishment of both legume and grass dramatically. After two months, most of the affected parts of the paddocks were occupied by *B. radicans*, a *Brachiaria* species with a better tolerance to inundations. *A. pintoi* was found very scarcely. Considering these observations, flooding damage might be one of the major restrictions in many parts of the Atlantic Zone, for a considerable part of this region consists of poorly drained soils.

[1]Muhammad Ibrahim M.Sc., Ph.D-student Tropical Pastures, CATIE.

6.9 Prospects for pasture improvement technologies in the Atlantic Zone

Although preliminary results from the PODYNUVA experiment (Chapter 4) and the introduction at farm level in Guácimo show promising results, observations in Rio Frio made clear that many facets with respect to the establishment of *B. brizantha/A. pintoi* associations and the management following establishment have to be investigated and validated. It is possible to obtain high quality fodder at a high production level when using grass-legume associations like *B. brizantha* in combination with *A. pintoi*, but the performance of the pasture under less favourable conditions is not clearly examined. More knowledge is required with regards to phytopathology, environmental stress, sowing methods and timing of sowing, and pasture grazing management.

Lack of financial resources can be regarded as one of the most important limiting factors for the introduction of the pastures. Introduction of improved pastures are accompanied by high costs of land clearing, labour and seed. High interests and restricted access to credit will not encourage farmers to adopt the improved pastures in the farming system, in particularly when the benefits of the improved pastures are not clear yet. Loans should be given to permit the farmers to sow improved pastures. However, before these steps are to be taken, more knowledge is required about the growth characteristics and management of the pasture. Training of farmers and adequate extension services are required to achieve correct management of the legume based pastures. Especially in regions with specialized dairy production, such as Rio Frio, there should be possibilities to increase production by introducing improved pastures. Compared to beef or dual purpose production systems, dairy production systems have a higher potential for pasture improvement, for farmers are assured of a rather stable income and milk production requires high quality fodder ('t Mannetje, 1992).

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APPENDIX I: Precipitation data

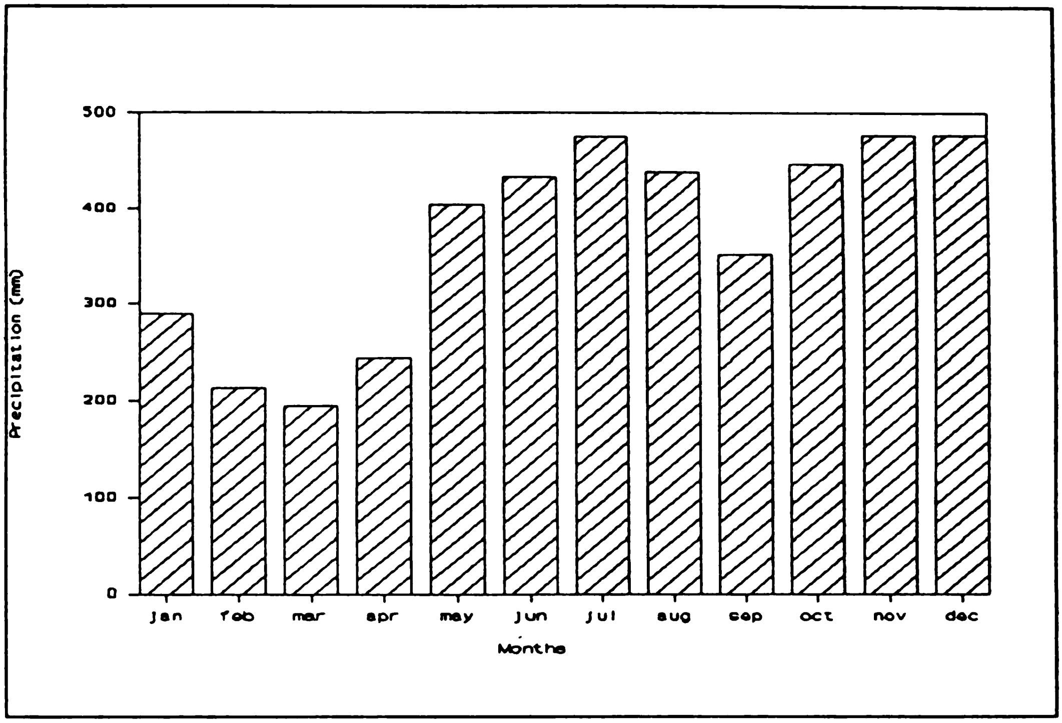

Fig I.1: Annual precipitation, Experimental Station "Los Diamantes", Guápiles, Monthly averages from 1950 until 1991. Instituto Meteorologico Nacional.

Table I.1: Precipitation at Experimental Station "Los Diamantes", Guápiles and Rio Frio in the first months of 1992.

Month	Precipitation (mm)		
	Los Diamantes		Rio Frio
	Annual[1]	1992[2]	1992[3]
Jan	288.7	155.3	87.4
Feb	212.0	219.8	135.1
Mar	194.1	171.7	162.8
Apr	243.4	317.5	223.2
May	403.4	447.5	

[1]Averages from 1950 until 1991 (Guápiles), Instituto Meteorologico Nacional

[2]Instituto Meteorologico Nacional

[3]Zector la Rambla, Horquetas, Sarapiqui, Instituto Meteorologico Nacional.

