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The nutritive value provided by native forage species during the dry season severely limits livestock production in Ecuador's tropical lowlands. Economic and management deficiencies make the use of adapted forage legumes the most feasible means of fixing atmospheric nitrogen and providing high quality feed during these periods of climatic stress. The compatibility and persistence of 18 grass-legume associations and the effect on forage production and quality resulting from the inclusion of a legume into the sward was studied from May, 1972 to February, 1973 on the coast of Ecuador. Three and six week clipping frequencies were used on *Pancium maximum* Jacq., *Pennisetum Purpureum* Schumach, *Hyparrhenia rufa* (Nees) Stapf., *Digitaria Decumbens* Stent., *Cynodon plectostachyus* (Schum.) Pilger, and *Cenchrus ciliaris* (L.) Link, each of which was subjected to five treatments. The control and N fertilized treatments were on pure stands of each grass species, while the legumes *Centrosema pubescens* Benth, *Macroptilium atropurpureum*, and *Desmodium intortum* (Mill.) Urb. were incorporated with the grass species in the remaining three treatments. *P. purpureum* outyielded the other grass species, followed by *P. maximum*, while there was no difference between the highest yielding N fertilized and *C. pubescens* treatments. Although N fertilization resulted in a greater overall production of dry matter, the incorporation of a compatible adapted legume resulted in a higher quality sward in terms of crude protein yield.

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THE COMPATIBILITY, PERSISTENCE, AND NUTRITIVE VALUE OF GRASS-LEGUME ASSOCIATIONS IN THE WET-DRY TROPICS OF COASTAL ECUADOR

By

ROBERT EARL HUDGENS

A THESIS PRESENTED TO THE GRADUATE
COUNCIL OF THE UNIVERSITY OF FLORIDA IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE

UNIVERSITY OF FLORIDA
1973

DEDICATION

This manuscript represents my primary contribution to the people of Ecuador, aside from whatever benefit my one-year presence at the Pichilingue Experimental Station offered. I retain from my experience a deep feeling for the glaring demographic needs of coastal Ecuador that are self-evident before one reads the statistics, and for the seemingly small group of people willing to work with whatever technology is available to improve the quality and richness of their lives and create a liveable world for their children. In retrospect, I wish I could have done more.

ACKNOWLEDGMENTS

Any study of this nature is as much a reflection of the graduate student's advisors, as of the graduate student himself. The most influential persons and the ones deserving the greatest credit for this study are Dr. G. O. Mott, who as Chairman of the Supervisory Committee, oversaw all phases of the author's graduate training with compassion and insight, and Dr. L. E. Tergas, who helped design and execute the field experiment. The author is also indebted to Dr. John Bishop for his guidance and valuable aid in the animal science aspects of this study as well as for his comradeship and moral support during the field work.

Appreciation is also extended to Dr. Hugh Popenoe, Dr. A. E. Kretschmer, and Dr. Raymond Crist for serving as members of the supervisory committee, and to Dr. J. E. Moore for providing materials and advice concerning animal nutrition analysis. Thanks are also given to Dr. R. C. Littell for his suggestions concerning statistical analysis of the data, and to A. S. Monplaisir for his assistance in computer programming.

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Abstract of the Thesis Presented to the Graduate Council of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Master of Science in Agriculture

THE COMPATIBILITY, PERSISTENCE, AND NUTRITIVE VALUE OF GRASS-LEGUME ASSOCIATIONS IN THE WET-DRY TROPICS OF COASTAL ECUADOR

By

Robert Earl Hudgens

August, 1973

Chairman: Dr. G. O. Mott
Major Department: Agronomy

The compatibility and persistence of 18 grass-legume associations and the effect on forage production and quality resulting from the inclusion of a legume into the sward was studied from May 1972 to February 1973 on the coast of Ecuador. Three and six week clipping frequencies were used on Panicum maximum Jacq., Pennisetum purpureum Schumach, Hyparrhenia rufa (Nees) Stapf., Digitaria decumbens Stent., Cynodon plectostachyus (Schum.) Pilger, and Cenchrus ciliaris (L.) Link, each of which was subjected to five treatments. The control and N fertilized treatments were on pure stand of each grass species, while the legumes Centrosema pubescens Benth, Macroptilium atropurpureum, and Desmodium intortum (Mill.) Urb. were incorporated with the grass species in the remaining three treatments. P. purpureum outyielded ($P<0.01$) the other grass species, followed by P. maximum, during the wet and dry seasons of each clipping frequency, while there was no difference ($P>0.05$) between the highest yielding N fertilized and C. pubescens treatments. Although N fertilization resulted in a greater overall production of dry matter, the incorporation of a compatible adapted legume resulted in a higher quality sward in terms of crude protein yields.

INTRODUCTION

Domestic demand for beef and the potential for foreign export have stimulated a growing interest in the production of livestock on the coast of Ecuador. The extreme variation in topography and ecology found within this area prohibits the mass recommendation of agricultural technology imported from the more advanced tropics without first obtaining regional information and isolating the factors which limit production for each of the distinct coastal zones.

At present major emphasis for improving commercial livestock production is being placed in the region Quininde, El Carmen, Santo Domingo de los Colorados, and Quevedo, with research efforts being centralized near the latter. The tropical forage research conducted by the Instituto Nacional de Investigacion Agropecuario (INIAP) has been concentrated at their Estacion Experimental Tropical Pichilingue. In recent years this research has primarily been concerned with Phase I (Mott and Moore 1969) "species introduction" and Phase II "environmental evaluation" with a small number of random clipping and fertility studies on species selected for adaptability, dry season viability, and overall resistance to disease and weed infestation. However it has been clearly observed that the principal factor reducing both the quantity and quality of forage produced is the uneven annual distribution of rainfall which subsequently effects animal gain and percent calf crop. The decline of

forage nutritive value during imbalanced seasonal production indicates a need for more information on the effects of pasture management, grazing management, nitrogen fertilization, supplemental feeding, and the incorporation of compatible tropical legumes into the pasture.

Although most of the tropical legume species currently in use in other areas of the tropical world originated in the Latin American tropics, their potential in domestic livestock production has not been fully exploited. This stems from the lack of adequate knowledge of the overall contribution of tropical legumes to pasture quality and animal production under wet-dry tropical conditions. Fundamental to this understanding is a comparison of nitrogen fertilization of pure grass stands with the incorporation of a compatible legume from the standpoint of the quality and quantity of forage produced throughout the year, which in turn will dictate suitable carrying capacity and grazing management.

The following study is designed to provide information on just such a comparison, as well as to establish a solid basis for the development of a production feeding system in the Quevedo area based on grass-legume associations. The objectives of the study were to analyze the compatibility of 18 grass-legume mixtures, their persistence under the existing wet-dry tropical climate, and the effect of the legume on overall forage production and quality. Since compatibility is a function of the species growth habit, both tall and short, bunch and rhizomatous growth habit grass species were used in combination with creeping and twining growth habit legumes. Also since persistence through the wet-dry climatic pattern from the point of view of animal production includes periodic defoliation, a grazing rotation management was simulated using two clipping frequencies and their consequent recovery intervals.

REVIEW OF LITERATURE

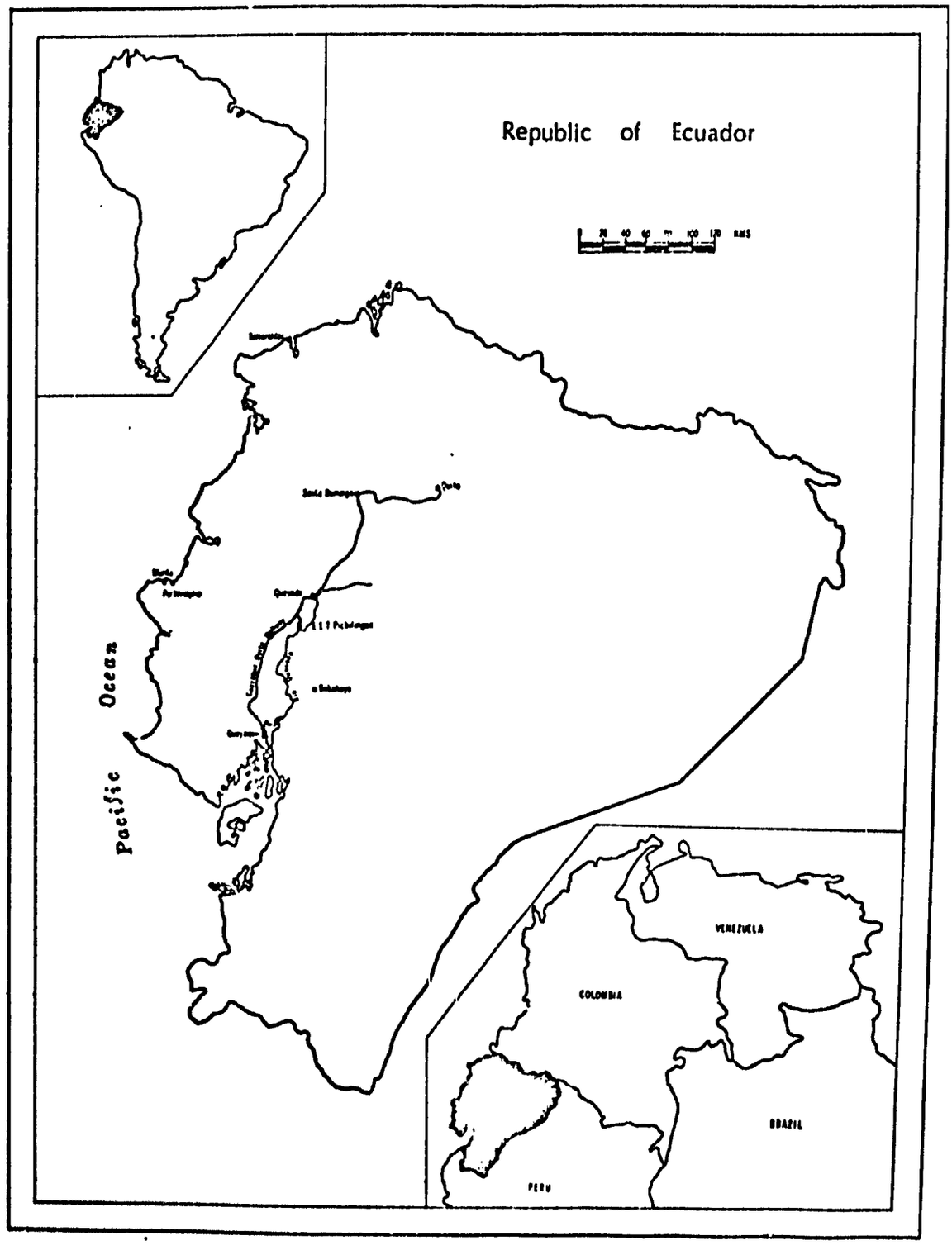
The Republic of Ecuador obtains its name from the fact that it is situated directly on the equator between 01°25'00" north latitude and 05°00'41" south latitude (see Figure 1). Its northern boundary is the mouth of the Rio Mataje on the Colombian frontier, and its southern boundary is formed by the union of the Rio Chinchipe and the Rio San Francisco on the Peruvian frontier. Ecuador extends from the Galapogos Islands (Archipielago de Colon) in the Pacific Ocean to the Amazonian region on the eastern slopes of the Andean Cordillera Real, with mainland Ecuador lying between 81°00'00" west longitude on the Pacific coast and 75°11'27" west longitude at the union of the Rio Aguarico and the Rio Napo (La Puntilla) on the Peruvian border (OEA 1972).

Existing Situation

Physical Resources

Ecuador has a total land area of 28,256,000 hectares of which 2,843,000 hectares are arable (FAO 1971). According to the Survey for the Development of the Guayas River Basin on the coast of Ecuador conducted by the Pan American Union in 1964, the western coast of the country contains 950,717 hectares of fertile alluvial soils resulting from the erosion of basic igneous and volcanic rocks of the Andean slopes to the east. Of this, 600,453 hectares are located in the dry tropical southern flood plain of the coast, while 350,264 hectares having

Figure 1. Map of the Republic of Ecuador



excellent soils are between the town of Quevedo and Santo Domingo de los Colorados. It is within this latter region that the Government of Ecuador is currently emphasizing the development of the commercial beef cattle industry, although the entire region north of Quevedo, some 767,250 hectares, has been classified a colonization region of high settlement capacity (Pan Am Union 1964). This is a forested area with undulating to level land which requires no irrigation, and which at present contains a low to moderate population density except for concentrations along roads, rivers, and around towns. A high rural population exists on 50,250 hectares with a population density of 14 people/km^2.

The 1962 national census for Ecuador reported a total population of 4,476,000 and a total population density of 16.5 people/km^2. The OEA projected population estimate for 1971 was 6,297,000 with a density of 23.3 people/km^2.

FAO statistics for 1970 indicate a population of 6,093,000 and a total cattle population of approximately 2,500,000. This results in roughly a 3:1 ratio between the human and the cattle populations. However, the human population growth rate, currently set at 3.5% for the years 1971-1975 and 4.1% for the remainder of the decade (OEA 1972) exceeds the annual increase in the cattle population which rose 2.5% between 1969-1971 (FAO 1971). It is this widening gap between the two growth rates which is the source of concern for governmental strategists.

Nutritional Needs

Total animal protein consumption per capita per day in 1970 was set at 15.1 grams which is a steady decline from the 16.2 figure of 1961 (FAO 1971). At the same time, the total per capita protein consumption, in-

cluding the aforementioned animal protein data, was 45.5 grams/day. This, too, has declined from 47.1 grams/capita/day in 1961, and when compared to the 64 grams/capita/day figure established as the recommended minimum daily requirement by the Food and Nutrition Board of the National Research Council of the United States (Bogert et al. 1966), the deficiency becomes readily apparent.

The Junta Nacional de Planificacion y Coordinacion Economica (1964) established nutritional requirements of 36.3 grams of animal protein/capita/day and 72.7 grams of total protein/capita/day. In 1968 Ecuador was 40.8% deficient in per capita animal protein consumption and 26.4% deficient in total per capita protein consumption, respectively. These calculations show somewhat of an improvement over 1963 which had a 50.1% deficiency in animal protein and a 34.0% deficiency in total protein per capita consumption.

Climate

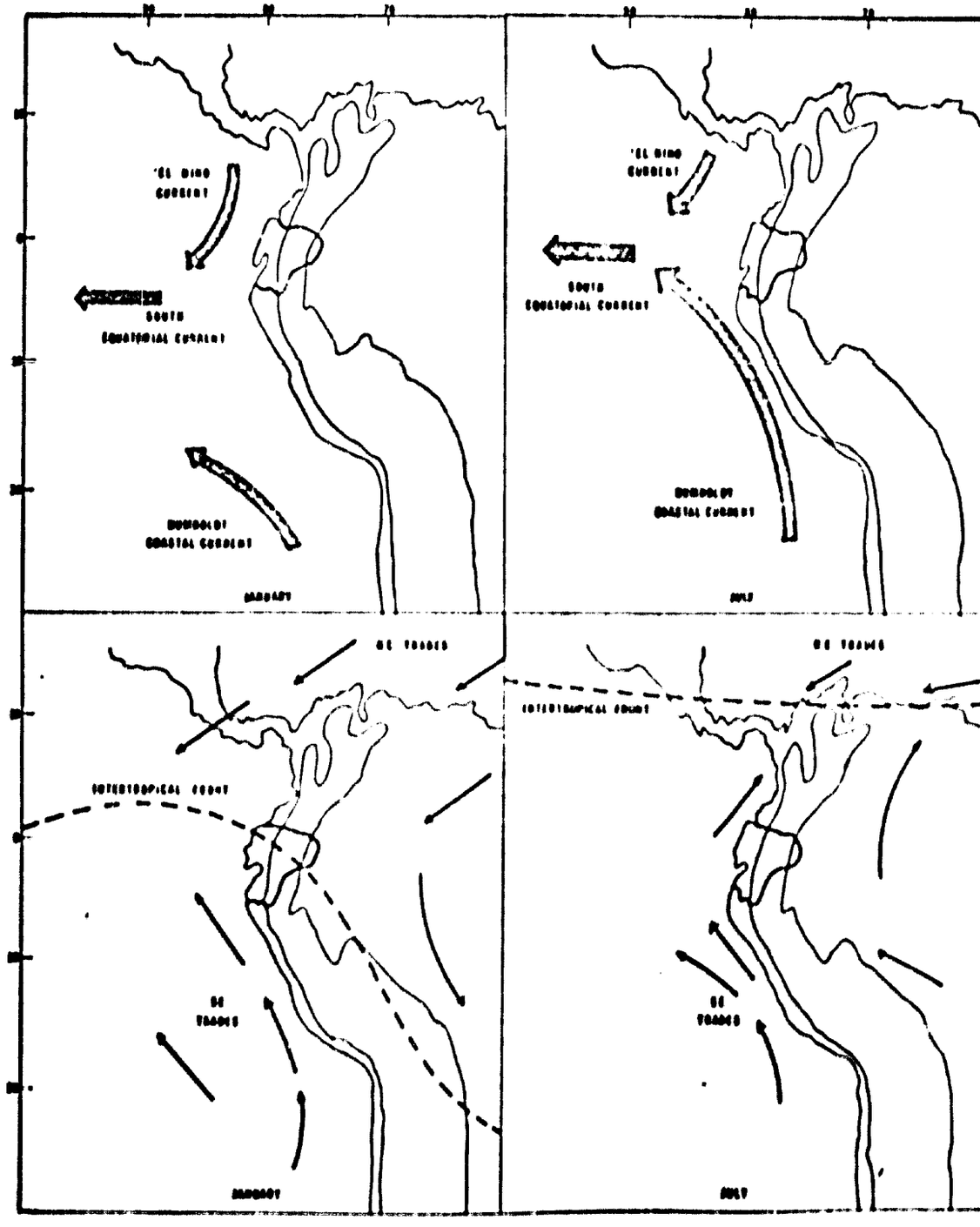
Due to its equatorial location, the climate at any given point within Ecuador is directly dependent upon the relative elevation. For example, the capital city, Quito, (00°12' S) at an elevation of 2,818 meters (9,252 ft) has a mean annual temperature of 13.4°C (56.1°F), whereas the city of Guayaquil (02°10' S) at an elevation of 6.1 meters (20 ft) has a mean annual temperature of 25°C (77°F). Although topography plays a decisive role in the life style and agricultural diversification of Ecuador, climate for distinct regions of the country are also influenced by proximity to the Pacific Ocean, atmospheric pressure, rainfall, and seasonal marine currents. This is reflected in land use and the pattern of population distribution.

The northwest coast of South America is unique among other areas of similar elevation at that latitude in the tropics because of its relatively low annual temperatures. There are two reasons for this. First, the Humbolt Current brings an accumulation of colder water from higher latitudes very close to shore, and secondly, the winds in this region are associated with the high barometric pressure of the Pacific anticyclone (see Figure 2). From May to December the winds are nearly rainless and often envelop the coastal strip in fog or low clouds which shut out the sun (OEA 1972). It is during this time of arid atmospheric conditions that the coast experiences its characteristic dry winter season. However, immediately following this period, the warm waters originating in the Gulf of Panama which form the El Nino Current cross the equator and sweep along the Ecuadorian coast causing considerable convectional and orographic precipitation inland. This condition normally continues through April and is responsible for the summer rainy season. The highest annual temperatures occur during the months of maximum rainfall (Griffiths 1965).

However, climatic patterns based on the interplay of ocean currents and their associated trade winds are not generally consistent from one year to the next. Although the amount of precipitation that falls over a range of years may appear uniform, its distribution within those years may have varied considerably. It is this unreliability of rainfall from one year to the next that is the principal climatic limitation to agriculture throughout the Guayas Basin and the adjoining coast, even in areas with average annual moisture surplus (Pan Am Union 1964).

The Estacion Experimental Tropical Pichilingue, 01°06' S and 79°29' W, is located in the Canton, Quevedo, Provincia de los Rios, 15 kilometers

Figure 2. Ocean Currents and the Pattern of Prevailing Winds Affecting Meteorological Conditions



Griffiths, J. F., et al. 1965. Research on tropical rainfall patterns and associated meso-scale systems. Report No. 8. U. S. Army Electronics Laboratories. Ft. Mammouth, New Jersey. p. 31.

south of the city of Quevedo, at an elevation of 73 meters (237 feet). The Servicio Nacional de Meteorologia e Hidrologia del Ecuador 1970 data from the station report a mean annual temperature of 24.7°C (77°F), an average maximum temperature of 34.5°C (95°F) and an average minimum temperature of 17.1°C (63°F), an annual rainfall of 2,208 mm (87 inches), 828.7 hours of sunlight per year, and a mean annual Relative Humidity of 85%. This would place Pichilingue and the Quevedo area in the "Tropical Moist Forest" of Holdridge's Classification of World Plant Formations and Natural Life Zones. In fact, this area marks the gradual transition from deciduous to evergreen forests and from the standpoint of humidity conditions, is one of the most favorable agricultural areas because its annual rainfall equals its potential evapo-transpiration (Pan Am Union 1964). Holdridge's "Tropical Moist Forest" classification has an evapo-transpiration ratio = 1.00 which confirms this agricultural potential (Holdridge 1967).

