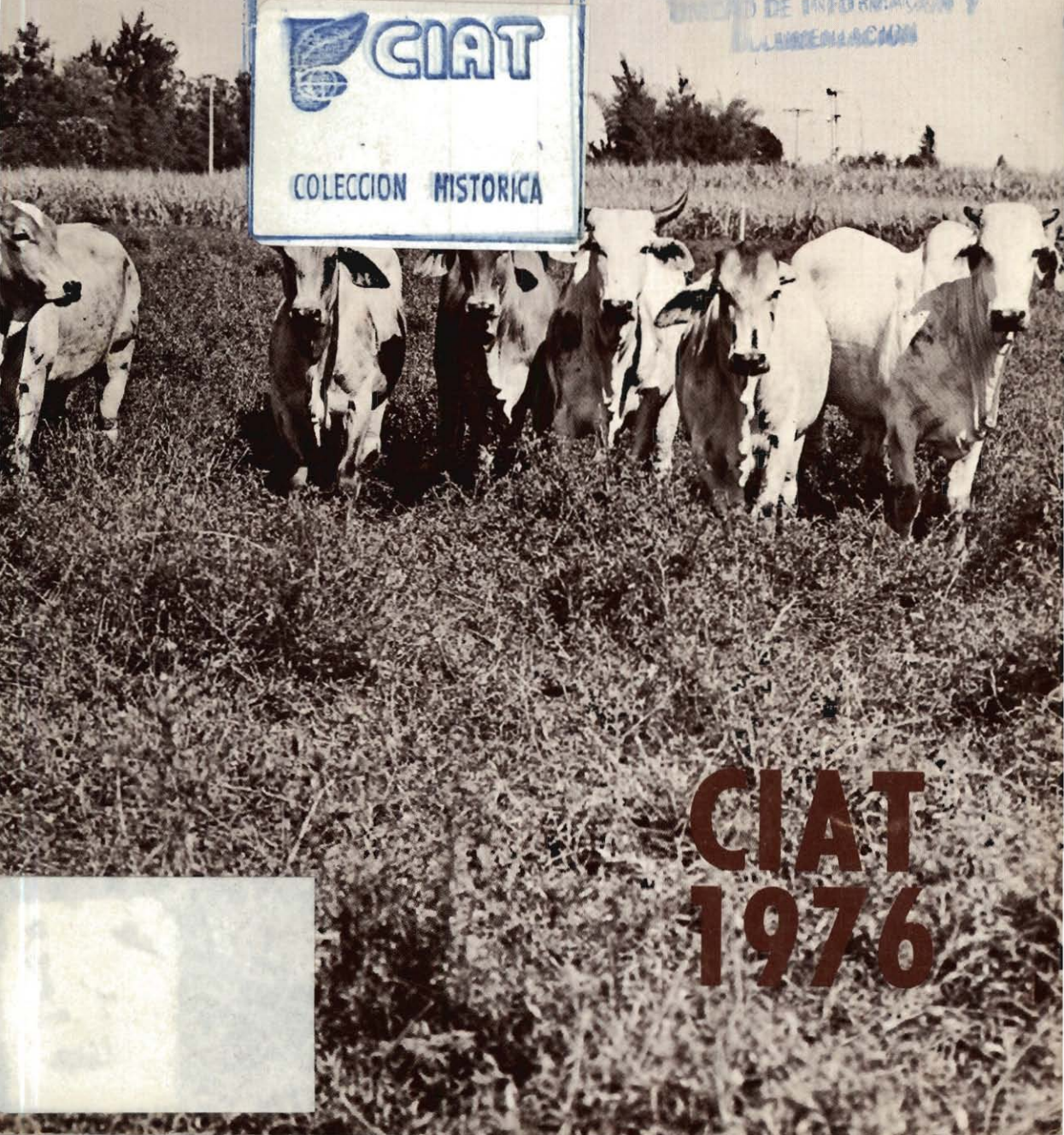
Beef production program



CIAT
1976

Beef production program

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Cables CINATROP

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* Left during 1976
**Assigned to more than one program
**Assigned to more than one program

CONTENTS

Climatic and edaphological data for locations where CIAT's Beef Program has done research work in 1976

Locations*	Altitude (meters) above sea level)	Temperature mean (°C)	Rainfall (mm/year)	Organic matter (%)	pH	P (Bray II) (ppm)	K (meq/100 g)	Soil texture
CIAT, Palmira (Valle)	1,000	24	1,000	6.8	6.9	46.3	0.44	Clay
Carimagua** (Meta)	200	27	2,031	4.3	4.7	1.6	0.08	Clay loam
Turipaná** (Córdoba)	13	28	1,200	3.1	6.8	13.0	0.68	Clay
Santander de Quilichao (Cauca)	1,212	24.8	1,899		4.9	4.0		

* These localities are situated in Colombia according to names of departments indicated

** Research at these locations is in cooperation with the Instituto Colombiano Agropecuario (ICA)

Beef production program

HIGHLIGHTS IN 1976

Agronomic assessment of a wide range of accessions of *Stylosanthes* spp. has been initiated in a search for adapted disease and stemborer resistance genotypes. Promising materials are the fine stemmed biotypes which appear to have better resistance to stemborer attack than the robust, woody growth forms. Particularly interesting is *S. capitata*, a free-seeding perennial which shows tolerance to high exchangeable aluminum and low available soil phosphorus levels. This species is also fairly resistant to anthracnose and stemborer attacks.

Species of *Zornia*, *Desmodium* and *Macroptilium* also contain ecotypes adapted to allic soils and possess resistance to diseases and pests. The new introductions are being tested in duplicate sets in space planted nurseries and in small sward plots at Santander and Carimagua.

Seed yields of 69 kg/ha acid scarified pure seed were recorded at Palmira from combine harvested areas of *S. guyanensis* (CIAT 136). The Carimagua crop was virtually a failure from disease and insect damage. Some 700 kilograms of pure seed were produced at the two locations.

New areas of a wide array of legume accessions were established at Santander where a lower incidence of stemborer and weeds should favor more consistent yields and longer stand life. Experiments have been initiated to define the responses of particular legume species to levels of phosphorus, defoliation and in the case of *Centrosema* sp. to support systems.

A seedbed preparation trial at Carimagua includes conventional as well as minimum tillage land preparation methods. The use of stubble mulch sweeps to undercut the savanna vegetation without turning the sod proved highly effective for controlling native vegetation, and at the same time, resulted in satisfactory sown species establishment. Band seeding and application of fertilizer in bands show distinct advantages over broadcast application.

Phosphorus application had a large effect on the phosphorus content of *S. guyanensis* and *Brachiaria decumbens* and broadcast application was much more efficient in increasing plant phosphorus contents than band application. Tropical Kudzu, Para and Tanner grasses responded strongly to potassium application and Kudzu showed marginal response to magnesium application.

Characterization of *Rhizobium* strains available in CIAT's collection indicated superior efficiency for use with *Stylosanthes* of two South American isolates over the

commercially available culture. A large collection of *Rhizobium* strains is being screened in pot culture in sterilized site soil to assess tolerances to low pH, low phosphorus availability and high aluminum level.

Applications of nitrogen fertilizer on irrigated Pangola grass pasture at rates of 168 and 672 kg/ha/year gave 690 and 1,803 kilograms liveweight gain per hectare, respectively.

Brachiaria decumbens provided better dry season grazing than *Melinis minutiflora, Hyparrhenia rufa* and *Paspalum plicatulum*. Animals grazing on native savannah burned at the end of the rainy season gained 57 kg/year while animals on pasture burned at the beginning of the rainy season gained only 27 kg/year.

In the Herd Systems Project, giving minerals consistently improves the calf crop (three years) by increasing conception rate and reducing the number of abortions. The most dramatic improvement in calf crop is caused by early weaning which removes a great lactation stress from the cow. Preliminary work on raising three-month-old weaned calves at Palmira has been successful, with liveweights at 9 and 18 months as good as normal weaned calves in the Llanos.

Cattle trypanosomes *(T. vivax* and *T. evansi)* have a wider distribution, in tropical areas of Central and South America, than was previously believed. In some areas the disease has a significant economic impact

Leptospirosis is emerging as the most prevalent reproductive disease in the tropical savannahs. Two preventive medicine measures for this disease are being tested in a trial herd.

Studies on the prevalence of anaplasmosis and babesiosis in Colombia were completed in 1976. The results of these studies indicate a high prevalence of anaplasmosis and babesiosis within the major cattle producing areas of the North Coast, the Eastern Plains and the Cauca Valley. Immunization methods against anaplasmosis and babesiosis using a minimum infective dose procedure were tested on eight beef and dairy farms located in the Cauca Valley. A total of 285 animals were involved in these experiments. The preliminary results from one ranch demonstrated that vaccinated animals gained 27 kilograms more per head than the nonvaccinated control, 18 weeks after field exposure.

The Acarology Unit's tick species checklist for Colombia was expanded to include 32 hosts and 23 tick species. The tick collection is extensively used for taxonomic training. Although good nutrition increased cattle tick resistance and tolerance, it appears that relatively low tick loads still directly caused significantly decreased blood values. Studies established that certain cattle body regions are consistently the most highly populated by *Boophilus microplus*, the tropical cattle tick. Animals grazing certain improved pastures may carry fewer ticks than those on native pastures.

A comprehensive economic survey has been initiated on 16 selected and representative farms on the Eastern Plains of Colombia monitoring each farm for 18 months.

Preliminary observations reveal the possible existence of external factors such as: transportation costs, opportunity cost of pastures in nearby regions, credit constraints and relative prices of different categories of animals which appear to be conditioning the adoption of technology. They also reveal that when certain recommended practices are introduced unilaterally, the net economic effect may even be negative.

PASTURES AND FORAGES

Plant Introduction

During 1975, CIAT directed extensive forage legume explorations under the sponsorship of the International Board for Plant Genetic Resources (IBPGR). This work was continued in 1976 with support from CIAT's core budget (Fig. 1).

Figure 1. Routes of forage legume explorations in Central and South America during 1976.

Seed or vegetative planting material of 1,600 accessions of tropical forage species, mainly legumes, was collected to broaden the genetic diversity of germplasm stocks in CIAT's forage collection (Table 1). Emphasis was on the search for germplasm carrying resistance to pests and diseases and adaptation to low base status savannah soils.

A collaborative project was organized in El Salvador with the Banco de Fomento and the United Nations Development Programme and Food Agriculture Organization participating in the collection of forage species throughout the country. Collecting in El Salvador yielded some new accessions of browse-type *Desmodium distortum* and *D. nicaraguense*. *Teramnus*, *Macroptilium* and *Stylosanthes* spp. were also added to the collection.

Table 1. Accessions in CIAT's forage germplasm bank as of November 1, 1976.

	No. of Accessions
Stylosanthes spp.	649
Desmodium spp.	208
Centrosema spp.	144
Macroptilium spp.	95
Miscellaneous legumes:	
Calopogonium	
Glycine	
Indigofera	
Leucaena	398
Teramnus	
Vigna	
Zornia	
Grasses	106
Total accessions	1,600

One of the functions of the CIAT forage introduction center is that of preserving a source of germplasm as stored seed. New germplasm storage facilities with controlled humidity and temperature rooms are nearly completed and the forage germplasm will be housed in the new building.

Distribution of forage germplasm is another important function of the program. Seed of promising species was supplied this year to pasture researchers in 16 tropical American countries.

Forage Species Evaluation

Accessions of each of the major legume genera including *Stylosanthes*, *Desmodium*, *Centrosema*, *Zornia*, *Macroptilium* have been checked for desirable forage characters and in each genus promising new material has been identified. Some os these new species forms are scarcely known to agriculture. Species showing promise at this stage of the evaluation program are the following.

Stylosanthes. From the IBPGR project and accessions contributed by other organizations, CIAT now has 650 accessions of *Stylosanthes* in its forage legume germplasm bank, which is managed as a working facility of international ealiber, to serve the lowland tropics.

Preliminary assessment of new accessions was done in the plant house where simple growth characters were measured and the stylos were tested for anthracnose resistance using artificial inoculation techniques. Of 600 stylo accessions tested for anthracnose tolerance, approximately 8 percent showed a high degree of tolerance to the disease. Appearances of resistant and susceptible reactions are shown in Figure 2.

Figure 2. Comparison of anthracnose resistant and susceptible accessions of *Stylosanthes*. Varieties of *S. capitata* have exhibited strong resistance to anthracnose (*Colletotrichum* sp.).

To date, stemborer attack has not been observed outside the Colombian Llanos region, where it seriously damages stylo stands. Observations indicate that this insect favors species which have a hard woody main stem (Fig. 3). Selection for stemborer resistance is in progress and as with anthracnose, differences in tolerance within and between species have already been observed.

Agronomic assessment of a wide range of *Stylosanthes* introductions has been initiated in a search for disease and stemborer-resistant genotypes adapted to allic soil conditions. Duplicate sets of stylo introductions have been established in replicated, space-planted plots, one set at Carimagua (in the Colombian Llanos) and another at Santander (in the Cauca region south of CIAT). A total of 141 stylo introductions are now under observation. A third set of accessions has been established at CIAT for observation and initial seed increase of new stylos.

The stylo accessions showing promise as forage cultivars include fine-stemmed biotypes of *S. guyanensis* and two introductions of *S. capitata*. (Fig. 4).

S. capitata is a hardy perennial species, native to eastern Brazil and Venezuela. Its distribution is restricted in comparison to the rather ubiquitous species *S. guyanensis* and *S. humilis*. *S. capitata* is adapted to very low fertility soils, derived from sandstone. This soil type is common in the Campo Cerrado region of Brazil. Several varieties were found to be tolerant to anthracnose and stemborer attacks. This species of stylo is slow to develop in the year of establishment. It is a prolific seeder and regenerates from self-sown seed (Fig. 5) In spite of the restricted distribution of the species, *S. capitata* accessions show a great deal of ecotypical variation.

In a plant house experiment, 14 varieties of *S. capitata* were compared with three varieties of *S. humilis* and eight perennial

Figure 3. A *Stylosanthes scabra* **plant severely damaged by stemborer (*Zaratha* sp.)**

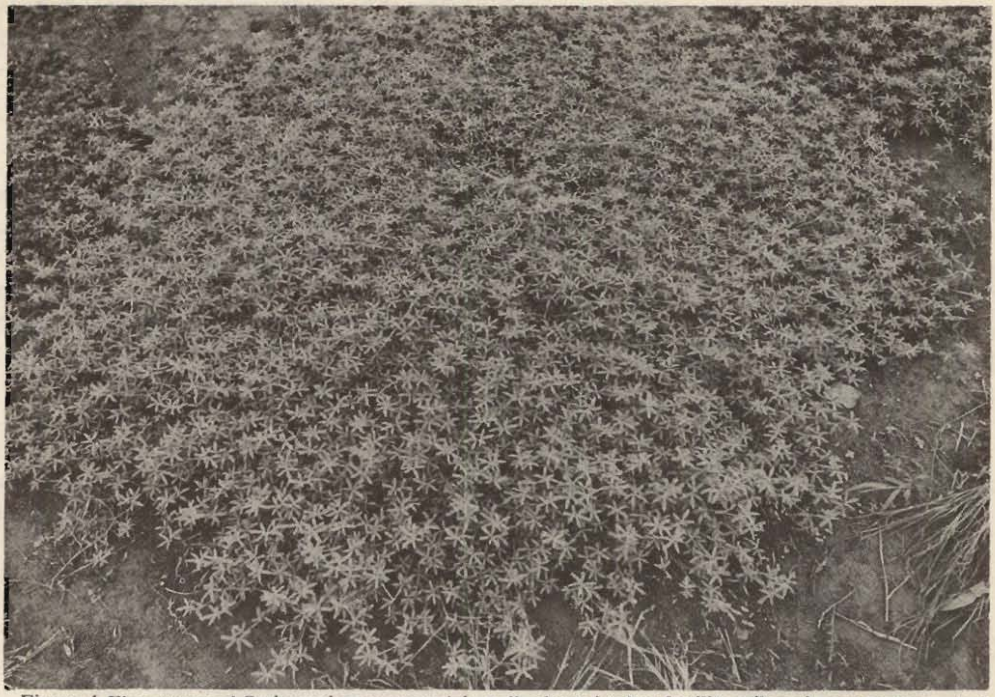


Figure 4. Fine-stemmed *Stylosanthes guyanensis* is well-adapted to low fertility soils and some ecotypes show tolerance to both anthracnose (*Colletotrichum* sp.) and stemborer (*Zaratha* sp.).

Figure 5. A *Stylosanthes capitata* plant (CIAT 1019) in full seed on the Eastern Plains of Colombia, at Carimagua.

species of *Stylosanthes*. One of the *S. humilis* varieties outyielded all 15 *S. capitata* accessions as well as all the other perennial species in the trial (Table 2).

The three highest yielding *S. capitata* accessions significantly outyielded nine other *S. capitata* varieties as well as seven other species including two accessions of *S. guyanensis* and one of *S. humilis* accessions. Slow initial growth of this otherwise very promising forage legume is one of its main disadvantages.

Table 2. Dry matter yields of 14 accessions of *Stylosanthes capitata* and 11 accessions of other *Stylosanthes* spp.

CIAT No.	*Stylosanthes* sp.	Dry matter yield per plant (total of two harvests)(g)[1]
1304	*humilis*	3.51a
1307	sp.	2.89b
1305	*humilis*	2.86b
1342	*capitata*	2.76b,c
1315	*capitata*	2.61b,c,d
1339	*capitata*	2.38b,c,d,e
1338	*capitata*	2.26c,d,e
1318	*capitata*	2.24c,d,e
1303	sp.	2.23d,e
1275	sp.	2.20d,e,f
1328	*capitata*	2.15d,e,f
1334	*capitata*	2.11d,e,f
1330	*humilis*	2.04e,f
1317	*guyanensis*	2.04e,f
1323	*capitata*	2.04e,f
1078	*capitata*	2.01e,f
1093	sp.	1.97e,f
1007	*capitata*	1.94e,f
1322	*capitata*	1.89e,f
1298	*capitata*	1.89e,f
1191	*capitata*	1.70f,g
1257	sp.	1.27g,h
1255	sp.	1.13h
1335	*guyanensis*	1.00h,i
1350	*capitata*	0.59i

1 L.S.D. at .05 = 0.53 and at .01 = 0.70

A series of grass/legume sward trials has been established at Santander. In each trial, stylo varieties were included as standards for comparison. Four grass species, *Andropogon gayanus, Panicum maximum, Hyparrhenia rufa* and *Brachiaria decumbens* were used in the various grass/legume combinations. In one experiment a mixture of legumes—*Macroptilium* sp. (CIAT 535), *Centrosema* hybrid (CIAT 1733) *Stylosanthes guyanensis* (CIAT 184), and *Desmodium* sp. (CIAT 336)—was planted with each one of the grass species.

This experiment was harvested three times during the year of establishment; yields are shown in Table 3. Of the three harvests, two were taken during the unseasonable and exceptionally long dry period experienced in the Cauca Valley. Dry weather reduced the *Desmodium* in the sward with a corresponding increase of stylo. *Macroptilium* showed moderate tolerance to extreme dry conditions.

Several one-grass/one-legume associations have been established at Santander. In general, stylo varieties displayed good early vigor and gave the best dry matter yields in the various grass/legume combinations. *Centrosema* and *Macroptilium* were slower to establish but their contribution to the sward increased with time. In each case, the nitrogen content of *Centrosema* hybrid exceeded that of the other legumes in these trials.

Drought tolerance was exceptionally good in *A. gayanus* and *B. decumbens* while guinea grass was the least tolerant to adverse weather conditions. *Hyparrhenia* also suffered seriously from dry conditons.

Table 3. **Dry matter yields and nitrogen and phosphorus content of four grasses and an associated legume mixture grown at Santander, 1976.**

Species	Dry matter yield[1]			Sward composition[2]		Nitrogen content[2]		Phosphorus content[2]	
	Grass	Legume	Total mixture	Grass	Legume	Grass	Legume	Grass	Legume
	(kg/ha)			(%)		(%)		(%)	
Guinea grass, Legume mixture	7,256	1,683	8,939	81.17	18.83	1.73	2.64	0.13	0.19
Andropogon gayanus, Legume mixture	5,808	1,811	7,619	76.23	23.77	1.36	2.53	0.15	0.19
Brachiaria decumbens, Legume mixture	2,630	4,225	6,885	38.37	61.43	1.67	2.63	0.16	0.17
Hyparrhenia rufa, Legume mixture	4,931	1,776	6,707	73.52	26.48	1.42	2.68	0.13	0.19

1 Total of three harvests during the year of establishment
2 Average of three harvests during the year of establishment

S. guyanensis is well-adapted to soil and climatic conditions in the Santander area. Growth rates of two accessions, CIAT 184 and 136 are being studied under two frequencies of cutting in pure legume stands. CIAT 184 is native to the Santander area and CIAT 136 is from the Llanos of Colombia. Both varieties have robust growth forms, produced high yields of dry matter in the year of establishment and displayed very good resistance to drought. Table 4 shows establishment yields, and phosphorus and nitrogen concentrations for these accessions at Santander.

CIAT's germplasm bank contains over 200 accessions of *Desmodium*. Two species, *D. canum* and *D. barbatum*, are particularly common in the savanna. They are usually associated with short grass pastures of *Paspalum notatum* and *Axonopus* spp. and colonize low fertility soils. A great deal of variability was observed

Table 4. **Establishment yields and phosphorus and nitrogen contents of two lines of *Stylosanthes guyanensis* grown at Santander, 1976.**

Lines	Dry matter yield[1] (kg/ha)	Mineral composition[2]	
		Phosphorus (%)	Nitrogen
S. guyanensis (CIAT 184)	11,250	0.16	2.22
S. guyanensis (CIAT 136)	9,762	0.16	2.64

1 Total of two yields
2 Average of two yields.

within each species, and some attractive forage types have been selected. Tables 5 and 6 show some of the growth characteristics of several *Desmodium* accessions.

The accessions of *Zornia* in the collection vary considerably in morphological characters and forage production. The genus contains a number of species and several of them are native in the Llanos and in the Campo Cerrado. A Brazilian and a Colombian ecotype have been selected for further studies.

One species of *Macroptilium* from the Venezuelan Llanos appears to be well-adapted to allic soils.

Table 6. **Rate of leaf appearance in seven *Desmodium* spp. accessions.**

Species and CIAT accession no.		Avg. no. of trifoliate leaves/day
D. canum	3037	1.95a[1,2]
D. heterophyllum	349	1.58b
D. barbatum	3010	1.52b
D. scorpiurus	3022	1.49b
D. barbatum	3031	1.37bc
D. canum	3005	1.19c
D. canum	3042	0.85d

1 L.S.D. at .01 = 0.2098 and at .05 = 0.1594
2 Values followed by different letters are significantly different at .01 by Duncan's Multiple Range Tests.

One of the grasses recently added to CIAT's collection, *Andropogon gayanus*

Table 5. **Rate of growth of *Desmodium* spp. on two Colombian soils.**

Species and CIAT accession no.		Soil location and plant growth (mg dry matter/plant/day)		Avg. for both soils	
		Carimagua	Santander	Accession	Plant growth (mg dry matter plant/day)
D. canum	3029	47.32[1]	51.53[1]	3035	49.95a[2]
D. barbatum	3031	46.99	52.08	3031	49.53a
D. canum	3035	46.44	53.44	3029	49.43a
D. canum	3044	45.82	46.06	3045	47.29ab
D. canum	3013	43.66	46.40	3028	45.98abc
D. canum	3041	43.47	44.14	3030	45.96abc
D. canum	3028	43.20	48.76	3044	45.95abc
D. canum	3030	42.75	49.16	3039	45.55abc
D. canum	3045	42.07	52.51	3042	45.19abc
D. canum	3036	41.93	44.26	3013	45.03abc
D. canum	3042	41.66	48.71	3041	43.81abc
D. canum	3032	41.44	43.42	3036	43.09bc
D. canum	3039	41.02	51.07	3032	42.41bc
D. barbatum	3061	35.08	37.62	3053	40.91cd
D. adscendens	3053	34.64	47.42	3015	36.64d
D. canum	3003	34.62	37.62	3061	36.38d
D. canum	3015	33.64	39.65	3003	36.12d
D. barbatum	3054	32.20	26.64	3054	29.47e

1 L.S.D. between soils at .01 = 1.85 and at .05 = 1.38. L.S.D. between varieties at .01 = 4.95 and at .05 = 3.76
2 Values followed by different letters are significantly different at .01 by Duncan's Multiple Range Test.

has very good forage characteristics. It is drought and fire-resistant and well-adapted to soil conditions of the Colombian Llanos. There it seeds prolifically and spreads rapidly as the light seeds are disseminated by wind and water.