APPENDIX II: Analyses of Variance of stolon characteristics and light penetration measurements

Table II.1: Analysis of Variance[a] of stolon length of A. pintoi in a B. brizantha/A. pintoi sward with two stocking rates and two replications.

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	Compute d F[b]
Total	7	7806		
Replication	1	18	18	0.14[ns]
Specie	1	2312	2312	18.35[*]
Stocking rate	1	5000	5000	39.68[**]
Specie*Stocking rate	1	98	98	0.78[ns]
Error	3	378	126	

[a]vc = 7.46%

[b]ns = not significant, ** = significant at 1% level, * = significant at 5%

Table II.2: Analysis of Variance[a] of the number of rooted points at stolons of A. pintoi in a B. brizantha/A. pintoi sward with two stocking rates and two replications.

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	Computed F[b]
Total	7	106.68		
Replication	1	0.13	0.13	0.03[ns]
Specie	1	84.50	84.50	20.69[*]
Stocking rate	1	8.82	8.82	2.16[ns]
Specie*Stocking rate	1	0.98	0.98	0.24[ns]
Error	3	12.26	4.09	

[a]vc = 1.34%

[b]ns = not significant, * = significant at 5% level.

Table II.3: Analysis of Variance[a] of light penetration at 0.5 m in a B. brizantha/A. pintoi sward with two stocking rates and two replications.

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	Computed F[b]
Total	7	928.36		
Replication	1	188.67	188.67	2.01[ns]
Stocking rate (SR)	1	374.70	374.70	3.98[ns]
Before/after grazing (G)	1	80.07	80.07	0.85[ns]
SR*G	1	2.70	2.70	0.03[ns]
Error	3	282.22	94.07	

[a]vc = 11.6%

[b]ns = not significant

Table II.4: Analysis of Variance[a] of light penetration at ground level in a B. brizantha/A. pintoi sward.

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	Computed F[b]
Total	7	88.22		
Replication	1	16.62	16.62	2.58[ns]
Stocking rate (SR)	1	8.06	8.06	1.25[ns]
Before/after grazing (G)	1	41.45	41.45	6.44[ns]
SR*G	1	2.77	2.77	0.43[ns]
Error	3	19.32	6.44	

[a]vc = 65.0%

[b]ns = not significant

Table II.5: Analysis of Variance[a] of light penetration at ground level in a B. humidicola/A. pintoi sward.

Source of variation	Degrees of freedom	Sum of Squares	Mean Square	Computed F[b]
Total	7	154.52		
Replication	1	2.51	2.51	1.29[ns]
Stocking rate (SR)	1	20.48	20.48	10.51*
Before/after grazing (G)	1	103.10	103.1	52.92**
SR*G	1	22.58	22.58	11.59*
Error	3	5.84	1.95	

[a]vc = 28.0%

[b]ns = not significant, ** = significant at 1% level, * = significant at 5% level.

APPENDIX III: Data of dry matter content and analyses of variance of botanical composition and light penetration measurements.

Table III.1: Dry matter content of *B. brizantha*, *A. pintoi* and weeds in a *B. brizantha/A. pintoi* mixture over three months.

Specie	Dry matter content (%)[a]		
	4 weeks	8 weeks	12 weeks
B. brizantha	14.5	21.5	22.6
A. pintoi	16.1	19.5	16.3
Weeds	15.8	23.1	23.0

[a]Average of two replications and three row distances.

Table III.2: Analysis of variance[a] of the portion of *B. brizantha* in the botanical composition, in a *B. brizantha/A. pintoi* mixture with two blocks (B), three row distances (R) and three measurements in time (T).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Computed F[b]
B	1	125.29	125.29	2.34[ns]
R	2	541.83	270.92	5.06[*]
T	2	1458.74	729.37	13.61[**]
R*T	4	196.09	49.02	0.91[ns]
Error	8	428.71	53.59	
Total	17	2750.66		

[a]vc = 10.2 %

[b]** = significant at 1% level, * = significant at 5% level, ns = not significant.

Table III.3: Analysis of variance[a] of light interception at 0.50 m in a *B. brizantha/A. pintoi* mixture, two months after emergence.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Computed F[b]
Total	5	417.50		
Block	1	12.24	12.24	0.17^{ns}
Row distance	2	260.06	130.03	1.79^{ns}
Error	2	145.20	72.60	

[a]cv = 13.1%

[b]ns = not significant

Table III.4: Analysis of variance[a] of light interception at ground level in a *B. brizantha/A. pintoi* mixture, two months after emergence.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Computed F[b]
Total	5	374.95		
Block	1	28.05	28.65	2.20^{ns}
Row distance	2	320.29	160.15	12.31^{ns}
Error	2	26.01	13.00	

[a]cv = 16.1%

[b]ns = not significant