Figure 3 presents the monthly rainfall range and the rainfall pattern for the period 1959-1970. During this period the yearly rainfall total ranged from 1,236 mm (49 inches) to 3,005 mm (119 inches), while the monthly extremes ranged from 0.1 mm (July) to 629 mm (January). The monthly temperatures ranged from an absolute minimum of 17.1°C (July) to an absolute maximum of 34.1°C (December). Although the temperature variation is relatively uniform both within and between years, the rainfall distribution is extreme. The Mapa Pluviometrico Parcial del Ecuador (1931-1960) of the Servicio Nacional de Meteorologia e Hidrologia denotes the Quevedo area with an 2,500-3,000 annual isohyet as shown in Figure 4. These isohyets characterize the rainfall pattern of the Ecuadorian Littoral, and indicate the increasing precipitation as one moves northward along the

Figure 3. Mean Monthly Rainfall Data for the Pichilingue Experimental Station [Servicio Nacional de Meteorologia e Hidrologia del Ecuador (1959-1970)]

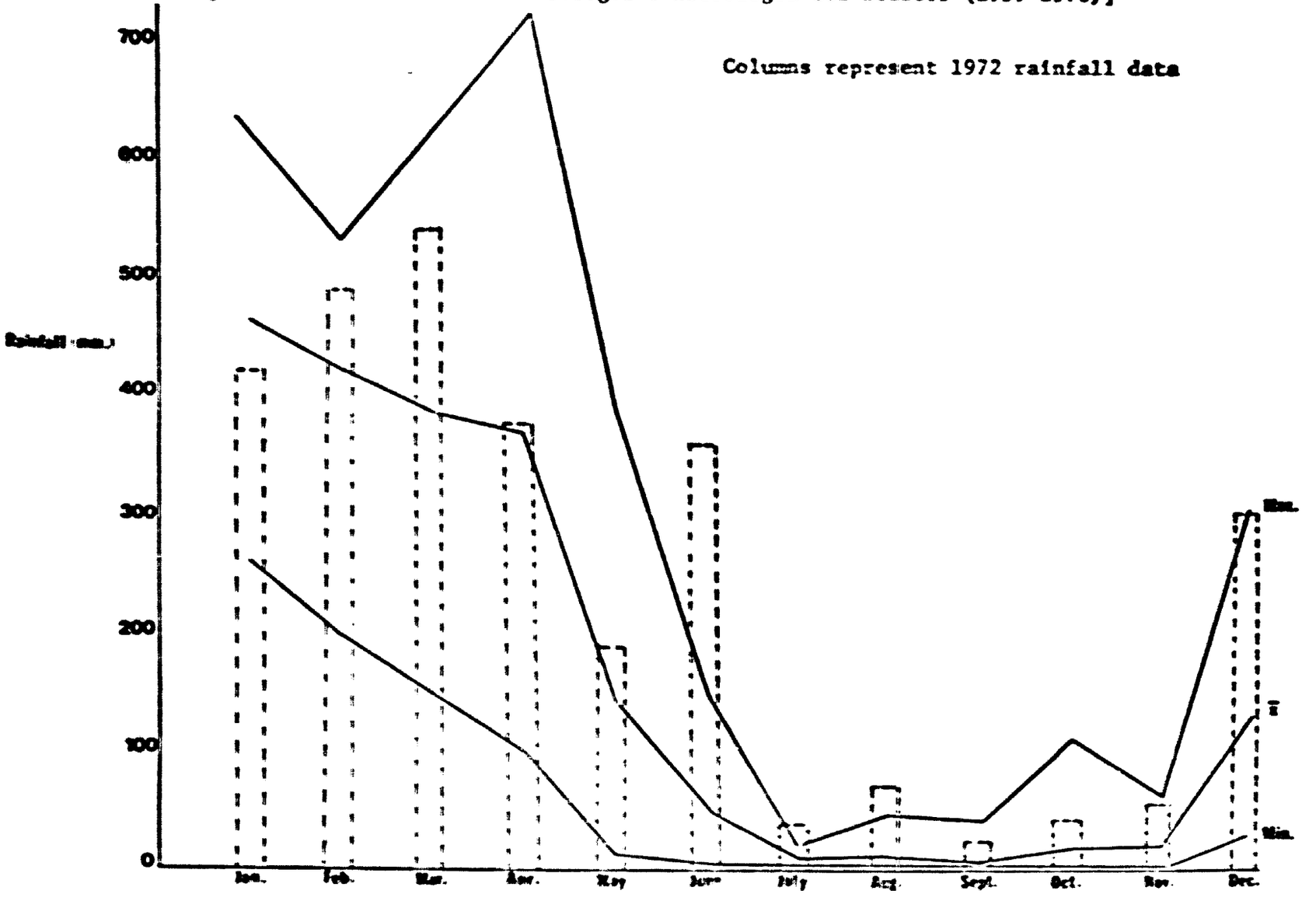
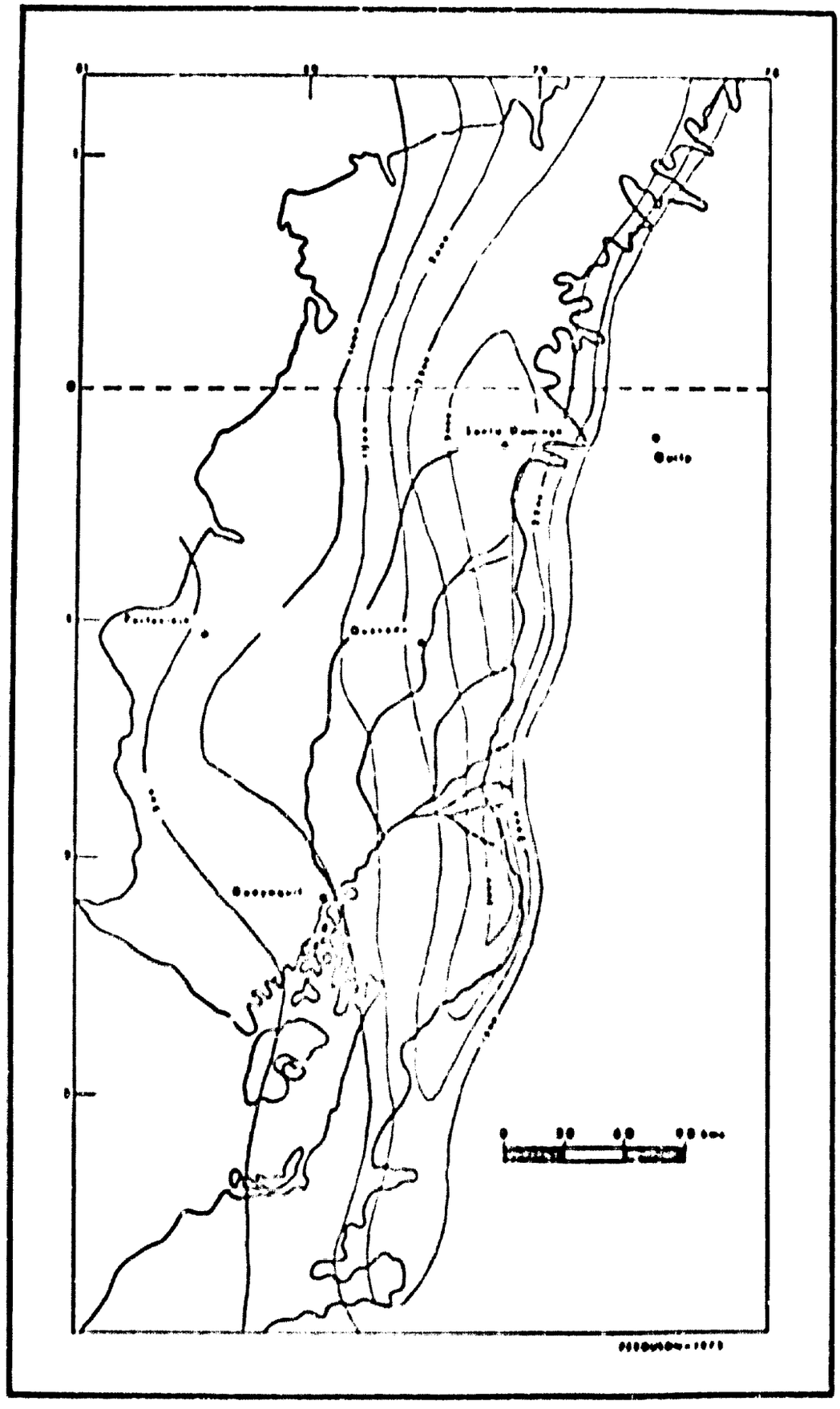


Figure 4. 1931-1960 Precipitation Isohyets of Coastal Ecuador (mm)



coast. However when it is realized that 93% of the annual total falls in the six month period December to May, (with the highest rainfall occurring in March and April) the wet-dry tropical environment is obvious. During the 1959-1970 period, the 6 month dry season rainfall at the Pichilingue Experiment Station averaged 5.7 mm to 40.6 mm, whereas during the 6 month rainy season, the monthly averages range from 122.5 mm to 451.4 mm.

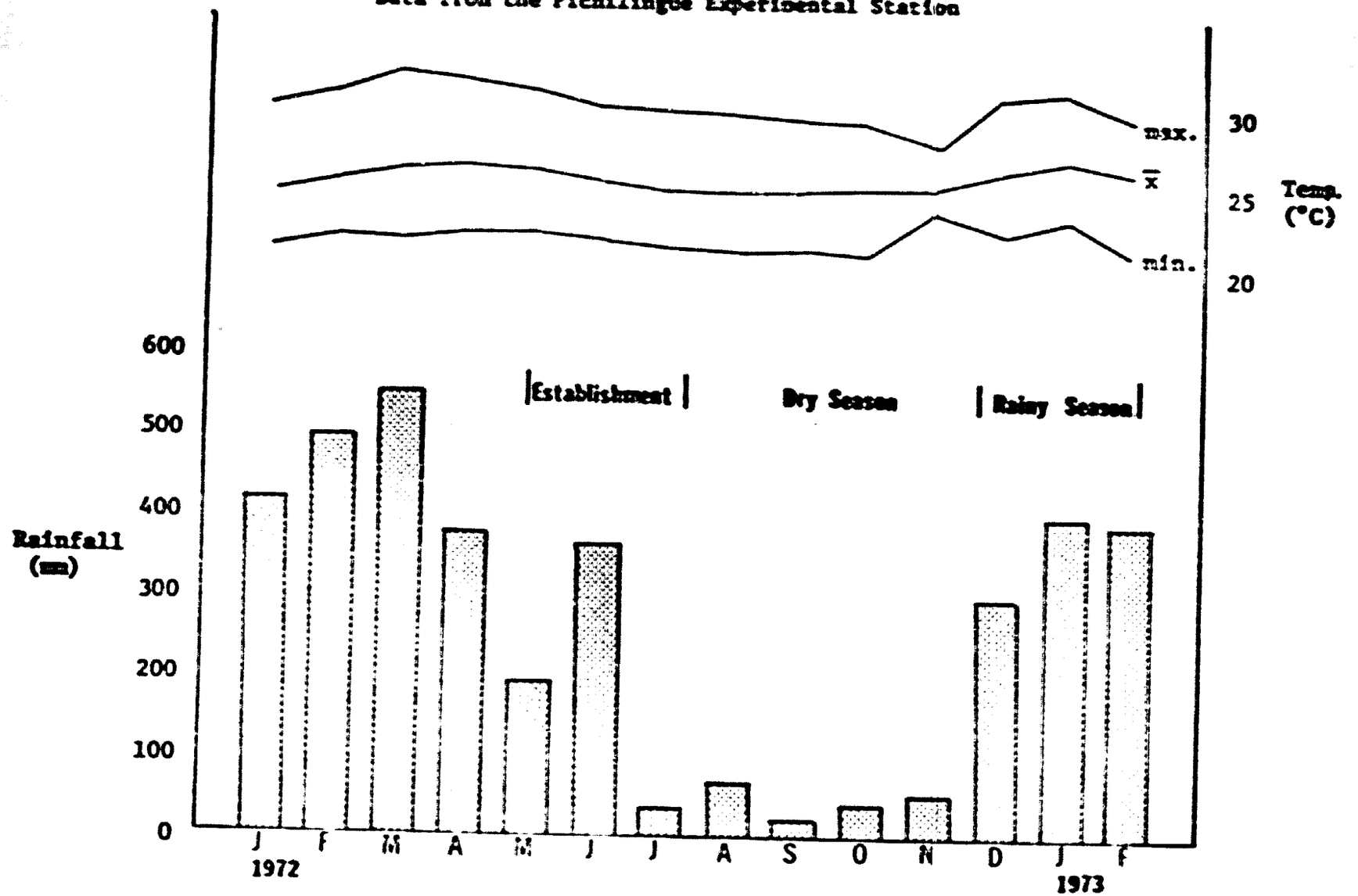
Normally the highest temperatures are experienced in the months of April and May with the lowest temperatures occuring during July and August. Strong southerly winds prevail during the month of May and are the cause of the high evapo-transpiration rates which begin in March and climax in May.

The weather conditions experienced in the course of this experiment are illustrated in Figure 5. The year 1972 was slightly atypical in that the month of June experienced 360 mm of rain compared to the aforementioned average of 40.6 mm. This can be explained by the prolonged duration of the El Nino Current whose effect tapered off toward the end of the month. However the dry season monthly total rainfall figures of 24 mm (Sept.) - 68 mm (Aug.) and the annual total of 2,897 mm (114 inches) still exceed the norm for the 12 year period.

Vegetation

The Quevedo area lies on the line of demarkation of broadleaf deciduous to evergreen broadleaf forest. Its vegetation is therefore broadleaf with discontiguous upper canopy which allows a dense tangle understory consisting of small trees, shrubs, and herbaceous plants. Most of the large buttress trees with aerial roots are in the genera *Ficus*, with

Figure 5. Servicio Nacional de Meteorologia e Hidrologia (1972-1973)
Data from the Pichilingue Experimental Station



characteristic Pambil palm (Catostigma spp.) and Bamboo (Guadua angustifolia) becoming more numerous as one moves north. The principal timber species are Moral (Chlorophora tinctoria), Jigua (Nectandra spp.), Figueroa (Carapa guianensis), Cerdo colorado (Ocotea spp.), Colorado (Pouteria spp.), Cedro (Cedrela fissilis), Amarillo de Guayaquil (Centriolobium patinense), Caracoli (Anacardium excelsum), Maria (Calophyllum longfolium), Guayacan (Tubebina chrysanths), Laurel (Cordial alliodora) and Balsa (Ochroma lagopus). The latter two species are most frequently found in secondary growth (Pan Am Union 1964).

Santillan (1971) reported the following weedy species in his Hyparrhenia rufa pasture experiment at the Pichilingue Experimental Station: Broadleaf weeds were Escoba (Sida acuta), Lulo (Solanum carolinensis), Bledo (Amaranthus spp.) Cojojo (Capsicum spp.) and Flor de cero (Aclepsias spp.). Grass species invaders were Paja brava (Paspalum paniculatum), Jenjibrillo (Paspalum conjugatum), Pata de gallina (Digitaria sanguinalis) and Paja de virgen (Cynodon dactylon).

Soils

The Pan American Survey of the Guayas River Basin (1964) describes the Geomorphology of the Quevedo-Santo Domingo area as a northern dissected plain with moderate to low relief, low rounded hills, and many entrenched streams. This alluvial plain includes Tertiaries incorporated in Quaternary deposits. The soils are of recent volcanic origin with slopes of 0-5% except where dissected by stream action. The topography of the area varies from elevations of 20 to 65 meters.

The relief of the Pichilingue Experimental Station characterizes the more undulating topography of the north coast and consists of a series of

small flat-topped hills having steep slopes extending into small hollows and stream courses (Hardy 1960). However there are also considerable areas of flat alluvial soils in the larger valleys throughout the meandering course of the Rio Quevedo.

Although variations in soil type and texture exist within the littoral, in general the pH is slightly acid and the texture ranges from sandy clay to clay loam. At the Pichilingue Experimental Station the normal root zone, which on pasture land averages 8 inches, is well drained, and consists of 40-60% sand, 20-46% silt, and 8-64% clay. Hardy (1960) reports a moisture equivalent of 37.5% and the apparent specific gravity of the aggregated soil as 0.98, which indicates that this soil is structurally suitable for root penetration. However, although the soil in its natural condition is highly porous and permeable, the cohesion is weak and the consistency can be damaged by cultivation. This results in a dusty soil when dry and a puddled impervious soil when wet. When the latter soil dries out it becomes extremely hard and forms a firm brittle crust.

Frei (1957) classifies the Pichilingue soil group as Latosolic Regosol to denote intermediate stages between the true immature Regosol, which forms over volcanic ash, and the mature Latosol. Hardy (1960) states that chemical analysis of this Pichilingue loam reveals a marked deficiency in available phosphorus, but an abundance of available potassium. The soil nitrogen status is fair to medium on recently cleared land, but declines rapidly with cultivation. Both foliar and soil analyses of cacao and coffee areas have reported high calcium contents, moderate magnesium levels, and frequent deficiencies in boron, zinc, and sulfur.

Table 1 presents a soil profile for Pichilingue loam, and Table 2 reports the soil analysis on the experimental site used in this study. The Comision de Estudios para el Desarrollo en la Cuence del Rio Guayas (1970) gave the Pichilingue soil series a Soil Capability Class rating of "III" which refers to a clay loam textured soil with moderately severe limitations which reduce the range and yield of crops.

Forage Production

The current acreage of natural and improved pastures in the Quevedo-Santo Domingo region has been estimated (CEDEGE 1970) to be 83,000 hectares which are presently supporting 40,000 head of cattle. This results in a carrying capacity of 0.5 animals per hectare (1 animal per 5 acres). The Secretaria General de Planificacion Economica (1966) suggested in their national agricultural survey that coastal littoral could support 1,022,005 head of cattle on 777,336 hectares of improved and on 229,083 hectares of natural pasture. Data from the Pichilingue Experimental Station indicate that improved pasture species such as Hyparrhenia rufa can support 2.5 to 3 animals per hectare (Santillan 1971). The uneven seasonal distribution of rainfall appears to be the principal limiting factor in forage production. During the rainy season there is an over-production of high quality forage which the existing livestock cannot utilize, while during the dry season, the forage production and nutritive value decline to the point of barely sustaining animal weights. Therefore, further investigation into means of increasing forage availability throughout the year and maintaining the nutritive value of dry season feed is urgently needed (Torgas 1972).

Table 1. SOIL PROFILE

Profile Description:	Pichilingue Loam
Association:	Pichilingue
Province:	Los Rios
Site:	Pichilingue Experimental Station
Elevation:	80 meters above Sea Level
Slope:	3%
Parent Material:	Volcanic ash
Natural Vegetation:	Broadleaf deciduous
Actual Use:	Cacao
Drainage:	Excellent internal, excellent external

0-30 cm - Very dark grayish-brown (10 YR 3/3 dry) loam, small blocky with some small (3 mm diameter) iron concentrations, moderate organic matter, pH 6.2 lower boundary indistinct.

30-90 cm - Yellowish-brown (10 YR 5/4 dry) clay loam, small blocky, moderate organic matter, pH 6.5 sharp lower boundary.

90 cm plus - Yellowish-brown (10 YR 5/8 dry) clay with black (10 YR 2/1 dry) mottles. The mottles increase in size with depth, blocky, sticky when wet, low organic matter, pH 6.0.

Pan American Union. Survey of the Development of the Guayas River Basin of Ecuador. Department of Economic Affairs, Pan Am Union, Washington, D. D. 1964, p. 198.

Table 2. SOIL ANALYSIS OF EXPERIMENTAL SITE

Depth of Sample: 0-30 cm

pH: 6.1

% Organic Matter: 5.62

Element	Data As Reported ppm	Fertilizer Basis lb/acre
Phosphorus	28.3	57
Potassium	640.0	1,280
Zinc	15.5	31
Manganese	275.0	550
Sulfur	26.0	52
Copper	16.5	33
	meq/100 g soil	
Calcium	13.0	5,200
Magnesium	2.4	576

Forage Research - Pichilingue

Species Introduction

The annual research reports (INIAP 1965-1971) reveal that major emphasis has been devoted to the introduction, selection, establishment, and management of adapted tropical grass and legume species. This was conducted on the basis of fresh weight yield, drought tolerance, freedom from disease and weed infestation, and recovery from clipping.

Management

In 1965 it was noted that buffelgrass (*Cenchrus ciliaris*) performed best under the existing climatological conditions when clipped at a 5-week interval with 200-400 kg N/ha/yr. In 1966 it was reported that Pangola (*Digitaria decumbens*) responded to 180 kg of nitrogen/ha and 135 kg phosphorus/ha, but not to potassium, whereas bermudagrass (*Cynodon dactylon*) responded to all three.

Nutritive Value

Paladines (1965) conducted a nitrogen fertilization-clipping interval study on elephant grass (*Pennisetum purpureum*) hybrid 534 in a regional trial outside the Pichilingue station (Milagro), and he noted a yield response up to 200 kg N/ha/yr, but concluded that the 6 week clipping interval maximized both yields and nutritive value. Pantaleon (1969) conducted a similar study on puntero (*Hyparrhenia rufa*) concluding that a clipping frequency of 30 to 45 days provided the optimum leaf-stem ratio, as well as the lowest crude fiber contents. Betancourt (1969) analyzed the response of guineagrass (Panicum maximum) to urea fertilization, and found that although 91 kgs N/ha/yr gave the best leaf-stem ratio, 273 kgs N/ha/yr yielded the most protein.