Advanced selections of forage legume cultivars are being tested under actual grazing conditions prior to release to national forage programs. Potential release material includes: one *Centrosema* hybrid (CIAT 1733), one *Desmodium* sp. (CIAT 336) and one *S. guyanensis* (CIAT 136).

Pasture Seed Production

The production of seed of potentially useful accessions has continued as the main objective of this unit during 1976. New seed production areas, involving two new locations and a wider array of legume species and experimental lines, have been established. In general, legumes have been concentrated at Santander and Restrepo, environments with more favorable soil and weed conditions than at CIAT (Palmira). Experiments have been initiated at these locations to investigate responses to various levels of phosphorus and defoliation and to evaluate support systems to assist in determining management systems appropriate for expanded production areas in the future. Grass seed production plots are located at Palmira and Santander. Seed harvested in the last year was predominantly *S. guyanensis* (CIAT 136).

Stylosanthes spp.

Twenty-five hectares of mature *S. guyanensis* (CIAT 136) planted at Palmira and Carimagua were directly combined in January and February 1976 (Fig 6). Table 7 provides details of these harvests. At Palmira, yields from different lots ranged from 35 to 139 kg/ha of acid scarified, pure seed. The average yield was 69 kg/ha. Yields at Carimagua were much lower, with individual lots ranging from 2 to 31 kg/ha and a location average of 3 kg/ha. Some 700 kilograms of pure seed were produced from these two locations.

Table 7. **Description of seed harvest and major yield determinants of *Stylosanthes guyanensis* (CIAT 136) at two locations.**

Factor	Location	
	Palmira	Carimagua
Seed harvest		
Crop area (ha)	10.3	15.0
Crop height (m)	1.5	0.8
Combine rate (ha/hr)	0.12	0.26
Yield (kg/ha)[1]	69	3
Yield determinants[2]		
Weed competition	+++	+
Anthracnose	+	++
Stem borer	-	+++
Bud worm	++	+++

1 Acid scarified, pure seed
2 - not present; +, present; ++, problem; +++, serious problem.

The rate of harvest with the combine was determined by the height, density, stickiness, seed yield and moisture content of the standing mature crop and relative humidity conditions on harvest days. At Palmira, a minimum forward speed and partial width of cut were necessary to assure effective separation and recovery of seed bearing fractions from a tall, dense, sticky, high-yielding crop. The harvest rate at Carimagua was higher due to both lower crop density and seed yield and, also, lower relative humidity conditions.

The major yield determinants at Palmira were weed competition *(Ipomoea* spp., *Amaranthus debius, Commelina diffusa, Sida* sp., *Cynodon dactylon)* and a bud

Figure 6. Combine harvesting of *Stylosanthes guyanensis* at CIAT, Palmira

worm, *Stegastra bosqueella* (Chambers) (Lepidoptera, Gelechidae). During seed processing with a conventional air screen cleaner, weed seeds of *C. diffusa* and *Sida* sp. caused separation problems. Weeds generally restrict the productive life of a stand to one, or at the most, two harvests.

At Carimagua, the combined and sequential effects of anthracnose, *Colletotrichum gloeosporioides* Penz; a stemborer, *Zaratha* sp. (Lepidoptera, Blastodanidae); and the *Stegastra* bud worm, were devasting. Future seed production of *Stylosanthes* lines susceptible to the stem borer and anthracnose will therefore be located elsewhere.

C. gloeosporioides is now regarded as being seed transmitted but sulphuric acid scarification of pods and seeds was shown to reduce the amount of seed-borne inoculum.

Small areas of 26 new accessions of *S. guyanensis, S. scabra, S. sympodialis* and *S. capitata* have been established at Santander.

Desmodium **spp.**

A stand of *Desmodium* sp. (Ciat 336) was harvested at Palmira by direct combining in early March 1976. Yield of scarified pure seed was 47 kg/ha. The development of an April 1976 planting at Santander has been severely retarded by a prolonged dry season. The seed yield potential of this line is also being investigated at Restrepo (altitude 1,400 meters, average annual temperature 20°C and annual rainfall, 1,020 milimeters).

Small areas of *D. heterophyllum* have recently been established at Palmira, Santander and Restrepo, to compare seed production characteristics in three contrasting environments. Twenty new accessions of various species of *Desmodium* have been established at Santander.

Centrosema sp.

Two F_7 lines of the hybrid *C. brasilianum* x *C. virginianum* are established on a bamboo and wire trellis system at Palmira. Flowering in 1976 was sparse and confined to early February as subsoil moisture promoted continued vegetative growth. Hand harvesting was completed by late March. Seed yields were very low, averaging only 16 kg/ha of pure seed. Yield potential is now being investigated at Santander, both with and without support systems.

Grass species

New areas of *B. decumbens, B. humidicola, A. gayanus* and *P. maximum* have been planted at Santander and Palmira. The prolonged dry period from May to September reduced seed yield and quality at first harvest and negated responses in two nitrogen rate experiments. Seed quality studies have been initiated comparing *P. maximum* seed harvested by hand and by direct combining.

Pasture Establishment and Maintenance

The objective of research in pasture establishment and maintenance is to develop low-cost systems for efficiently establishing legumes and grasses alone and in association on the allic soils of the tropical savannahs of South America. Studies include seedbed preparation, different aspects of planting including band versus broadcast seeding and fertilizer application, compaction, nutrient requirements, the interaction between species and fertilizers, sources and methods of applying phosphorus, fertilizer requirements for establishment under different drainage regimes and fertilizer maintenance requirements for grasses under grazing management.

Seedbed preparation

Most improved pastures are established in savannah regions after conventional plowing and disking or using heavy offset discs to completely destroy existing vegetation, leaving a reasonably smooth, weed-free surface and a plow layer 10-15 centimeters deep. With experience and quality seed, excellent pasture stands can be obtained with this type of seedbed preparation. It is, however, costly in terms of power and machinery required and it exposes the soil to extreme erosion hazards. A seedbed preparation trial was established in 1974 but discontinued for several reasons. It was established again in 1975 and includes the following treatments: (a) no tillage, with and without herbicide control of vegetation; (b) minimum tillage in which a fluted coulter is used to work up a very narrow band (approximately two centimeters) into which the introduced species are seeded, with and without herbicide; (c) the use of stubble mulch sweeps to undercut the savannah vegetation at a very shallow depth to separate the plant crown from the root system. The sweeps are used to cultivate 30-centimeter strips leaving 30 centimeters of undisturbed savannah between cultivated strips. In an additional treatment (d) the sweeps are used to cultivate the entire surface, thus destroying

most of the native vegetation. This method of cultivation leaves the surface well-protected with all of the crowns and top growth remaining on the surface of the soil. The last treatment (e) is the conventional method of seedbed preparation involving a light plowing and subsequent disking.

Figure 7 shows the effects of tillage and herbicides on plant density of native species, population of introduced species and production of forage. Almost complete control was achieved with conventional seedbed preparation and this system resulted in the highest average yields for the species planted. Good control of native vegetation was achieved with the stubble mulch sweeps with or without herbicide treatment and stands of most species were adequate for these treatments, along with the no-tillage herbicide control treatment. However, yields at six months were very much affected by degree of control of native species. Yields decreased in the order of conventional > sweep strip tilled with herbicide control > sweep tillage of entire surface > strip tillage without herbicide control > no tillage with herbicide control > no tillage with no herbicide control. It was not possible to measure the influence of tillage treatment on soil loss or run-off losses. However, it is almost certain that the erosion hazard would be much greater for conventionally tilled seedbeds than with any of the other seedbed preparation systems. The stubble mulch sweep system provides excellent ground cover during the establishment phase for the seeded pasture.

A major advantage of the stubble mulch sweep is its low power requirement. It is estimated that stubble mulch tillage of the entire surface would cost approximately one-quarter as much as conventional tillage and stubble mulch tillage of strips would cost correspondingly less depending on the fraction of the total surface tilled. Another advantage of the sweep is that it should be well-adapted to animal draft implements and possible to manufacture locally. The first year's results of this trial indicate the need for more extensive testing of alternative systems of seedbed preparation, to replace or modify the conventional systems.

Planting systems

Most pastures in developing savannah regions are seeded manually either with seed or vegetative material. Stands are very erratic due to seed of unknown quality as well as to other factors. Grasses are usually surface-seeded with no covering after conventional seedbed preparation. Ranchers usually wait for a few hard rains to settle the surface of the soil before seeding, otherwise, small-seeded species like *Melinis minutiflora* and *H. rufa* will be covered too deeply with almost certain loss of stand. The most important factors in obtaining a good, uniform stand appeared to be: (a) proper compaction of the seed to assure good seed-soil contact and capillary flow of moisture from below to the surface where the seedling is struggling to survive; and, (b) adequate fertilizer in the seedling zone to assure good seedling vigor, especially important with the very small-seeded species which have hardly any nutrient reserve in the seed. Phosphorus is especially important in assuring seedling vigor in allic savannah soils that are almost universally extremely low in available phosphorus.

Compaction. In this trial, three different associations were planted with three systems of compaction consisting of: (a) a no-compaction check; (2) compaction in the band only; and, (3) compaction of the total surface. Band compaction was accomplished with an Allis Chalmers

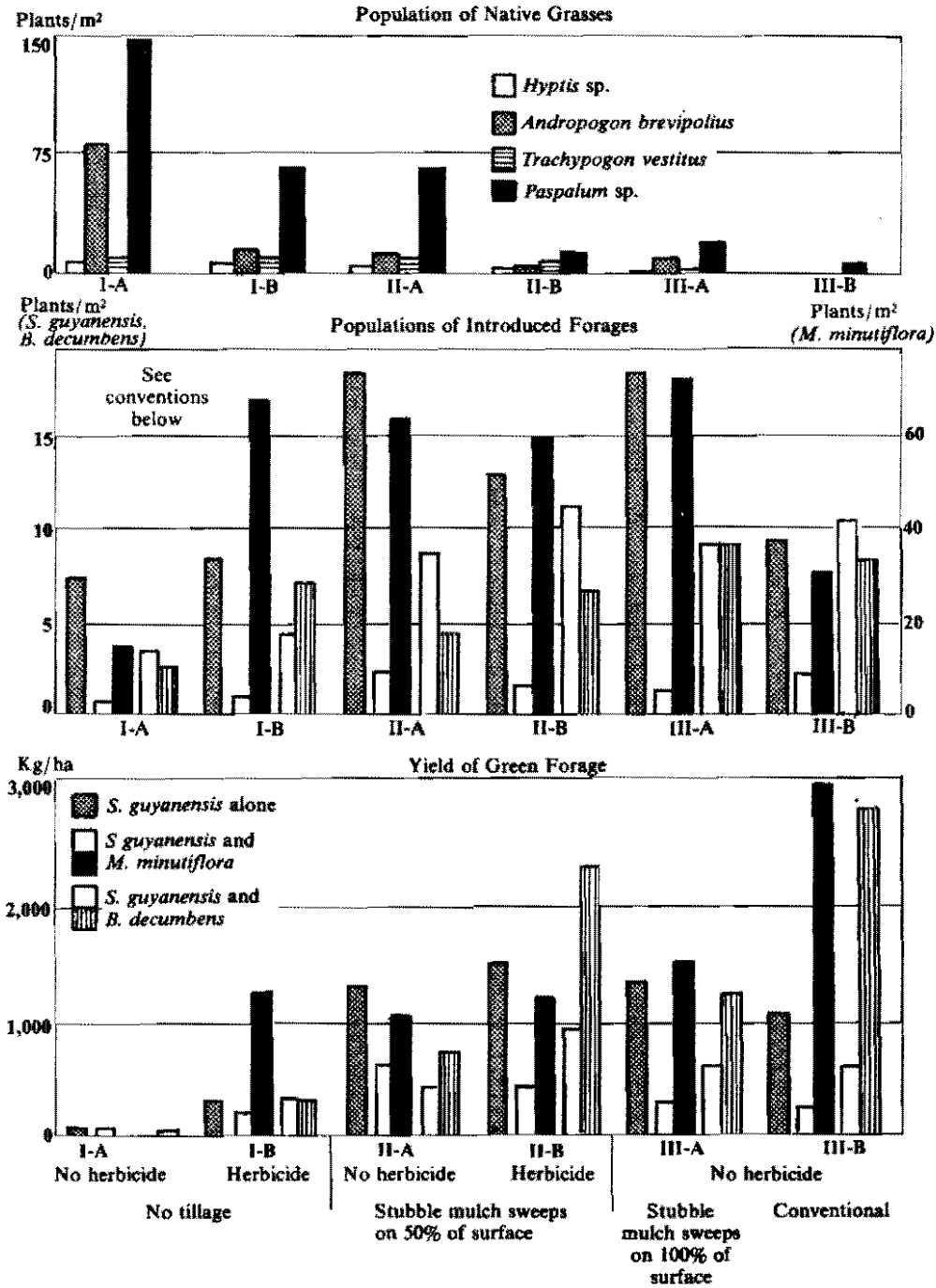


Figure 7. Effects of different methods of preparing the soil and of controlling native vegetation on populations of native grasses and populations and yields of introduced forages, at Carimagua, 1975-76.

planter press wheel directly over the seeded band. Total surface compaction was obtained with a compactor built of old automobile tires, with approximately the same weight per unit surface area as the band compactor.

Figure 8 shows the effect of compaction treatments on stands and forage yields of association of *Stylosanthes* with *H. rufa*, *M. minutiflora* and *B. decumbens*. Stand counts and yields are shown for the legume and grass components of the mixtures as well as weeds. Compaction, both in the band and over the entire surface, greatly enhanced the establishment of *Stylosanthes* in all mixtures, which was reflected in *Stylosanthes*, yields for all mixtures.

There was considerably less effect of compaction on stands of the associated grasses. However, compaction did have a very favorable effect on yields of *H. rufa* and *B. decumbens*. *M. minutiflora* is one of the easiest of the grass species to establish. This may account for its popularity in many savannah regions. Although weed counts were rather high in all associations, weed yields were almost insignificant, reaching their lowest level in the *Stylosanthes-Melinis* association. Note that in some cases, the scale is different for the grass component and legume component of the different associations.

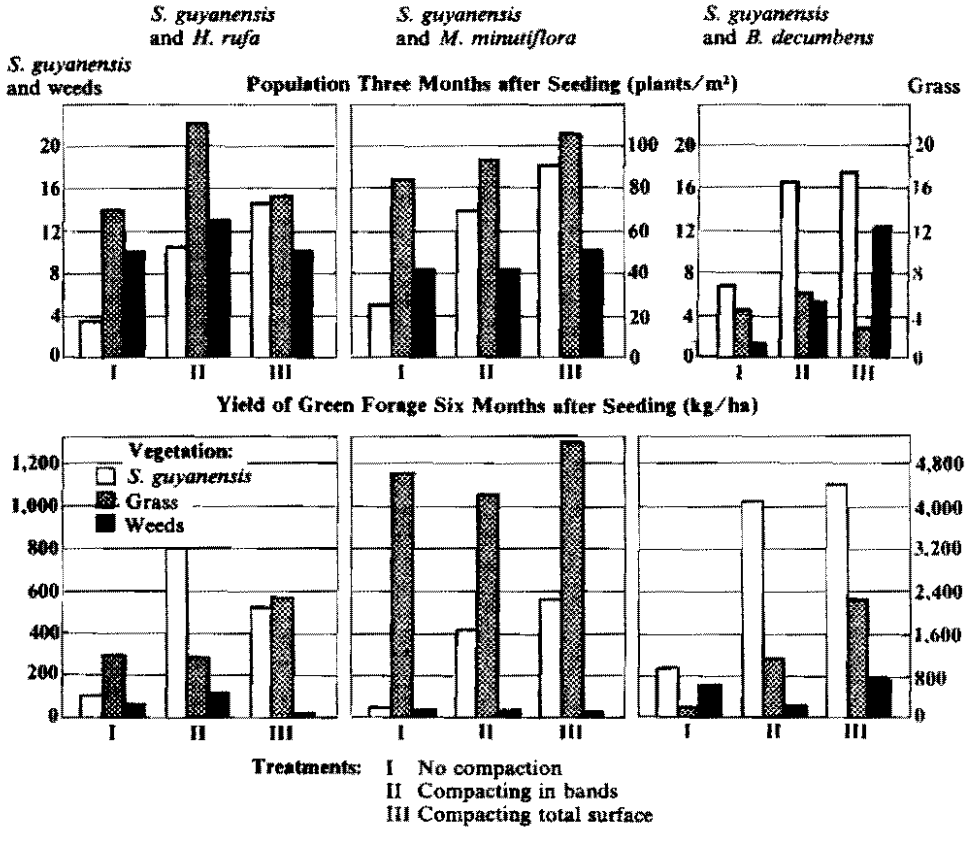


Figure 8. Effects of compacting treatments on the stablishment and performance of three forage associations at Carimagua, 1975-76. In all graphs, *S. guyanensis* and weed populations are on the left vertical scale and the respective grass populations are on the right vertical scale.)

The compaction trial was conducted on a conventionally-prepared seedbed. As progress is made with alternative systems for seedbed preparation, additional work will be required to determine the need for compaction. It appears that it may be less essential with sweep tillage than with conventional tillage since the seedbed is less disturbed and surface mulch tends to buffer the soil against rapid changes in soil moisture, promoting better seedling development than on conventionally prepared, bare land.

Phosphorus levels and systems of application. Three levels of phosphorus — 10, 40 and 70 kg P_2O_5 / ha — were applied broadcast and in bands, using basic slag as the source. The slag was mixed directly with seeds, thus seed was also broadcast or banded depending on how the phosphorus fertilizer was applied.

Figure 9 clearly shows that there is a definite advantage to band seeding and fertilizer application. It appears to be more important for the legume than for the grass. Stand counts fail to explain the yield differences. On the average, there were slightly better stands of *Stylosanthes* when it was bandseeded but there was no significant nor consistent difference in total stands and grass stands. Band seeding and fertilizer application apparently create a more favorable fertility environment for the developing seedling than do broadcast applications. The fertilizer is concentrated in the seedling zone and phosphorus availability is greater during the seedling stage when it appears to be especially critical for small-seeded forage species.

Figure 10 shows effects of phosphorus and method of application on phosphorus content in *S. guyanensis* and associated grasses when they were cut the first time after five months and the second time after 10 months. The first cut was at the end of the rainy season and the second cut was after the dry season as another rainy season was beginning. Phosphorus rates had a marked effect on the phosphorus content of *Stylosanthes* and *Brachiaria* and broadcast application was much more efficient than band application at the first cutting after five months. This effect tends to disappear in the second cutting. There is very little effect on the phosphorus content of *M. minutiflora* or *Paspalum plicatalum*. Figure 11 shows the effect of phosphorus rates and method of application on nitrogen content of the four species in this trial. At the first cutting there was a slight indication of greater effect of broadcast-applied phosphorus in *Stylosanthes* and *Brachiaria* but the major effect appears to be one of dilution with nitrogen levels generally decreasing with increasing levels of applied phosphorus which resulted in increased dry matter yields.

Brachiaria is generally considered to have relatively low fertility requirements and it is used widely throughout South America in allic soil regions. However, during the establishment phase on an oxisol at Carimagua it was extremely responsive to phosphorus, as can be seen in Figure 12. Response to potassium was less striking. This experience is in line with other observations and experiences at Carimagua where most forage species respond very strongly to applied phosphorus during the establishment phase.

A trial was established in early 1976 to evaluate three grass species associated with Kudzu *(Pueraria phaseoloides)* in a poorly-drained low area. The grasses included were Tanner, Pará and Alemán *(Brachiaria rugulosa, B. mutica* and *Echinochloa polystachya).* In Figure 13 tnere is a very strong interaction between phosphorus and potassium. Kudzu, Pará and Tanner yields were extremely low

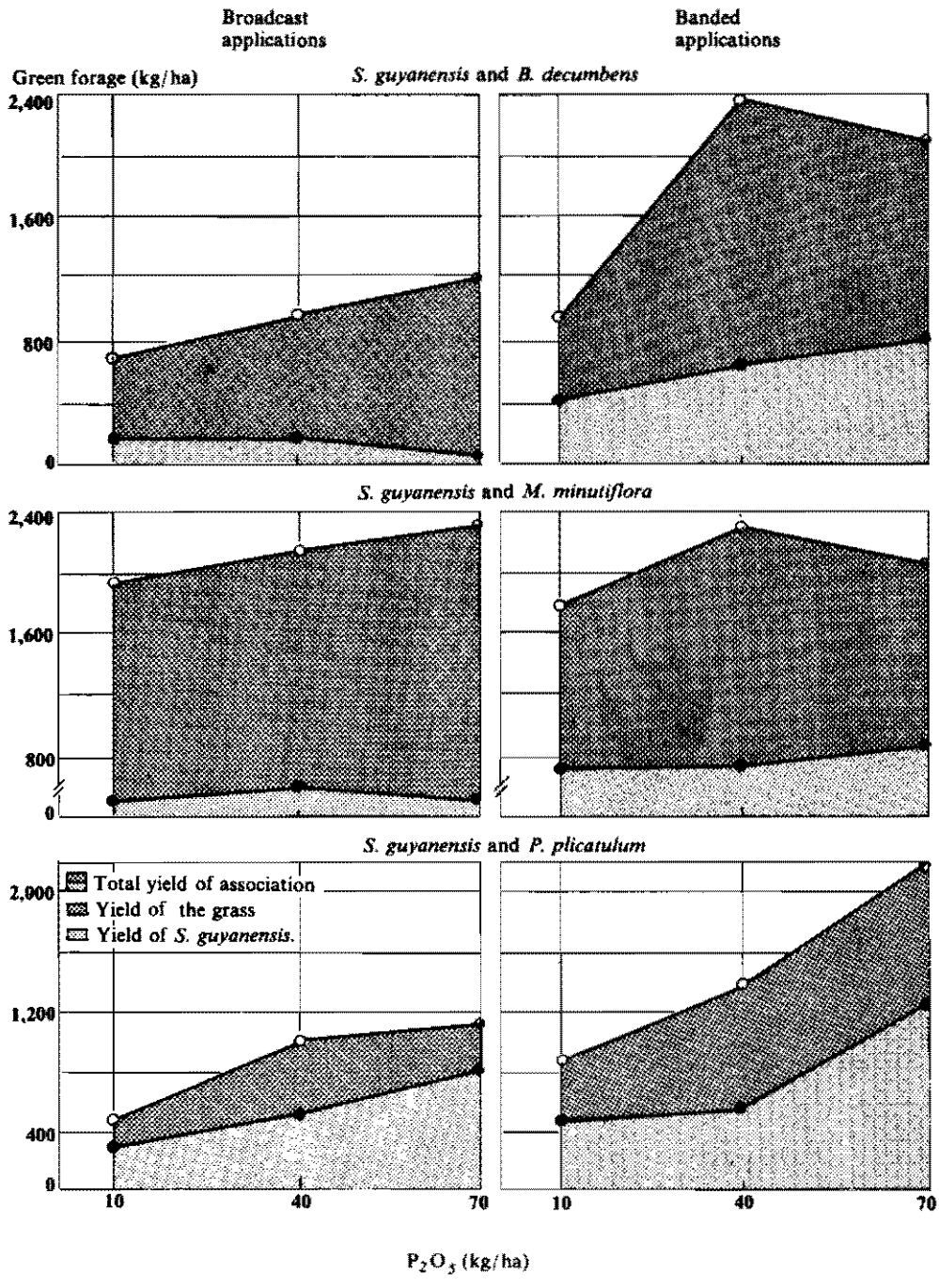


Figure 9. The effects of three levels of phosphorus and two methods of applying phosphorus and seeding on yields of three forage associations, at Carimagua, 1975-76.