Buffelgrass was shown to have the highest overall crude protein content (average 13.9%) and the lowest fiber content (31.3%) when compared to guineagrass which had 12.1% protein and 31.9% fiber, Pangola (11.0% protein and 31.9% fiber), and Puntero with 10.0% protein and 31.6% fiber (INIAP 1965). In 1967, 90.9 kg of nitrogen yielded 37.4 tons/ha of guineagrass and 84.5 tons/ha of elephantgrass. Elephantgrass proved to have the highest crude protein percentage after both 30 days (15.1%) and 75 days (10.5%), while also containing the smallest percentage fiber (27% after 30 days and 30.8% after 75 days). This may be the result of inadequate sampling (i.e., analyzing leaf material only). Buffelgrass showed the greatest decline in protein content over this period (14.8% to 8.4%). In this study the guineagrass crude protein content ranged from 8.8% to 14.3%, while in the 1966 study the range was 5.2% to 19.2%. In a clipping trial with 30, 45, and 60 day intervals, it was discovered that guineagrass flowered after 30 days whereas elephantgrass and Puntero flowered after 45 days. Since it is generally true that nutritive value drops at flowering from a grazing animal point of view, it was concluded that 60 day clipping intervals were too long.

Establishment

During the years 1966 to 1968 three different seeding rates were reported as optima for Puntero. They were 3 kg seed/ha at one meter spacings, 13 kg seed/ha at 75 cm to 1 meter spacing, and 13 kg seed/ha at 50 cm spacings. In 1970 it was noted that Pangola and bermudagrass were very slow to establish and required two thorough weedings. Guineagrass yielded 21.9 tons/ha and Puntero yielded 11.7 tons/ha in that same year.

Grass-Legume Associations

A study of 8 grass-legume associations was conducted in 1971 using grazing animals. *Brachiaria mutica-Glycine wightii* and *Panicum maximum-Centrosema pubescens* mixtures were shown to be the most compatible and the best accepted by animals. The animals found tropical kudzu (*Pueraria phaseoloides*) and *Calopogonium mucunoides* unpalatable, while the performance of Siratro (*Phaseolus atropurpureus*) was severely limited due to the presence of leaf blight. At the end of one year, the guinea-centro association had 73% grass and 23% legume.

Forage Research Abroad

Nitrogen Fertilization vs. Quantity and Quality of Tropical Forages

When other plant nutrient requirements are met, nitrogen is the main factor restricting the production and nutritive value of tropical pastures (Salette 1970; Bryan 1962). The quantities of nitrogen required for high producing tropical grasslands exceed those required for temperate zones because of leaching, nitrification, very high growth rates in tropical grass species, and low amounts of available nitrogen found in tropical soils (Henzell 1962). Vincente-Chandler and Figarella (1958) showed that the application of 100 to 400 lbs of nitrogen per acre at the end of the rainy season increased the protein content of 3 successive dry season samplings without increasing overall yield. However, Little *et al.* (1959) found that both the yield and the protein content of napiergrass (*P. purpureum*), guineagrass, and Pangola increased with higher nitrogen rates under irrigated conditions, while Tergas and Blue (1971) added that although nitrogen fertilization was beneficial from the standpoint of increasing yields and nitrogen contents of *H. rufa*, it was of little value

in maintaining high forage nitrogen levels during the dry season in the tropical savannahs of Costa Rica. Vincente-Chandler et al. (1959) discovered that guineagrass yield increased to the 880 kgs nitrogen rate of application and the protein content and protein yield increased to the 1760 kgs of nitrogen rate, however the efficiency of nitrogen utilization in terms of dry matter produced per pound nitrogen decreased as the rate of nitrogen increased. Grof and Harding (1970) stated that nitrogen efficiency was greatest at 140 kg N/ha/yr on the humid tropical coast of North Queensland. This rate of application resulted in a yield increment of 38 kilograms of dry matter per kilogram of nitrogen applied.

Mott (1970) showed that the application of nitrogen fertilizer had a residual effect on subsequent yields of Colonial guineagrass in Brazil the following years. This suggests that after initial high rates of N fertilization, smaller annual applications may suffice to meet the requirements of the grass.

Nitrogen Fertilization vs. Animal Product

Holmes (1968) derived a linear regression of yield of animal product based on the amount of nitrogen applied. His results show a linear increase in yield up to about 450 kgs of N/ha, and that each kilogram of nitrogen yielded about 15 kilograms of milk. Bryan and Evans (1971) added that there was also a response in animal gain to nitrogen fertilization of Pangola, where 168 kgs N/ha/yr resulted in a 699 kgs/ha live weight gain (LWG) and a carrying capacity of 3.6 animals/ha, while 448 kgs N/ha increased the live weight gain to 1106 kgs and the carrying capacity to 5.6 animals /ha. Oakes (1960) confirms such reports by his work in the West Indies where he obtained 1,000 lbs LWG/acre/yr from Pangola plus 300 lbs of sulphate of ammonia. Grof (1970) obtained a 41% increase in

live weight gain in North Queensland using guineagrass plus 150 kgs N/acre/yr compared to guineagrass alone.

Economics of Nitrogen Fertilization

Although the yield response of tropical grasses from increased increments of nitrogen is sigmoid with strong increases in yield up to 800 kgs/ha/yr, normal rates of nitrogen fertilization in the tropics seldom exceed 250 kgs/ha/yr (Salette 1970). There are two primary reasons for this. The first deals with the economics of fertilizer costs relative to yield response in the tropics, and the second concerns the critical management of nitrogen fertilizations under climatic regimes of high rainfalls and high soil nutrient leaching. Teitzel et al. (1971) obtained high seasonal animal production (1,100 kgs LWG/ha) in Queensland, Australia using 340 kgs N/ha/yr, but concluded that the additional cost of the fertilizer offsets the higher productivity of the forage. Bryan and Evans (1971) also obtained high live weight gains and high carrying capacities (5.6 animals/ha) using 448 kgs N/ha/yr, which confirms that nitrogen fertilizers can satisfy the very large nitrogen requirements of the vigorous tropical grasses, but they add that nitrogen fertilizers are very expensive at this time, and until the commercialization of synthetic nitrogen in tropical areas changes this, a cheaper source of nitrogen, such as that symbiotically fixed by legume Rhizobium, will have to suffice. Henzell (1970) states that although nitrogen fertilizer is available immediately to the grass plant, it is also exposed to losses before uptake by the plant whereas nitrogen fixed symbiotically by legumes is used directly for plant growth and incorporated into the legume plants without significant loss. Fertilizer nitrogen is exposed to losses either by

volatilization of ammonium, or by the bacterial dentrification or chemo-dentrification of nitrogen gas or its oxides. The potential leaching of nitrates is especially critical under high rainfall conditions such as those which exist in the tropics. In an earlier article he stated that nitrogen recoveries of 50%-75% are good, although the range is normally less than 10%-80% (Henzell 1962). Other authors suggest that the recovery of fertilizer nitrogen seldom exceeds 50% (Dily et al. 1960; Martin 1962). Henzell (1970) stated further that nitrogen incorporated in the legume plant must undergo a series of transformations before it becomes available for uptake by non-legumes. This occurs after it has passed through a grazing animal, or after it has been released from legume plants and residues through the process of underground transfer.

Legume Nitrogen Fixation

Nitrogen fixation in temperate forage legumes such as Alfalfa (Medicago sativa) and White Clover (Trifolium repens) has been known for many years. Woodhouse (1958) quoted nitrogen fixation estimates ranging from 50 lbs per acre for annual temperate legumes to 200 lbs per acre for alfalfa, while the estimates of Walker et al. (1954) ranged from 70-220 kgs N/ha/yr. However, nitrogen fixation in tropical legumes has been the subject of much discussion in recent years. At present there is good evidence that under comparable conditions tropical legumes can fix nitrogen in about the same quantities as their temperate counterparts (Moore 1962; Henzell and Norris 1962; Henzell 1967). Henzell (1967) stated that the range of nitrogen fixation rates for tropical legumes in Northern Australia is 0-310 kgs/ha/yr. Whitney et al. (1967) reported that Centrosema pubescens fixed 240 kgs of nitrogen/ha in associations. Such perfor-

mance has also been duplicated elsewhere in the world such as Nigeria (Moore 1960) and Malaya (Bryan 1962). Stylosanthes humilis fixed 196 lbs n/acre/yr during its first season in Northwest Australia (Wetselaar 1967).

Nitrogen Transfer

The transfer of nitrogen from temperate legumes to associated temperate grasses has been demonstrated by many authors (Walker et al. 1954; Butler and Bathurst 1956; Butler et al. 1959; Simpson 1965). These studies have shown that up to one-half of the total nitrogen fixed by white clover have been transferred either by gradual release or by the sloughing off and decay of nodules. The highest rates of nitrogen have been demonstrated to be transferred by grazing animals, but in most cases this distribution was very uneven (Whitehead 1970; Shaw et al. 1966). Cowling et al. (1964) showed that 28-65% of the total N present in a mixed, ungrazed sward was transferred and that the transfer was considerably higher in the third year than in the first two years. Whitehead (1970) further stated that very little nitrogen was transferred in the establishment year and that maximum rates are unlikely to be attained before the third year depending on the frequency and height of defoliation. Wilson (1942) made one of the earliest comprehensive reviews of this subject and noted that although there is some evidence that nitrogen may be transferred via the excretion of organic compounds from living roots, repeated defoliation of white clover has shown that the decomposition of root and nodule tissue is probably the main route in the transfer of nitrogen.

Henzell (1962) was one of the first to study the nitrogen fixation and transfer of both temperate and tropical legumes at the same time. He concluded that although the temperate legume species fixed more nitrogen on the whole, the tropical legume Indigofera spicata fixed as much nitrogen as alfalfa during the first year, while Desmodium uncinatum transferred more nitrogen during the second year of the experiment than did the other five legumes. However only 0.6-1.7% of the total nitrogen fixed over the two year period was transferred which may be explained by the fact that no return of top growth to the soil was permitted. Bryan (1962) reported that in the Philippines Centrosema pubescens increased the crude protein content of the associated grass Melinis minutiflora from 11.9% for the pure grass stand to 22.3% for the mixture when dead legume tissue was returned to the soil. He also commented that the same comparison in Australia had increased the crude protein content of the M. minutiflora from 7.1% when grown alone to 9.1% when associated with centro. Fernando (1961) reported significant increases in both dry matter yields and protein content when centro was included in a Brachiaria brizantha pasture in Ceylon. However other authors have indicated that although the protein yields of the grasses increased when the legume was included, the dry matter yields of the mixed swards were not appreciably higher than those of the pure grass (Kyneur 1966; Whitney 1969). Jones et al. (1967) showed that while the nitrogen and dry matter yields of Phaseolus atropurpureus (Siratro) in association with grasses in southeast Queensland was closely correlated with rainfall, the yields were equivalent to that from a grass receiving 190 kgs N/ha/yr. He also mentioned that the nitrogen transfer to the associated grass increased with

time. Norman (1960) found that the total yield of the buffelgrass (Cenchrus ciliaris)-Townsville lucerne (Stylosanthes humilis) mixture was approximately equal to the yield of buffelgrass alone plus 500 kg of ammonium sulphate/ha/yr or roughly double that of the unfertilized grass alone.

Kretschmer (1966) reported after four years of investigation in South Florida that Siratro-Pangola mixtures yielded 8.8 tons of forage/ha/yr with a crude protein content of 7.1% compared to 5 tons of forage/ha/yr for Pangola alone.

Whitney et al. (1967) found that Desmodium intortum when grown alone fixed 340 lb N/acre, but in association with two tropical grasses it transferred less than 5%. In the same study Centrosema pubescens was shown to fix 110 lb N/acre in associations but transferred 6-11% of that fixed. Leaf fall appeared to be a more important source of transfer than leaching of nitrogen from live legume tops or release from nodules and roots following defoliation. Birch et al. (1967), in a study in Kenya, reported that a soil analysis on plots occupied by grass-legume associations showed that the legume built up a mineralizable surface organic horizon through the contribution of litter and roots which readily decomposed and on mineralization increased the amount of nitrates in the underlying soil. The effect of the legume was most significant during the early period of the wet season when soil nitrogen mineralization was the most pronounced, and the magnitude of the effect depends on which grass species is associated as well as the climatic conditions governing mineralization of the legume residues. Other authors have reported a negligible amount of nitrogen transfer in the short run and quite low rates over periods of

six months to two years (Vallis et al. 1967; Henzell et al. 1968). Henzell (1970) concluded that there is still no conclusive evidence for an active process causing direct transfer of nitrogen from live legumes to associated non-legumes. Nitrogen transfer from actively growing legumes is usually small, and could probably be attributed to the passive release of nitrogen from both the aerial and subaerial portions of the plant or to the leaching of dead and decomposing vegetative material. Norris (1972) added that the process of nitrogen turnover is slow, whereas the capacity of grasses to take up nitrogen is very high. Therefore, even at the maximum rate of turnover possible for legumes, the potential growth of an associated grass may be limited.

Nutritive Value of Tropical Pastures

Minson and McLeod (1970) have shown that the dry matter digestibilities of tropical grasses are generally lower than that of temperate grasses. This may be due to genetic differences because taxonomically the tropical and temperate grasses belong to different sub-families, or to the high correlation between dry matter digestibility and temperature. Van Soest (1965) stated that chemical composition on the whole is much more closely related to digestibility than to voluntary intake, and the interrelationships between intake, digestibility, and chemical composition are highly species oriented. Butterworth (1967) added that both the proximate composition and digestibility of grass constituents are directly influenced by the maturity and stage of growth of the grass. Norris (1972) pointed out that the nitrogen percentage of unfertilized or fertilized pure grass pastures may fluctuate widely even to the extent where despite the presence of large amounts of forage it frequently falls below the

maintenance level required for animals. Hamilton et al. (1970) found that milk production from tropical pastures is generally low. Their study with supplements indicates that the main factor limiting production from well fertilized pastures is the low intake of digestible energy, due to the inability or unwillingness of dairy cows to eat a sufficient amount of tropical pasture feeds, which are of low digestibility even when well managed and grazed at a young stage of growth. Cizek (1970) showed that the dry matter disappearance of legumes is slightly greater than that of grasses, and that the voluntary intake of forages and rumen transit time increase rapidly with digestibility in the range of 30-75% apparent digestibility. Minson and Milford (1966) stated that age was the most important factor determining energy content of Pangola, Siratro (Phaseolus atropurpureus), and Sorghum almum. The energy content decreased with age, and increased with increased crude protein contents. Minson and Milford (1967) found that when sheep were offered mature Pangola, the voluntary intake was low, but by including 10-20% legume in the diet, the voluntary intake of Pangola increased, probably due to the elimination of a crude protein deficiency. As the proportion of the legume in the diet increased, there was an increase in the voluntary intake of the entire diet, and an increase in both the dry matter and crude protein digestibilities. This is important in light of the work by Conrad (1966) which showed that a close relationship exists in ruminants between the content of indigestible plant residues in the digestive tract and the total amount of feed consumed. Milford and Minson (1965) added that excess crude protein contents in tropical grasses at an early stage of growth, following heavy applications of nitrogen fertilizer, adversely affect voluntary intake. They found that intake declined 33% with Chloris

gayana that had been heavily fertilized in an attempt to increase the crude protein content from 8% to 13.5%. They also found that although the aging and maturing of forages is usually regarded as being closely associated with a decline in voluntary intake, this does not always apply to tropical forages. The dry matter intakes of Cenchrus ciliaris and Digitaria decumbens did decrease with age, but that of Chloris gayana and Phaseolus atropurpureus did not. They isolated the relative decline of crude protein content to be responsible for this.

Kretschmer (1971) summarized by saying that although the quality of tropical legumes is considerably less than their temperate counterparts, the digestibility of the tropical legumes is greater and does not decrease as rapidly with age as does that for most of the tropical grass species. Also since the protein levels in most tropical legumes in almost all stages of growth is adequate for maximum animal production, the legume component of the sward can act as a protein supplement in pastures where the tropical grass species protein content is the limiting factor in animal production.

Animal Performance on Grass-Legume Associations

Much information has been compiled in temperate areas concerning increased dry matter, protein and animal yields from clover-grass swards (Van Keuren and Heinemann 1958). Similar data has come from the subtropical areas of Australia (Humphreys 1967; Hutton 1968). Moore (1962) found that in the humid tropics of Nigeria Centrosema pubescens increased the average content of crude protein in stargrass (Cynodon plectostachyus) shoots from 11% in its absence to 15%, and it raised the liveweight gain of cattle from 1.12 to 1.35 lb/acre/day in the wet season and from 0.67 to 1.00 lb/acre/day in the semi-dry season. Stobbs (1969) reported 419 kg

live weight gain (LWG) from Centrosema pubescens-Hyparrhenia rufa pastures in Uganda, compared to 345 kg LWG from the grass pastures. Grof and Harding (1970) stated that centro-guineagrass (Panicum maximum) yielded 36% more live weight gain than guineagrass alone in North Queensland and carried 3.5 animals/ha over a two year period. Hall (1970) showed that animal production on unimproved native range increased from less than 9 kg LWG/ha to 112 kg LWG/ha with the use of a guinea-Siratro mixture.

Aronovich et al. (1970) found that in Brazil a mixture of Pangola-centro produced 17% more live weight gain/ha than did the control and carried 2.4 animals/ha. The mean gain per steer per year was highest for the grass-legume mixture, but the mean gain per hectare per year was highest for the nitrogen fertilization treatment which carried 3.3 animals per hectare. Bryan and Evans (1971) also reported higher ($P<0.05$) live weight gains per hectare from high rates of nitrogen fertilization compared to the use of Pangola plus Lotononis bainesii and D. intortum which gave mean live weight gains of 507 kg/ha. However, this may partially have been due to their failure to maintain adequate amounts of the legume in the sward.

Management of Grass-Legume Associations

Although tropical legumes are adapted to low fertility, acidic soils, they are slow to establish and lack initial vigor. Grof (1965) noted a response to phosphorus during establishment in the humid tropics of northeastern Australia. Stobbs (1969) reported that centro-H. rufa plots fertilized with phosphorus had a significantly higher total nitrogen and available phosphorus content, and that they produced substantial

increases in subsequent crop yield compared to non-fertilized grass-legume plots. Younge et al. (1964) in his four year study of Desmodium spp. in Hawaii found a marked response to phosphorus, potassium, molybdenum and zinc. When adequately fertilized, the legumes were fully competitive with aggressive grasses such as kikuyu (Pennisetum clandestinum), Pangola and Dallisgrass (Paspalum dilatatum). Anderson (1956) stated that low levels of soil molybdenum prevent the Rhizobium fixation process even in the presence of abundant nodules. Another common deficiency limiting the performance of legume symbiosis is that of sulfur, which was shown to prevent protein build-up in Stylosanthes humilis by Jones and Robinson (1970). Andrew and Hegarty (1969) examined the toxicity effects of manganese in tropical legume nutrition and noted that Centrosema pubescens had a manganese toxicity threshold of 1,600 ppm in the dry matter of its top leaves, compared to thresholds of 1,160 ppm for Desmodium uncinatum and 840 ppm for Phaseolus atropurpureus.

Norris (1972) stated that the most important factors for the success of tropical legumes in the order of their priority are the establishment of a fully effective symbiosis, provision of adequate plant nutrition for the symbiosis to function, and the imposition of a grazing regime that allows the legume to persist and contribute nitrogen. He discussed the strain specificity of certain tropical legumes for appropriate cross inoculation group strains of Rhizobium. Jones (1967) analyzed the response of legume production to clipping frequency and reported a linear increase of dry matter yields up to a 16-week cutting interval. His four week cutting interval severely reduced the legume stand for one season. Whiteman in two separate studies in 1970 found that clipping reduced the number of nodules and weight per nodule in both D. intortum and P. atropurpureus.

However grazing caused a greater reduction than cutting in terms of plant and nodule weight and legume yield. Henzell (1967) also reported that Desmodium intortum and Phaseolus atropurpureus perform best under infrequent defoliation.

The response of tropical grasses in terms of seasonal productivity and nutritive value has long been studied. Schofield (1945) found that the crude protein contents of stargrass (C. plectostachyus) and guineagrass first increased then decreased under frequent clipping depending on the relative status of soil nutrients. French et al. (1960) reported data from Venezuela, Tanganyika, Puerto Rico, Guatemala, and Trinidad on the relative increase of crude protein and crude fiber contents of elephantgrass, guineagrass, and paragrass (Brachiara mutica). Brockington (1960) found that in Northern Rhodesia the quality of H. rufa declined rapidly in the early part of the wet season when there was uninterrupted plant growth and maturation. Crude protein contents fell from 18.9% in December to 2.7% in January during the period of greatest dry matter production, however he noted that adequate clipping management reduced this quality decline. Bryan and Sharpe (1965) reported higher dry matter yields, nitrogen contents, and nitrogen recovery from high rates of nitrogen fertilization at long clipping frequencies and greater clipping heights in southeastern Queensland.

Description of Species Used

Panicum maximum Jacq.

Guineagrass, also locally called Cauca, Saboya, or Chileno on the coast of Ecuador, is a tufted perennial native to tropical and sub-tropical Africa. McIlroy (1972) points out that it is relatively drought tolerant,

of high nutritive value when young, and combines well with tropical legumes. He reports yields of 122 tons of green fodder per hectare per year from the Philippines and Australia. On the coast of Ecuador where it is most commonly established by the division of plant crowns, yields of 100 tons of fresh forage per hectare have been reported (INIAP 1971).

Pennisetum purpureum Schumach

Napiergrass or elephantgrass is very tall-growing (4 to 5 meters), high yielding (180 tons fresh forage/ha/yr), a perennial species which occurs naturally near streams and rivers in tropical Africa and is widely distributed in Nigeria (McIlroy 1972). Although grazing management is difficult with this grass, it has shown promise as cut forage or silage. Grof (1969) reports on the selection and development of the Merker variety released as Capricorn elephantgrass from the Biloela Research Station, and adds that in combination with centro gave higher live weight gains than guinea-centro. The hybrid variety 534 released from the Pichilingue Station is established by stem cuttings and reported yields up to 300 tons of green forage/ha/yr (INIAP 1971).

Hyparrhenia rufa (Nees) Stapf.

Known as Puntero or Jaragua grass, H. rufa is a drought resistant tufted perennial found throughout tropical Africa, Central, and South America (Whyte et al. 1959). McIlroy (1972) reports that the young growth of this species is of value, especially after burning, but that the nutritive value decreases toward flowering. Tergas et al. (1971) explains that this grass generally flowers at a time when the soil is drying and when there is subsequently less mineralization and uptake of

nutrients by the plant. Santillan (1971) reports yields of 120 tons of fresh forage/ha/yr when established by seed in the Pichilingue Experimental Station.

Digitaria decumbens Stent.

Pangola is a stoloniferous, perennial turf grass native of South Africa. Since introduced to the southeast United States of America, Pangola has produced more beef in south Florida than any other grass tested (McIlroy 1972). This species, which is propagated by sprigs or stolens, persists under continuous close grazing, survives both flooding and drought, but makes its best growth on well drained moist soils. Yields of 65 tons of green forage/ha/yr have been obtained on the coast of Ecuador (INIAP 1971). Resistant varieties are currently being developed against a number of pests such as aphids (Schizaphis spp.), rust disease (Puccinia oahuensis), and Pangola stunt virus (Teitzel et al. 1972). Harding (1972) reports that it has been difficult to keep an adequate proportion of most tropical legumes in association with Pangola except under moderate grazing, and Desmodium heterophyllum is the only legume compatible with it under heavy stocking pressure.

Cynodon plectostachyus (Schum.) Pilger

Stargrass, occasionally referred to as giant stargrass or Naivasha stargrass, is a very aggressive stoloniferous perennial native to East Africa, which forms a dense turf up to 120 cm in height when propagated vegetatively. McIlroy (1972) stated that a high nitrogen status and close grazing are essential for the maintenance of a good pasture. Caro-Costas et al. (1961) reported that stargrass yielded 1,350 kg DM/ha/yr

and carried 3 animals to the hectare when fertilized heavily in the humid mountain regions of Puerto Rico. Data from the Pichilingue Station in Ecuador report yields of 90 tons of green forage/ha/yr (INIAP 1971).

Cenchrus ciliaris (L.) Link

buffelgrass or African foxtail is a perennial 30-90 cm in height which is suited to lower rainfall climates such as those of its tropical Africa, India, and Indonesia (McIlroy 1972). For establishment 20 pounds of seed/ha are used on the coast of Ecuador where yields of 80 tons of green forage/ha/yr have been obtained (INIAP 1971). Norman (1966) found that Stylosanthes humilis combined well with buffelgrass at the Katherine Research Station in Australia.

Centrosema pubescens Benth

Centro is a prostrate trailing perennial which is easily established from seed, highly resistant in grazed swards, and adapted to soils of medium to high fertility with good drainage (Harding 1972). Grof and Harding (1970) report that promising introductions from Costa Rica appear to have resistance to cool seasons, red spider mites, and Cercospora leaf spot.

Macroptilium atropurpureum (formerly Phaseolus atropurpureus D. C.)

Hutton (1968) reports that a new cultivar "Siratro", which he developed in Brisbane, Australia, by crossing two Mexican ecotypes of P. atropurpureus, has resistance to root-knot nematode and little leaf virus. McIlroy (1972) states that Siratro has become the most adaptable and widely used of the tropical legumes in Queensland. It is a vigorous,

twining, perennial legume that tolerates drought and low-fertility soils and establishes readily from seed. Kretschmer (1971) noted that in mixture with Hyparrhenia rufa the Siratro survived the dry season and began rapid growth at the commencement of the rainy season while the associated grass was still dormant. Sonoda et al. (1971) described the disease web-blight (Rhizoctonia solani Kuhn.) which caused heavy defoliation of Siratro during October in south Florida. However, they noted that new growth was free of the disease and that clipping appeared to retard it.

Desmodium intortum (Mill.) Urb.

Greenleaf Desmodium was derived from crosses of three introductions from El Salvador and Guatemala. It yields less seed and is slower to establish than D. uncinatum but once established it is more vigorous and hardier than Silverleaf (Hutton 1968). Bryan (1969) reports that it is used commonly on non-irrigated pastures in Australia in pure stands, as hay, or in pasture mixtures. McIlroy (1972) adds that it grows well on most soil types and tolerates poor drainage and flooding. However, Harding (1972) reports that this semi-decumbent legume usually only grows well during the first season, and deteriorates rapidly due to leaf fungal diseases, Amnemus weevil, and little leaf disease.

METHODS AND MATERIALS

Factors Studied

A. Species (9 total species)

B. Fertilization (2 treatments)

C. Recovery Interval (2 rest periods)

Factor Levels

A. Species:

1. Grass species:

Panicum maximum Jacq.	Guineagrass (var. Pichilingue)
Pennisetum purpureum Schumach	Elephantgrass (hybrid 534)
Hyparrhenia rufa (Nees) Stapf.	Puntero
Cenchrus ciliaris (L.) Link	Buffelgrass (var. Biloela)
Digitaria decumbens Stent.	Pangola
Cynodon plectostachyus (Schum.) Pilger	African Stargrass (#2)

2. Legume species:

Centrosema pubescens Benth	Centro
Macroptilium atropurpureum	Siratro
Desmodium intortum (Mill.) Urb.	Greenleaf Desmodium

B. Fertilization Treatments:

1. Grass plots unfertilized (control)

2. Grass plots + 100 kg N/ha/yr

C. Recovery Intervals:

1. 21 day rest period (3 week clipping frequency)

2. 42 day rest period (6 week clipping frequency)

Treatments

1. Control (each grass species unfertilized)

2. Fertilized (each grass species + 100 kg N/ha/yr)

3. Centro (each grass species + C. pubescens)

4. Siratro (each grass species + M. atropurpureum)

5. Desmodium (each grass species + D. intortum)

Experimental Procedure

Site

A one-hectare experimental site in the livestock section of the Pichilingue Experimental Station was selected on May 3, 1972, on the basis of its uniform topography, accessibility, closeness to irrigation facilities, location in relation to planned road construction and future pasture program development, and the adaptability of existing fences. The area selected was a segment of an 8 year-old Pangola pasture that was badly in need of renovation. This pasture had been grazed extensively, irrigated during the dry seasons, and fertilized annually with 100 kg of nitrogen in the form of urea. Two hectares of adjacent land were selected for the fistulated steer which was used for dry matter

digestibility determinations. This area was selected because it was near existing corrales and irrigation facilities, and because it had a relatively uniform established stand of guineagrass.

Land Preparation

On May 5, 1972, the sod on the experimental site was turned and broken up using a John Deere 2020 disk plow and harrow. The area was then raked to remove remaining litter. The existing fences were reinforced with new posts and new wire, and a new section was added to enclose the experimental area, and a new gate was constructed. On May 11, 1972, 400 pounds of simple superphosphate was applied which was calculated to supply approximately 72 to 80 kg P/ha. The first application of 50 kilos of nitrogen occurred on May 31, 1972. Urea was applied in bands (shallow furrows) beside the rows and covered with soil immediately to prevent losses via volatilization.

Establishment

Three legume species and Cenchrus ciliaris (buffelgrass) were seeded on May 12, 1972. Immediately prior to seeding the Centrosema pubescens (centro) and Macroptilium atropurpureum (Siratro), formerly Phaseolus atropurpureus, seeds were scarified in concentrated Sulfuric Acid for 15 minutes which boosted their germination rate over 85%. The Desmodium intortum and buffelgrass seed germination rate in three consecutive tests (May 8-10) was over 75%, but the Hyparrhenia rufa (Punteroc) seed showed no germination. This may have been due to seed storage in double-lined plastic bags in very warm climatic conditions which is not conducive to seed viability.

The presence of Desmodium and Centrosema species in the native vegetation of the area suggested that free-living soil Rhizobium were a natural resource. For this reason, along with the cost factor and time delays involved in the importation of innoculum, the legume species in this study were not artifically innoculated. This did not appear to hamper the nitrogen fixation of the legumes in any way, and periodic examinations of legume roots showed ample and extensive nodulation. Seeding amounts per plot were calculated on the basis of commercial per acre recommendations. Fifteen grams each of Siratro and Desmodium seed and 25 grams each of buffel and centro seed were weighed out for each of their designated plots and proportioned equally in the field according to rows.

Vegetative propagation of the remaining species, including Puntero, was begun 15 days (May 27-31) following the seeding of the legume species. This permitted closer observation and control over their establishment. Stem cuttings with three nodes each were used for Pennisetum purpureum (elephantgrass) and were placed in the soil with two of the three nodes beneath the surface. Viable stolons were propagated in the case of Digitaria decumbens (Pangola) and Cynodon plectostachyus (stargrass), and divisions of the crown were used for Panicum maximum (guineagrass) and Puntero. It should be pointed out that vegetative establishment of Puntero is slow, difficult, and not done commercially. Five transplanting attempts were made before complete establishment was attained. The amount of vegetative material used was calculated on the basis of 10 cubic meters/ha which varied slightly according to species and propagative material used.

To simplify seeding one of the four bamboo stakes denoting each plot was color coded to indicate grass species and another was flagged with fragments of different colored plastic material to indicate treatment. A wooden rake-like device was constructed with four spikes spaced 50 cm apart. This facilitated the hand seeding by scratching furrows in the soil surface and insured uniform row spacings.

Pure grass plots (treatments #1 and #2) were planted with one meter spacings between rows and 50-75 cm between plants, except for buffelgrass, stargrass, and Pangola, which contained both 50 cm rows and plant spacings. This resulted in five (one meter) rows per pure grass plot for guineagrass, elephantgrass, and Puntero, and nine (50 cm) rows for the remaining three grasses. Four legume rows were interspaced in the former case, and substituted for the interspaced grass rows in the latter. Therefore, each grass species was established as closely as possible to its recommended seeding rates and distances, and in each grass-legume plot 44% of the seeded surface was legume.

Clipping Procedure

Table 3 presents the work calendar for this experiment. An equalizing or staging cut was made on July 26, 1972, eleven weeks after establishment. A total of 10 clippings were made every three weeks following this date for the period August 15, 1972-February 20, 1973, on one-half the plots. On every other harvest date both the 3 and 6 week clipping frequencies were harvested. Clipping was accomplished by the use of a sickle-bar mower mounted on a John Deere 140 tractor. The height was set at 15 cm and care was taken to follow a standardized procedure in that each plot was harvested in the same direction each time.

Table 3. SCHEDULE OF MAJOR ACTIVITIES

Date	Activity
May 3, 1972	Selected experimental site
May 5	Seed bed preparation and soil sampling
May 12	Seeded legumes and buffelgrass (Superphosphate application, 72-80 kg P/ha)
May 27-31	Vegetatively propagated grass species; first fertilization treatment (50 kg N/ha as urea)
July 26	Equalizing cut
August 15	3 week sampling
September 5	3 week sampling & 6 week sampling
September 26	3 week sampling
October 17	3 week sampling & 6 week sampling
November 7	3 week sampling
November 28	3 week sampling & 6 week sampling
December 19	3 week sampling
December 21	Second 50 kg N/ha application (broadcast NH_4NO_3)
January 9, 1973	3 week sampling & 6 week sampling
January 30	3 week sampling
February 20	3 week sampling & 6 week sampling

Sampling

Two one-half kilogram samples of fresh forage were randomly collected from each plot containing a grass-legume association and placed in labelled cloth bags. One of these samples was weighed immediately in the field, and its weight in grams noted both on the bag and in a ledger. When the harvest was completed these bags were then placed in a forced air, kerosene-heated drying room and dried for a minimum of 24 hours at 45°C. The dried sample that had been weighed previously in the field, was reweighed while still hot, and from this weight difference the percent moisture was calculated. The other dried sample was then hand separated into its grass, legume, and weed components which were weighed individually for the calculation of Botanical Composition. The first sample, and the grass and legume components of the second sample were then ground through a Wily Mill (1 mm screen) and sub-samples were taken for nitrogen content and dry matter digestibility analysis.

This allowed analysis of the nutritive value of both the total association and its individual components. However in the case of the pure grass plots, only one one-half kilogram sample was taken, because the nutritive analysis of individual components was not necessary. In this way, the total number of field samples which had to be handled in the course of this experiment was reduced from 2,700 to 2,160 samples.

The fresh weight yield was measured from the 15 square meters of each plot at each clipping frequency, and this figure together with the percent moisture calculation, were used in determining the dry matter yields per hectare. All clipped debris was removed from each plot after each harvest.

Observations

Field observations were made throughout the 11 week establishment phase and prior to each harvest. This was done on a plot by plot basis with special attention given to insect damage, recovery vigor, weediness, ground cover, nutrient deficiency symptoms, disease infestation, lodging after fertilization, flowering, and general compatibility of the grass-legume swards.

Nitrogen Determination

Approximately 2,000 samples were analyzed for nitrogen using a micro-Kjeldahl apparatus and a technique developed by Muller (1961) in Turrialba, Costa Rica. Digestion was done in concentrated Sulfuric acid with potassium sulphate, copper sulphate, and sodium selenite as catalysts. Samples were distilled into Boric acid solution and titration was accomplished using .02 N Sulfuric acid.

Dry-Matter Digestibility Determination

The Nylon-bag Technique (Lowrey 1969), which involved rumen incubation of 10 gram samples of dry ground forage for 72 hours in 100 mesh nylon bags (5 x 15 cm), was used to estimate digestible dry matter content of the forages studied. Weights of the oven-dry bags before and after incubation were measured and the percentage dry matter disappearance recorded. Six bags were attached to each 250 ml water-filled polyethylene bottle which served as a weight and prevented passage beyond the rumen. A one year-old fistulated Brahma-criollo steer was used. A minimum of 5 bottles (30 samples) per run and a maximum, late in the experiment, 8 bottles (48 samples) were placed in the rumen. Monson et al. (1969) in

his comparison of Nylon-bag in-vivo with two stage in-vitro digestion techniques reported correlation coefficient of 0.92 ($P<0.01$) between the two techniques, and other authors have reported significant correlations between Nylon-bag cellulose digestibility and conventional cellulose digestibility (Hopson 1963) and Nylon-bag dry matter disappearance compared with TDN and dry matter digestibility (Neathery 1972).

Standards of 6 and 10 week-old bermudagrass and 2, 6, 8, and 10 week-old Pangola Digitgrass were obtained from the Animal Nutrition Laboratory of the University of Florida, and analyzed using the Nylon-bag Technique at the Pichilingue Experimental Station. The in-vitro percent organic matter digestibility of these standards ranged from 45.9% to 69.7%. The mean dry matter disappearance percentages for these samples when analyzed by the Nylon-bag Technique ranged from 32.5% to 59.1%. However, the results were found to be highly correlated in each case as shown in Figures 6 and 7. The correlation coefficient for Nylon-bag compared with the in-vitro was 0.95 ($P<0.01$), while that for the in-vivo comparison was 0.99 ($P<0.01$).

Statistical Analysis

Yield data from all clippings of all plots was keypunched on IBM computer cards and analyzed by the statistical analysis system (SAS) designed by Barr and Goodnight (1972) of North Carolina State University. Analyses of variance were run on data broken down into seasons, on the data of each sampling, and on data separated according to clipping frequency. Duncan's new multiple range tests were used to determine significant differences at the 0.05 probability level for grass species, treatments, and recovery intervals studied. In addition to the computer analyzed

Figure 6. Correlation of Nylon-bag Technique Data with <u>In-vitro</u> Technique Data

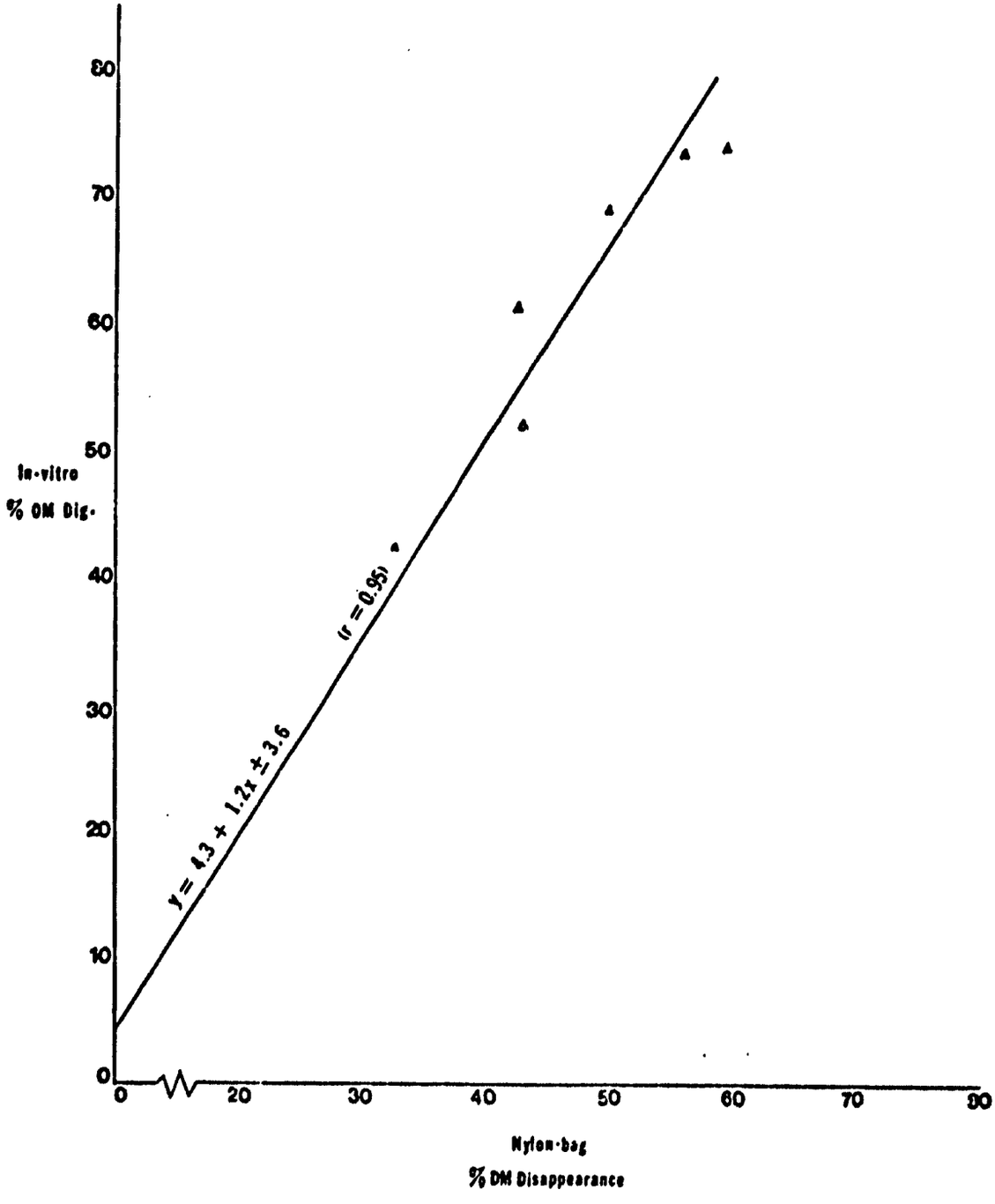
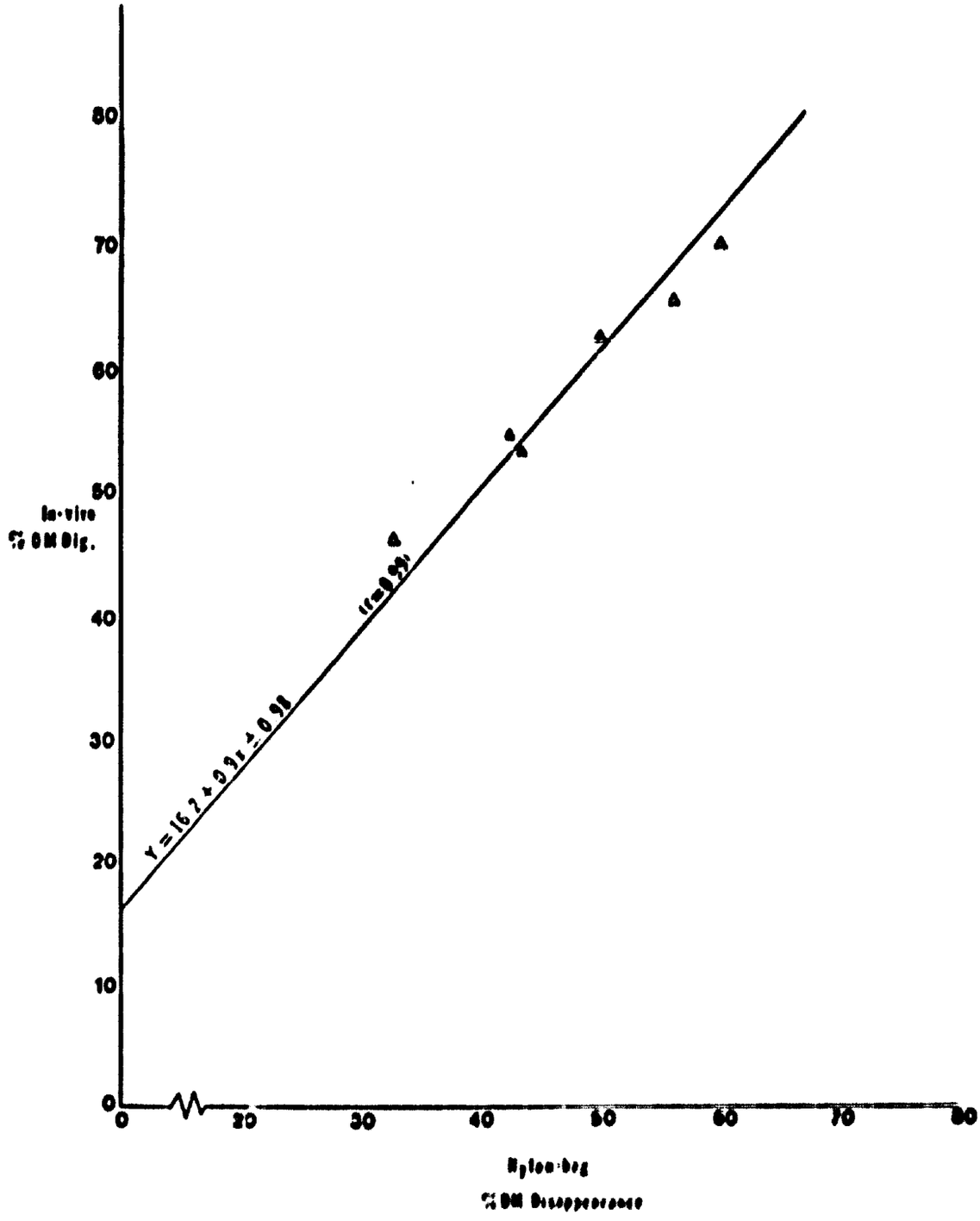