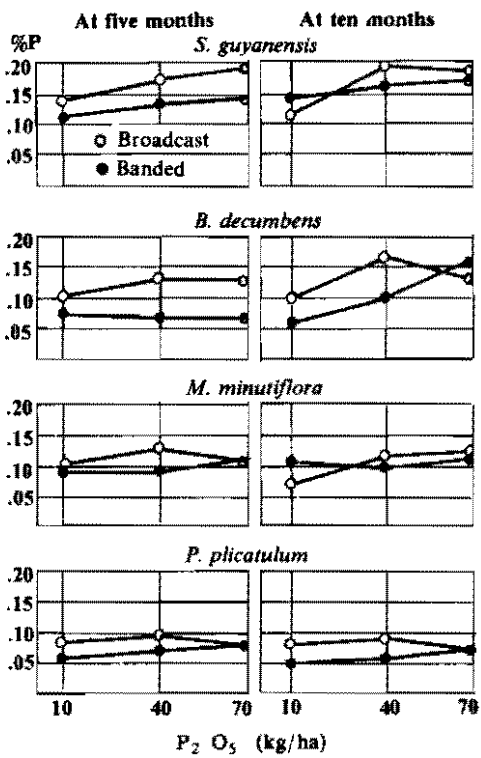


Figure 10. Effects of three levels of phosphorus and two methods of applying phosphorus and seeding on the phosphorus content of four forage species at five and ten months after seeding, at Carimagua, 1975-76.

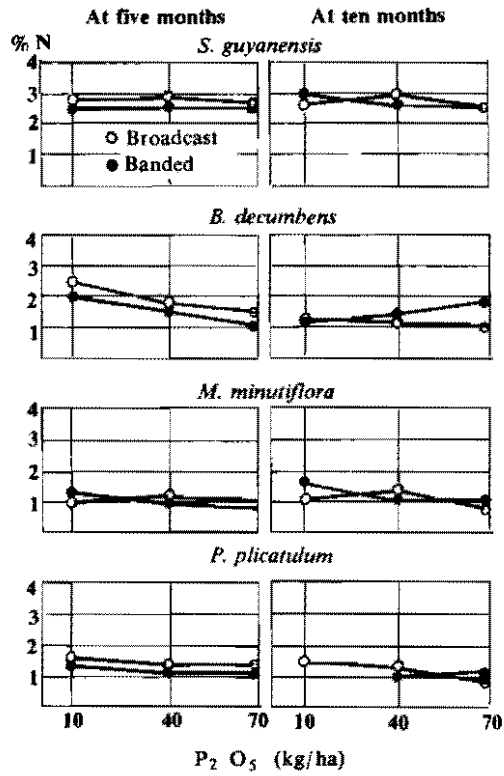


Figure 11. Effects of three levels of phosphorus and two methods of applying phosphorus and seeding on the nitrogen content of four forages at five and ten months after seeding, at Carimagua, 1975-76.

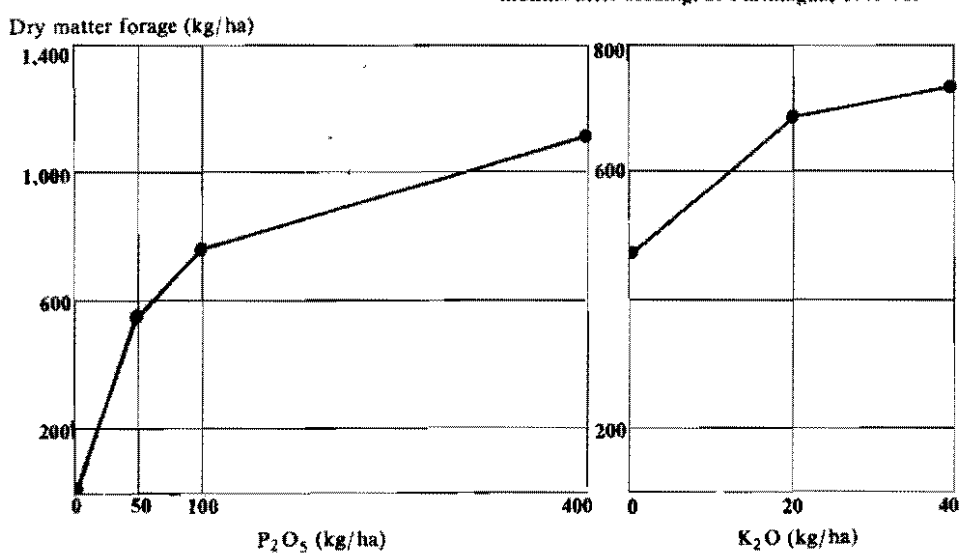


Figure 12. Effect of phosphorus and potassium on the dry matter yield at first cutting of *B.decumbens*, at Carimagua, 1976.

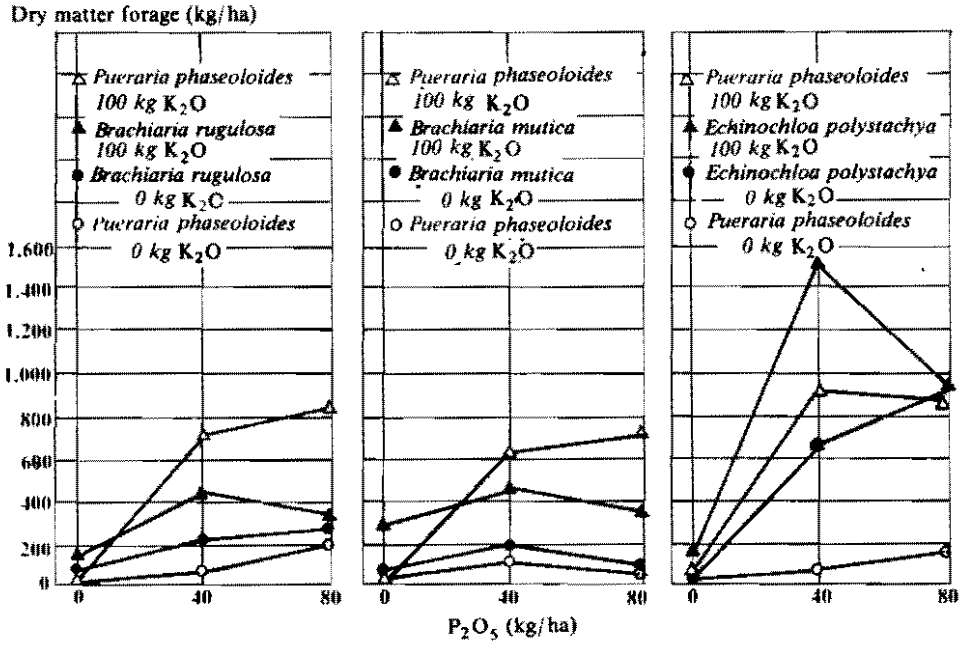


Figure 13. Effect of phosphorus and potassium on the yields of three grass-legume associations in poorly drained soil at Carimagua, 1976.

without added potassium fertilizer. Alemán is strikingly different in response pattern. Kudzu and Alemán were especially responsive to phosphorus. These species may have promise for poorly drained, low areas for accumulating high quality forage for summer grazing when these soils remain moist while the higher savannahs become extremely dry.

Field experience with Kudzu in Carimagua revealed nutritional problems. A greenhouse trial was initiated in early 1976 to study these problems. Figure 14 shows the effect of potassium and magnesium on yields of Kudzu in a greenhouse trial using Carimagua soil. The response to potassium is clear. There was also an apparent visual response to

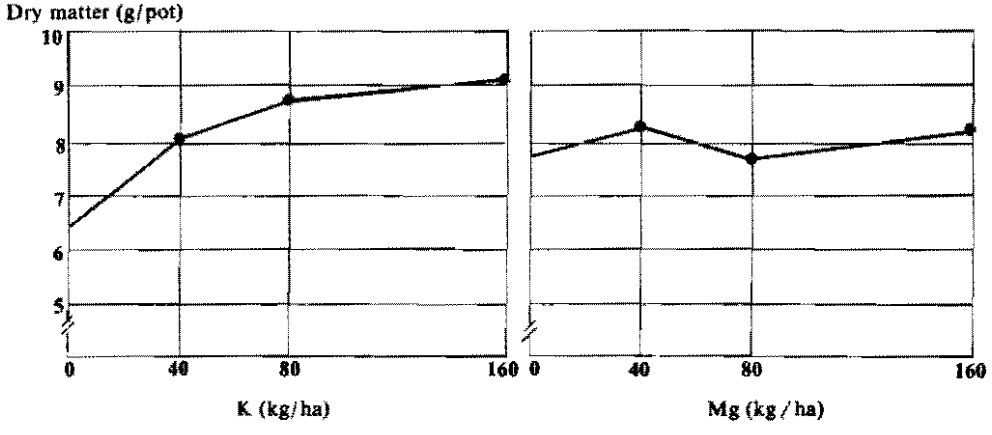
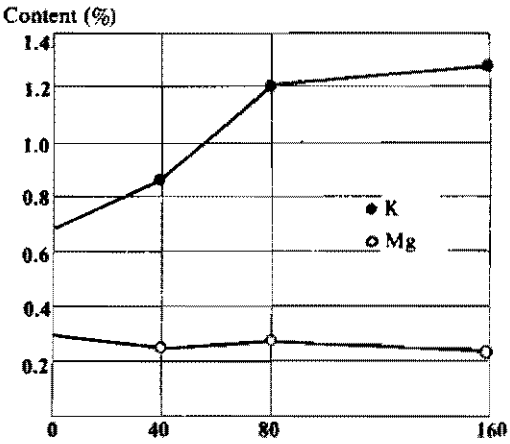


Figure 14. Effect of potassium and magnesium on dry matter yield of *P. phaseoloides* in Carimagua soil, in greenhouse tests, 1976.



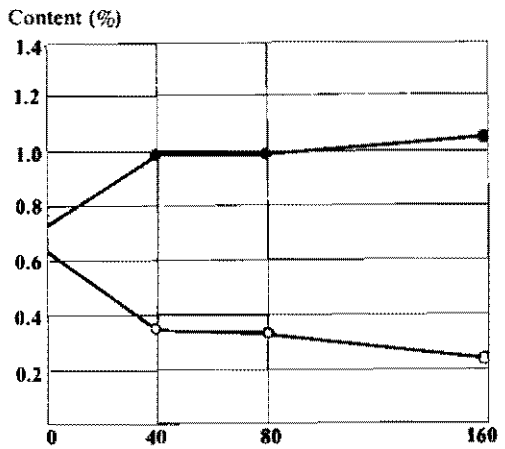


Figure 15. Effect of potassium and magnesium on percentage content of those elements in young leaves of *P. phaseoloides* in Carimagua soil, in greenhouse tests, 1976.

magnesium but this was not borne out by dry matter yields. Magnesium deficiency symptoms which appeared, especially in treatments with high calcium and/or potassium applications, disappeared with application of magnesium. In Figure 15 the effects of potassium and magnesium are shown. Tissue content of magnesium was much higher when it was applied at low levels of potassium fertilization, but at 80 and 160 kg/ha of potassium, the difference in magnesium content due to added magnesium was very slight.

Soil Microbiology

Characterization of an extensive collection of *Rhizobium* strains against promising host plant forage accessions (mainly *Stylosanthes* spp.) is being pursued on three levels. First, aseptic tube culture permits large scale screening for compatability of host and bacterium. Culturing effective associations in Leonard jar assemblies allows strains to be ranked in order of efficiency. CIAT 79 (CB 756), a strain commonly used for inoculating *Stylosanthes,* performed poorly in these tests, averaging only 17th in efficiency order, whereas a local isolate (CIAT 71) is frequently high on the list (Table 8). However, the results emphasize the specificity of host-strain interaction. CIAT 71 failed to nodulate one of the accessions, so that although less efficient, the wider spectrum strain CIAT 308 (isolated at Cali, Colombia) has more potential as an inoculant. A collection program to search

Table 8. Relative symbiotic nitrogen fixation efficiency[1] of *Rhizobium* strains with *Stylosanthes* accessions.

	Stylosanthes Accession[3]					
Strain[2]	184	136	107	64A	1152	1053
CIAT 71	1	4	6	4	NN[4]	4
CIAT 301	6	5	5	22	NN	NN
CB 756	12	14	24	23	16	13
CIAT 308	3	8	7	13	2	1
CIAT 693	11	1	8	6	11	26
CIAT 530	NN	NN	NN	NN	NN	3

1 Value is place of strain in list of 35 strains ranked in order of efficiency
2 Only 6 of the 35 strains are included
3 All *S. guyanensis* except 1053 which is *S. scabra*
4 No nodulation.

for highly effective, wide-spectrum strains continues to be an important part of forage soil microbiology work.

At the third level of testing, the most efficient strains are screened in pot culture in sterilized site soil to assess their tolerance to low pH, low phosphorus availability and high aluminum level. Pot culture confirms that CIAT 71 and CIAT 301 (isolated from nodules of *Stylosanthes* collected in Brazil) are consistently better than CIAT 79 (Fig. 16).

It remains to be seen whether the superior efficiency of these and other strains is maintained in the field when they are subjected to the additional stress of competition for infection sites from inefficient, naturally-occurring *Rhizobium* populations.

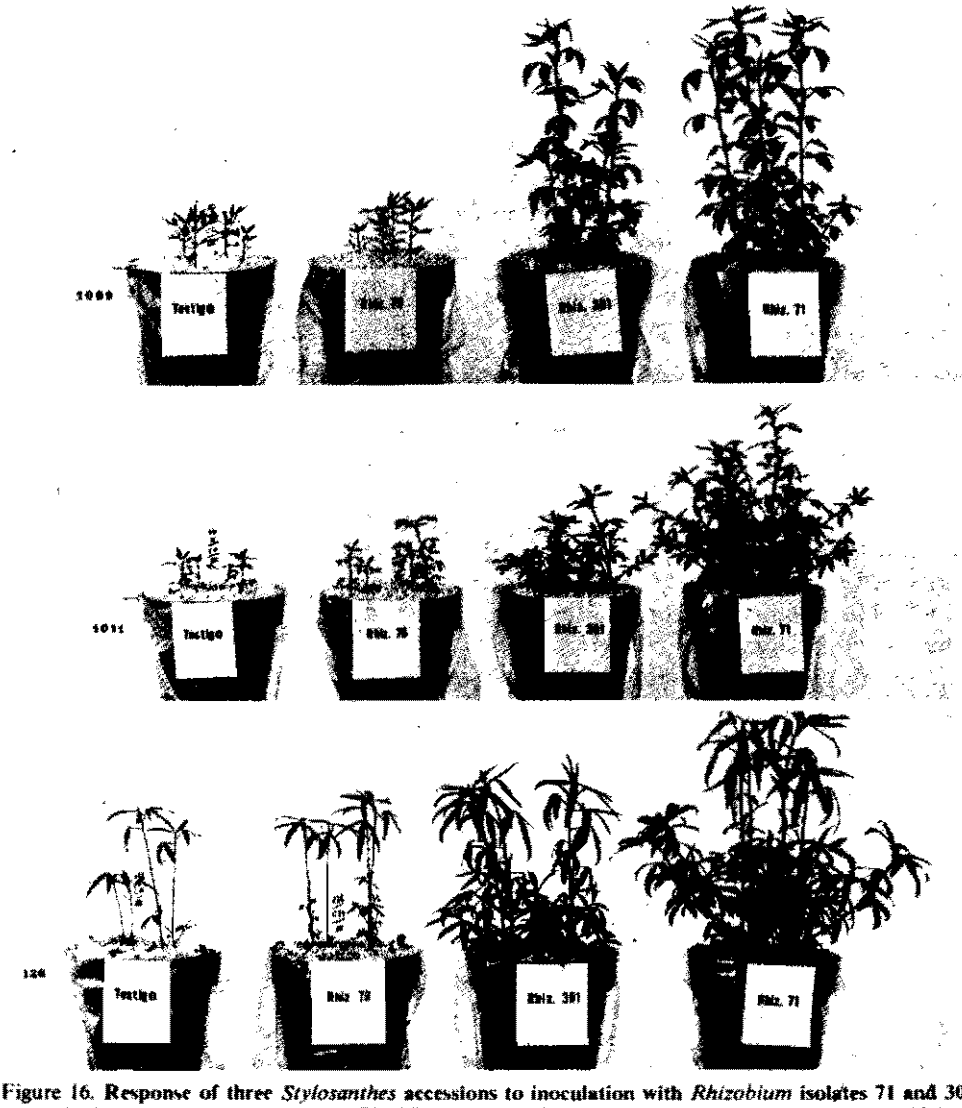


Figure 16. Response of three *Stylosanthes* accessions to inoculation with *Rhizobium* isolates 71 and 301 compared with the recommended strain 79 (CB 756) and uninoculated control plants. Accession 1009 is *S. scabra;* 1011 is *S. viscosa;* and 136 is *S. guyanensis.*

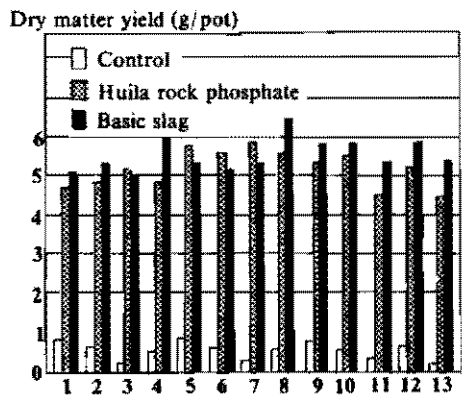
Efficient Use of Phosphorus on Tropical Soils

Phosphorus fertility management is very difficult in the allic soils of the tropics because of their low phosphorus fertility status and high fixation of fertilizer phosphorus. Recent research results indicate a number of possible new approaches to phosphorus management in tropical soils in order to improve phosphorus fertilization efficiency. Given the urgent need for more agricultural opportunities and increased food production in the tropics, a comprehensive research project was initiated in which laboratory, greenhouse and field research efforts of a team of specialists are coordinated and focused on improving phosphorus efficiency and increasing the productivity of tropical soils.

The Phosphorus Project was initiated in October 1975 as a special project. It is funded by the International Minerals Corporation and the World Phosphate Institute; some of the project's work is cooperative with the International Fertilizer Development Center. Research activities not discussed in the Annual Report of the Bean Program are summarized in this section.

Stylosanthes responses to phosphorus sources on allic soils

Greenhouse experiments for screening *Stylosanthes* species and ecotypes in an oxisol (Carimagua) for tolerance to low levels of phosphorus and for responses to low (rock phosphates) and high (basic slag) available phosphorus sources were initiated. Average yields of two cuts (Fig. 17) showed that all the 13 species and ecotypes studied responded well to 200 kilograms of P_2O_5/ha, independently of the sources. Only with *S. scabra* 1009 was there a significant difference in yield between the treatments with Huila rock phosphate and basic slag. Basic slag at 200 kilograms of P_2O_5/ha produced 23 percent more dry matter than the Huila rock treatment. On the other hand, Huila rock phosphate produced more dry matter than basic slag in the case of *S. guyanensis* 136 and 1073, and *S. scabra* 1050 and 1053. It was impossible to obtain good growth of this legume in the Carimagua soil without adding phosphorus, at least for establishment.



Stylosanthes species and CIAT No.

1	64A	*guyanensis*
2	184	"
3	136	"
4	1009	*scabra*
5	1073	*guyanensis*
6	1050	*scabra*
7	1053	"
8	1092	"
9	1057	"
10	1058	"
11	1082	"
12	1091	*montevidensis*
13	1019	*capitata*

Figure 17. *Stylosanthes* and ecotypes screened in an oxisol (Carimagua) for tolerance to low (rock phosphate) and high (basic slag) available phosphorus sources, (average of two cuts).

Dissolution of various phosphorus sources

Laboratory experiments were initiated on the dissolution of rock phosphates: Huila and Pesca from Colombia, Tennessee from U.S.A. and Gafsa from Morroco, and two other phosphorus sources (triple superphosphate (TSP) and basic slag) applied to an Oxisol from Carimagua and a volcanic ash soil from Popayán. In general, the results show a drastic reduction in available phosphorus extracted with Bray I and II solutions after 16 days of incubation at greenhouse temperature with only a slight further decrease after 35, 66 and 186 days.

Figure 18 shows the effect of incubation time on phosphorus availability in Carimagua soil, measured by Bray I and Bray II, when 300 ppm of phosphorus was applied from six different sources. Apparently, for soils fertilized with TSP or basic slag it is possible to use either Bray I or II to determine plant-available phosphorus. but when phosphorus is added as rock phosphate, the Bray I method seems to give a better measure of the available phosphorus in the soil. Bray II extractant solution is strongly acid and partially dissolves the rocks, showing high soil phosphorus concentrations that generally do not correlate with plant response.

Phosphorus status and fixation capacity of tropical acid soils

The phosphorus status and chemical characteristics of 14 acid soils from Colombia were studied. Table 9 shows

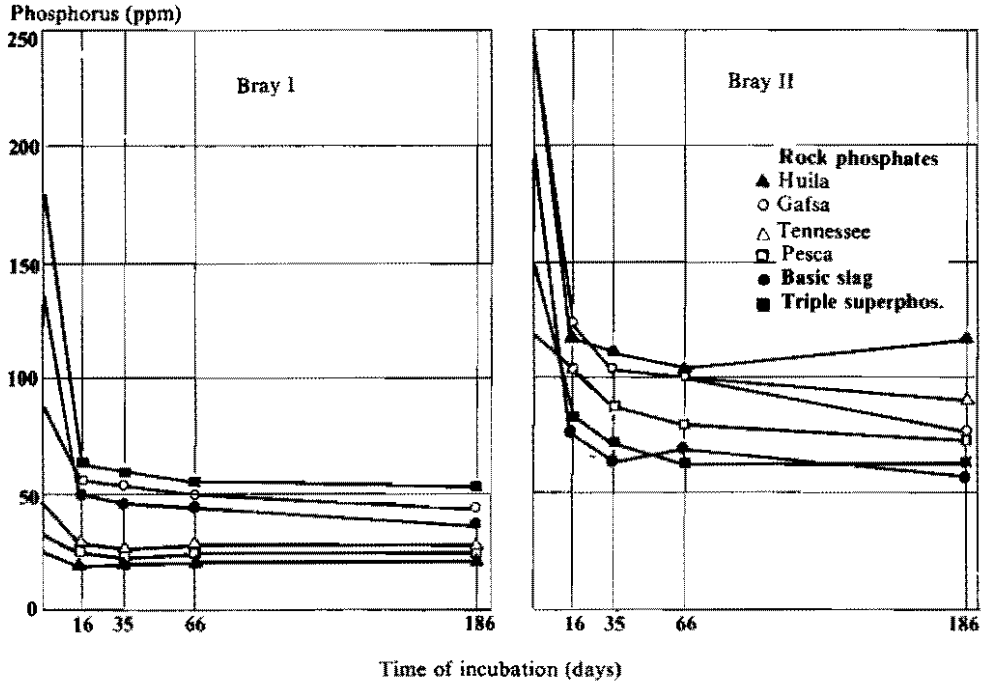


Figure 18. Effect of incubation time on the solubility of 300 ppm of phosphorus from different sources applied to an Oxisol from Carimagua.

Table 9. **Phosphorus fixation capacity and some chemical characteristics of 14 acid soils from Colombia.**

Soil	P fixation capacity (%)	P fixation capacity (mg P/100 g)	pH H_2O	Organic matter (%)	Extr. Al pH 4.8 (meq/100 g)	Reac. Al $MgCl_2$ (meq/100 g)	Exch. Al KCl (meq/100 g)	% Al Satur.	Total acidity (meq/100 g)	Titrat. acidity to pH 8.2 (meq/100 g)	Mn KCl (ppm)	Mn HCl + H_2SO_4 (ppm)	P Bray I (ppm)
Bermeo	74.0	370.0	5.5	28.8	14.2	10.8	1.4	32.7	54.0	146.8	2.7	17.7	.2.1
El Meson	72.0	360.0	5.0	16.5	15.2	11.8	1.3	76.9	31.8	162.5	1.5	10.1	1.4
La Selva	71.8	358.8	5.0	22.5	13.7	10.8	1.5	47.2	38.2	144.8	9.7	14.6	2.6
Facatativá	69.0	345.0	5.3	22.5	15.7	8.9	2.0	40.4	44.6	134.9	12.4	24.6	2.6
Unidad 10	45.5	227.5	5.5	11.8	6.2	13.7	0.5	14.1	45.6	108.3	8.9	14.8	2.8
Pamplona	33.5	167.5	5.1	9.2	6.2	11.8	4.2	38.2	42.8	51.9	6.4	11.7	2.3
Andes	33.0	165.0	5.1	6.2	1.9	6.9	0.8	6.7	6.4	14.8	92.1	136.0	1.6
Cachimbalito	29.5	147.5	4.3	9.5	4.4	6.5	3.4	62.9	43.2	45.5	16.8	23.3	3.0
Carimagua	22.0	110.0	4.2	4.3	4.1	5.5	3.1	92.0	28.4	29.2	1.5	5.9	2.1
Melendez	18.0	90.0	5.3	6.3	1.2	7.0	0.2	2.5	4.8	31.0	61.6	116.9	1.4
Platanares	16.5	82.5	4.9	4.0	2.9	5.9	1.9	56.2	14.6	22.1	13.5	20.9	1.6
La Libertad	15.5	77.5	4.9	2.9	4.2	4.4	3.3	90.2	26.1	23.5	14.4	18.1	3.7
Lebrija	15.5	77.5	4.5	4.2	5.7	4.9	6.2	96.1	24.5	21.6	0.3	5.8	1.4
Abrego	11.0	55.0	4.6	2.9	1.5	2.9	1.7	42.4	21.6	14.7	2.7	24.8	0.7

some of the chemical characteristics which largely determine the phosphorus fixation capacity. The soils have fixation capacities between 11 and 74 percent. Phosphorus retention was very high for andosols and relatively low for kaolinitic soils high in iron hydroxides.

The influence of organic matter, aluminum extracted with NH_4OAc at pH 4.8, reactive aluminum titrated between pH 8.2 and 8.5 with $MgCl_2$, and total acidity titrated to pH 8.2 in $MgCl_2$, on the phosphorus fixation capacity is evident. Soils with more than 10 percent organic matter showing high reactive and extractable aluminum have a high phosphorus fixation capacity. Exchangeable aluminum does not correlate with phosphorus retention indicating that perhaps much phosphorus fixation is due to other forms of aluminum and probably to iron hydroxides, in the case of ultisols and oxisols.

Effect of soil amendments on phosphorus availability

The effect of soil amendments such as lime and silicate on the availability of phosphorus, both native soil phosphorus and different sources of fertilizer phosphorus was studied.

Lime

In January 1976, a greenhouse experiment was initiated using four levels of $CaCO_3$, and three levels of phosphorus form different sources. Soils from Carimagua and Popayán were used, and beans (*Phaseolus vulgaris* L.), cowpea (*Vigna sinensis*), and Guinea grass (*Panicum maximum* L.) were planted successively in that order. The results for beans are discussed in the Annual Report of the Bean Program.

Guinea grass was used as an indicator plant to detect the residual effect of both lime and phosphorus applications, after beans and cowpea were harvested. Figure 19 shows that this grass responded very well to phosphorus applications, regardless of source, and that liming the soils has a negative or no effect on dry matter yields. In a recent, unpublished study by Spain, Andrew and Vanden Berg, common guinea was one of the tropical grass species that showed a marked yield increase with increasing aluminum concentration (up to 2.0 ppm) in solution culture. It is possible that in the case of the soil from Carimagua, the highest percentage

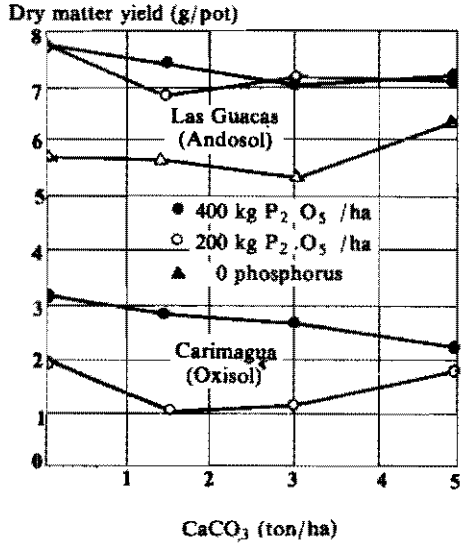


Figure 19. Effects of level of application of lime and phosphate on the yields of tops of Guinea grass (*Panicum maximum*) (average of three phosphorus sources). No yield was observed at zero level of phosphorus on the Carimagua soil.

aluminum saturation (73%) in unlimed soil coresponded to an optimum level of aluminum in the soil solution for guinea grass. These results also indicate the possibility of using rock phosphate instead of water soluble phosphorus sources in allic soils when tropical grasses like common guinea are established. The main effect of lime may be to supply calcium to the plant.

Silicates

Two greenhouse experiments were initiated to study the effect of silicate slag on the availability of phosphorus applied as water soluble phosphate to soils from Carimagua and Popayán. Figure 20 shows the effect of applying Tennessee Valley Authority (TVA) calcium silicate slag and high furnace slag from Paz del Rio (Colombia) on dry matter yields of guinea grass when 400 kg P_2O_5/ha were applied as monocalcium phosphate. For Carimagua soil, yields increased with the first increment of the two silicate slags used (one ton SiO_2/ha). With Popayán soil, the yield increase was not significant for any of the levels of silicate applied. Both silicates increased soil pH and decreased percentage aluminum saturation of the soil. Phosphorus extracted by Bray I and II increased with increasing rates of TVA silicate and slightly decreased with the high furnace slag application. In general, the plants were low in phosphorus but apparently not in calcium when silicates were applied. Increased yields were associated with improved plant phosphorus and calcium nutrition. Calcium silicate treatments did not decrease the phosphorus fixing capacity of the soils (20% for Carimagua and 45% for Popayán). When silicate slags are utilized, application 15 days prior to planting appears to allow sufficient reaction time (Fig. 21).

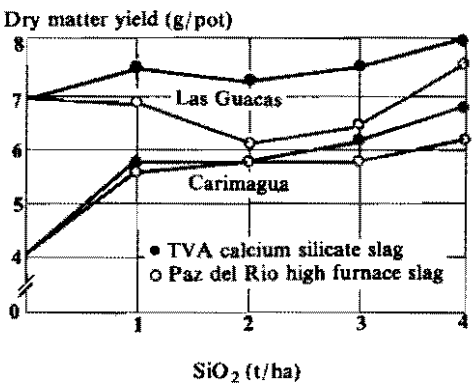


Figure 20. **Effect of application of Tennesse Valley Authority (TVA) calcium silicate slag and Paz del Rio high furnace slag on dry matter yield of Guinea grass (*Panicum maximum*) (average of three cuts).**

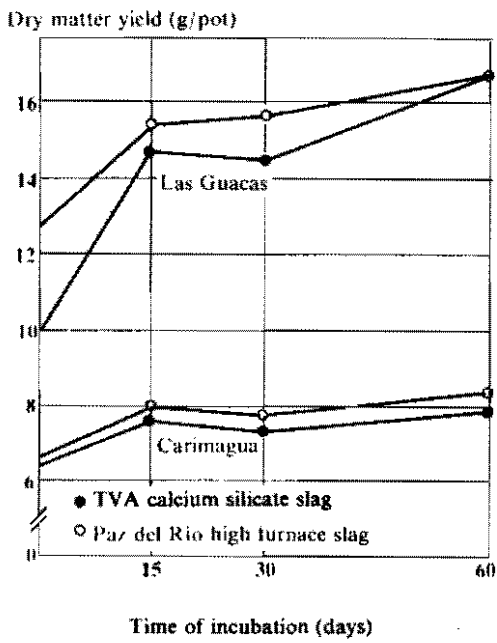


Figure 21. **Effect of time of incubation of Tennessee Valley Authority (TVA) calcium silicate slag and Paz del Rio high furnace slag before planting, on dry matter yields of Guinea grass (*Panicum maximum*) (average of three cuts).**

PASTURE UTILIZATION

Carimagua

Research has continued in Carimagua to determine the effects of burning as a management practice on the productivity of the savannah. The experiment was designed to compare burning the savannah at one time at the beginning of the dry season with sequential burning through both dry and wet seasons. The experiment was modified this year to allow the animals access to the sequentially/burned pastures, 15 days after burning rather than one month afterward. Table 10 presents the results of liveweight changes obtained for the year November 1975-November 1976. Animal growth was higher this year in all treatments, and the gains observed during the dry season are particularly interesting. It appears that the savannah is improving with time although improved gains during the dry season can also be associated with a milder dry season in 1976.

The introduced grasses, *M. minutiflora*, *H. rufa* and *B. decumbens* and the native *P. plicatulum* were grazed for the second year. The results obtained this year are presented in Tables 11 and 12. *Brachiaria* appears in a separate table since one additional set of pastures was added during the year, and also because the management of this grass was different during the dry season; the three grasses in Table 11 are rested during the dry season and *Brachiaria* (Table 12) is grazed. Previous years' results indicate that animals at all stocking rates lose weight, in some cases severely, during the dry season. However, results with *Brachiaria* last year indicate that animals gained some weight, which was confirmed this year.

The productivity of *M. minutiflora*, *H. rufa* and *P. plicatulum* was disappointing. Weight gains per animal per year are very similar to those obtained on savannah burned at the end of the rainy season, and the gains per hectare are no more than doubled. *Brachiaria*, however, provides good dry season grazing. Weight gains during the rainy season are not high, but the high stocking rate obtained during the rainy season makes it a useful choice, provided its productivity can be sustained over time, without high fertilizer inputs.

Table 10. Seasonal and yearly weight changes of steers grazing the tropical savannah in Carimagua, November 1975-November 1976.

Management treatment	Weight changes					
	Dry season		Rainy season		Year	
	(g/day)	(kg/animal)	(g/day)	(kg/animal)	(g/day)	(kg/animal)
Burning the total area:						
0.20 steers/ha	337	38	251	53	282	91
0.35 "	228	26	273	57	257	83
0.50 "	116	13	188	40	164	53
Sequential burning:						
0.20 steers/ha	306	35	385	81	359	116
0.35 "	79	9	357	75	260	84
0.50 "	-107	-12	296	62	155	50

Table 11. **Weight gains of steers grazing three tropical grasses during the rainy season in Carimagua, May to November 1976.**[1]

Treatment	Gain per animal		Gain per hectare
	(g/day)	(kg/176 days)	(kg/ha/176 days)
Melinis minutiflora			
0.7 steers/ha	325	57	41
1.0 "	269	47	49
1.4 "	148	26	35
Hyparrhenia rufa[2]			
0.7 steers/ha	194	34	29
1.0 "	166	29	32
1.4 "	139	24	39
Paspalum plicatulum[3]			
0.7 steers/ha	369	65	47
1.0 "	248	44	45
1.4 "	293	52	70

1 Pasture was rested during the dry season
2 Stocking rates were 0.9, 1.3 and 1.7 from the beginning of grazing in November 1975 until August 1976 when they were decreased
3 An attack of "false army worm" occurred this year (as in 1975), but it was not necessary to remove the animals from their paddocks

The management trial with *M. minutiflora*, comparing year-round grazing with and without nitrogen supplementation (urea+molasses), and grazing during the rainy season only, was continued for one more year. This year's results are presented in Table 13. For the second consecutive year nitrogen supplementation positively affected the total annual gain per animal, and the compensatory gain in unsupplemented animals was very small. If good results of supplementation are sustained, then it may be economical to use *M. minutiflora* during the dry season.

Table 12. **Weight gains of steers grazing *Brachiaria decumbens* in Carimagua.**

Stocking rate in dry/rainy season	Dry season		Rainy season		Weight gain per ha per year (kg)
	(g/day)	(kg/animal)	(g/day)	(kg/animal)	
Second year of grazing:[1]					
0.9/0.9 steers/ha	254	44	322	57	95
1.3/1.3 "	258	45	289	51	130
1.7/1.7 "	199	34	182	32	118
First year of grazing:[2]					
0.9/1.6 steers/ha	123	21	391	69	137
1.3/2.3 "	145	25	336	59	179
1.7/3.0 "	44	8	326	57	198

1 Pasture planted in 1974
2 Pasture planted in 1975

Table 13. Weight changes of steers grazing *Melinis minutiflora* under three systems of management at Carimagua, December 1975-November 1976.

Treatment	Dry season		Rainy season		Year
	(g/day)	(kg/animal)	(g/day)	(kg/animal)	(kg/animal)
Grazing all year:					
0.44 steers/ha	-225	-26	535	112	86
0.88 "	-182	-21	458	96	75
Grazing all year + urea + molasses during the dry season:					
0.44 steers/ha	298	34	492	102	137
0.88 "	208	24	289	61	84
Grazing during the rainy season only:					
0.44 steers/ha	-	-	599	104	-
0.88 "	-	-	292	51	-
1.3 "	-	-	268	46	-

Nevertheless, resting the pasture during the dry season is the most attractive way of utilizing this species, if the farmer has a good native pasture for the animals during the dry season.

Twelve paddocks of 25 hectares each were prepared in a new trial this year to study new alternatives for the management of tropical savannahs during the dry season and their effects on animal production. This area will be used over the next few years for a series of experiments which will include nitrogen and mineral supplementation during the dry season and supplementary grazing with tropical legume-grass mixtures.

Beginning in 1976 for a two-year period, the use of nitrogen (urea + cassava meal) at different levels will be tested and the interaction of nitrogen supplementation and minerals in different seasons of the year will be determined. As part of the first-year trial the interaction between urea + cassava supplementation during the dry season and mineral supplementation (phosphorus and calcium) administered throughout the year, only during the rainy season or not al all, was investigated. Figure 22 presents the results of this trial. Treatment or interaction effects were not significant because of high variability within the treatments caused by uneven consumption of the supplement. Cassava meal was chosen as the carrier for urea rather than cane molasses because of its better availability in most of the savannah areas. Although differences were not significant there was a clear tendency for animals with year-round mineral supplementation to gain more weight, while nitrogen supplementation had an additive effect on those animals which received minerals.

Weight gains of animals grazing savannah burned either at the end of or the beginning of the rainy season were compared. Animals grazing on savannah

becomes unlimiting should have come at 40-45 kilograms of forage. In tropical forages, in contrast to temperate species, plant selection by animals is very active, even in low-growing pasture species like Pangola. The maximum point of forage availability for maximum consumption, after selection, is therefore high and is important to know for planning of pasture management.

PRODUCTION SYSTEMS

Herd Systems I Experiment At Carimagua (ICA-CIAT)

The herd systems project is a relatively large experiment designed to study the effects of certain management factors on production and reproduction during the life cycle of beef cattle in the Eastern Plains of Colombia. This zone is similar in many respects to other large areas in the interior of South America where beef cattle production is the major enterprise.

Treatment variables between herds include pasture systems, mineral supplementation, and protein (urea) supplementation during the dry season. Within herd treatments include early (84 days) versus normal weaning, and alternate use of Zebu and San Martinero bulls in each herd.

Pasture treatments

The pasture treatments are: native pasture throughout the year, native pasture during the dry season and molasses grass *(M. minutiflora)* in the rainy season, and molasses grass throughout the year.

For 1976 there were no significant differences (P≤05) in calving percent and no abortions were recorded among the three different pasture systems (Table 14); however, cows grazing native pasture plus molasses grass in the dry season tended to have higher calving rates than cows on molasses grass the entire year (81.4, 82.3

Table 14. **Reproductive performance of cows during the third calving year (June 1975-June 1976) in Herd System I.**

		1976					1974-76	
Treatment[1]	Herd	No. of cows	No. of births	No. of abortions	Calving (%)	Abortions (%)	Total births	Total abortions
Control (native pasture)	1	28	14	10	50.0	35.7	33	22
Native pasture	2	33	10	3	30.3	9.1	39	6
and salt	3	32	18	4	56.2	12.5	47	5
Native pasture	4	32	23	0	71.9	0.0	65	0
and minerals	5	33	28	0	84.8	0.0	67	0
Native pasture, minerals	6	35	26	0	74.3	0.0	72	2
+ molasses grass	7	35	31	0	88.6	0.0	72	0
Molasses grass	8	35	28	0	80.0	0.0	69	0
and minerals	9	33	28	0	84.8	0.0	67	2

1 In addition to the pasture treatments, all herds receive salt; herds 4-9 also receive complete minerals; and herds 2,4,7 and 9 receive a protein supplement during the dry season of 0.5 kg molasses, 80 g urea and 4 g sulfur/head/day

and 78.4%) respectively. The same trend prevails when the three-year results are averaged; however, two abortions each were recorded in the native plus molasses grass and in the molasses grass pasture groups in previous years (Table 15).

The calving interval was significantly ($P<.01$) less for cows on native plus molasses grass (15.7 months) than for cows on molasses grass alone (17.7 months) or native grass (16.6 months). This was probably due to a better supply of forage throughout the year which allowed the cows to recover more quickly from the stress of lactation.

The reproductive performance of cows permanently on molasses grass varies with the length of the dry season as the quality and quantity of this grass are greatly reduced during this period (Table 16). In 1976, two cows were lost apparently due to a lack of forage during the dry season. However, the major effect of that severe dry season will probably manifest itself in 1977 reproductive performance.

Mineral supplementation

One of the treatments that consistently gives positive results is feeding a complete mineral mix free choice. In 1976, 82.1 percent more births were recorded in the herds receiving minerals (51 births) than in those herds receiving only salt (28 births). Six abortions were observed in herds receiving salt as compared to no abortions in cows receiving minerals (Table 14). Calving rate for cows receiving minerals was almost double that of cows not receiving minerals. While abortions account in part for the low calving percentage, there is still a 26 percent reduction in calving rate caused by the lack of minerals, perhaps due to a type of anestrous or undetected early abortions.

The three-year average reproductive performance of herds with and without minerals parallel 1976 results. Calving rates were 71.9 versus 47.7 percent; abortions 0 versus 10. percent; average births per cow 2.13 versus 1.43; and the calving interval was 1.4 months less in cows receiving minerals. This is partially explained because they did not abort — a factor which lengthens the calving interval. The fact that cows receiving minerals had more conceptions per cow (2.13) than cows receiving salt alone (1.58) indicates that mineral supplementation is important in fertility as well as in maintaining pregnancy in cows on mineral deficient soils.

Urea-molasses supplementation

A molasses-urea-sulfur (500-80-4 g/head/day) mixture is fed daily in the dry season to herds 2, 4, 7 and 9. The supplementation period is determined by the dry season which varies somewhat in duration and severity. As in previous years, in 1976 there was no increase in reproductive performance due to supplementation (69.2 versus 74.1% calf crop with and without supplementation, respectively). The three-year averages (Table 15) show a slight disadvantage for cows receiving supplementation, a phenomenon which should be investigated further since it persists year after year and is contrary to the expected effect.

Early weaning

At the beginning of the experiment, five cows from each herd (2-9) were selected to have their calves weaned early at 84 days of age. Calves from all other cows in each herd are weaned normally at eight months.

The reproductive performance of the early weaned group (14 % of all cows in the trial) is significantly better than the other

Table 15. **Calving interval, conceptions, abortions and births in Herd System I, May 1973-June 1976.**

Treatment	Herd	No. of cows	Calving interval[1] (mo)	Total conceptions	Average conceptions per cow	Total abortions	Average abortions per cow	Total births	Average births per cow	Calf crop (%)
Minerals										
Salt	2,3	65	18.0	103	1.58	11**	17**	93	1.43	47.7
Salt + minerals	4,5	65	16.6	132	2.13	0	0	132**	2.13	71.9
Pasture										
Native grass	4,5	65	16.6	132	2.03	0	0	132	2.13	71.0
Native grass + molasses grass	6,7	70	15.7**	146	2.08	2	.03	144	2.06	68.6
Molasses grass	8,9	68	17.7	138	2.03	2	.03	136	2.00	66.7
Supplementation										
None	3,5,6,8	135	16.6	268	1.98	6	.04	262	1.94	64.7
Urea + molasses	2,4,7,9	133	16.8	251	1.88	8	.06	243	1.83	60.9
Weaning										
Normal	2-9	225	17.4	403	1.79	13	.06	390	1.73	57.8
Early	2-9	40	13.7**	103	2.56**	2	.05	101	2.52**	84.2

[1] Calculated from cows having calved two or more times, one calving of which occurred after June 1975.

Table 16. **Percent calf crop by years for 1974-1976 in Herd Systems I.**

Treatment	Herd	Calving rate (%)			3-year average[1]	
		1974	1975	1976	Calving rate (%)	Calving interval (mo)
Control	1	51.8	18.5	50.0	39.3	18.4
Native pasture	2	33.3	54.5	30.3	39.4	20.2
and salt	3	18.7	74.2	56.2	49.0	17.2
Native pasture	4	59.4	71.9	71.9	67.7	16.0
and minerals	5	60.6	57.6	84.8	67.7	17.2
Native pasture and	6	54.3	77.1	74.3	68.6	15.5
minerals + molasses grass	7	51.4	65.7	88.6	68.6	16.2
Molasses grass	8	65.7	51.4	80.0	65.7	17.6
and minerals	9	78.8	39.4	84.8	67.7	18.2

1 Calculated from cows having calved two or more times, one calving of which occurred after June 1975.

cows (Table 15) Over three years, early weaned cows had a 27.3 percent shorter calving interval (13.7 months); 43 percent more conceptions per cow (2.56); and 45.7 percent more births per cow (2.52) than normal weaned cows.

There are no early weaned cows which have not had at least one calf while 10.9 percent of those cows without minerals and 3.4 percent of those on molasses grass (with minerals) but weaned normally have never calved. Number of calves produced by early- and normally-weaned cows are shown in Table 17. The results indicate that a combination of early weaning plus mineral supplementation on native pasture would consistently give a 70 percent calf crop.

Table 17. **Percentage of cows producing none, one, two or three calves during three calving years (1973-1976) in Herd Systems I.**

Treatment	Herd	No. of calves							
		0		1		2		3	
		Weaning treatment							
		Normal	Early	Normal	Early	Normal	Early	Normal	Early
Minerals									
Salt	2,3	10.9	0	60.0	30.0	29.1	30.0	0	40.0
Salt + minerals	4,5	0	0	19.2	0	73.1	30.0	7.7	70.0
Pasture									
Native	4,5	0	0	19.2	0	73.1	30.0	7.7	70.0
Native + molasses	6,7	0	0	13.3	0	78.3	30.0	8.4	70.0
Molasses	8,9	3.4	0	8.6	0	82.8	40.0	5.2	60.0
Weaning	2-9	3.6	0	24.9	7.5	66.2	32.5	5.3	60.0

Converting the average births per cow (normal weaned, 1.73 and early weaned, 2.52) over a three-year period to calving percentage demonstrates that 26 calves/100 cows can be gained each year (58 versus 84% calf crop) with early weaning. This practice, in effect, partially solves the problem of nutritional stress on the cow during her most critical period (lactation).

Mineral analyses

In a special collaborative project with the University of Florida and the U.S. Agency for International Development (AID), a PhD candidate carried out detailed analyses in 1976 to determine the mineral compositions of the pastures and selected blood parameters for cows in the Herd Systems Project.