Figure 7. Correlation of Nylon-bag Technique Data with <u>In-vivo</u> Technique Data



yield data, data on the legume's contribution of nitrogen to the associated grass was analyzed manually by grasses and seasonal cuttings by the method described by Snedecor (1956) and Duncan (1955).

RESULTS AND DISCUSSION

Results of this experiment will be discussed in chronological order beginning with the 11 week establishment phase and continuing through the two clipping frequencies which will be separated and analyzed by dry season (August-November) and rainy season (December-February) performances. Review of each clipping frequency will follow the discussions of their respective seasonal components.

Establishment

Under ordinary circumstances, improved pastures would be established at the onset of the rainy season to take advantage of the optimum growth conditions inherent during this time. Planting would normally occur in late December or January while the soil can still be worked and unwanted vegetation turned. However this experiment was designed in April upon arriving in Ecuador, and with a certain amount of risk, established from May to July in hopes of generating data on the compatibility, persistence, and nutritive value of 18 grass-legume associations during the dry season, which is the critical period for forage and animal production on the coast of Ecuador. Figure 3 shows that the monthly rainfall during the course of this experiment was above the mean for the 1959-1970 rainfall data. The months of June, July, and August are partially noteworthy in that the variation exceeded the average maximum amounts recorded during the aforementioned 12 year period, which insured the establishment of the grass and legume species of this experiment.

The legume and buffelgrass seed germinated rapidly in the field, and all species showed vigorous seedling development. Although sprinkler irrigation pipes were set up in the experimental site, abnormal rainfall during the month of June (300 mm) negated the need for additional soil moisture.

Of the five grass species which were vegetatively propagated, Puntero was the most difficult to establish, whereas guineagrass and elephantgrass established readily. The propagation of Pangola and stargrass was complicated by weed infestation, however the aggressive character of stargrass soon became evident and this species dominated all weed competition. Pangola, on the other hand, was much slower to establish and less competitive; as a result it was plagued by weeds throughout the course of this experiment to the point where the weed component of the sward botanical composition was so great that this species was eliminated from the study.

Less than one week following the seeding of the legume species, insect damage became apparent. Although visible on all legume species, damage was particularly severe on Desmodium intortum, and on May 30, three weeks after seeding, approximately 40% of the desmodium plots were reseeded. Insecticide applications (as shown in Table 4) were necessary to control the Diabrotica spp., Spodoptera spp. (Army worm), Mayetiola spp. (Hessian fly) and other larva and leaf cutting beetles during the establishment phase of this experiment. Although some insect damage was noted on both grass and legume species throughout the seven month sampling period, no insecticides were applied. This biotic factor, together with the factor of weed competition were left uncontrolled once all species were securely established and were used as selection criteria for the 18 grass-legume associations. Diseases also appeared on certain grass and legume species

Table 4. INSECT CONTROL

Date Of Application	Type Of Insecticide	Dosage	Amount Insecticide Applied (liters) *
May 17	Sevin	20 ml/20 liters	20
May 31	Dieldrin 50%	100 g/20 liters	120
June 15	Malathion	25 g/20 liters	80
June 20	Dieldrin 50% + Sticker	200 g/liter 20 ml/20 liters	80 40
June 21	Dieldrin 50% + Sticker	200 g/liter 20 ml/20 liters	80 40
June 30	Malathion	25 g/20 liters	40
July 11	Malathion	5 cc/liter	80

*: total amount applied: 580 liters

during the course of the study and will be discussed according to their occurrence. Minor rabbit damage on Desmodium intortum seedlings was noted on June 20, 1972, but once frequent clipping was initiated, no further rodent damage was visible.

Two complete hand weedings (June 15 and 16; July 10 and 11) were necessary during the establishment phase. On each occasion, all debris was removed from the experimental area to prevent the build-up of potential insect breeding grounds, as well as to prevent the weedy species from simply vegetatively propagating themselves again under the rather optimum climatic and edaphic conditions. Unwanted vegetative growth in the inter-plot alleys was at first eliminated by machete, but when this as well as the idea of mechanical mowing, proved infeasible, herbicides were relied upon. The herbicide Karmex (80 grams/20 liters of water) slowed the weed growth, which was especially severe during the rainy season, and Karmex in combination with machetes provided adequate weed control in the alleys.

The development of numerous runners by centro allowed this species to obtain the most rapid ground cover whereas the erect growth of the greenleaf desmodium provided the slowest cover and consequently more area for weed growth. Siratro flowers were noted on July 11, approximately two months after seeding, and the vegetative development was delayed as a result.

Table 5 presents the fresh weight yield data (mean for the three reps) for the establishment period. Buffelgrass gave the highest fresh weight yields of any of the grass species followed immediately by guineagrass and elephantgrass, in that order. This may be due to the fact

Table 5. ESTABLISHMENT DATA
Fresh Weight Production (kg/ha) 11 Weeks After Seeding

	Control	Fertilized	Centro	Siratro	Desmodium
Guineagrass	13,268	16,919	12,778	13,424	14,571
Elephantgrass	9,621	13,045	12,056	9,192	12,510
Puntero	697	1,445	1,490	909	3,025
Pangola	86	354	4,066	909	3,005
African Stargrass	707	1,747	2,727	1,995	5,379
Buffelgrass	17,475	23,131	16,010	16,414	17,172

that the buffelgrass was seeded rather than vegetatively propagated and because it was seeded two weeks prior to the other species. The fertilizer treatments of the aforementioned grass species outyielded the other treatments, whereas the legume treatments outyielded both the control and the fertilized treatments in Pangola and stargrass. The fertilizer treatment response was to be expected since in the presence of ample soil moisture, the fertilizer nitrogen was immediately available to the actively growing plants of the more vigorous grass species whereas the legume Rhizobium symbiosis was just developing and not yet functioning at its optimum or potential levels. The centro and desmodium treatments also performed better than the other treatments in Puntero, which like Pangola and stargrass showed less vigor resulting in a sward whose botanical composition was comprised primarily of the rapidly growing legume species.

3 Week Clipping Frequency: Dry Season

The dry season, previously referred to in Figure 5, extended from late July through November (1972). The total rainfall for this period was 227 mm and the temperature averaged 24.9°C. Six samplings at 3 week intervals were made during this 18 week period. The quantitative data obtained is summarized in Table 6. The elephantgrass yield was significantly higher at the 5% level, as determined by the Duncan's multiple range test, than the other grass species. The guineagrass yield ranked second and was also different from that of the other grass yields ($P<0.05$). The yields of the fertilized, unfertilized (control), and centro treatments were greater ($P<0.05$) than the yield of the other treatments for this period.

Table 6. Dry Season Quantitative Production Data - 21 Day Rest Period

Grass	Treatment	Dry Matter Yield Total 6 harvests	Dry Matter Yield Growth rate	Component Yield for 6 harvests Grass	Component Yield for 6 harvests Legume
		kg/ha	$g/m^2/day$	kg/ha	kg/ha
Guinea	Control	5,725	4.5	5,595	---
	Nitrogen	8,057	6.4	7,975	---
	Centro	6,510	5.2	4,629	1,621
	Siratro	5,967	4.7	5,343	244
	Desmodium	5,402	4.3	4,383	797
Elephant	Control	8,340	6.6	8,111	---
	Nitrogen	8,850	7.0	8,277	---
	Centro	8,604	6.8	6,839	1,326
	Siratro	9,144	7.3	8,129	645
	Desmodium	7,452	5.9	6,638	577
Puntero	Control	5,892	4.7	4,381	---
	Nitrogen	5,592	4.4	4,465	---
	Centro	4,860	3.9	2,491	1,969
	Siratro	5,544	4.4	3,729	349
	Desmodium	4,296	3.4	2,713	849
Pangola	Control	4,734	3.8	3,638	---
	Nitrogen	4,932	3.9	3,706	---
	Centro	5,208	4.1	2,073	1,218
	Siratro	4,356	3.5	2,455	258
	Desmodium	4,044	3.2	2,113	81
Star	Control	6,216	4.9	5,837	---
	Nitrogen	5,946	4.7	4,837	---
	Centro	5,376	4.3	3,392	1,094
	Siratro	4,800	3.8	3,845	150
	Desmodium	4,614	3.7	3,431	232
Buffel	Control	3,828	3.0	3,520	---
	Nitrogen	4,602	3.7	4,089	---
	Centro	4,134	3.3	2.505	1,048
	Siratro	3,378	2.7	2,725	103
	Desmodium	4,248	3.4	3,105	247

The legume Centrosema pubescens had the highest total yield of any of the legumes with all six of the grass species which implies that it recovered vigorously under the relatively severe defoliation regime, persisted well in spite of low rainfall, maintained itself in the botanical composition of the sward, and was compatible with all of the grass species tested. Centro yielded more than twice as much legume as did Siratro or greenleaf desmodium in association with guineagrass, elephantgrass, and Puntero, and four to five times as much legume with the remaining stoloniferous growth habit grass species. It should be noted that in the last clipping harvest of this season, the centro-grass associations significantly (5% level) outyielded the fertilized treatment and in four of the five former harvests there was no significant difference in yield between the centro-grass and fertilized grass treatments.

Table 7 summarizes the qualitative data for the dry season performance at the 21 day rest period. The differences in total digestible dry matter yield between grasses and between treatments was more of a reflection of differences in dry matter yield than in differences in percent digestible dry matter. However the results of the crude protein aspect of the nutritive value were interesting. The effect of moisture stress and frequent clipping was most evident in the case of the Pangola control treatment where the crude protein content declined steadily from 16.2% at the beginning of the season to 9.0% after 18 weeks. Similar trends were noted in the stargrass control (13.5% to 13.8% C. P.) and buffelgrass control (14.5% to 11.2% C. P.), however the incorporation of the legumes, particularly centro, stabilized this decline in all six grass species.

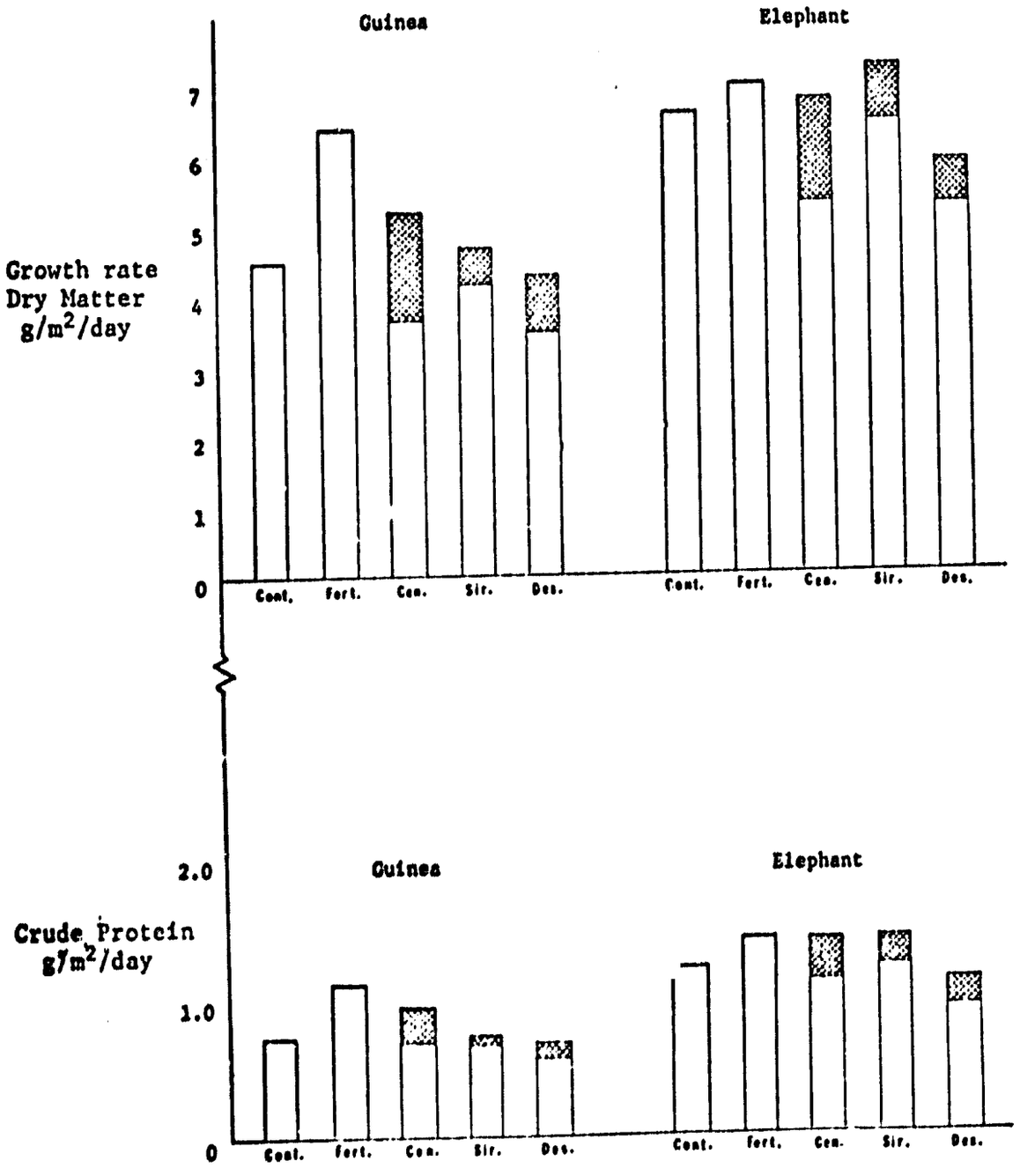
Table 7. Dry Season Qualitative Production Data - 21 Day Rest Period

Grass	Treatment	Digestible Dry Matter Percent	Digestible Dry Matter Yield	Crude Protein Percent	Crude Protein Yield
		%	kg/ha	%	kg/ha
Guinea	Control	53.3	3,051	15.3	894
	Nitrogen	51.9	4,182	16.3	1,345
	Centro	52.3	3,405	17.7	1,172
	Siratro	53.7	3,204	15.2	913
	Desmodium	52.9	2,858	15.8	860
Elephant	Control	55.8	4,654	18.0	1,534
	Nitrogen	58.4	5,168	19.4	1,724
	Centro	55.7	4,792	20.2	1,749
	Siratro	54.5	4,983	18.5	1,716
	Desmodium	56.5	4,210	18.8	1,406
Puntero	Control	54.8	3,229	14.0	834
	Nitrogen	52.6	2,941	14.6	834
	Centro	52.9	2,570	18.8	914
	Siratro	51.1	2,833	13.7	798
	Desmodium	50.9	2,187	15.6	679
Pangola	Control	52.3	2,475	13.6	700
	Nitrogen	51.4	2,535	13.5	675
	Centro	52.0	2,708	17.2	899
	Siratro	49.6	2,161	13.6	619
	Desmodium	49.9	2,018	13.8	495
Star	Control	53.8	3,344	16.0	1,033
	Nitrogen	52.8	3,139	15.0	927
	Centro	53.9	2,898	18.3	1,020
	Siratro	53.3	2,558	15.1	721
	Desmodium	53.8	2,482	13.9	657
Buffel	Control	55.8	2,136	13.1	519
	Nitrogen	54.7	2,517	13.7	638
	Centro	57.2	2,364	18.3	777
	Siratro	58.7	1,983	14.3	495
	Desmodium	57.8	2,455	14.2	620

Figures 8 and 9 show the relationship between dry matter yield, botanical composition, and crude protein yields for treatments by grass species for this period. These comparisons were made on the basis of the results of the statistical analysis of the dry matter yield, which stated that the yields of elephantgrass and guineagrass were the highest, and were significantly different from each other and from the other grass species, while the yields of stargrass and buffelgrass were lower yielding and also significantly different from each other. This graphical representation of the data makes it obvious that an increase in the yield of dry matter is not automatically followed by a corresponding and proportional increase in the yield of crude protein. For example, note that the dry matter yields of elephant-centro, star-centro, and buffel-centro were lower than the yield of grass plus nitrogen, however the crude protein yields of the grass-legume associations in each case were equal to or higher than those of the nitrogen treatment. The guineagrass data proved something of an exception to this as can be seen in the consistent relationship between treatments and their dry matter and crude protein yields. However, the guinea-centro association outyielded the control treatment in both respects. Although grass-centro associations did not show as much of a growth response as resulted from nitrogen fertilization, their yield was generally as high as that of unfertilized grass and their crude protein content much higher.