Pastures. The results of the pasture analyses are summarized in Tables 18 and 19. Nitrogen content of native grass increased with decreasing rainfall while that of molasses grass dropped significantly ($P<.01$) in the dry season. There were no significant differences in the values of *in vitro* organic matter digestibility between periods, however molasses grass showed a slight but significantly ($P<.01$) higher value than native grass. Phosphorus content of native grass was lower ($P<.01$) than that of molasses grass in the rainy season. In the dry season both grasses had similar phosphorus contents, due to an increase in the phosphorus content of the native grass and a decrease of phosphorus in molasses grass. In both grasses, calcium and magnesium decreased in the dry season. Molasses grass had a higher calcium content ($P<.01$) than native grass in the rainy season. Potassium and sodium values increased in the dry season in both grasses. Copper and cobalt values were higher in the dry season than in the wet ($P<.01$). Molasses grass had a higher copper content than native grass ($P<.01$). The values of iron, manganese, zinc and molybdenum did not differ between periods. Iron and manganese contents of native grass were higher than those of molasses grass, while zinc was higher in molasses grass ($P<.01$).

The concentration of most of the nutrients in native grass increased during the dry season, probably due to the effect of rotational burning during those periods which permitted regrowth of higher quality grass.

Blood parameters. The levels of serum inorganic phosphorus are shown in Table 20 and Figure 26. Complete mineral supplementation increased serum phosphorus levels at all bleeding times ($P<.01$), and the effect was more prominent in the rainy season. In both treatments, serum phosphorus level was lowest in the early rainy season when the cows were gaining weight rapidly and highest in the dry season when cows were losing weight. Cows receiving the urea-molasses-sulphur supplement during the dry season had reduced serum phosphorus levels in herds on salt only (6.76—4.54 mg%) but increased serum phosphorus level in herds on complete minerals (5.81-6.48 mg%) The physiological status of the animals also influenced serum phosphorus. The average value for lactating cows was 4.46 mg% compared to 5.05 mg% for dry cows ($P<.01$). Complete mineral supplementation did not affect serum calcium levels, but calcium level was influenced by season. As indicated in Table 21, serum calcium was higher in the beginning of the rainy season than in the other seasons ($P<.01$). Complete supplementation increased serum magnesium ($P<.01$) in the dry season (Table 22), even though the complete mineral supplement did not include

Table 18. *In vitro* organic matter digestibility (IVOMD) and average nitrogen, phosphorus, calcium, magnesium, potassium and sodium content of native and molasses grasses.[1]

Grass	Period[2]	No. of obs.	Variable (%)						
			IVOMD	Nitrogen	Phosphorus	Calcium	Magnesium	Potassium	Sodium
Native	Early rainy season	20	44.33a[3]	1.31b	.10a	.15b	.19c	.85a	.009a
	Late rainy season	16	43.60a	1.42bc	.11a	.12a	.14b	.78a	.009a
	Dry season	24	45.52a	1.52c	.15b	.12a	.14b	1.01b	.016b
Molasses	Early rainy season	12	47.78b	1.43c	.21c	.23d	.20c	1.10c	.006a
	Late rainy season	16	48.94b	1.50c	.24c	.20c	.18c	1.17c	.007a
	Dry season	8	49.34b	1.21a	.17b	.13a	.13a	1.19d	.011b

1 Values for all nutrients expressed on a dry matter basis
2 Early rainy season, May-August; late rainy season, September-December; dry season, January-April
3 Means in the same column bearing different letters are different ($P \leq .01$)

Table 19. Average microelement content of native and molasses grasses.[1]

Grass	Period[2]	No. of obs.	Element (ppm) Iron	Manganese	Zinc	Copper	Cobalt	Molybdenum
Native	Early rainy season	20	555b[3]	161b	15.7b	1.5a	.07a	.44a
	Late rainy season	16	618b	156b	9.4a	1.5a	.09a	.50a
	Dry season	24	540b	227c	14.2b	2.0b	.13b	.68a
Molasses	Early rainy season	12	326a	92a	18.5c	2.6c	.06a	.50a
	Late rainy season	16	308a	106a	18.6c	2.4c	.06a	.51a
	Dry season	8	646a	78a	17.9c	3.0d	.15b	.43a

1 Values for all nutrients expressed on a dry matter basis
2 Early rainy season, May-August; late rainy season, September-December; dry season, January-April
3 Means in the same column bearing different letters are different ($P<.01$).

magnesium. Urea-molasses-sulphur supplements also increased serum magnesium levels ($P<.01$). Serum copper (Table 23) was increased by complete minerals ($P<.01$) in the rainy season but not in the dry season, when the value was lower than that of the rainy season. Serum zinc level (Table 24) was affected by season and physiological status of the cows. Dry cows had higher serum zinc (109.9 µg%) than lactating cows (101.9 µg%) ($P<.01$).

Comparison between cows on different pastures. Pasture treatments were native (herds 4 and 5), combinations of native and molasses grass (herds 6 and 7) and molasses grass (herds 8 and 9). For herds 6 and 7 grazing native pasture during the dry season and molasses grass during the rainy season, serum mineral values were generally similar to those of the herds on the corresponding pastures. Cows grazing molasses grass pastures showed higher

Table 20. Serum inorganic phosphorus levels of cows on native pastures supplemented with salt or complete minerals.

Treatment[1]	Herd	Sampling date Apr. 1975	Jun. 1975	Oct. 1975	Dec. 1975	Mar. 1976
		mg %				
Salt	2	5.21 (33)[2]	2.98 (33)	3.45 (32)	4.59 (33)	4.54 (33)
	3	3.03 (33)	3.57 (32)	5.02 (32)	3.26 (29)	6.76 (32)
Complete minerals	4	5.13 (32)	4.96 (32)	5.98 (31)	5.17 (31)	6.48 (31)
	5	4.77 (32)	4.00 (33)	5.83 (33)	6.32 (32)	5.81 (32)
Means herds 2 and 3		4.12ay (66)[3]	3.27ax (65)	4.24ay (64)	3.97ay (62)	5.63az (65)
Means herds 4 and 5		4.95by (64)	4.44bx (65)	5.91bz (62)	5.75bz (63)	6.14bz (63)

1 Herds 2 and 4 received urea-molasses-sulfur supplement during dry season
2 Numbers in parenthesis are number of observations from which the mean was calculated
3 Means bearing different x, y, z letters on the same line and different a, b, c letters in the same column are different ($P<.01$)

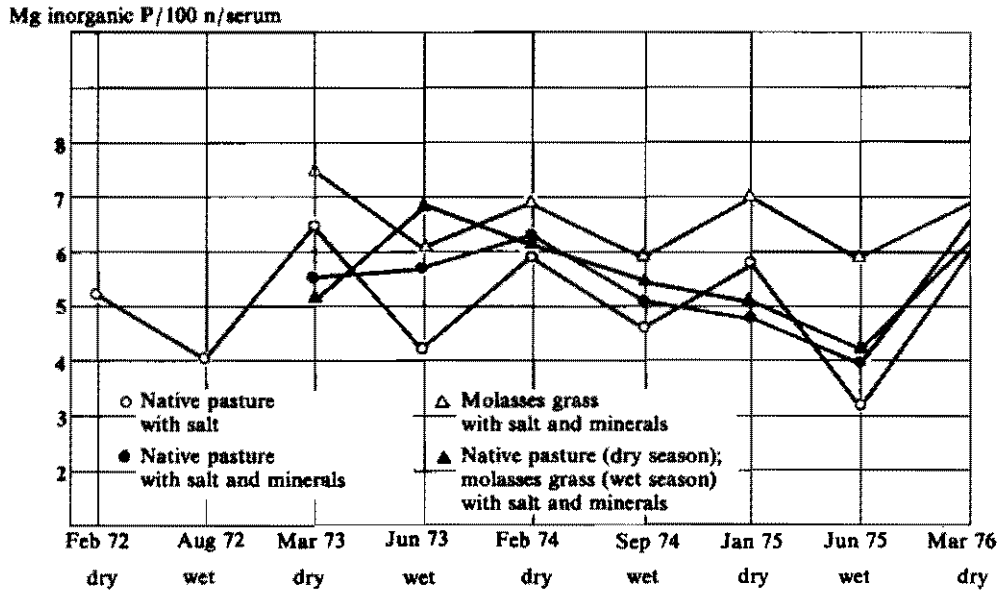


Figure 26. **Mean serum inorganic phosphorus levels of grade zebu females from before first mating to six years of age in the Llanos of Colombia.**

serum phosphorus levels than those on the native pasture, except in the October sampling (Table 25). High serum phosphorus levels in June indicated that molasses grass could maintain serum phosphorus during the period of rapid gain for the animals in the early rainy season. Urea-molasses-sulphur supplementation increased serum phosphorus levels in cows on native grass but decreased this level in cows on molasses grass ($P<.01$). The effect of physiological status appeared again in this comparison. As in the first comparison, serum calcium levels were lower ($P<.01$) in the dry season (Table 26). Cows grazing molasses grass tended to have higher serum calcium ($P<.05$) but lower serum magnesium levels ($P<.01$) Table 27.

Table 21. **Serum calcium levels of cows on native pastures supplemented with salt or complete minerals.**[1]

Treatment	Herd	Sampling date		
		Apr. 1975	Oct. 1975	Mar. 1976
		mg %		
Salt	2	9.80 (33)	10.01 (32)	9.95 (33)
	3	10.67 (33)	9.39 (32)	9.01 (32)
Complete minerals	4	10.32 (32)	9.43 (32)	9.11 (31)
	5	9.58 (30)	9.35 (32)	9.56 (32)
Means of all herds		10.12y (128)	9.55x (128)	9.41x (128)

1 See footnotes to Table 20.

Table 22. Serum magnesium levels of cows on native pastures supplemented with salt or complete minerals.[1]

Treatment	Herd	Sampling date		
		Apr. 1975	Oct. 1975	Mar. 1976
		mg %		
Salt	2	2.38 (33)	2.17 (32)	2.37 (33)
	3	2.42 (33)	2.25 (32)	2.61 (33)
Complete minerals	4	2.31 (32)	2.26 (32)	2.71 (31)
	5	2.32 (30)	2.07 (32)	2.73 (32)
Means herds 2 and 3		2.40ay (66)	2.21ax (64)	2.49ay (65)
Means herds 4 and 5		2.31ay (62)	2.17ax (64)	2.72by (63)

1 See footnotes to Table 20.

also indicates that urea-molasses-sulphur supplementation decreased serum magnesium levels of cows on molasses grass pasture ($P<.05$). In the rainy season, the cows which grazed the native pasture year-round had higher serum copper levels than the other herds even though the serum copper value was higher in the rainy season than in the dry season in all pasture groups (Table 28). Serum zinc levels of the cows grazing on native pasture were higher in the dry season ($P<.01$) as in the previous comparison (Table 29). Molasses grass pasture did not show any effect on serum zinc. Dry cows had 110.5 µg% serum zinc, which was higher than that of lactating cows (103.6 µg%) ($P<.01$).

Toward the end of the year, a more detailed analysis of the blood constituents was started by employing the metabolic profile test which will assist in the interpreting the production performance data by relating of metabolic status of the cow to her performance. More details of this work are given in the Animal Health section of this report.

Table 23. Serum copper levels of cows on native pasture supplemented with salt or complete minerals.[1]

Treatment	Herd	Sampling date	
		Oct. 1975	Mar. 1976
		µg %	
Salt	2	80.3 (31)	68.1 (33)
	3	84.4 (32)	61.1 (32)
Complete minerals	4	86.7 (32)	58.8 (31)
	5	113.0 (32)	59.6 (32)
Means herds 2 and 3		82.4ay (63)	64.7ax (65)
Means herds 4 and 5		99.8by (64)	59.2ax (63)

1 See footnotes to Table 20.

Table 24. Serum zinc levels of cows on native pasture supplemented with salt or complete minerals.[1]

Treatment	Herd	Sampling date	
		Oct. 1975	Mar. 1976
		µg %	
Salt	2	100.9 (30)	112.1 (33)
	3	98.4 (31)	113.2 (32)
Complete minerals	4	102.7 (32)	124.8 (31)
	5	95.1 (32)	107.2 (32)
Means of all herds		99.2x (125)	114.2y (128)

1 See footnotes to Table 20.

Table 25. **Inorganic phosphorus levels of cows on native and molasses grass or molasses grass pastures.**

Pasture[1]	Herd	Sampling date			
		Apr. 1975	Jun. 1975	Oct. 1975	Mar. 1976
		mg %			
Native	4	5.13 (32)[2]	4.96 (32)	5.98 (31)	6.48 (31)
		4.77 (32)	4.00 (33)	5.83 (31)	5.81 (32)
Native +	6	5.18 (35)	4.72 (33)	5.37 (34)	5.66 (35)
Molasses	7	4.93 (34)	4.37 (35)	4.98 (35)	6.15 (35)
Molasses	8	5.44 (35)	6.20 (33)	5.47 (33)	7.66 (35)
	9	5.67 (33)	5.60 (32)	5.29 (33)	5.94 (32)
Means herds 4 and 5		4.95ay (64)[3]	4.44ax (65)	5.91bz (62)	6.14az (63)
Means herds 6 and 7		5.06axy(69)	4.54ax (68)	5.17ay (69)	5.91az (70)
Means herds 8 and 9		5.55bx (68)	5.90by (65)	5.38ax (66)	6.84bz (67)

1 Herds 6 and 7 in Oct. 1975 bleeding period were on molasses grass pastures, and in the other periods were on native pastures. Herds 4, 7 and 9 received urea-molasses-sulfur supplement during dry season
2 Numbers in parenthesis are number of observations from which the mean was calculated
3 Means bearing different x,y,z letters on the same line and different a,b,c, letters in the same column are different ($P \leq .01$)

Early weaning project at CIAT

In an early weaning trial initiated on three private ranches in the Eastern Plains of Colombia in 1975 an average increase of 600 percent in the pregnancy rate of cows (four months post-weaning) was recorded when their calves were weaned 90 days postpartum, compared to cows still nursing thir calves. The early weaned calves were brought to CIAT in March 1975, where they were assigned to one of four rearing regimes (Table 30) for 55 days (Period 1). After Period 1, all calves were pastured together on Pará grass (*Brachiaria mutica*) (Period 2) until they were 18 months of age (Table 30 and Fig. 27). As reported last year (CIAT Annual

Table 26. **Serum calcium levels of cows on native and molasses grass or molasses grass pastures.**[1]

Pasture	Herd	Sampling date		
		Apr. 1975	Oct. 1975	Mar. 1976
		mg %		
Native	4	10.38 (32)	9.43 (32)	9.11 (31)
	5	9.38 (30)	9.35 (32)	9.56 (32)
Native +	6	10.33 (35)	10.42 (34)	9.50 (35)
Molasses	7	9.88 (33)	9.82 (35)	9.73 (35)
Molasses	8	10.50 (35)	10.01 (34)	9.19 (32)
	9	9.97 (33)	9.80 (32)	9.62 (32)
Means of all herds		10.12c (198)	9.81b (199)	9.46a (197)

1 See footnotes of Table 25.

Table 27. Serum magnesium levels of cows on native and molasses grass, or molasses grass pastures.[1]

Pasture	Herd	Sampling date		
		Apr. 1975	Oct. 1975	Mar. 1976
		mg %		
Native	4	2.31 (32)	2.26 (32)	2.71 (31)
	5	2.32 (30)	2.07 (32)	2.73 (32)
Native + Molasses	6	2.32 (35)	1.98 (34)	2.29 (35)
	7	2.21 (33)	2.10 (35)	2.52 (35)
Molasses	8	1.94 (35)	2.16 (34)	2.26 (32)
	9	2.13 (33)	1.76 (32)	2.10 (32)
Means herds 4 and 5		2.31by (62)	2.17bx (64)	2.72cz (63)
Means herds 6 and 7		2.28by (68)	2.04ax (69)	2.41bz (70)
Means herds 8 and 9		2.03bx (68)	1.97ax (66)	2.18az (64)

1 See footnotes of Table 25.

Report, 1975), calves receiving concentrate gained faster ($P<.01$) than calves without concentrate, during Period 1 of the experiment.

In Period 2 of the experiment, all groups previously without concentrates increased in average daily gain (ADG). Although ADG was similar in all groups in Period 2, the greatest improvement over Period 1 was noted in the groups previously on *Stylosanthes guyanensis* and Pará which gained 134 and 90.5 percent faster, respectively, in Period 2 than they did in Period 1. It must be noted that *Stylosanthes* was finely chopped before feeding which prohibited any selective eating and partially explains the poor performance of the calves on that diet.

Table 28. Serum copper levels of cows on native, native and molasses grass or molasses grass pastures.[1]

Pasture	Herd	Sampling date			
		Oct. 1975		Mar. 1976	
		µg %			
Native	4	86.7	(32)	58.8	(31)
	5	113.0	(32)	59.6	(32)
Native + Molasses	6	87.7	(34)	62.7	(34)
	7	83.8	(34)	63.8	(35)
Molasses	8	86.6	(34)	75.7	(32)
	9	87.7	(31)	66.9	(32)
Means herds 4 and 5		99.8by	(64)	59.2ax	(63)
Means herds 6 and 7		95.8ay	(68)	63.2ax	(69)
Means herds 8 and 9		87.1ay	(65)	66.3ax	(64)

1 See footnotes of Table 25.

Table 29. Serum zinc levels of cows on native, native and molasses grass or molasses grass pastures.[1]

Pasture	Herd	Sampling date			
		Oct. 1975		Mar. 1976	
		µg %			
Native	4	102.7	(32)	124.8	(31)
	5	95.1	(32)	107.2	(32)
Native + Molasses	6	108.6	(34)	105.7	(34)
	7	100.7	(32)	104.2	(35)
Molasses	8	124.8	(25)	112.9	(32)
	9	99.5	(31)	103.1	(32)
Means herds 4 and 5		98.0a	(64)	115.8b	(63)
Means herds 6 and 7		104.8a	(66)	105.0a	(69)
Means herds 8 and 9		110.8a	(56)	108.0a	(64)

1 See footnote of Table 25.

Table 30. **The effect of type of forage and concentrate on growth performance of early weaned calves from four to 18 months of age.**

Forage	Liveweight gain (kg)					
	Concentrate					
	None		750 g/head/day (period)[1]		Avg.	
	Wt. gain	Avg. daily gain	Wt. gain	Avg. daily gain	Wt. gain	Avg. daily gain
Grass (Pasture)						
Cynodon nlemfuensis (Star)						
Period 1[1]	21.7	.394ab[3]	27.6	.502c	24.6	.448a
Period 2[2]	147.7	.339	152.0	.411	149.8	.405
					174.4	.410
Brachiaria mutica (Para)						
Period 1	11.7	.200a	16.7	.304	13.8	.252
Period 2	141.0	.381	126.3	.341	133.6	.361
					147.4	.347
Legume (Hand-fed)						
Desmodium distortum						
Period 1	19.0	.345ab	27.7	.504c	23.4	.424a
Period 2	143.0	.386	142.3	.384	142.6	.386
					166.0	.390
Stylosanthes guyanensis						
Period 1	8.7	.158	17.0	.309	12.8	.233
Period 2	137.0	.370	147.0	.397	142.0	.384
					154.8	.364
Average, Period 1	15.1	.274	22.2	.404		
Period 2	142.0	.384	141.8	.383		

[1] Period 1 = 55 days (4th to 6th of month of calf's life)
[2] Period 2 = 370 days (6th to 18th month of calf's life; all calves in Para pasture)
[3] Figures in columns with same letters are not significantly different (P=<.01).

The groups receiving concentrates in Period 1 gained an average of 47.4 percent faster than those without concentrates (274 versus 404 g/day, for no concentrate and with concentrate, respectively). The two fastest gaining groups on concentrate (calves grazing *Cynodon nlemfuensis* and *Desmodium distortum)* gained at a slower rate when they were put on Pará pasture while the two slower growing groups on concentrates gained faster during Period 2 when no concentrate was offered.

It is apparent from the weight gain data

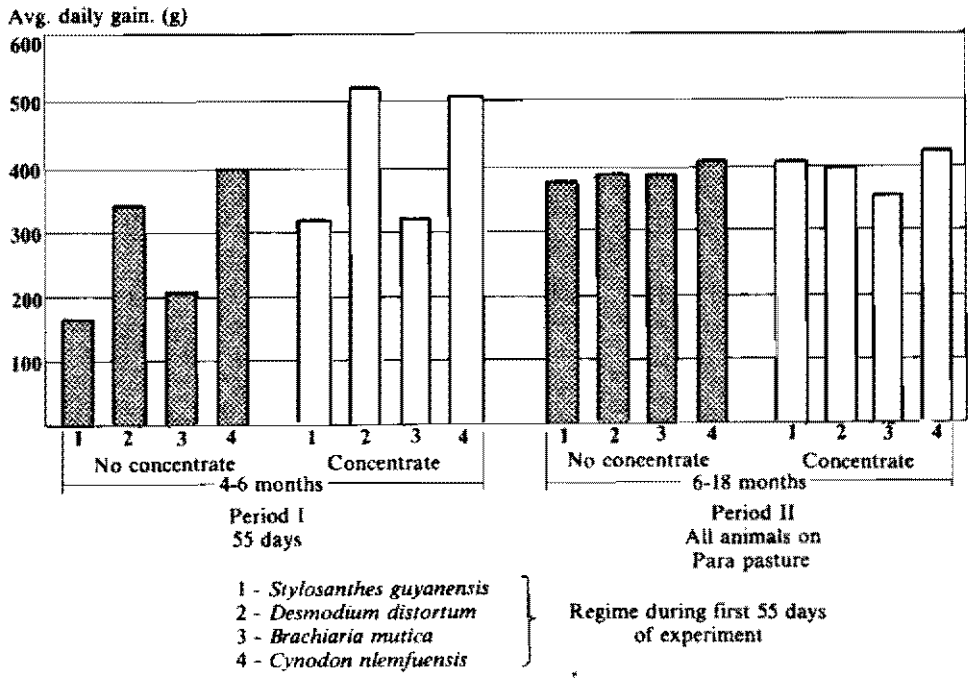


Figure 27. **Effect of type of forage (with and without concentrate) on performance of early weaned calves from four to 18 months of age.**

(Table 31) that the star grass in this experiment provided the best forage. Animals initially on Star grass gained 8.6 percent better than the average for the experiment while animals initially on Pará gained 8.9 percent less than the average. Since there was a 92.2 percent difference between the highest and lowest gains in Period 1 and only a 12.1 percent difference in gains in Period 2, it appears that the feeding regime during the first two months influenced the difference in final weight

Table 31. **Effect of pasture regime during the first two months post-weaning on animal performance to age 18 months.**[1]

	Pasture for first 55 days				
No. of animals	*Cynodon nlemfuensis* 6	*Desmodium distortum* 6	*Stylosanthes guyanensis* 6	*Brachiaria mutica* 6	Average
Initial weight (kg) (4 months)	59.6	66.2	67.5	61.6	63.7
Weaning weight (kg) (9 months)	146.7	151.7	120.7	128.0	136.8
Final weight (kg) (18 months)	234.0	232.2	222.3	209.0	224.4
Wieght gained (kg) (4-18 months)	174.4	166.0	154.8	147.4	160.6
Percent weight change from average for experiment (%)	+8.6	+3.4	-3.7	-8.9	

[1] All groups were pastured on Para grass from 6-18 months.

more so than that during the Period 2.

Since, at the end of the experiment, the weight difference among groups caused by the Period 1 feeding regime still exist, growth retardation due to the feeding regime during the first months of the calf's life was not apparently offset by compensatory growth on Pará pasture by 18 months of age.

It was not possible to compare the final (18-month) weight of these animals with their normally weaned counterparts in the private ranches from which they came; however, their 18-month weights are as good as those of 18-month-old animals in the Herd Systems Project at Carimagua. Future early weaning projects are necessary to establish a pasture and animal management regime that can be adapted to a cow-calf program in areas where early weaning is needed to improve reproduction by relieving the lactation stress from the cow.

Evaluation of Intensively Grown Forages

Cassava tops left after the root harvest are occasionally fed to ruminants in certain parts of the tropics; however, little attention has been given to cassava as a forage crop. Results of an earlier trial (CIAT Annual Report, 1973) showed that large quantities of dry matter (DM) (20 t/ha/yr) and protein (4 t/ha/yr) can be produced when cassava is planted especially to produce forage.

Analysis of the aerial part of the plant (Table 32) shows that the leaves are especially high in protein (28%) and that the entire plant contains approximately 20 percent protein when harvested at 90-day intervals. The fact that the high quality leaves make up more than half of the plant enhances its potential as a forage crop.

Table 32. **Proximate percentage analysis of cassava forage harvested at 90 days, CIAT, 1976**

	Plant part (%)		
	Leaf	Petiole	Stalk
Percent of total plant	52	15	33
Dry matter content	29	18	15
Nitrogen	4.38	1.65	1.76
Protein (N x 6.25)	28.0	11.3	11.0
Ether extract	15.3	14.3	13.0
Crude fiber	9.0	21.9	25.2
Ash	8.1	8.5	7.8

To evaluate the general performance of cassava forage in ruminant diets, 24 grade Zebu steers were randomly assigned to one of the three treatments described in Table 33. All forages were cut and chopped fresh daily and fed *ad libitum* allowing for approximately 10 percent refusal. Sugar cane (whole plant) was harvested in a rotation pattern so that the cane was always about one year old. All animals were fed individually so that each treatment had eight replicates.

The cassava stakes were planted in beds (1.2 meters wide) with a .3 meter spacing within and between rows giving approximately 100,000 plants/ha. The forage was cut 20 centimeters above the ground every 90 days. Seven cuttings were made during an 18-month period before regrowth was substantially reduced. *Desmodium distortum* was sown in rows 60 centimeters apart and harvested every 60 days. Production was markedly reduced after the third cutting as flowering occurred earlier after each successive cutting.

Average daily gain, feed efficiency and dry matter consumption were not significantly affected by the different sources of protein (Table 33). Due to an unexpected low intake of cassava and *Desmodium*, the animals in group 1

Table 33. **Performance of 18-month-old steers fed three different sources of protein, plus freshly chopped sugar cane for 112 days.**[1]

Parameters	Treatments		
	Cane + 1.6 kg cottonseed meal	Cane + cassava forage	Cane + *Desmodium distortum*
No. animals	8	8	8
Initial weight (kg)	230	241	241
Final weight (kg)	303	311	306
Avg. daily gain (kg)	.657	621	.584
Avg. daily consumption cane (kg)	3.67	4.03	3.31[2]
Avg. total daily consumption (kg)	5.29	5.55	5.25
Feed efficiency	8.00	8.90	9.00
Kg protein/kg gain	1.13	.74	.74
Percentage protein of supplement	46.0	22.1	16.8
Percentage protein in diet consumed	14.0[3]	8.0	8.2

[1] All feed data is on a dry matter basis

[2] Signficantly ($P \leq .05$) less than treatment 2

[3] Significantly ($P \leq .01$) greater than 2 or 3.

consumed significantly ($P < .01$) more protein/head/day. Since animal performance between groups was not different, it appears that an excessive amount of protein which was inefficiently utilized by Group 1. Groups 2 and 3 received approximately the same amount of protein; however, group 2 ate significantly more sugar cane which was reflected in slightly better gains. Because of the lower consumption of protein per unit gain the same two groups were 52.7 percent more efficient in converting protein into liveweight gain.

Cane production

Approximately 0.28 hectare of mature cane (13,250 kilograms DM) was harvested during the trial, providing most of the energy for 1,664 kilograms of liveweight gain. On an annual basis, cane production would be 47,321 kg DM/ha, providing sufficient energy for 5,423 kilograms of liveweight gain. Thus, one hectare of well managed sugar cane in the Cauca Valley, providing 70 percent of the DM requirements, would be sufficient to feed approximately 30 growing-fattening steers under local conditions.

The trial indicates that fresh cassava forage can be successfully fed to ruminants and could be competitive nutritionally with other sources of plant protein. No signs of HCN toxicity or other adverse affects were noted from feeding the freshly cut cassava.

Future investigation in this area should be directed to defining cassava forage quality and efficient utilization in various stages of the beef production system.

ANIMAL HEALTH

Introduction

The animal health group consists of two units, animal pathology and animal microbiology whose goal is the development of economic preventive medicine programs in beef cattle, emphasizing the complex interaction of disease and nutrition. Accordingly, studies continued on the epidemiology of trypanosomiasis, leptospirosis and the economics of animal disease.

Complementary to this, work was initiated on metabolic profiles of Zebu cattle to provide insight into the condition known as wasting disease or "secadera" complex.

Trypanosomiasis (Trypanosoma vivax, T. evansi)

Work carried out by thesis students gave significant results and the investigations were extended for another year involving collaboration with the Instituto Colombiano Agropecuario (ICA), the International Center for Medicine (ICM), the University of Antioquia and the London School of Hygiene and Tropical Medicine.

T. vivax is an important tsetse-transmitted pathogen in Africa. It has also been reported at various times in this century from all the Latin American countries with an Atlantic coast line between Panama and the Amazon mouth in Brazil. There are also reports from the two West Indian islands of Guadalupe and Martinique. However, the number of observations in the literature are fragmentary and the lack of a serological means of diagnosis has delayed work in several basic areas. These are: confirmation that the trypanosome is identical with the tsetse-transmitted *T. vivax* of Africa; definition of the true geographical distribution of the infection in the Americas; definition of prevalence and incidence within the geographic distribution; identification of the means of transmission in the Americas in the absence of tsetse; investigation into the possibility of a sylvatic cycle of transmission; and, lastly, the estimation of the economic significance of the infection.

A trainee in the pathology unit set up an indirect fluorescent antibody test (IFAT) for the parasite in CIAT in 1973. Another student made further modifications during 1976 applying the test to the situation in the Cauca Valley of Colombia where clinical episodes associated with trypanosomes were known to occur. It was concluded that the entire valley was endemic for the infection, a situation previously unsuspected. The means of transmission was not identified but characteristics of the vector were established. Clinical episodes of disease were demonstrated as having important economic impact on individual farmers. There were similarities to riverine tsetse situations in Africa. However, there is diagnostic confusion in the field between trypanosomiasis, anaplasmosis and babesiosis.

These results were the basis for an expanded investigation. A lysate was prepared from a Colombian isolate and sent to the London School of Hygiene and Tropical Medicine for analysis of enzyme patterns and comparisons with isolates from Africa. Present serological results from 197 farms in eight Colombian regions (departamentos) indicate the probability of the trypanosome being endemic in all tropical areas of Colombia where there is a

cattle industry. Serum samples have also been obtained from Brazil, Ecuador, El Salvador and Paraguay and others have been promised from Costa Rica, Panamá and Perú. These will be used to investigate the possiblity of a greater geographical distribution than previously realized. However, interpretation of these results requires confirmation of the specificity of IFAT in the field. There is no cross fluorescence occurring among anaplasmosis, babesiosis or *T. evansi*, but *T. theileri* and toxoplasmosis require final elimination as potential causes of error. Under Colombian conditions the test appears to reliably diagnose *T. vivax* on a herd basis.

The International Center for Medicine in Cali is collaborating in the search for a vector and a check list is being prepared of all arthropods biting cattle on farms where transmission is occurring.

Although *T. evansi* is not an important pathogen for cattle in South America, disease epidemics in horses can seriously hinder the management of range cattle. It is commonly believed that the epidemiology of the infection involves only domestic animals. Evidence collected in 1975 indicated that the capybara (*Hydrochoerus hydrochoeris)* is a wild animal reservoir for the trypanosome in the Colombian Llanos. In 1976, a research trainee using a cloning technique and a slide agglutination test demonstrated that isolations made from dogs, horses and capybara in the same location were antigenically similar.

Leptospirosis

Previous work (CIAT Annual Report, 1975) showed that 63.5 percent of the animals in the Colombian Llanos had a serological reaction to various *Leptospira* types. *L. hardjo* and *L. sejroe* were the more prevalent types, with *L. hardjo* giving the greatest number of intensive reactions (1:400 or more).

To extend these studies, a herd was selected on one of the farms that had been observed closely because of elevated abortion rates and a high prevalence of leptospirosis. The herd consists of 100 breeding cows and seven bulls grazing 400 hectares of native savannah with salt and bonemeal supplementation. The farm is located 65 kilometers from Puerto López on the road to Puerto Gaitán in the Departamento of Meta.

The basic objective of this study was to obtain a thorough understanding of the pathogenesis, epidemiology and effect on productivity of these major *Leptospira* types while at the same time developing a practical, preventive medicine approach.

The initial test for leptospirosis resulted in 70.5 percent reactors for one or more serotypes. Sera were examined for 15 different serotypes known to occur in cattle, and *L. hardjo* and *L. sejroe* were the most prevalent, with *L. hardjo* giving the highest titers. Two additional serum samplings were collected and examined using the microscopic agglutination test (MAT) with standard strains obtained from the Panamerican Zoonosis Center, Buenos Aires. Table 34 shows the animals in this herd with titers to *L. hardjo* compared with the number of abortions detected for each animal. *L. hardjo* antibodies are being used as indicators to monitor the pathogenesis of infection since this serotype is being reported as the most pathogenic for cattle in similar areas of the world.

Six animals with high serological titers (1:800 for *L. hardjo)* were necropsied. They all had gross kidney lesions characterized

Table 34. **Cows from the Colombian Llanos trial herd that had recorded abortions during a ten-month interval, and their *Leptospira* titer.**

Cow No.	No. of abortions	*L. hardjo* titer	Cow No.	No. of abortions	*L. hardjo* titer
1	1	200	16	1	400
2	1	800	17	1	200
3	2	100	18	1	0[1]
4	1	50	19	2	200
5	2	50	20	1	200
6	2	50	21	1	1,600
7	1	0[1]	22	1	200
8	1	50	23	1	1,600
9	2	1,600	24	1	0[1]
10	2	100	25	1	100
11	2	100	26	2	400
12	1	400	27	1	800
13	1	100	28	1	100
14	1	100	29	1	0[1]
15	1	50	30	1	800

[1] Four cows with no antibodies detected.

by necrotic areas in the cortex and atrophic kidney lobules. Microscopically, these lesions reflected a chronic interstitial nephritis compatible with leptospirosis. A *Leptospira* strain was isolated from these cows and the bacteria isolated is being classified and typed.

Kidney function tests could provide insight as to the evolution of the disease. Four clinical-pathology tests have been used. Eight cows from the trial herd that had high *Leptospira* titers were tested for urine specific gravity and pH, and for creatinine in the blood serum. The results were compared with those from cows with low titers. The averages shown in Table 35 indicate a lower specific gravity in infected cows. The kidney, in this case, cannot concentrate the urine sufficiently and as a

Table 35. **Comparison of blood serum and urine parameters in cows with different *Leptospira* titers from Colombian Llanos trial herd.**

	No. of cows	Average of *L. hardjo* titers	Urine[1]		Blood[2]
			Specific gravity	pH	Creatinine
High titer animals	8	800	1.008	6.28	2.36
Low titer animals	8	50	1.019	6.42	2.00

[1] Average of 3 samples (consecutive days).

[2] Average of 2 samples 10 weeks apart.

consequence specific gravity is lowered. Creatinine is also used to measure kidney function. It is elevated when kidney function is impaired. Serum creatinine seems to be a reliable diagnostic test because it is not affected by dietary protein catabolism or exercise. The group with high *Leptospira* titers had slightly elevated serum creatinine values.

Even though the herd is actively infected with *Leptospira* (21 animals have titers to *L. hardjo* of 1:400 or higher) not all animals with significant titers had detected abortions in the last 10 months (Table 34) Moreover, abortions have been reported from cows that do not have detectable antibodies for *Leptospira*. This could mean that animals infected with *Leptospira* do not always abort and that abortions due to other unknown causes are also occurring in the herd. The interaction between nutrition and disease under such circumstances is worth exploring and metabolic profiles (discussed later in this section) may be useful for this purpose.

Knowledge of the *Leptospira* transmission pattern will be helpful in formulating a preventive medicine approach for control. Wild rodents are common reservoirs for *Leptospira*. Eighty wild rodents were captured in the forest to which the 100-cow trial herd has access and four *Leptospira* isolations were made by culturing kidney tissue. There were three isolations from *Proechymis* sp. (spiny rat), all classified as *L. australis** and one isolation from *Caluromys philander* (Philander opossum) classified as *L. tarassovi*. Cattle on this farm have significant serological reactions to *L. hardjo* and *L. sejroe*. Therefore, if wild animals are not disseminators or carriers of the same *Leptospira* that affect cattle under the lowland savannah conditions the bacteria is probably being perpetuated by carrier cattle. This opens up the possibility of controlling the spread of infection by treating carrier animals. Moreover, if leptospirosis is the main cause of abortions, productivity could be increased by reducing the disease infection rate. Two preventive medicine measures are being tested in this herd for immediate application. Animals in the herd have been assigned to three groups: one group of 35 cows for antibiotic treatment; a second group of 35 vaccinated with specific vaccine types; and the remaining untreated 30 cows as controls.

The first group is being treated with Streptomycin to reduce the excretion of *Leptospira* through the urine of carrier animals. Two doses are being applied 12 weeks apart with the second dose scheduled for the end of this year.

The second group of animals is being treated with a commercial bacterin that contains *L. pomona, L. hardjo* and *L. grippotyphosa*. There are no commercial vaccines that include the *Leptospira* prevalent in the tropical savannahs.

The isolation of a *Leptospira* from affected cattle points to the possibility of producing experimental infections and carrying out a more detailed study of the pathogenesis, pathogenecity and evolution of the disease under controlled conditions.

Economics of Controlling Foot and Mouth Disease

Studies on the economic impact of foot and mouth disease in beef cattle continued. A collaborative project with ICA, was started, to obtain reliable field data that can be used to measure the impact of foot and mouth disease and the returns on

* These classifications were confirmed by the Panamerican Zoonosis Center, Buenos Aires.

investment in its control. The methodology developed in collaboration with the CIAT Economics group will utilize the data collected to guide national institutions in planning future control strategies. Data are being collected from an area in the Urabá regions of Colombia and a survey has been designed for the Córdoba region as well (see the Economics Section of this report).

Studies on Metabolic Profiles and "Secadera" Complex

In the lowland tropical savannahs of Latin America, efforts are being made to increase beef production at minimum cost. However, some of the improved technology and new management practices add to existing stresses of production, and may introduce hidden factors that endanger the metabolic health of the animals, thus exacerbating the general debilitating effect of noxious agents not often significantly important with adequate nutrition. It is hoped that the study of metabolic profiles will be a valuable tool for monitoring the health of the animals on a herd basis as well as predicting and diagnosing the nature of existing problems.

Metabolic profiles monitor the adequacy of dietary intake for production and are based on the assessment of blood clinical parameters. The method depends on the fact that imbalances between feed input and production output are reflected in abnormal concentrations of key metabolites in the blood, leading to negative balance and disease. The Metabolic Profile Test (MPT)* uses blood clinical parameters in a special combined analytical system, basing the identification of pathological abnormalities on statistical deviations from the population mean.

The Herd Systems Project experiment at the Carimagua Station has provided a satisfactory site for testing the method with beef cattle. In this context, the MPT is being used on Zebu breeding cows to identify the development of critical pathological situations arising from various management practices and production inputs.

Due to the original experimental design, the effects of mineral ssupplementation and pasture type on the profiles can not be measured simultaneously. In order to overcome this, and for the purpose of statistical analysis, the herds have been divided into two major groups. Group I comprises herds (2, 3, 4, 5) on native grass against which the effect of mineral supplementation is being measured. Group II comprises herds (4, 5, 6, 7, 8, 9) with mineral supplementation against which the effect of pasture type is being measured. Effects of lactation status are being considered between and within groups.

Herd 1 is under conventional management and serves as a negative control. The performance of cattle under natural conditions was taken in the original design of the Herd Systems Project as a base line against which to measure the effect of improved management practices in the other herds.

The effect of reproductive status of cows on blood parameters, weight and weight gains, is being analyzed. Four reproductive conditions of breeding cows are included in the test model: (a) lactating-pregnant; (b) dry-pregnant; (c) lactating-open; and, (d) dry-open. Further details of the experimental design of metabolic profiles on the Herd Systems Project are given in the Biometrics section of the Annual Report.

* Payne and others, Compton (1970)

As an example of the analytical mechanism of the test, Table 36 gives comparative mean values for metabolic profiles, weight and weight gains, for different pastures and mineral treatments. Samplings were in June and August 1976.

Several blood parameters were influenced by pasture type in both months. Significant differences were found for packed cell volume (PCV), glucose, urea, phosphorus, albumin and hemoglobin levels.

In June, PCV, glucose and urea mean values were significantly higher in herds grazing native + molasses grass (6, 7) than in those grazing native grass alone (4,5) ($P<0.01$), and molasses grass alone (8,9) ($P<0.01$). In contrast, blood phosphorus mean values were higher in June in animals grazing molasses grass, than in those grazing native + molasses grass ($P<0.01$), and native grass alone ($P<0.01$). Albumin levels in the same month were higher in animals on native grass and native + molasses grass, than in those grazing molasses grass alone ($P<0.01$). This parameter followed essentially the same trend as urea, with which it is closely related since both reflect protein intake.

In August, which was a drier month in the Llanos mean blood values for urea and albumin were significantly higher ($P<0.01$) in herds on native grass (4,5) than in herds on molasses grass (8,9). PCV and hemoglobin values in the same month were higher ($P<0.01$ and $P<0.05$, respectively) in cattle on native + molasses grass (6,7), than in those on native grass alone. Glucose mean values, perhaps following the same trend as urea and albumin, were higher for those animals grazing native and native + molasses grass, than for those grazing molasses grass alone ($P<0.01$). Phosphorus mean values in August continued to be higher ($P<0.01$) in those animals grazing molasses grass (8,9) than in those on native grass.

The effect of mineral supplementation on the metabolic profiles of herds grazing native savannah is also shown in Table 36. In June, mean values for PCV, glucose, urea, calcium and hemoglobin were higher ($P<0.01$) for herds 2 and 3 with no supplement, than for herds 4 and 5 receiving mineral supplementation. However, mean values for phosphorus were higher ($P<0.05$) for herds 4 and 5 with supplement, than for herds 2 and 3 without supplementation.

In August, mean values for urea, potassium and hemoglobin were higher ($P<0.01$) in herds 2 and 3 with no minerals than in herds 4 and 5 with mineral supplement. Mean values for phosphorus, as in June, continued to be higher ($P<0.01$) in herds 4 and 5 with minerals. Magnesium and globulins also showed higher mean values ($P<0.01$) in herds 4 and 5, than in 2 and 3. The interpretation of these early results should be done cautiously since many more estimates are needed. It is especially important that year-round data be available to reflect seasonal changes in forage quality and quantity.

As reported last year, the condition known as "secadera" appears to be an important problem occurring in the lowland tropical savannahs of Colombia, and possibly, in similar beef producing areas in other Latin American countries. Of 37 ranches surveyed last year in the Llanos, 13 (35%) reported the condition. A common opinion among veterinarians working in the Llanos is that nutritional stress in animals which are carriers of anaplasmosis causes a recrudescing clinical infection. Other infectious and parasitic diseases such as leptospirosis,

Table 36. Comparative mean values of metabolic profiles, weight and weight gains under different variables independent of herd distribution. Herd Systems I (June and August of 1976).

					Blood parameters											
Treatment	Herd	Month	No. of cows	PCV[1] (%)	Glucose (mg/100 ml)	Urea (mg/100 ml)	P (mg/100 ml)	Ca (mg/100 ml)	Mg (mg/100 ml)	Na (meq Liter)	K (meq/liter)	Total protein (g/100 ml)	Albumin (g/100 ml)	Globulin (g/100 ml)	Hemoglobin (g/100 ml)	Weight (kg)	Weight gains (kg)
Control	1	June	26	37.42	67.18	29.12	3.26	10.62	2.48	137.01	5.73	7.99	2.64	5.35	14.17	324.08	10.92
		August	26	43.15	76.73	28.58	2.92	10.78	2.26	140.13	5.63	8.45	2.48	5.97	14.58	311.65	-12.42
Minerals (Group I)																	
Salt	2,3	June	63	34.16	95.11	36.53	3.93	10.34	2.14	150.63	6.34	7.40	2.66	4.74	14.53	322.03	19.75
		August	63	42.35	77.37	28.33	2.08	10.57	2.16	137.66	5.61	8.14	2.60	5.55	15.59	331.62	9.58
Salt + minerals	4,5	June	64	32.68	59.38	30.95	4.53	9.50	2.25	147.98	6.54	7.65	2.75	4.91	13.45	338.33	20.53
		August	64	41.41	81.18	19.84	4.51	10.91	2.41	141.07	5.21	8.39	2.52	5.86	14.11	334.39	-2.25
Pasture (Group II)																	
Native grass	4,5	June	64	32.68	59.38	30.95	4.53	9.50	2.25	147.98	6.54	7.65	2.75	4.91	13.45	338.33	20.53
		August	64	41.41	81.18	19.84	4.51	10.91	2.41	141.07	5.21	8.39	2.52	5.86	14.11	334.39	-2.25
Native grass + Molasses grass	6,7	June	68	34.59	67.00	34.46	4.68	9.48	1.98	148.36	5.99	7.80	2.67	5.12	13.43	337.44	31.38
		August	67	43.24	77.39	14.68	5.41	10.38	2.24	146.29	5.55	8.19	2.57	5.64	14.63	337.87	-0.25
Molasses grass	8,9	June	61	32.13	48.39	29.40	6.34	9.64	1.76	151.71	6.05	6.96	2.46	4.45	13.33	312.36	23.44
		August	61	42.95	68.03	12.63	5.55	11.15	2.38	141.06	5.42	8.00	2.41	5.58	14.47	308.15	-4.21
Supplement (Dry season)[2]																	
None	3,5,6,8	June	126	32.89	64.96	34.07	4.66	9.69	2.09	149.93	6.42	7.48	2.66	4.82	13.61	321.73	19.00
		August	126	42.03	73.24	17.73	4.16	10.53	2.35	136.91	5.39	8.01	2.50	5.50	14.42	312.76	-8.15
Urea + molasses	2,4,7,9	June	130	33.92	69.32	31.72	5.03	9.78	1.97	149.35	6.04	7.43	2.22	4.80	13.74	333.86	20.65
		August	129	42.29	78.18	19.95	4.62	10.95	2.24	146.13	5.49	8.34	2.54	5.80	14.96	333.78	-19.10
Weaning																	
Normal	2,3,4,5,6,7,8,9	June	219	33.36	67.29	33.12	4.86	9.72	2.03	150.25	6.27	7.43	2.63	4.79	13.67	326.55	24.41
		August	217	42.38	76.39	19.30	4.42	10.75	2.30	141.83	5.47	8.18	2.54	5.63	14.68	321.58	-2.50
Early	2,3,4,5,6,7,8,9	June	37	33.78	66.54	31.46	4.82	9.85	2.05	145.73	5.98	7.64	2.66	4.97	13.73	347.68	29.30
		August	38	43.18	74.42	16.35	4.38	10.73	2.28	140.34	5.33	8.23	2.43	5.80	14.83	332.82	-12.26

1. Packed cell volume or hematocrit

2. L.S.D. between mean values at .01 and .05 levels

3. From December 1975 through March 1976

trypanosomiasis and babesiosis have also been incriminated as contributing factors to the complex. Most cases of secadera occur in cows 3-11 years old, with an average age of 5.5 years. Affected animals walk with difficulty, suffer from ataxia and severe anemias and often end up starving to death.