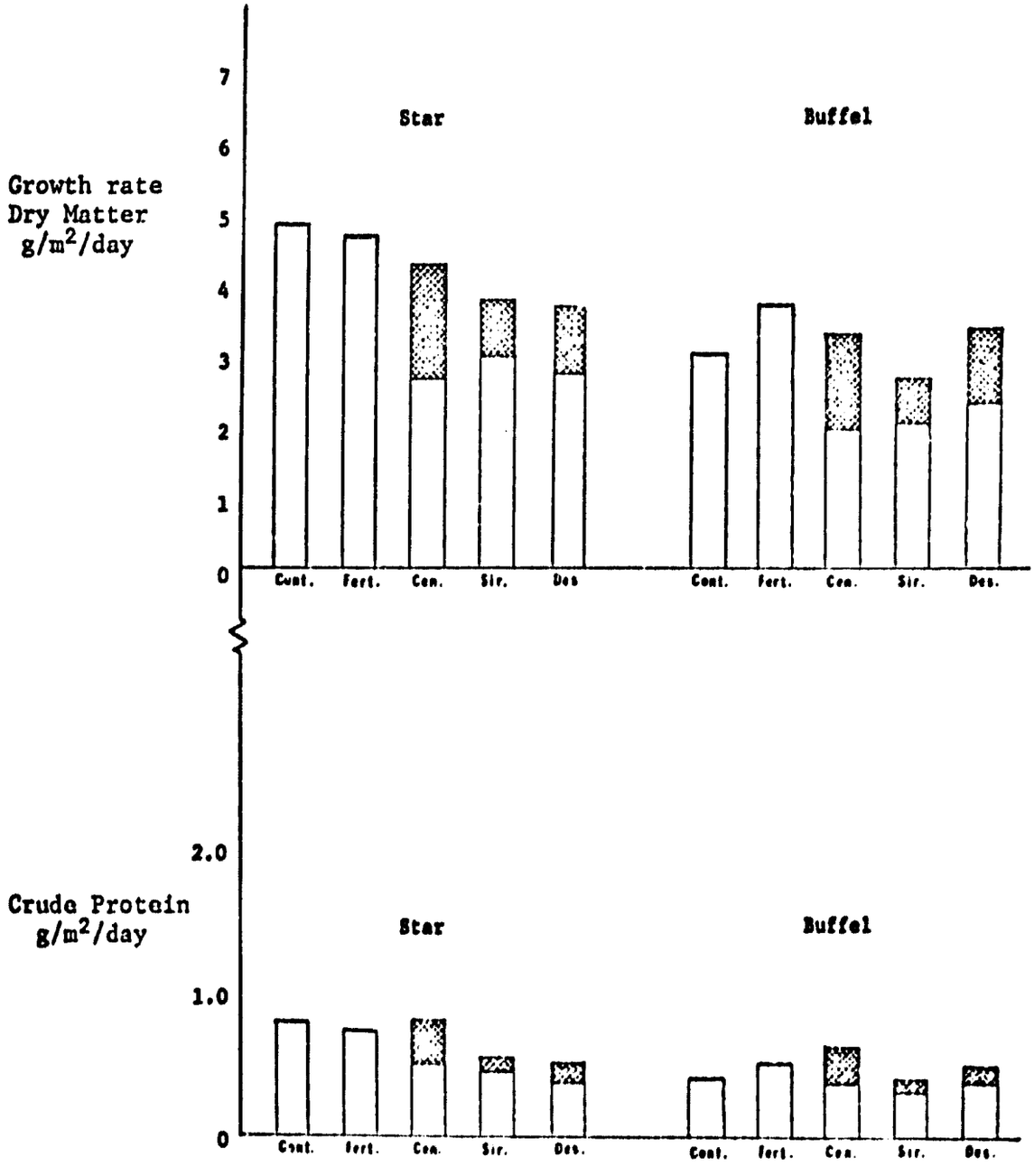
The unfertilized control treatment yielded in the highest growth response and digestible dry matter in Puntero and stargrass which reflects the relatively optimum natural soil fertility of the area. However in both cases the centro associations yielded as much or more crude

Figure 8. Growth Rate and Crude Protein Production of Guineagrass and Elephantgrass for the 21 Day Rest Period: Dry Season†



† Shaded areas represent the legume component of the sward

Figure 9. Growth Rate and Crude Protein Production of Stargrass and Buffelgrass for the 21 Day Rest Period: Dry Season†



† Shaded areas represent the legume component of the sward

protein per hectare. A similar response to the fertilized treatment was noted in guineagrass and in buffelgrass. Legume associations resulted in the best overall dry season (21 day rest period) performance of both elephantgrass and Pangola. The crude protein content of the elephantgrass was significantly higher (5% level) than the other treatments when associated with the legume Centrosema pubescens, while the crude protein content of buffelgrass was significantly higher than the other treatments when associated with both centro and Siratro.

Two patterns corresponding to the growth habits of the grass species were observed in the yield data of the various treatments over time. The yield pattern of guineagrass, elephantgrass, and Puntero followed roughly a convex curve starting and ending at approximately the same level with high points occurring during the second, third, and fourth harvests. While the yield pattern for the stoloniferous grass species followed a sharp triangular configuration characterized by a severe growth rate increase from the first to the second harvest and a relatively steady yield decline throughout the season to a level equal to or slightly below the yield level of the first harvest.

Fluctuations in the botanical composition of the sward from the point of view of the legume can best be understood by focusing on the legume Centrosema pubescens which was present in the swards of all six grasses in greater proportions than the other legumes as shown in Table 8. The amount of centro in association with guineagrass and elephantgrass increased from the first to the third harvests in a convex pattern similar to that of the yield data, whereas the amount of centro associated with Puntero decreased in a linear fashion from 55% to 30%. With the stoloniferous grass s; fos the centro percentage increased over time from

Table 8. Botanical Composition of Grass-Legume Associations for the 21 Day Rest Period: Dry Season

	Legume Range	$\bar{X}$* Botanical Composition Grass	Legume	Weed
	%	%	%	%
Guinea				
Centro	11 - 39	73	22	5
Siratro	2 - 6	89	5	6
Desmodium	3 - 25	83	12	5
Elephant				
Centro	7 - 22	81	14	5
Siratro	3 - 11	90	6	4
Desmodium	1 - 12	90	7	3
Puntero				
Centro	30 - 55	50	41	9
Siratro	2 - 11	66	6	28
Desmodium	5 - 37	60	20	20
Pangola				
Centro	15 - 35	34	23	43
Siratro	1 - 16	48	7	45
Desmodium	1 - 6	54	3	43
Star				
Centro	5 - 37	58	22	20
Siratro	1 - 4	76	2	22
Desmodium	1 - 8	70	5	25
Buffel				
Centro	13 - 44	48	27	25
Siratro	2 - 5	76	3	21
Desmodium	2 - 9	73	5	22

*: mean of 18 values for the season

roughly 10% to 35%, and the competitiveness of the legume and the grass attained a certain balance in all cases according to the aggressiveness of the grass species. With the bunch type grass species, the centro runners covered the open areas between grass plants and rows, thereby preventing the growth of unwanted vegetation. The only instance of overwhelming weed competition was noted in Pangola which from the second harvest onward suffered from the Puccinia oahuensis (rust) disease, which was spread extensively on leaf lesions caused by Schizaphis spp. (aphids). The weed component of the Pangola-centro sward showed a severe linear (4-78%) increase in proportion to the decline of the Pangola, however increase of the legume component was relatively minor by comparison. When the Pangola failed to recover at the beginning of the rainy season, this species was eliminated from the study. On August 15, minor disease symptoms were noted on clipped elephantgrass leaves. Samples analyzed by the plant pathology laboratory of the Pichilingue Experiment Station identified Pyricularia grisea disease. Clipping encouraged this disease, however at no time did the disease reach a degree of severity which would limit the normal growth and development of the elephantgrass plants.

The web-blight disease (Rhizoctonia solani Kuhn) appeared prior to the first harvest of the dry season and plagued Siratro throughout this period causing heavy defoliation and reducing the rate of regrowth. This accounts for the poorer performance of this species. During the third harvest (September 26), little leaf virus disease symptoms were noted on Desmodium intortum. Although this did not destroy existing vegetation as did the web-blight disease, it stunted regrowth which was

reflected in yield data. On the whole, the plots containing desmodium and Siratro associations were much weedier than those with centrosema mixtures.

The yields of all grass species and their respective treatments declined sharply from the fourth to the sixth harvests (October 17-November 28). It was during this time that the small plot border effect, which was noticed as early as the second harvest, became very pronounced. Mid-plot chlorosis was most evident in the buffelgrass plots, especially in the unfertilized treatment and in those plots containing Siratro and desmodium. However, the unfertilized treatment of all the grass species demonstrated nutrient deficiency symptoms. On December 15, just before the seventh harvest, during the transitional period preceeding the rainy season an unbiased, visual ranking of the extent of the border effect of each plot was conducted. The rank was alloted on a graduated scale (1-10) depending on the degree of the border effect. Another survey was conducted January 5, three weeks after the second nitrogen fertilizer application (50 kg N/ha in the form of ammonium nitrate). The fertilizer treatment observations decreased an average of 5 units per observation, while the unfertilized treatments decreased 1.33 units per observation. The border effect ranking of the grass-legume plots decreased an average of 1.0 units. It is therefore evident that plant growth during the extended dry season, particularly when subjected to frequent defoliation, is limited not only by moisture stress, but also by available soil nitrogen. The total yield of all six grass species studied in this experiment declined as the dry season progressed. With the sudden commencement of the rainy season following a prolonged dry season, there was a flush of growth due both to the availability of moisture

and to natural soil nitrification. For this reason, the border effect diminished in the unfertilized treatment observations. However if additional nitrogen is available at this time, such as NH_4NO_3, plant growth responds accordingly, as was seen in the five fold response of fertilizer treatment border effect observations compared to unfertilized treatment observations. It also appeared that the presence of the legume in the sward of six grass species reduced, if not completely eliminated, the border effect.

When the grass component of each association was isolated and analyzed individually for crude protein, it was found that elephantgrass and buffelgrass in association with centro had significantly higher (5% level) crude protein contents than their respective control treatments. Unfertilized elephantgrass contained 18% crude protein, compared to 20% crude protein when grown with centro. The buffelgrass protein content increased from 13.1% when unfertilized to 15.1% with centro.

3 Week Clipping Frequency: Rainy Season

The 12 week sampling period from December 1972 to the termination of the experiment in late February 1973 will be referred to as the rainy season. Total precipitation for this period amounted to 1,079 mm, and the mean temperature was 26.5°C. Seventy-nine days of rainfall were noted, which resulted in an average of 26 days of rain per month compared to 7 days of rain per month for the formerly discussed dry season. Quantitative data for the 4 harvests is summarized in Table 9. The elephantgrass yield was significantly greater at the 5% level than was the yield of the other grass species tested, while the centro and fertilized

Table 9. Rainy Season Quantitative Production Data-
21 Day Rest Period

Grass	Treatment	Dry Matter Yield Total 4 harvests	Dry Matter Yield Growth rate	Component Yield for 4 harvests Grass	Component Yield for 4 harvests Legume
		kg/ha	$g/m^2/day$	kg/ha	kg/ha
Guinea	Control	5,480	6.5	4,814	---
	Nitrogen	7,760	9.2	7,026	---
	Centro	7,124	8.5	5,202	445
	Siratro	5,452	6.5	3,334	264
	Desmodium	5,688	6.8	3,953	177
Elephant	Control	8,524	10.1	6,059	---
	Nitrogen	10,328	12.3	8,909	---
	Centro	9,308	11.1	6,793	840
	Siratro	9,616	11.4	6,741	194
	Desmodium	7,916	9.4	6,024	91
Puntero	Control	4,924	5.9	3,560	---
	Nitrogen	6,268	7.5	4,625	---
	Centro	5,764	6.9	3,625	503
	Siratro	6,048	7.2	2,994	19
	Desmodium	5,256	6.3	2,251	103
Pangola	Control	4,208	5.0	---	---
	Nitrogen	5,268	6.3	---	---
	Centro	5,776	6.9	---	---
	Siratro	4,808	5.7	---	---
	Desmodium	4,588	5.5	---	---
Star	Control	5,272	6.3	3,951	---
	Nitrogen	6,712	8.0	4,439	---
	Centro	5,872	7.0	1,935	710
	Siratro	4,412	5.3	1,673	158
	Desmodium	4,660	5.5	1,799	16
Buffel	Control	4,164	5.0	2,944	---
	Nitrogen	6,644	7.9	5,214	---
	Centro	5,764	6.9	2,161	678
	Siratro	4,468	5.3	2,808	58
	Desmodium	5,300	6.3	2,498	71

treatments, although not significantly different from each other, were significantly higher at the 5% level than the other three treatments. This fact verifies the potential of legume utilization, once a compatible, adapted legume species is adequately established. The legume Centrosema pubescens yielded more than either of the other legume species with all six grass species, and in the late dry season (harvests 5 and 6) and in the early rainy season (harvest 7), centro significantly outyielded the other four treatments.

Since digestible dry matter yields are partially a function of yield, the qualitative data presented in Table 10 reports that fertilized treatments of all six grass species showed the highest yields. However the crude protein picture evolved differently. Figure 10 illustrates the relationship between yield and crude protein production for the two highest yielding grass species. The centro-elephant and Siratro-elephant associations both produced more dry matter per hectare than the control, but less than the fertilized treatment. However both these associations yielded more crude protein per hectare than did either the control or fertilized treatment.

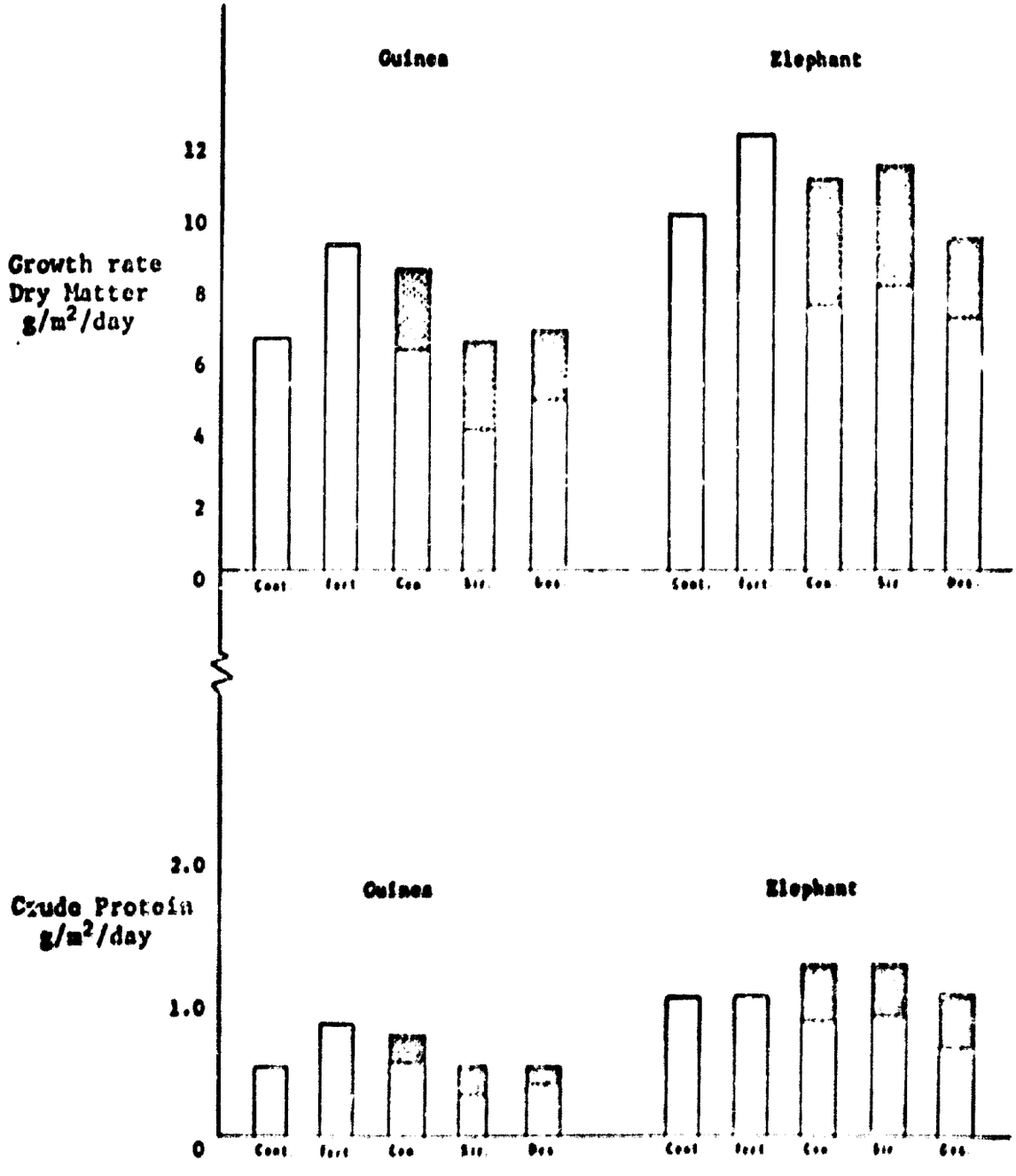
Centro started the rainy season with an advantage over the other two legumes because, to this point, no disease and very little insect damage had been noted on it whereas the development of both Siratro and desmodium had been limited by disease. Weed competition became a primary consideration once ample soil moisture was available, as can be seen in Table 11, the percentage of weeds in the botanical compositions of all six grass species increased.

Disease symptoms on centro, later classified as Cylindrocladin spp. by the plant pathology laboratory of the Pichilingue Experimental Station,

Table 10. Rainy Season Qualitative Production Data - 21 Day Rest Period

Grass	Treatment	Digestible Dry Matter Percent	Digestible Dry Matter Yield	Crude Protein Percent	Crude Protein Yield
		%	kg/ha	%	kg/ha
Guinea	Control	49.7	2,724	11.1	601
	Nitrogen	46.7	3,624	12.5	982
	Centro	49.2	3,505	12.4	884
	Siratro	49.6	2,704	11.1	601
	Desmodium	47.0	2,673	11.2	621
Elephant	Control	55.0	4,688	15.3	1,235
	Nitrogen	54.3	5,608	16.1	1,259
	Centro	50.4	5,054	16.0	1,491
	Siratro	54.9	5,279	15.1	1,472
	Desmodium	53.0	4,195	15.3	1,209
Puntero	Control	52.5	2,585	10.2	500
	Nitrogen	50.8	3,184	11.3	705
	Centro	50.3	2,899	11.8	734
	Siratro	50.9	3,078	10.1	594
	Desmodium	48.0	2,523	10.8	566
Pangola	Control	53.6	2,255	11.0	463
	Nitrogen	54.0	2,845	10.8	632
	Centro	46.7	2,697	14.0	796
	Siratro	50.1	2,408	10.7	516
	Desmodium	43.7	2,234	10.4	465
Star	Control	48.4	2,552	12.8	669
	Nitrogen	51.4	3,450	13.8	895
	Centro	50.0	2,936	14.2	812
	Siratro	49.5	2,184	12.1	525
	Desmodium	49.6	2,311	11.7	532
Buffel	Control	53.6	2,232	11.1	453
	Nitrogen	55.7	3,701	12.5	841
	Centro	53.9	3,107	13.0	763
	Siratro	53.3	2,381	11.1	489
	Desmodium	50.5	2,676	12.2	646

Figure 10. Growth Rate and Crude Protein Production of Guineagrass and Elephantgrass for the 21 Day Rest Period: Rainy Season†



† Shaded areas represent the legume component of the sward

Table 11. Botanical Composition of the Grass-Legume Associations for the 21 Day Rest Period: Rainy Season

	Legume Range	X* Botanical Composition Grass	Legume	Weed
	%	%	%	%
Guinea				
Centro	3 - 20	70	6	24
Siratro	4 - 8	62	5	33
Desmodium	1 - 5	70	3	27
Elephant				
Centro	2 - 14	65	9	26
Siratro	0 - 5	68	2	30
Desmodium	0 - 2	75	1	24
Puntero				
Centro	3 - 19	58	8	34
Siratro	0 - 2	54	1	45
Desmodium	0 - 6	49	2	49
Star				
Centro	4 - 32	32	12	56
Siratro	1 - 9	39	3	58
Desmodium	0 - 2	41	1	58
Buffel				
Centro	4 - 32	38	12	50
Siratro	1 - 2	62	1	37
Desmodium	0 - 5	49	1	50

*: mean of 12 values for the season

were first noted during the first week of January, 1973. Four weeks later the damage was extensive in all plots containing centro, and only the new leaf material appeared to be free of the disease. This disease occurred at a time of high rainfall and high humidity, so the decomposition of dead tissue and recycling of nutrients were extremely rapid. For this reason, the associated grass species in all cases showed a much more rapid flush of growth with centro than with the other legume species, and weed growth was stimulated in a similar manner. A cafeteria grazing trial study reported in the Pichilingue annual research publication (INIAP 1971) indicated the same disease infestation during the same seasonal time period with a guinea-centro association. In their study, the percentage of centro in the sward increased steadily from October until late January (20-40%), then it dropped to less than 10% in approximately one month. Recovery, however, was very rapid, and by May (i.e., two months) the percent of centro in the sward had returned to approximately 25%. The results of these two studies suggest that although mature centro tissue is susceptible to fungal attack at the beginning of the rainy season, regrowth is free of the disease. The nutrients released by the decomposing leaf and root tissue are available for immediate uptake by the associated grass plants whose growth is thereby stimulated. The guineagrass which was either associated with centro or fertilized with nitrogen during this rainy period, was found to have a significantly higher (5% level) crude protein content than when the same species were subjected to other treatments. Unfertilized guineagrass contained 11.1% crude protein, whereas guineagrass grown in association with centro or fertilized with nitrogen contained 12.4% and 12.5% crude protein, respectively. How-

ever, because the experiment currently being discussed was conducted during the first year of forage growth, the amount of data generated on the recovery and nitrogen contribution of centro is insufficient. Therefore further investigation in this area is needed.

Overall Analysis of the 21 Day Rest Period (Both Seasons)

When all the data for the 21 day rest period was combined and analyzed, elephantgrass and guineagrass were significantly higher yielding ($P<0.05$) than the other grass species, while the fertilized treatment outyielded the other treatments. However it should be noted that the Duncan's multiple range analysis showed that although the centro yields were lower than those obtained by nitrogen fertilization, these differences were not significant at the 5% level. In 60% of the harvests, the fertilizer treatment was found to outyield the other treatments, whereas in 40% of the harvests the centro treatment yield was higher. The desmodium treatment and the buffelgrass and Pangola species showed the poorest performance overall.

The crude protein content of each of the legume species was determined from pooled samples collected at each harvest. Centro had the highest average (mean for 60 analyses) crude protein content (25.3%), followed by desmodium (21.5%) and Siratro (21.1%), respectively.