Malnutrition is rampant in cattle in allic tropical savannahs of Colombia and other countries due to the low nutritional value of native grasses, especially in the dry season. Animals at a low plane of nutrition are constantly in a delicate metabolic balance. This balance is easily upset by changes in input and output. The stress of calving and lactation is so great in the Llanos, as repeatedly observed with the cows in the Herd Systems Project experiment, that without proper nutritional input before and after calving, the metabolism of the animals is thrown totally out of balance. Animals fall into a negative balance state that may eventually lead to the wasting disease.

The data already obtained by applying the MPT to the Herd Systems Project experiment supports the hypothesis that the condition is caused by malnutrition, often leading to inanition and death.

If wasting disease or secadera in the Llanos is due to the low plane of nutrition and lactational stress on cows as is now speculated, the calving rate of Zebu cows in the region is important for a better understanding of the disease complex. If annual calving rates in the Llanos range from 42 to 52 percent, it can then be assumed that at any given time several females of breeding age will be subjected neither to the stress of pregnancy nor to the stress of lactation. This must account for reports of secadera cases among groups of apparently healthy cows, all under the same management regime.

International Cooperation

A collaborative project was developed with the Empresa Brasilera de Pesquisas Agropecuarias (EMBRAPA) research station at Campo Grande, Mato Grosso, in Western Brazil. The objective was to establish the prevalence of five major diseases in the area directly influenced by the National Beef Cattle Center. The information obtained will be used as a basis for planning future research in animal health. A survey was designed and executed in cooperation with the EMBRAPA animal health group and the CIAT Biometrics and Animal Health units.

Six-hundred and twenty animals from 62 farms were sampled. This size sample estimates prevalence with a confidence level of 95 percent. The mean prevalence of hemoparasites was significantly lower than the figures reported for the Llanos of Colombia. In relation to reproductive diseases, the mean prevalence for leptospirosis (72.8%) is similar to that found in Colombian Llanos and merits further investigation of the importance of this disease to reproductive performance.

CIAT staff have studied the results of this survey with the beef team at Campo Grande, and suggestions been given for future research activities in animal health. Management practices have been suggested and further collaborative projects, including training, are being discussed.

SPECIAL PROJECT FOR RESEARCH ON ANAPLASMOSIS AND BABESIOSIS

From November 1975 to November 1976, the work program of the Texas A&M University Group at CIAT is financed by AID and oriented toward developing more efficient economic control of hemoparasitic diseases of cattle in the tropics. Research activities were focused on: (a) development of more practical diagnostic methodology; (b) epizootiology of hemoparasitic diseases; (c) evaluation of immunization systems for control of anaplasmosis and babesiosis, and (d) training.

Development of Diagnostic Methodology

A rapid latex agglutination test (RLA) for diagnosing *Babesia argentina* infection was developed. Although complement fixation (CF) and indirect fluorescent antibody (IFA) tests are routinely used as diagnostic tests for *Babesia* spp. infections in cattle, there is a need for a more rapid and reliable test for these infections.

The agglutination test, utilizing latex particles (0.82 microns in diameter), sensitized with *B. argentina* antigens, proved to be effective in the diagnosis of *B. argentina* in natural and artificial infections. Comparisons among visual reactions for the test are shown in Figure 28.

In experimental infections with *B. argentina* the first detectable positive agglutination reactions coincided with the appearance of parasitemia. Positive reactions were noted with known positive sera which had been stored for up to 18 months. Animals with natural infections of *B. argentina*, proven by blood smears and IFA and CF tests, also showed reactions to the latex agglutination test.

Antibodies to *Babesia* spp. were detected in dried blood samples using the IFA test. It was confirmed that blood dried on filter paper can be used as a source of antibody to *Babesia* spp. infection in cattle. There was good correlation between the antibody titer of duplicate serum and dried blood samples collected from animals infected with Babesia spp. The use of dried blood samples in the IFA test is more practical and economical than using serum samples in diagnosing bovine babesiosis

Figure 28. Agglutination pattern observed in the rapid latex agglutination test (RLA) to diagnose infection with *Babesia argentina*. (A) shows a positive reaction with serum of an animal infected with *B. argentina*; (B) is a negative reaction with serum from a non-infected animal.

under field conditions in the tropics.

The CF and IFA tests were used to determine the *Babesia* spp. antibody response in calves before and after ingestion of colostrum from cows immune to babesiosis in comparison with antibody response in calves artificially infected with *Babesia* spp. Both the CF and IFA tests were approximately equal in their ability to detect colostral antibodies. Serologic titers were positive for *B. bigemina* and *B. argentina* during the first week of life and persisted for as long as 20 weeks. The protection of calves from clinical babesiosis was believed to be due to protective antibodies in the colostrum from immune cows.

Epizootiology

During the year additional data were obtained on the prevalence of anaplasmosis and babesiosis among beef and dairy cattle herds in the Cauca Valley of Colombia. These data, combined with the results of previous epizootiological studies conducted in the North Coast region and in the Eastern Plains of Colombia, are presented in Table 37. The high prevalence of reactors indicates that anaplasmosis and babesiosis are endemic within the major cattle producing areas of the North Coast and Eastern Plains as well as within the Cauca Valley. The wide range of reactors among herds within these endemic areas indicates that a large population of noninfected and thus susceptible indigenous cattle is present and substantiates reports by ranch owners that anaplasmosis and to a lesser extent babesiosis are among the major cattle diseases in the areas.

Immunization against Anaplasmosis and Babesiosis

An immunization procedure using the minimum infective dose was evaluated last year using stabilates stored in a dry ice chest at -60°C. Since it was observed that organisms lost viability after eight months of storage, new stabilates were prepared and stored in liquid nitrogen at -196°C. Stabilates were titrated using different dilutions, doses and routes of infection in order to find the best practical method under field conditions.

Ten-fold, serial dilutions of *Anaplasma marginale* stabilate were tested for infectivity. All dilutions were infective when given intravenously (IV) and subcutaneously (SQ) except for dilution 10^{-3} when administered SQ. A direct correlation was found between amount of inocula and antibody response but clinical reactions were observed more frequently when

Table 37. Average percentage prevalence and range of *Anaplasma* and *Babesia* reactors in Colombia.

Region	Species		
	A. marginale	*B. bigemina*	*B. argentina*
Caribbean Coast	93 (63-100)	77 (56-90)	n.a.[1]
Eastern Plains	72 (18-91)	59 (38-92)	12 (0-43)
Cauca Valley (dairy)	62 (16-98)	60 (24-94)	44 (12-69)
Cauca Valley (beef)	63 (0-89)	23 (0-58)	26 (0-75)
Total	72 (0-100)	55 (0-90)	19 (0-75)

[1] Not available.

using lower dilutions. For practical purposes a dilution of 10^{-2} administered SQ was chosen for immunization of animals on commercial farms.

Babesia spp. stabilates were used undiluted and diluted ten-fold to 10^{-2}. The 10^{-2} dilution was found infective only for the *B. argentina* stabilate. Inoculations of stabilates administered SQ. did not give consistent results in both *Babesia* species. Dilutions of 10^{-1} administered IV provided a more uniform response without severe clinical reactions and it was chosen for immunization of animals on commercial farms. Hematological and serological responses of dilutions presently used in the field are presented in Table 38.

Attempts to Attenuate *Babesia argentina*

Because of severe *B. argentina* reactions suffered by some of the animals in the previous field experiments, attempts to attenuate the pathogenicity of the existing isolate were made following the method described by Callow and Mellors in Australia. Twelve splenectomized calves were used for this purpose. A group of ten calves was used to evaluate the vaccine in comparison with a non-attenuated vaccine. After field challange, all animals were found resistant to natural infection from *Boophilus microplus* ticks.

In the field, several groups of calves have been immunized with this passaged strain. None of the calves have required specific treatment. The information obtained so far indicates that a degree of alteration has occurred. More evaluation is required under laboratory and field conditions before this strain can be considered to be attenuated.

Field Immunization Program

Eight commercial dairy and beef farms located in the Cauca Valley are being used to evaluate, under field conditions, the applicability and economics of the immunization system against anaplasmosis and babesiosis using the minimum infective dose procedure. Up to now 285 calves have been included in the experiment, half were vaccinated and half used as controls. After vaccination, routine samplings of blood and weight measurements were made in each group to determine the response to vaccination under field

Table 38. **Mean results of hematological and serological response from titration of stabilates stored in liquid nitrogen.**

Organisms[1]	Dilution	Dose/ route[2]	Animals infected/ total used	Incubation parasitemia (days)	Maximum parasitemia (%)	Maximum CF titer	PCV decrease	No. of animals treated
Anaplasma marginale	10^{-2}	2cc/SQ	10/10	28	2.5	1/80	-9%	6/10
Babesia bigemina	10^{-1}	2cc/IV	10/10	7	0.9	1/40	-7%	2/10
Babesia argentina	10^{-4}	2cc/IV	6/6	15	0.01	1/20	-4%	1/6

[1] *A. marginale* stabilate contained 1.2 x 10^9 organisms per ml. *B. argentina* stabilate contained 4 x 10^8 organisms per ml.

B. bigemina stabilate contained 2 x 10^8 organisms per ml.

[2] SQ = subcutaneously; IV = intravenously.

challenge. Evaluation of the immunization program is still in progress on seven of the farms. Preliminary results from one farm are presented in Figures 29 and 30.

This farm is representative of the cattle farms located on the marginal areas of the Andean mountains and the Cauca Valley. Cows and unweaned calves are kept on tick-free pastures at elevations above 2,200 meters. When calves are weaned they are moved to the lower tick-infested valleys where farmers have reported serious losses among weaned calves due to anaplasmosis and babesiosis.

A group of 20 grade crossbred calves, 7-8 months of age were selected for immunization. The calves were weighed and divided into two groups, equal with respect to body weight. One group of 11 calves were immunized while the second group of nine calves left as controls. A nonsignificant difference in weight gains was observed between the immunized and control calves at the end of the 12-week post-immunization period (Fig. 29).

Following recovery from immunization, the remaining 19 calves were exposed to field challenge. Between the second and third post-challenge weeks, the control calves started to develop acute signs babesiosis. By the third week, the PCV's of the controls had decreased an average of 15 percent. All of the controls required specific treatment for babesiosis and one calf died in spite of treatment. The immunized calves developed low *Babesia* parasitemias and small decreases in PCV's but did not require treatment.

All of the immunized and control calves developed detectable *Anaplasma* parasitemias during the seventh post-challenge week. All of the control and

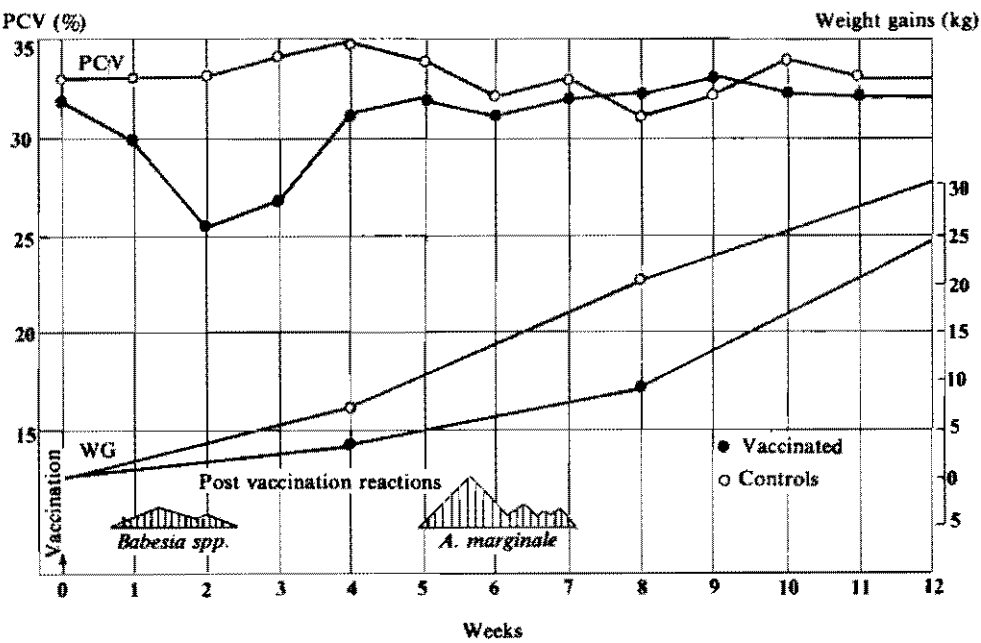


Figure 29. Effect of vaccinations against *A. marginale* and *Babesia spp.* and their relationships to anemia (PCV) and weight gains (WG) in 19 calves before field exposure - San Julián farm.

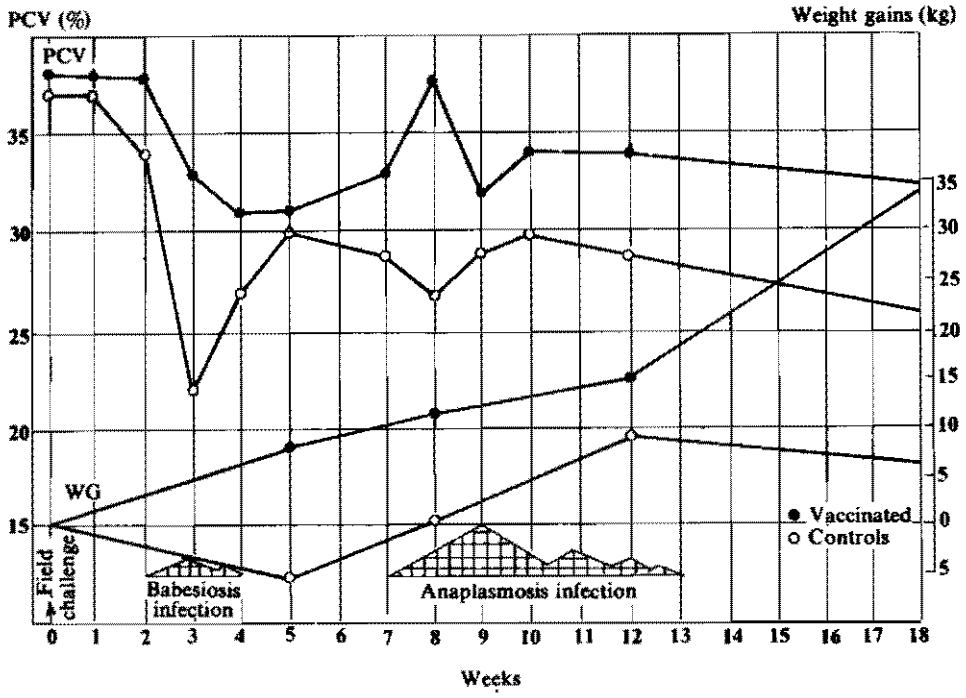


Figure 30. Effect of field challenge with *Boophilus microplus* ticks infected with *Babesia* spp. and *A. marginale* on anemia (PCV) and weight gains (WG) in 19 calves - San Julián farm.

some immunized calves required specific treatment for anaplasmosis.

At the end of the field challenge period (18 weeks) the inmmunized calves had gained an average of 27 kilograms more per head than had the control calves, a statistically significant difference (Figure 30).

Collaborative Project

A collaborative project between the University of Illinois and Texas A&M University, (USA), ICA and CIAT for the evaluation of immunization methods against bovine anaplasmosis, was organized during a meeting of the collaborating groups at CIAT in March 1976. The project began in July with the assembly of 130 experimental Normandy calves at ICA's Tibaitatá station near Bogotá (2,600 meters elevation, mean temperature 14°C). The calves are being periodically examined and various parameters monitored to establish base line information prior to beginning immunization procedures early in 1977. The immunization methods employed will be evaluated under field conditions in an anaplasmosis endemic area when the calves are moved to the ICA Turipaná station near Montería, (elevation 50 meters, mean temperature 27°C).

Training

During 1976, training of veterinarians primarily from Latin America continued. Special emphasis was given to recent advances in the serologic diagnosis and control of anaplasmosis and babesiosis. Nine professionals received training in

CIAT: two were North Americans working on advanced degrees from Texas A&M University while seven were Latin Americans receiving postdoctoral trainig in hemoparasitology as Postgraduate interns in CIAT. The Latin American professionals included representatives from Colombia, Perú, Brazil and the Dominican Republic. Requests for training in hemoparasitology were also received from the Governments of Bolivia, Brazil, Ecuador and Venezuela.

SPECIAL PROJECT IN ACAROLOGY

Activities of the Acarology Unit in CIAT are conducted as a special project in the Center. Funding for the unit is through the Ministry of Overseas Development in the United Kingdom.

Serious production losses from tick infestations have been recorded on all tropical continents. In the Americas, approximately 70% of the total cattle population is found in tick-infested areas (between the 32nd north and south latitudes with a few foci found as far as the 35th latitudes). Ticks are not only important vectors of disease but also reduce weight gains and otherwise affect host performance through direct parasitic effects. Ticks transmit every class of infectious agent known (protozoa, rickettsia, fungi, bacteria, spirochaetes and viruses) and infest amphibians, reptiles, birds and mammals.

In 1976, the research program has concentrated on studies of tick identification and distribution, disease transmission and ecology on and off the host. Information dissemination and training activities were integrated with research work. The unit assisted in identifying ticks taken from 45 species of birds which were collected as part of a non-CIAT-related survey on the Carimagua station. Of special concern is the fact that migratory birds found in Colombia may be introducing new tick species and/or diseases infecting man and/or animals.

Tick Identification and Distribution

The Unit's tick species checklist was expanded to include 32 host and 23 tick species. The major area of collection was the Eastern Plains of Colombia with minor collecting being done in the North Coast region, the Cauca Valley, and Tolima and Cundinamarca regions of Colombia. The tick collection is extensively used for taxonomic training.

Disease Transmission

The common belief that *Boophilus microplus* is the principal transmitter of *Anaplasma marginale* is not supported by experimental evidence. After a series of eight *B. microplus* tick transmission trials, the only successful modes of *A. marginale* transmission were found to be trans-stadial (transference of infection between developmental tick stages on one host) and intra-stadial (transference of infection to other hosts using developmental tick stages). Transovarial transmission (transference of infection through the tick egg to the next generation) never occurred during these trials. In the field, intra-stadial transmission between animals by *B. microplus* would seem possible only if management practice allowed the close apposition of animals. Such mechanical transmission would appear more likely with ticks requiring two or three hosts to complete their cycles than with *B. microplus* which need only one.

On- and Off-host Ecology

A doctoral candidate continued ecological studies of ticks economically important to the Colombian cattle industry. This work stresses three areas of tick control improvement: (a) the provision of localized ecological data for greater efficiency of traditional chemical acaricide application; (b) the greater current attention to mechanisms, assessment and utilization of naturally tick resistant cattle; and, (c) the continued need for revolutionary biological tick control techniques.

Natural seasonal incidence studies of *B. microplus* on *Bos taurus* and *B. indicus* cattle, untreated with acaricides, have covered 17 of the 20 months of the program (four dry and three wet seasons) in the Cauca Valley. The distinct seasonality of parasitic tick numbers was compared with the success and longevity of ticks reared in field vials from 1,000 meters (enzootic) to 2,500 meters (epizootic), and under control conditions. The non-parasitic ticks were limited geographically and seasonally by low temperature inhibition of egg development, and seasonally by egg and larval dessication. Tick load tolerance of cattle under various environmental conditions was concurrently observed by monitoring changes in hemoglobin and packed cell volume values of the field-infested cattle, and of experimental cattle on high and low nutrition planes with single and repeated artificial infestations. Hemo- and endoparasitic effects were largely eliminated by regular use of drugs. Although good nutrition increased cattle tick resistance and tolerance, it appears that relatively low tick loads still directly caused significantly decreased blood values.

Field, corral and barn studies established that certain cattle body regions were consistently highly populated by *B. microplus*. Ticks migrate to these regions irrespective of the point of larval application, and were associated with distinct skin-surface temperature regimes. Thus, micro-environmental stress may operate on ticks in conjunction with immunological host resistance. This work is currently focussing on possible differential tick mortality rates in various host body regions from microclimatic and tick feeding-density aspects.

Ticks may alternatively or additionally exhibit such highly contagious on-host distribution by differential attraction to the various body regions for successful engorgement. Preliminary studies on the validity of such "feeding-site predilection" concepts have begun for *B. microplus* and *Anocentor nitens* on cattle and horses, and will be emphasized in early 1977. Such behavior could exploit the already vulnerable pre-feeding tick phases on cattle and increase their natural parasitic mortality even more.

Reports from cattlemen in Colombia indicate that animals grazing molasses grass (*M. minutiflora*) carry fewer ticks than those on other improved or native pastures. In a preliminary trial in the dry season, 40,000 *B. microplus* larvae were placed at the base of molasses grass plants. All larvae had died after 34 days, while the control, a bermuda grass (*Cydodon dactylon)* had viable ticks for more than 70 days after infestation, when the trial ended. This trial is presently being repeated during the rainy season and a full-sacale field grazing trial is proposed to complement existing data and add the dimension of observations on the interaction between ticks, grass and grazing cattle. The ideal would be to observe the tick/cow/grass triangle through a minimum of two full seasons (two wet and two dry) to observe

changes in the tick population, cattle weight gain and durability of pasture. Likewise a variety of improved pastures with native species as controls would be advantageous.

Information Dissemination and Training

During 1976, staff of the CIAT acarology unit assisted in training five veterinarians, one PhD candidate and two special trainees. Assistance was also given in laboratory training courses. The unit's staff met with some 50 visitors. A tick study set of 78 color and black/white slides (with Spanish commentary) was prepared for training purposes. A literature review (CIAT Annual Report, 1975) was extended to include the geographic distribution, hosts and authors for 200 tick species of the neotropical faunal region.

ECONOMICS

In 1976 the Economics Unit of the Beef Production Program concentrated in three major areas: (a) economic evaluation of different alternatives in the control of foot and mouth disease; (b) productive behavior of the cattle industry in Colombia; and, (c) microeconomic evaluation of beef cattle production in the Colombian Llanos and of factors internal and external to the farm, conditioning the adoption of technologies.

Economic Evaluation of Alternative Control Strategies of Foot and Mouth Disease

An epidemiological model of foot and mouth disease for endemic situations was designed and reported in 1975 as part of the methodology developed in collaboration with the Animal Health and Biometrics Units of CIAT. The model simulates the annual incidence and prevalence of foot and mouth disease on a long-term basis by means of semi-Markov stochastic processes.

Objectives

On the basis of this epidemiological model, a methodology was developed in 1976 to evaluate different alternatives corresponding to: no disease control, different vaccination levels, and finally, eradication. In this way, the optimum economic level of control for a given region or country may be derived.

The model is also designed to evaluate the "externalities" present in the control of foot and mouth disease. The private optimum level of control is inferior to the social optimum level since each producer only considers those benefits internal to the farm, underestimating the total social benefit by ignoring spillover benefits to the other farms from reducing their probability of contagion. The latter constitutes what is known as externalities.

To verify the validity and applicability of the methodology the North Coast of Colombia was chosen for a case study not only because it is an important cattle raising area but also because it borders on the disease-free zone extending from Panama northward.

Methodology

In order to estimate economic losses from the disease, two microeconomic models were formulated in FORTRAN

(for computer use): one for breeding, and the other for fattening farms. In these models the development and production of the herd, and the cash flows of the farms were simulated. In both models, the point of departure is a stabilized herd whose production parameters reflect technology prevailing in the region. The economic losses considered were: morbidity, mortality, and the cost of additional resources required to manage sick animals. These losses were measured as the difference between the farm income flows over time with and without the disease. The benefit from each level of control is the reduction achieved in economic losses from disease. In turn, a comparison of costs and benefits associated with each level of control allows the identification of the optimal economic strategy.

Breeding model

The gross annual income of the stabilized herd without foot and mouth disease was determined on the basis of the number of predicted animals sold and of milk production. The net income was obtained by deducting variable costs. To derive the farm's gross income flow considering the probability of an outbreak of foot and mouth disease, the morbidity values (measured as incidence) and the increase in mortality rate, estimated by means of the epidemiological model, were used. These values depend as much upon vaccination levels on the farm as vaccination levels in the region. During a year of a foot and mouth disease outbreak, lower production parameters are used in relation to each sick animal. These are: lower milk production, lower birthrate, lower weight in calves and culled cows sold during the year, and greater management costs. Also, the model accounts for changes in size and composition of the herd during the year of the outbreak and in subseqent years. The control variable for returning to the pre-outbreak stabilized herd, is the number of calves on the farm for future cow replacement as these cannot be bought outside the ranch due to the risk of reintroducing the disease. Also, the number of calves available for replacement is limited by the existing birthrate[1].

Fattening model

On the fattening farms, net income is estimated monthly from information on age and weight of unfattened calves at purchase, an average weight gains curve according to age, average mortality rate, purchase and sale prices, and average expense per calf. The selling age and weight of the calves were determined by maximizing the discounted value of expected net income. In making sales and purchases calculations it was assumed that these transactions take place throughout the year[2]. In order to generate farm income flow with foot and mouth disease, morbidity and mortality data for the disease, and a weight gains curve for animals with the disease was used[3]. The model calculates the new optimum selling age of sick animals since it is not possible to replace them immediately with healthy animals due to the required quarantine. Hence, the demographic component of the simulation model projects subsequent herd development in which healthy animals are sold at one age and sick ones at another. The

1 This assumption is not needed at the farm level, but it is necessary at the aggregate level since purchase for replacement is not feasible.

2 This assumption at the farm level allows generalization of results at the regional level.

3 The production parameters with foot and mouth disease were taken from: Animal Health Project - "The Battle against Foot and Mouth Disease and Control of Brucellosis", Document No. 16, ICA, November, 1970.

income flow with foot and mouth disease is projected up to the month in which the last animal affected left the herd.

Results

Results are presented for a cattle population of 4.4 million head. This total approximately corresponds to the existing cattle population of the Departamento of Córdoba on the North Coast of Colombia.

Table 39 presents morbidity results and Table 40 shows the annual mortality from foot and mouth disease in a steady-state situation, for in-farm and regional vaccination levels varying from 0 to 100 percent. These results are based on the previously described epidemiological model. The results obtained at the ranch level were weighted by the proportion of total stock represented by each type of cattle farm in order to obtain regional estimates.

Table 41 presents the annual private and social costs and benefits for the region in a situation of long run equilibrium, for different vaccination levels. It is assumed that the annual unit cost of control is constant and independent of the vaccination scale. Annual social net benefits are maximized at 90 percent vaccination, which is thus the optimal vaccination strategy from society's point of view. The optimum vaccination strategy from the private point of view is only 60 percent; i.e., definitely inferior to that of society (Table 41, column 3). This difference, due to the existence of externalities, justifies governmental actions or campaign to control the disease.

In order to analyze the optimal strategies when unit cost of vaccination increases, net benefits were evaluated at costs 50 and 100 percent higher than the original values. In both cases, the optimum private strategy was reduced to 40 percent while the

Table 39. Annual morbidity from foot-and-mouth disease over the long run as a function of the vaccination level on the farm and in the region (Percentages)

Vaccination level on the farm (%)	Vaccination level in the region (%)										
	0	10	20	30	40	50	60	70	80	90	100
0	19.0	17.7	16.3	15.1	14.1	12.2	10.6	5.5	4.7	3.3	2.5
10	18.2	16.4	15.2	14.1	13.2	11.5	10.0	5.3	4.5	3.1	2.3
20	16.6	15.1	14.0	13.0	13.1	10.6	9.3	4.9	4.3	3.0	2.2
30	15.1	13.7	12.7	11.9	11.1	9.7	8.5	4.5	3.9	2.7	2.1
40	13.5	12.3	11.4	10.7	10.0	8.8	7.7	4.1	3.6	2.5	1.9
50	11.6	10.6	9.9	9.2	8.7	7.7	6.7	3.7	3.2	2.2	1.7
60	8.9	8.2	7.7	7.2	6.8	6.0	5.3	3.0	2.6	1.8	1.4
70	5.4	5.0	4.8	4.5	4.3	3.8	3.4	2.0	1.7	1.2	1.0
80	2.9	2.8	2.6	2.5	2.4	2.2	2.0	1.2	1.1	0.8	0.6
90	1.17	1.12	1.08	1.05	1.01	0.95	0.9	0.6	0.54	0.41	0.33
100	0.162	0.159	0.157	0.155	0.153	0.15	0.14	0.12	0.11	0.09	0.08

* Refers to annual average coverage, with 3 vaccination cycles.

Table 40. **Annual mortality rate from foot and mouth disease over the long run as a function of the vaccination level on the farm and in the region (x 1,000)**

Vaccination level on the farm (%)	Vaccination level in the region (%)										
	0	10	20	30	40	50	60	70	80	90	100
0	4.75	4.42	4.07	3.77	3.51	3.05	2.65	1.37	1.17	0.82	0.62
10	4.18	3.77	3.49	3.24	3.02	2.64	2.3	1.2	1.03	0.72	0.53
20	3.48	3.16	2.94	2.73	2.54	2.22	1.94	1.03	0.89	0.62	0.46
30	2.87	2.6	2.41	2.25	2.1	1.85	1.61	0 85	0.74	0.52	0.40
40	2.02	1.84	1.71	1.6	1.5	1.32	1.15	0.62	0.54	0.37	0.28
50	1.16	1.06	0.98	0.92	0.86	0.77	0.67	0.37	0.32	0.22	0.17
60	0.62	0.57	0.54	0.5	0.47	0.42	0.37	0.21	0.18	0.13	0.10
70	0.27	0.25	0.24	0.22	0.21	0.19	0.17	0.1	0.09	0.06	0.05
80	0	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0	0

optimum social strategy fell to 70 percent of vaccination coverage[4].

4 This would be the case, if for example, the costs per vaccinated animal in the anti-foot and mouth disease campaign in Urabá were charged to the private costs of caccination.

In the absence of reliable primary information, the simulation results were based on secondary data sources and on data from other countries adapted to conditions on the North Coast of Colombia. Therefore, results must be cautiously interpreted. Given that epidemiological

Table 41. **Annual private and social costs[1] and benefits corresponding to different vaccination levels on North Coast of Colombia[2] in millions of $Col. of 1975.**

Vaccination level	Annual costs (1)	Gross private benefits (2)	Net private benefits (3) (2)-(1)	Gross social benefits (4)	Net social benefits (5) (4)-(1)
0	-	(430.1)[3]	(430.1)	(430.1)	(430.1)
10	11.5	35.2	23.7	64.4	52.9
20	22.9	61.9	38.9	122.3	99.4
30	34.4	85.5	51.1	173.0	138.6
40	45.8	110.4	64.5	220.7	174.8
50	57.3	122.4	65.1	274.2	216.9
60	68.8	135.8	67.0	323.2	254.4
70	80.3	85.7	55.4	386.6	306.3
80	91.7	85.4	-6.3	404.1	312.4
90	103.2	65.8	-37.3	415.8	312.6
100	114.7	54.0	-60.6	421.5	306.8

1 It is assumed that there are no discrepancies between the social and private costs A cost of $Col 25/head/year was used
2 With a total cattle population of 4,410,372
3 The annual cost from foot-and-mouth disease in an endemic situation according to the adopted assumptions

parameters are location specific, in order to obtain valid estimates for the region, an agreement was signed with ICA to obtain primary information relevant to the Urabá and Córdoba regions on the North Coast of Colombia. This agreement involves the Animal Health, Biometrics and Economics units at CIAT, and the departments of Economics, Cattle Production, and Biometrics at ICA. The objective is to compare losses from the disease at two vaccination levels and to estimate cost and benefits on moving to higher levels. For this purpose, a survey of ranches without foot and mouth disease is being conducted in Urabá, where periodic measurements are taken. Parallel measurements are also taken on farms with outbreaks of foot and mouth disease. A sampling of farms in the Córdoba region was also designed to determine the frequency of outbreaks, the rates of attack and the lethatlity of the disease. This study will be completed during 1977.

At the same time, other strategies such as eradication through slaughter, and through a vaccination-slaughter sequence are being economically evaluated.

Productive Behavior of the Cattle Industry in Colombia

Continuing the study of the cattle industry in Colombia, the aggregate behavior of stocks and slaughter from 1940-75 was evaluated.

In Colombia, beef is the most important product in the family budget, representing between 10 and 12 percent of a worker's budget. From 1940 to 1975 its consumption per person varied according to slaughter cycles, tending to decline slightly. This is due to production increases which were counterbalanced by increases in population and in exports.

Available information is not sufficient for designing a policy to induce significant production increases. This would require the identification and quantification of the fundamental economic relationship to predict the effects of the different variables and policy instruments on investment behavior, cattle sales, and on meat consumption. This study represents a first attempt to begin such an analysis.

Once the inventory series by age and sex from 1940-75 were estimated, a supply, demand and inventory model was developed including such economic variables as cattle prices, crop prices, disposable incomes, and such explanatory policy variables as the agrarian reform, credit and price controls. This model allows for the identification and quantification of the fundamental parameters over short run. It is based on similar theoretical models on aggregate production behavior which have been successfully applied in Argentina, Brazil and Chile.

Preliminary results

In general, the results of the econometric model agree with the theoretical model. The aggregate demand for cattle was estimated as being relatively inelastic with respect to price and income.

Estimates obtained for the price parameters in the supply function (slaughter) in terms of both magnitude and sign, were as expected on the basis of the theoretical model. The aggregate slaughter of females reacts inversely to price (Figure 31) which implies that as the price of beef goes up producers retain females to generate future supply, and as a consequence, sales are reduced over the short run. These results are consistent with observed behavior of beef cattle inventories during price fluctuations; that is,

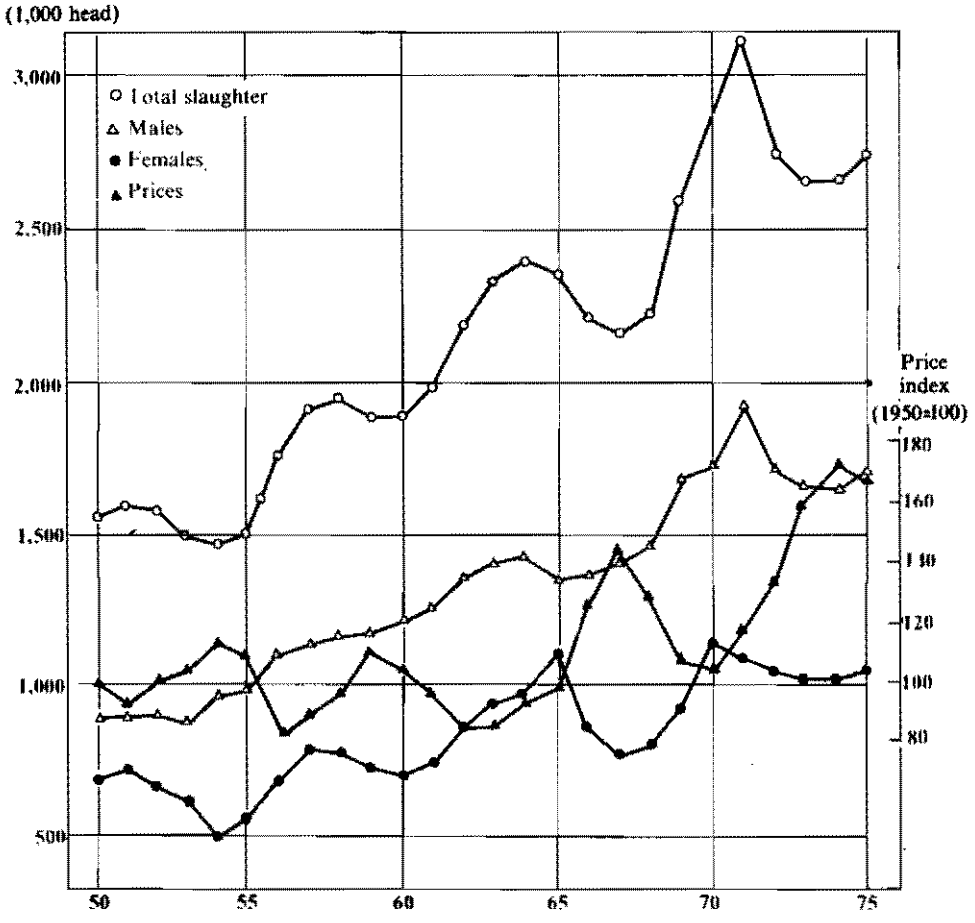


Figure 31. Slaughter, including unregistered and exports on foot, and real prices of beef cattle in Colombia, 1950-75.

price elasticities in the inventory functions are positive indicating that when prices rise, inventories of both males and females increase. On the other hand, when the prices of cotton, rice, maize and beans rise there is a decrease in inventories.

The behavior of milk prices in the short run supply functions, as well as inventories, indicates that when milk prices rise, sales of females decline, consequently increasing the breeding herd.

The volume of credit granted by the Caja Agraria and the banking system in general, does not appear to significantly influence slaughter supply, even though this variable was introduced with different lags (1-5 years). However, credit from the Fondos Ganaderos, and granted under Law 26, had a significant effect (P .01) on female inventory behavior[5]

5 It must be noted that credit from the Fondos Ganaderos and under Law 26 is supervised credit.

Price control, expressed as a binary variable, did not significantly explain either slaughter supply or domestic demand. In the case of the supply function, however, price control was already reflected in the series of wholesale cattle prices. At the consumer level, the price controls have been generally inoperative, therefore no significant relationship was expected.

Generally, the estimated values for the fundamental parameters of the functions of supply and demand, and their respective elasticities over the short run, represent a preliminary approximation of their true magnitude and value.

It must be noted that the model only measures short term effects; this representing a serious limitation since some policy effects manifest themselves only in the long run. Smuggling was excluded from the analysis for lack of data. Climatic conditions were also excluded due to difficulties involved in constructing a representative climatic index. Such an exclusion seriously limits the study since the scarcity of pasture resulting from droughts can seriously restrict production and cause slaughter variations. While these and other macroeconomic aspects were excluded due to lack of data, nevertheles they merit research.

Cattle Production Systems in the Llanos

Relatively little is known about the economics of cattle production systems in the savannas of Colombia and about those economic restraints which might condition adoption of existing technology. Therefore, the objective of the study is to characterize the region according to: (a) the present systems of production; (b) factors internal to the farm (natural resources and management) and external factors (credit policies, prices, input availability) which represent current restictions on technology adoption; and (c) the economics of practices such as using minerals, early weaning, and improved pastures.

The study is being carried out in the Carimagua region in order to complement and document with primary information, data obtained from prior studies (CIAT Annual Report 1975).

On the basis of agrological, climatic and natural vegetation studies conducted by the Food and Agriculture Organization (FAO), and road maps, a zone of 300,000 hectares was selected for study. A census of farms in the region was obtained from the census office and complemented with aerial photographs and field work. The principal criteria for selecting farms were: (a) scale of operation; (b) location and distance to supply centers and markets; (c) specialization in breeding or fattening; and (d) the use of mineral supplements.

From 200 farms which met the typical conditions of poor soil and less than 20 percent lowland, 16 farms were selected; of these, six of them have been analyzed as the first contacts in the area. For each of the farms selected, monthly visits were planned for a period of 18 months, beginning in April 1976. At present, the farms' natural resources have been studied, the cattle numbered, and monthly overall farm records have been kept for the last six months. The animals have been weighed in order to measure different technological parameters.

The principal external factors considered are: (a) price of cattle, (b) transportation costs, (c) level of utilization (opportunity cost) of natural pastures in nearby regions (piedmont), and in general, those

external factors which may condition the degree of intensification, specialization and location of cattle production in the area. The principal internal factors considered are: (a) natural resources as farm size, proportion of high and low lands, soil quality, pasture and infrastructure; (b) management practices —division, rotation and carrying capacity of the pastures, fire control, sanitary practices, marking, use of minerals, early weaning, forms of transportation, age and season of sales; (c) production— birthrate, mortality, weight increase, breeding season, weight losses; and, (d) expenses and income, —purchase and sale price of inputs and outputs, and wages.

Preliminary observations

Several principal observations have been made:

(a) A high degree of specialization exists in the piedmont in fattening operations and in the savannahs in cowcalf operations. In 1975, 131,459 head of fat cattle were extracted from the Department of Meta (police check point, "retén", of Bogotá) of which only 3,000 head came from the savannah region ("retén" of Pt. López). Through this last "retén" 30,000 cattle passed to be fattened and finished in the piedmont.

(b) In the more fertile lands of the piedmont non-capital intensive technology is available that increases carrying capacity without reducing the daily weight gains per animal.

(c) In the savannah, the cost of truck transportation has increased in real terms, approximately 10 and 25 percent respectively in each of the last two years. The cost per animal per kilometer from Villavicencio (piedmont) to Bogotá is only half the cost per kilometer in the Llanos.

(d) Cattle movements from the savannah to lands of the same owner in the piedmont have been observed. In 1976, three of six farms transferred and average of 30 percent of their animals to the piedmont; under normal production conditions, these farms would not extract more than 15 percent of their animals. None of the farms studied reported a uniform extraction during the last three years.

(e) In none of the three farms which have obtained credit, did the loan institution accept savannah land where the investment was made as collateral.

(f) On the four farms which had some mechanization (forage seeding, building of dams, road construction), the machinery was also used by the same owners on other enterprises or lands in the piedmont.

(g) In areas near the farms under study, there are farmers with good land who have seeded improved pastures and charge a pasturage fee substantially lower than in other areas (Col.$45-80/animal/mo.)

(h) The stocking rate is much lower than what is technically feasible on the savannah. The average stocking rate is one animal on 5.5 hectares in the dry season and 7.1 hectares per animal in the rainy season.

(i) On the three farms where early weaning is being practiced, the age of the early-weaned animals varied from 7 to 15 months, depending on the size and condition of each calf.

(j) On one farm, mineral supplementation for the first three years increased the birthrate to 62 percent

and have considerably reduced abortions However, the slow recovery of nursing cows resulted in increased cow mortality because they were unable to pull themselves out of the bogs near watering points in their weakened condition. In 1976, 6 percent of the nursing cows on the ranch died in this manner.

(k) The average weight of nursing cows under savannah conditions and supplemented with minerals was 273 kilograms in the rainy season (weighed six months after the rains began); however, individual weights varied between 210 and 400 kilograms. The average weight of the heifers at breeding was 235 kilograms with a range between 210 and 286 kilograms.

(l) In 1976, the average sale price of finished animals in the Llanos was approximately Col.$14/kg while the average price of feeders and heifers was Col.$16/kg. Average price of pregnant cows was Col.$18/kg.

Working hypotheses

Observations to date suggest the following working hypotheses.

(a) While present conditions of low opportunity cost of pastures in the piedmont and the high cost of transportation from the savannah are maintained, piedmont farms will continue to specialize in fattening and, the savannah in cow-calf operations.

The low opportunity cost of pastures in the rainy season in the piedmont creates a high demand for feeder cattle. This would explain the difference found in the prices of fat and lean animals. It explains why farmers transfer more animals from the savannah to the improved pastures in the piedmont than the normal annual extraction rate, even though the savannah has maximum carrying capacity during the same season (rainy season). This may be attributed (in the case of steers) to greater daily weight gain in the piedmont (600 grams compared to 350 grams on savannah pasture), and in the case of cows, for reasons of ease of management. However, the stocking rate in the piedmont is still inferior to its potential which would explain the slow adoption of available, low-cost and easily applied technology, in the area.

The cost of road transportation has risen in real terms during the last two years; hence the price of cattle as well as specialization of production in each area is more dependent upon transportation costs. Feeder cattle cost less to move on foot, than by truck in terms of cash outlay This contributes to the specialization on finishing in the piedmont and breeding in the savannah.

(b) The low cost of land in the savannah limits the possibility of using it as collateral to adopt capital-intensive technologies, i.e. extensive use of improved pastures. This restricts the adoption of capital intensive technology even on the supposition of profitability.

(c) The adoption of improved management practices in an isolated manner —use of minerals, division of pastures, and early weaning in the savannah,— does not seem to greatly increase productivity over traditional systems. On the farms analyzed, "early" weaning occurred on the average at 12 months, which is almost the age of natural weaning. The use of minerals alone appears to stimulate some cows to reproduction levels above biologically safe levels for present savannah conditions. This would contribute to the death of the

most productive cows due to calving and lactation stresses.

In relation to the use of minerals, the difference found with experimental results in Carimagua (see discussion on page 35 Herd System Project I) appear to be due to the age, initial condition and the composition of the breeding herd. The experimental herd was originally formed by heifers with an average weight at breeding of 280 kilograms while the average weight at breeding observed in the study was 235 kilograms. Another difference between ranch and experimental systems is that ranch savannahs are burned in a less controlled way than the experimental station. In 1975, two of the six farms observed had accidental fires on 50 and 100 percent of their savannah. Although mineral supplementation increases the pregnancy rate accidental fires appear to increase the number of abortions due to poor nutrition of first pregnancy heifers. Also, water on the experiment station is provided by wells while on the savannah, the only sources of water are the watering holes along natural streams. This notably increases the risk of death in bogs of those cows weakened by calving and lactation.

In 1977, information will continue to be collected in order to evaluate some of these hypotheses and to obtain empirical information on the different parameters involved.

TRAINING

In 1976, 12 postgraduate interns received individual training in the areas of animal health, pastures and forages and animal management. The average length of training was seven months, for a total of 84 man-months. These trainees were selected for advanced training from several different countries to better prepare them for research responsibilities in their respective national institutions.

Seven research scholars are working on their master's degrees. Three have completed academic studies and are conducting thesis research projects in the various disciplines of the Beef Production Program. The other four are at various universities completing their academic requirements and are expected to do their thesis research at CIAT.

Seven special trainees (three months or less at CIAT) received short-term training, learning specific research or analysis techniques within the various disciplines.

A two-month short course in epidemiology of animal diseases was organized and supervised in the field by members of the beef team as part of an overall course organized and funded by the Panamerican Zoonosis Center. The major portion of the course, in CIAT, consisted of a disease survey in Santander de Quilichao, in the Cauca region of Colombia. Field work was done in collaboration with the Cauca secretary of agriculture, the regional livestock association (Fondo Ganadero del Valle). the Caja Agraria, ICA and private ranchers.

The objective of the course was to teach a systematic approach for collecting and interpreting fundamental biological data within a beef cattle zone to construct an accurate description of the disease situa-

tion. Based on general information of the zone provided by the collaborating institutions, the seven trainees (two from Brazil, and one each from Chile, Honduras, the Dominican Republic, Mexico, and Guatemala) were divided into groups which surveyed 35 farms.

From the smaller herds (≤120 head) blood samples were taken from 20 animals and from the larger herds (500-2,500 head) 40 animals were bled. A total of 750 animals were sampled representing a population of 12,401. A questionnaire was completed for each farm to obtain data on production and nutritional parameters. Serum samples were analyzed in the laboratory for hemoparasites and reproductive diseases. At the end of the two-month course, the trainees held a field day at one of the ranches. They presented their preliminary results and discussed with the cattlemen possible means of improving beef production in the area.

Data obtained from questionnaires and laboratory analyses is being evaluated and will be used not only for evaluating the student's performance but also as a guide for preventive medicine regimes to be established for animal experimentation which will be conducted in this area.

Eight visiting research associates either began or completed their dissertation research as the final phase of their doctoral program. All candidates are sponsored by other organizations; however, CIAT covers some of the research related costs.

Due to a lack of special project funding, no beef cattle production specialist course was offered this year. However, a course is being developed for a group, primarily from Guatemala, which will begin in January 1977. The first three-month phase of the course will be taught at CIAT and the subsequent seven-month field phase will be done under supervision by CIAT personnel on private ranches in Guatemala.

Two visits were made to Ecuador to assist personnel at Instituto Nacional de Investigaciones Agropecuarias (INIAP) in setting up a beef cattle production course for the coastal region where training programs are contemplated for workers in various levels of the livestock sector.

A detailed analysis is given in the training and conference section of the annual report.

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