6 Week Clipping Frequency: Dry Season

The quantitative data for the three harvests of this 18 week period is summarized in Table 12. The yield of the three tall growing, bunch type grass species was significantly greater than the other grass species

Table 12. Dry Season Quantitative Production Data - 42 Day Rest Period

Grass	Treatment	Dry Matter Yield Total 3 harvests	Dry Matter Yield Growth rate	Component Yield for 3 harvests Grass	Component Yield for 3 harvests Legume
		kg/ha	$g/m^2/day$	kg/ha	kg/ha
Guinea	Control	10,146	8.1	10,095	---
	Nitrogen	9,633	7.6	9,567	---
	Centro	9,870	7.8	7,187	2,639
	Siratro	9,618	7.6	8,861	202
	Desmodium	8,592	6.8	7,592	843
Elephant	Control	21,933	17.4	21,808	---
	Nitrogen	19,338	15.3	19,048	---
	Centro	21,180	16.8	15,611	5,263
	Siratro	19,440	15.4	17,629	1,527
	Desmodium	18,303	14.5	16,615	1,580
Puntero	Control	8,046	6.4	7,352	---
	Nitrogen	8,595	6.8	7,888	---
	Centro	7,185	5.7	3,583	3,476
	Siratro	7,494	5.9	5,718	928
	Desmodium	7,515	6.0	5,048	2,154
Pangola	Control	4,629	3.7	3,819	---
	Nitrogen	5,256	4.2	4,046	---
	Centro	7,080	5.6	2,104	3,013
	Siratro	4,482	3.6	2,629	500
	Desmodium	4,476	3.6	2,579	613
Star	Control	6,528	5.2	6,188	---
	Nitrogen	6,477	5.1	6,331	---
	Centro	7,128	5.6	4,110	2,516
	Siratro	5,328	4.2	4,662	441
	Desmodium	6,909	5.5	6,601	183
Buffel	Control	6,756	5.4	6,488	---
	Nitrogen	5,661	4.5	5,376	---
	Centro	7,248	5.8	4,866	2,159
	Siratro	5,421	4.3	4,551	116
	Desmodium	6,498	5.2	5,397	694

and significantly different from each other in the order of their respective inherent genetic capacity. All grass species reached physiological maturity and produced reproductive tillers under this clipping frequency, so that only the climatic and edaphic factors limited total plant development. Elephantgrass was the highest yielding species, and formed a complete canopy which controlled weed growth by shading. This was also true of guineagrass, the second highest yielding species. Puntero yields were of the next highest order, but because of plant spacing, much of their botanical composition was weeds. Because of the lack of disease and insect pests previously discussed in the 21 day rest period dry season, the centro associations significantly outperformed the Siratro and desmodium associations, however there was no significance between the centro, fertilized, and unfertilized treatment yields. During the final harvest of this season, the yield of the diseased Pangola treatments were significantly lower than the yields of the other grass species, and when it failed to recover during the rainy season, it was eliminated from the study. The yields of all the grasses except elephantgrass and Puntero declined in roughly a linear manner as the dry season progressed. The elephantgrass and Puntero yields increased during the second harvest, then dropped sharply to a point well below the level of the first harvest.

The qualitative data presented in Table 13 indicates that the guineagrass fertilized, stargrass-centro, and buffelgrass-centro treatments were higher in percent digestibility and therefore in digestible dry matter production than the other treatments, respectively. Both the crude protein content and yield were highest in the centro-grass associations.

Table 13. Dry Season Qualitative Production Data - 42 Day Rest Period

Grass	Treatment	Digestible Dry Matter Percent	Digestible Dry Matter Yield	Crude Protein Percent	Crude Protein Yield
		%	kg/ha	%	kg/ha
Guinea	Control	48.4	4,901	13.0	1,355
	Nitrogen	51.6	4,971	11.9	1,175
	Centro	47.2	4,659	16.1	1,595
	Siratro	48.3	4,645	13.0	1,304
	Desmodium	47.8	4,107	14.3	1,281
Elephant	Control	51.3	11,252	16.1	3,724
	Nitrogen	53.1	10,268	14.5	2,8[illegible]1
	Centro	49.2	10,421	18.5	4,020
	Siratro	52.3	10,167	14.6	2,883
	Desmodium	52.7	9,646	15.1	2,840
Puntero	Control	55.3	4,449	13.0	1,082
	Nitrogen	54.4	4,676	12.1	1,047
	Centro	53.0	3,808	17.6	1,309
	Siratro	50.6	3,792	13.6	1,046
	Desmodium	51.9	3,900	14.0	1,069
Pangola	Control	51.7	2,393	12.6	612
	Nitrogen	49.8	2,617	12.3	695
	Centro	49.2	3,483	16.8	1,170
	Siratro	47.5	2,129	12.4	569
	Desmodium	47.2	2,113	12.2	574
Star	Control	47.0	3,068	11.3	738
	Nitrogen	49.5	3,206	12.2	825
	Centro	51.3	3,657	16.1	1,213
	Siratro	46.8	2,494	11.7	627
	Desmodium	46.4	3,206	13.2	941
Buffel	Control	52.7	3,560	11.1	749
	Nitrogen	53.1	3,006	11.2	630
	Centro	55.8	4,044	15.9	1,154
	Siratro	51.8	2,808	13.1	712
	Desmodium	54.4	3,535	12.4	819

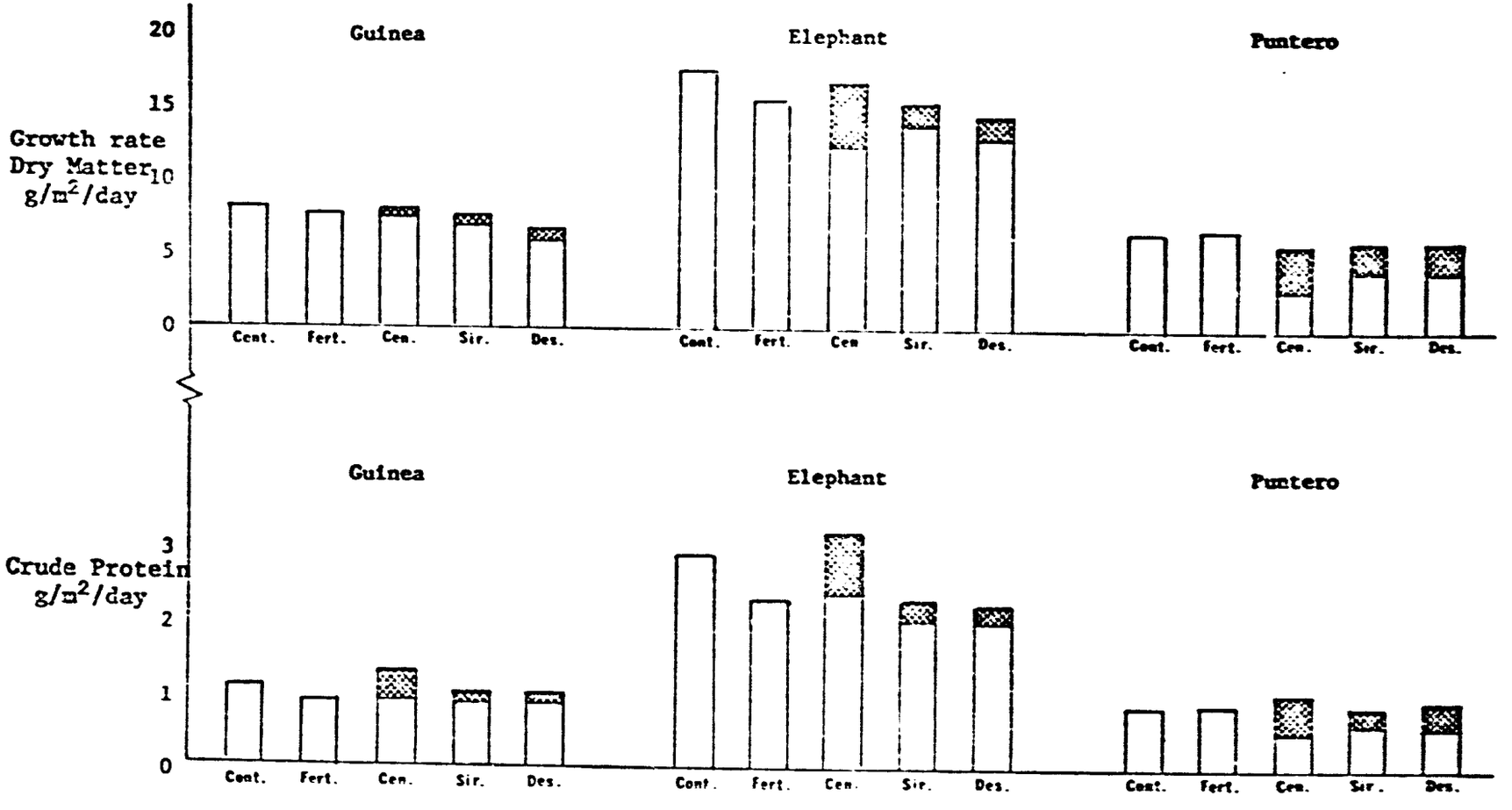
Figures 11 and 12 graphically represent the relationship between dry matter production, botanical composition, and crude protein yields for five of the six grass species and their respective treatments. Here again, although the dry matter yields of the centro-grass associations were comparable to those of the fertilized and unfertilized treatments, their crude protein yields were significantly higher in all six grass species.

Table 14 indicates the fluctuation in botanical composition during this period. The centro-grass associations contained a much greater amount of legume in the sward of all grass species except buffelgrass than did the associations of the other legumes in which the legume performance was limited by diseases.

6 Week Clipping Frequency: Rainy Season

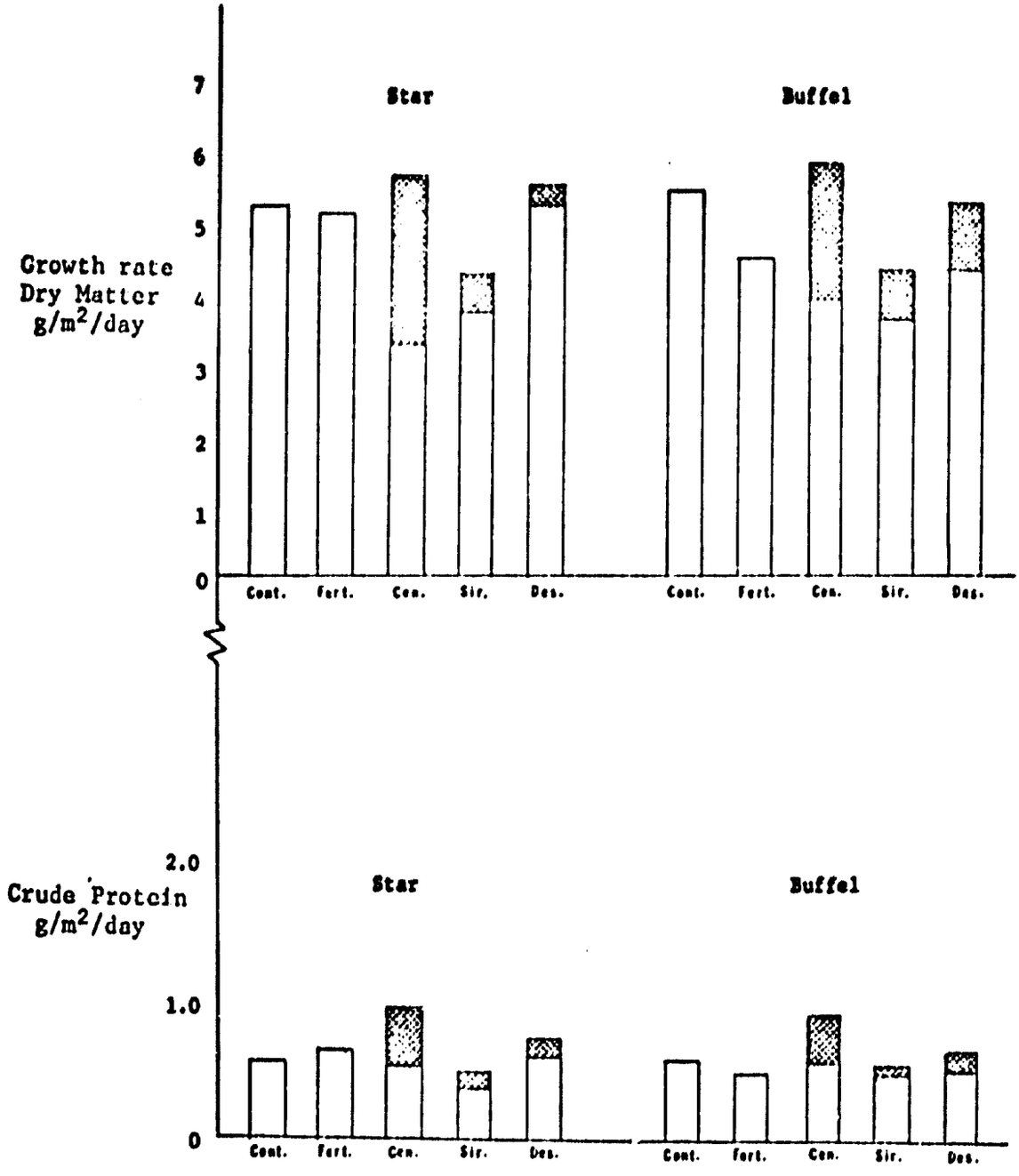
Tables 15 and 16 summarize the quantitative and qualitative production data for this 12 week period. The same three tall growing bunch type grass species produced significantly more dry matter in the same order as during the dry season. There was no significant difference between the yields of the short growing species at the 5% level, and although the three legume associations showed greater dry matter production than did the fertilized and unfertilized treatments, the differences were not significant. This is the result of a number of previously discussed factors such as high natural soil fertility, increased rates of soil nitrification which occur during the first weeks of a rainy season following a prolonged dry period, and disease limitations on all three legume species which caused a turnover and cycling of nitrogen

Figure 11. Growth Rate and Crude Protein Production of Guineagrass, Elephantgrass, and Puntero for the 42 Day Rest Period: Dry Season†



† Shaded areas represent the legume component of the sward

Figure 12. Growth Rate and Crude Protein Production of Stargrass and Buffelgrass for the 42 Day Rest Period: Dry Season†



† Shaded areas represent t' legume component of the sward

Table 14. Botanical Composition of the Grass-Legume Associations for the 42 Day Rest Period: Dry Season

	Legume Range	$\bar{x}$* Botanical Composition		
		Grass	Legume	Weed
	%	%	%	%
Guinea				
Centro	9 - 47	70	29	1
Siratro	2 - 10	93	6	1
Desmodium	4 - 15	90	9	1
Elephant				
Centro	12 - 37	75	24	1
Siratro	3 - 13	92	7	1
Desmodium	1 - 14	92	7	1
Puntero				
Centro	42 - 54	51	48	1
Siratro	11 - 15	73	13	14
Desmodium	8 - 40	68	24	8
Pangola				
Centro	37 - 63	23	46	31
Siratro	4 - 17	53	12	35
Desmodium	7 - 22	50	15	35
Star				
Centro	29 - 42	58	35	7
Siratro	6 - 11	87	8	5
Desmodium	1 - 4	96	2	2
Buffel				
Centro	2 - 22	86	11	3
Siratro	1 - 35	72	17	11
Desmodium	5 - 33	74	14	12

*: mean of 9 values for the season

Table 15. Rainy Season Quantitative Production Data - 42 Day Rest Period

Grass	Treatment	Dry Matter Yield: Total 2 harvests	Dry Matter Yield: Growth rate	Component Yield for 2 harvests: Grass	Component Yield for 2 harvests: Legume
		kg/ha	$g/m^2/day$	kg/ha	kg/ha
Guinea	Control	8,654	10.3	7,924	---
	Nitrogen	8,914	10.6	8,281	---
	Centro	10,744	12.8	10,202	490
	Siratro	10,280	12.2	8,482	1,130
	Desmodium	12,772	15.2	11,203	782
Elephant	Control	18,440	22.0	18,356	---
	Nitrogen	18,002	21.4	17,515	---
	Centro	17,886	21.3	15,771	1,773
	Siratro	16,804	20.0	16,365	348
	Desmodium	17,680	21.1	16,950	76
Puntero	Control	6,714	8.0	6,148	---
	Nitrogen	7,080	8.4	6,490	---
	Centro	7,774	9.3	6,512	1,105
	Siratro	7,878	9.4	5,323	1,102
	Desmodium	7,912	9.4	5,854	633
Pangola	Control	4,328	5.2	---	---
	Nitrogen	4,900	5.8	---	---
	Centro	6,896	8.2	---	---
	Siratro	5,594	6.7	---	---
	Desmodium	3,970	4.7	---	---
Star	Control	4,868	5.8	4,768	---
	Nitrogen	7,246	8.6	6,153	---
	Centro	6,118	7.3	4,084	1,166
	Siratro	6,056	7.2	4,140	1,078
	Desmodium	5,532	6.6	5,043	79
Buffel	Control	5,658	6.7	5,394	---
	Nitrogen	5,102	6.1	4,880	---
	Centro	5,716	6.8	3,920	553
	Siratro	6,130	7.3	3,838	346
	Desmodium	5,356	6.4	3,809	73

Table 16. Rainy Season Qualitative Production Data - 42 Day Rest Period

Grass	Treatment	Digestible Dry Matter Percent	Digestible Dry Matter Yield	Crude Protein Percent	Crude Protein Yield
		%	kg/ha	%	kg/ha
Guinea	Control	44.1	3,816	9.8	842
	Nitrogen	43.6	3,887	11.0	983
	Centro	39.2	4,212	11.6	1,245
	Siratro	39.9	4,102	9.6	978
	Desmodium	40.6	5,185	10.1	1,274
Elephant	Control	47.8	8,814	12.2	2,213
	Nitrogen	49.9	8,983	12.5	2,270
	Centro	45.9	8,210	14.2	2,522
	Siratro	50.0	8,402	10.8	1,805
	Desmodium	47.5	8,398	12.5	2,171
Puntero	Control	52.6	3,532	8.5	571
	Nitrogen	50.7	3,590	9.8	688
	Centro	47.1	3,662	11.0	857
	Siratro	46.9	3,695	9.6	753
	Desmodium	53.6	4,241	9.0	714
Pangola	Control	49.5	2,142	7.5	330
	Nitrogen	46.2	2,264	9.4	462
	Centro	45.4	3,130	12.7	847
	Siratro	46.1	2,579	10.1	561
	Desmodium	43.7	1,735	9.5	369
Star	Control	43.1	2,098	8.6	414
	Nitrogen	45.8	3,319	11.0	801
	Centro	42.7	2,612	12.9	758
	Siratro	44.3	2,682	10.3	620
	Desmodium	46.8	2,589	10.3	561
Buffel	Control	52.3	2,959	9.4	512
	Nitrogen	50.4	2,571	10.5	517
	Centro	50.2	2,561	11.6	651
	Siratro	46.2	2,832	9.6	581
	Desmodium	50.4	2,699	9.6	505

contained in the legume plant parts. Complete physiological development of all species occurred under this infrequent defoliation and optimum climatic period.

Although the legume-grass associations gave the highest dry matter, digestible dry matter, and crude protein yields with four of the six grass species, the fertilized treatment outyielded the other treatments in all three aspects of production with stargrass.

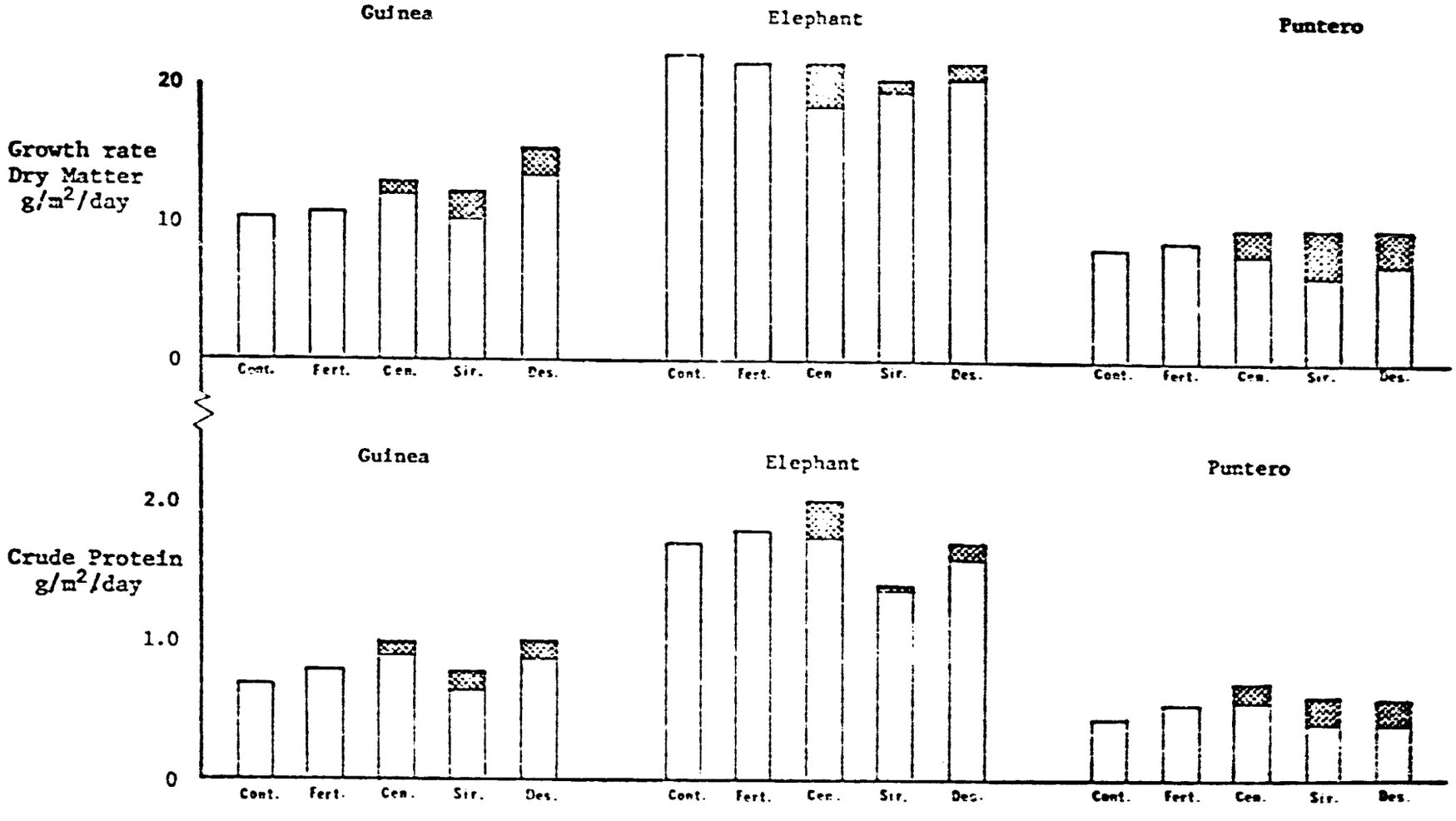
Figure 13 illustrates the relationship between dry matter and crude protein yields for this period for the three highest yielding grass species. Once again, the centro-grass associations produced as much or more dry matter as did the fertilized or unfertilized treatments, but their respective yields of crude protein were significantly higher.

The botanical composition data for the 42 day rest period during the rainy season is found in Table 17. The previously discussed viral and fungal disease limitations of desmodium and Siratro diminished during this period, while the percentage of centro in the swards dropped considerably due to fungal attack.

Overall Analysis of the 42 Day Rest Period (Both Seasons)

When all the data for the 42 day rest period was combined and analyzed statistically, elephantgrass, guineagrass, and Puntero significantly outyielded the other treatments at the 5% level, and were significantly different from each other in the same manner as they had performed seasonally. There was no significant difference between the treatments for this period, however a ranking from lowest to highest, showed centro finishing above the unfertilized and fertilized treatments, in that order.

Figure 13. Growth Rate and Crude Protein Production of Guineagrass, Elephantgrass, and Puntero for the 42 Day Rest Period: Rainy Season†



† Shaded areas represent the legume component of the sward

Table 17. Botanical Composition of the Grass-Legume Associations for the 42 Day Rest Period: Rainy Season

	Legume Range	$\bar{x}$* Botanical Composition Grass	Legume	Weed
	%	%	%	%
Guinea				
Centro	2 - 7	94	5	1
Siratro	5 - 17	83	11	6
Desmodium	3 - 9	88	6	6
Elephant				
Centro	8 - 12	88	10	2
Siratro	1 - 3	97	2	1
Desmodium	0 - 1	96	1	3
Puntero				
Centro	4 - 24	84	14	2
Siratro	11 - 18	67	15	18
Desmodium	7 - 9	74	8	18
Star				
Centro	8 - 36	63	22	15
Siratro	15 - 20	67	18	15
Desmodium	1 - 2	91	2	7
Buffel				
Centro	3 - 20	66	11	22
Siratro	5 - 6	63	5	32
Desmodium	1 - 2	66	2	32

*: mean of 6 values for the season

As was noted during the discussion of the overall 21 day rest period, centro had the highest average (mean of 30 analyses) crude protein content and the smallest range or degree of crude protein fluctuation of the 3 legume species studied. Centro averaged 23.3% crude protein during the 42 day rest period compared to 25.3% for the 21 day rest period. Siratro contained an average of 20.2% crude protein, and desmodium averaged 19.4% crude protein for the 42 day rest period.

SUMMARY AND CONCLUSIONS

The compatibility of 18 grass-legume associations, their persistence during both the wet and dry seasons, and the effect on forage production and quality caused by the inclusion of adapted tropical legumes into the sward was studied in the Pichilingue Experimental Station on the coast of Ecuador. This experiment was conducted from May 1972 through February 1973. Two clipping frequencies and their respective 21 day and 42 day recovery intervals were used on guineagrass, elephantgrass hybrid 534, Puntero, Pangola, stargrass, and buffelgrass. Five treatment evaluations were made with each grass species. The control and nitrogen fertilized treatments were on pure grass plots, while the legumes centro, Siratro and greenleaf desmodium were incorporated with the grass species in the remaining three treatments. Simple superphosphate at the rate of 72 kg of P/ha were applied to all plots prior to establishment. The 100 kg N/ha nitrogen fertilization treatment was subdivided into two 50 kg N/ha applications. During the May 31, 1972 application, urea was used in furrows alongside the plant rows, and on December 21, 1972, ammonium nitrate was broadcast over the established grass plots.

A randomized block design with 90 plots (5 x 10 meters) in three replications was used, with 30 square meters serving as the net experimental area per plot. During the course of the experiment 2160-1/2 kilogram forage samples were brought from the field, dried, separated into their botanical composition components, ground through a Wiley Mill,

and analyzed for nitrogen and digestible dry matter. Observations and fresh weight yield measurements were made in the field during the establishment phase and throughout the experiment.

During the 11 week establishment period, insect and weed infestation required control and some minor rodent damage was noted on the tender legume seedlings. However these factors were used as selection criteria once all species were securely established, and in one instance later in the study, the combined attack of Schizapis spp. (aphids) and Puccinia cahuensis (rust) on Pangola forced the elimination of this species from further study.

During establishment, buffelgrass outyielded the other grass species, followed by guineagrass and elephantgrass in that order, and the nitrogen fertilized treatments outyielded the other treatments. We may conclude from this, that grasses established by seed develop more rapidly than vegetatively propagated species, and if supplied with adequate soil nitrogen this greater increment of growth can be further expanded. However the legume treatments outyielded both the control and fertilized treatments in stargrass, Pangola, and Puntero because with these grass species, establishment was slow and consequently the legume contribution to the total botanical composition was greater.

The most severe defoliation regime and climatic stress conditions of this experiment were present during the dry season of the 3 week clipping frequency. Elephantgrass and guineagrass, in that order, showed the greatest recovery during this period, while as a group the centro, fertilized, and unfertilized treatments were significantly higher yielding than the other two legume treatments, which were limited by disease. Al-

though the nitrogen fertilized treatment produced more dry matter per hectare, the centro-grass associations yielded more crude protein per hectare than did the fertilized treatments. This pattern was repeated throughout the experiment, but was of most importance during the dry season when the nutritive value of forages is the most limiting factor in animal production.

At the beginning of the subsequent rainy season, a flush of growth was noted in all grass species, however the centro-grass and fertilized treatments significantly outyielded the other three treatments. At the beginning of the rainy period, the amount of centro in the mixtures of all grass species was greater than the amounts of the other legumes which were recovering from fungal and viral diseases. However after a month of heavy rain, fungal disease caused extensive defoliation of mature centro leaf material. The growth of the associated grass species was stimulated and the content of crude protein in the grass increased in response to the recycling of nutrients released by the decomposition of this material. Young centro leaf material appeared to be free of this disease, and some overall centro recovery was noted two months after the initial disease infestation.

Under the 6 week clipping frequency, all grass species attained physiological maturity so that yields were correlated with the inherent genetic vigor of the respective grass species. The differences between yields were also less significant.

The performance of all species studied was considered representative of experience obtained elsewhere within the tropics of similar climatic and edaphic conditions. Of the three legumes studied, centro was

clearly the best legume in terms of compatibility with all six grass species, persistence, and nutritive value. The dry matter production of centro-grass associations was not significantly different from that obtained by nitrogen fertilization regardless of species, season, or clipping frequency. However the centro-grass associations yielded more crude protein per hectare.

Ecuador is facing a growing deficit of per capita protein consumption. Livestock production on its tropical lowland coast is limited by the nutritive value of its native forage species during the prolonged dry season. The intensification of grazing pressure by increasing livestock numbers to fully utilize the abundant forage produced during the rainy season is not feasible if there is insufficient high quality forage available to carry the same animals through the dry season. Although improved grass species are available, at present there is very little, if any, commercial production of seed or vegetative material. Pasture renovation and management technology are not widely known, and the use of fertilizers is still considered economically prohibitive. For these reasons the utilization of adapted forage legumes, which are present in abundance in the native vegetation, is feasible both from the standpoint of their ability to fix atmospheric nitrogen and because they can provide highly nutritious livestock feed during critical climatic stress periods. Further research in the areas of animal selectivity, management, carrying capacity, micro-nutrient fertilization, inoculation, and seed production will be required before grass-legume associations can be exploited to their full potential in developing tropical countries.

APPENDIX

Table 18. Analysis of Variance for Dry Matter Production: Dry Season - 3 Week Clipping Frequency

Source	DF	Sum of Squares	Mean Square	F
Grass	5	5,139,728	1,027,946	35.84 **
Treatment	4	473,440	118,360	4.13 **
Grass x Treatment	20	488,392	24,419	0.85 NS
Rep	2	141,036	70,518	2.46 *
Grass x Rep	10	253,493	25,349	
Treatment x Rep	8	147,588	18,449	
Grass x Treatment x Rep	40	1,262,334	31,558	
Total	89	7,906,000	88,831	

*: Statistically Significant ($P<0.05$)
**: Highly Significant ($P<0.01$)
NS: Not Statistically Significant

Table 19. Duncan's Multiple Range Test on Mean D.M. Production by Grasses: Dry Season - 3 Week Clipping Frequency

VI	IV	III	V	I	II
673	771	873	899	1055	1413
				*	*

I: P. maximum
II: P. purpureum
III: H. rufa
IV: D. decumbens
V: C. plectostachyus
VI: C. ciliaris

The responses not underscored by the same line are significantly different at the 5% level.

Table 20. Duncan's Multiple Range Test on Mean D.M. Production by Treatment: Dry Season - 3 Week Clipping Frequency

t_5	t_4	t_3	t_1	t_2
831	922	964	965	1055

t_1: Control
t_2: N fertilized
t_3: C. pubescens
t_4: M. atropurpureum
t_5: D. intortum

The responses not underscored by the same line are significantly different at the 5% level.

Table 21. Analysis of Variance for Dry Matter Production: Rainy Season - 3 Week Clipping Frequency

Source	DF	Sum of Squares	Mean Square	F
Grass	5	11,292,208	2,258,442	43.55 **
Treatment	4	2,482,097	620,524	11.96 **
Grass x Treatment	20	955,260	47,763	0.92 NS
Rep	2	1,253,316	626,658	12.08 **
Grass x Rep	10	592,491	59,249	
Treatment x Rep	8	622,155	77,769	
Grass x Treatment x Rep	40	1,793,384	44,835	
Total	89	18,990,912	213,381	

*: Statistically Significant ($P<0.05$)
**: Highly Significant ($P<0.01$)
NS: Not Statistically Significant

Table 22. Duncan's Multiple Range Test on Mean D.M. Production by Grasses: Rainy Season - 3 Week Clipping Frequency

IV	VI	V	III	I	II
1232	1317	1346	1413	1575	2285
					*

I: *P. maximum*
II: *P. purpureum*
III: *H. rufa*
IV: *D. decumbens*
V: *C. plectostachyus*
VI: *C. ciliaris*

The responses not underscored by the same line are significantly different at the 5% level.

Table 23. Duncan's Multiple Range Test on Mean D.M. Production by Treatments: Rainy Season - 3 Week Clipping Frequency

t_1	t_5	t_4	t_3	t_2
1357	1392	1450	1650	1791

t_1: Control
t_2: N fertilized
t_3: C. pubescens
t_4: M. atropurpureum
t_5: D. intortum

The responses not underscored by the same line are significantly different at the 5% level.

Table 24. Analysis of Variance for Dry Matter Production: 3 Week Clipping Frequency

Source	DF	Sum of Squares	Mean Square	F
Grass	5	7,147,162	1,429,432	55.86 **
Treatment	4	957,339	239,335	9.35 **
Grass x Treatment	20	570,238	28,512	1.11 NS
Rep	2	285,607	142,803	5,58 **
Grass x Rep	10	199,447	19,945	
Treatment x Rep	8	240,103	30,013	
Grass x Treatment x Rep	40	1,044,758	26,119	
TOTAL	89	10,444,654	117,355	

**: Highly Significant (P<0.01)
NS: Not Statistically Significant

Table 25. Duncan's Multiple Range Test on Mean D.M. Production by Grasses: 3 Week Clipping Frequency

VI	IV	V	III	I	II
931	956	1078	1089	1263	1762
				*	*

I: P. maximum
II: P. purpureum
III: H. rufa
IV: D. decumbens
V: C. plectostachyus
VI: C. ciliaris

The responses not underscored by the same line are significantly different at the 5% level.

Table 26. Duncan's Multiple Range Test on Mean D.M. Production by Treatments: 3 Week Clipping Frequency

t_5	t_1	t_4	t_3	t_2
1055	1122	1133	1239	1349

t_1: Control
t_2: N fertilized
t_3: C. pubescens
t_4: M. atropurpureum
t_5: D. intortum

The responses not underscored by the same line are significantly different at the 5% level.

Table 27. Analysis of Variance for Dry Matter Production: Dry Season - 6 Week Clipping Frequency

Source	DF	Sum of Squares	Mean Square	F
Grass	5	252,571,527	50,514,305	178.90 **
Treatment	4	2,684,475	671,119	2.38 **
Grass x Treatment	20	4,165,643	208,282	0.74 NS
Rep	2	1,088,109	544,054	1.93 *
Grass x Rep	10	1,333,455	133,346	
Treatment x Rep	8	2,230,894	278,862	
Grass x Treatment x Rep	40	12,812,982	320,325	
Total	89	276,887,086	3,111,091	

*: Statistically Significant ($P<0.05$)
**: Highly Significant ($P<0.01$)
NS: Not Statistically Significant

Table 28. Duncan's Multiple Range Test on Mean D.M. Production by Grasses: Dry Season - 6 Week Clipping Frequency

IV	VI	V	III	I	II
1728	2106	2158	2589	3190	6680
			*	*	*

I: P. maximum
II: P. purpureum
III: H. rufa
IV: D. decumbens
V: C. plectostachyus
VI: C. ciliaris

The responses not underscored by the same line are significantly different at the 5% level.

Table 29. Duncan's Multiple Range Test on Mean D.M. Production by Treatments: Dry Season - 6 Week Clipping Frequency

t_4	t_5	t_2	t_1	t_3
2877	2905	3053	3224	3316

t_1: Control
t_2: N fertilized
t_3: C. pubescens
t_4: M. atropurpureum
t_5: D. intortum

The responses not underscored by the same line are significantly different at the 5% level.

Table 30. Analysis of Variance for Dry Matter Production: Wet Season - 6 Week Clipping Frequency

Source	DF	Sum of Squares	Mean Square	F
Grass	5	434,815,449	86,963,090	138.52 **
Treatment	4	2,924,690	731,173	1.16 NS
Grass x Treatment	20	14,033,170	701,658	1.12 NS
Rep	2	1,233,938	616,969	0.98 NS
Grass x Rep	10	8,217,199	821,720	
Treatment x Rep	8	4,509,729	563,716	
Grass x Treatment x Rep	40	23,685,090	592,127	
Total	89	489,419,264	5,499,093	

**: Highly Significant (P<0.01)
NS: Not Statistically Significant

Table 31. Duncan's Multiple Range Test on Mean D.M. Production by Grasses: Rainy Season - 6 Week Clipping Frequency

IV	VI	V	III	I	II
2569	2796	2982	3736	5137	6881
			*	*	*

I: P. maximum
II: P. purpureum
III: H. rufa
IV: D. decumbens
V: C. plectostachyus
VI: C. ciliaris

The responses not underscored by the same line are significantly different at the 5% level.

Table 32. Duncan's Multiple Range Test on Mean D.M. Production by Treatments: Rainy Season - 6 Week Clipping Frequency

t_1	t_2	t_4	t_5	t_3
4033	4270	4395	4435	4595

t_1: Control
t_2: N fertilized
t_3: C. pubescens
t_4: M. atropurpureum
t_5: D. intortum

The responses not underscored by the same line are significantly different at the 5% level.

Table 33. Analysis of Variance for Dry Matter Production: 6 Week Clipping Frequency

Source	DF	Sum of Squares	Mean Square	F
Grass	5	318,055,080	63,611,016	260.8 **
Treatment	4	1,375,997	343,999	1.41 NS
Grass x Treatment	20	4,407,140	210,337	0.86 NS
Rep	2	162,431	81,215	0.33 NS
Grass x Rep	10	2,492,752	249,275	
Treatment x Rep	8	1,473,999	184,250	
Grass x Treatment x Rep	40	10,179,045	254,476	
TOTAL	89	337,946,443	3,797,151	

**: Highly Significant ($P<0.01$)
NS: Not Statistically Significant

Table 34. Duncan's Multiple Range Test on Mean D.M. Production by Grasses: 6 Week Clipping Frequency

IV	VI	V	III	I	II
2064	2282	2487	3048	3969	7563
			*	*	*

I: P. maximum
II: P. purpureum
III: H. rufa
IV: D. decumbens
V: C. plectostachyus
VI: C. ciliatis

The responses not underscored by the same line are significantly different at the 5% level.

Table 35. Duncan's Multiple Range Test on Mean D.M. Production by Treatments: 6 Week Clipping Frequency

t_4	t_5	t_2	t_1	t_3
3484	3518	3540	3557	3828

t_1: Control
t_2: N fertilized
t_3: C. pubescens
t_4: M. atropurpureum
t_5: D. intortum

The responses not underscored by the same line are significantly different at the 5% level.

Table 36. Servicio Nacional de Meteorologia e Hidrologia Data

Month	Temperature			Relative Humidity		Precipitation		
	$\bar{x}$	$\bar{x}$ max.	$\bar{x}$ min.	$\bar{x}$	min.	Total	# Days	Max. Day
	°C	°C	°C	%	%	mm	days	mm
1971								
January	24.3	29.0	21.0	85	56	259	23	46
February	23.9	29.7	20.9	89	65	477	26	75
March	25.3	31.1	21.7	86	59	746	28	151
April	25.0	31.0	21.6	86	62	140	19	43
May	23.7	28.8	20.5	86	65	4	7	1
June	23.1	28.4	20.1	88	67	51	19	16
July	22.2	27.7	19.1	87	67	0	2	0
August	22.5	27.7	19.1	85	64	1	5	1
September	23.3	29.2	19.7	83	60	18	11	15
October	23.2	28.6	19.7	83	62	11	9	3
November	23.2	28.4	19.7	80	61	15	6	11
December	24.5	30.0	20.6	82	60	123	19	57
1972								
January	24.8	29.9	21.1	84	53	418	26	106
February	25.3	30.7	21.5	84	58	489	25	57
March	26.0	31.9	21.8	82	55	541	23	104
April	26.2	31.4	22.2	83	52	375	25	88
May	26.0	30.6	22.1	84	57	189	15	43
June	25.2	29.8	21.8	87	61	360	11	67
July	24.8	29.8	21.3	85	62	38	2	31
August	24.8	29.4	21.0	85	61	68	8	51
September	24.9	29.1	21.0	86	61	24	9	10
October	24.9	29.0	20.8	85	62	42	8	19
November	25.0	27.6	23.4	81	52	55	9	47
December	26.0	30.6	22.2	85	58	298	26	59
1973								
January	26.7	30.9	22.5	87	64	397	29	65
February	26.8	29.1	21.0	87	58	384	24	52

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BIOGRAPHICAL SKETCH

Robert Earl Hudgens was born on May 2, 1945, in Oakland, California. In June 1962, he graduated from Pacific High School in San Leandro, California where he had served two terms as president of the student body. From August 1962 to June 1965, he attended Whitworth College in Spokane, Washington. In September of 1965, he entered the University of California at Davis and began studying International Agricultural Development. In June 1967 he received the Bachelor of Science degree.

He joined the Peace Corps in August 1967 and arrived in Bolivia in November 1967, where he worked for three years in the colonization and rural settlement programs in the tropical lowlands on the eastern side of the Andes. Upon completion of his assignment, he returned to the United States by land, and entered the University of Florida in January 1970. He returned to South America in March 1972 and worked for one year at the Pichilingue Experimental Station on the coast of Ecuador conducting the thesis research for the degree of Master of Science in Agriculture for which he is currently a candidate.

During the four years that Mr. Hudgens was in Latin America, he toured 15 countries and experienced first hand the needs, frustrations, and potentials of agricultural development in the American tropics.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Agriculture.

Gerald O. Mott, Chairman
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Agriculture.

Hugh L. Popenoe
Director International Programs

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Agriculture.

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Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Agriculture.

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This thesis was submitted to the Dean of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Master of Science in Agriculture.

August, 1973

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