Pasture-Livestock Research and Training Program

For
(CIAT)

Centro Internacional de Agricultura Tropical

[1967]

A
Proposal
by

. V. Crowder
Assoc. Prof., International
Plant Breeding
Cornell University
Ithaca, New York

R. E. Blaser
Prof. of Agronomy
Virginia Polytecnic Institute
Blacksburg, Virginia

TABLE OF CONTENTS

FOREWORD

This proposal was prepared as a guideline for developing a productive pasture-animal research and training program for the Centro Internacional de Agricultura Tropical (CIAT). The purpose of the program is to provide needed high animal protein foods for human consumption to improve health, strength, vigor, and initiative incentives of individual persons and the prosperity of farmers and economies of developing countries in the humid tropics by using the land, animal and climatic resources more effectively. In countries where consumption of animal protein is low (an estimated supply of 25.6 gm. in Colombia as compared to 64.4 gm. daily per person in the U.S.), the natural grasslands represent a reservoir whereby food production can be increased in two ways: (1) bringing unproductive and idle lands into more efficient use to increase output per hectare and (2) increasing output per animal. Furthermore, as the human population increases, the better and more accessible grasslands will be diverted toward production of foodstuffs for direct human consumption. Even as this evolutionary process continues, immense tracts of less tillable land will remain for pasture development. Improvement of the natural grasslands and efficient production and utilization of sown pastures are long-range and formidable tasks that CIAT should assume.

The efficient production of livestock products from ruminants on soils not suited to crops for direct human consumption depend on adaptive, and later original, research information, pilot demonstration, and training of farm technicians and extension and research personnel. The resolving of the biological complex of climatic, soil, plant, and animal input factors and their interplay for efficient animal production depends on an integrated team approach as given under program objectives and procedures (Sections II and V).

The projection encompasses a comprehensive and expansive scope, recognizing that its elaboration must be appropriately and conveniently phased into the developmental activities of CIAT and collaborative institutions as prescribed by available human and physical resources. The costs of the program will be very sizeable;

the deterrents do not appear to be unsolvable; the potentialities for improvement are excellent.

It was suggested that this proposal be projected to include African investigations. Political unrest in several African countries and time scheduling did not permit travel to this continent for a review of pasture-animal developments in the various ecological zones and discussions with pasture and animal professionals. The problems, along with objectives and procedures for resolving them, given in this report apply specifically to the hot, humid tropics but should have general application to the International Institute of Tropical Agriculture Pasture and Forage Program.

PROGRAM OBJECTIVES

To investigate and develop simple year-around pasture and forage systems of a quantity and nutritional value for efficient production of various livestock enterprises and to disclose maximum economic potentials of producing livestock commodities from tropical soils and environments as needed sources of protein and energy for humans.

To attain economic success in this project all input factors, as soils, pastures, nimal nutrition, animal health, etc., are important and must be coordinated and directed toward high outputs per animal and per land area. It is imperative to stress outputs per animal and per land area as high forage yields are meaningless if their utilizable energy for animal production is low Likewise, excellent animal hygiene controls or other manipulations that do not function to maintain and increase economical utputs of animal products are academic.

An integrated team approach directed toward fully exploiting the complex interplays f climatic-soil-plant-animal factors in producing animal products should be enthusiastically pursued. Some goals to be attained are: (1) Improved animal nutrition through se of long-lived pasture perennials with high dry matter production, (2) rapid production cycles - first calf born when heifers are less than 30 months old, (3) long nd efficient reproductive life of cows with a yearly average of an 85% raised calf rop, (4) cattle with desirable marketable carcasses weighing 275 kilos in two years, nd (5) dairy cows with uninterrupted and reasonably high levels of production (average 13-15 kilos daily for 280 days) for successive lactations.

All of the subsequent objectives should be administrated and directed toward realizng the primary objective in a total program of research. Cheaply produced feed is mperative as livestock production cannot attain economic status without it; thus the owing and utilizing of pasture and forages for profitable livestock enterprises ould have first research priority While research is in progress, however, priorities y need to be altered.

Investigations with Sown (improved and introduced) Pasture Species

Phase 1 To characterize and select sizeable land sites that may be economically developed for significant production contributions because of favorable soil and ecological factors for growing desirable pasture plants.

a Broad soil classification maps are to be made from aerial photographs by a team of specialists (plant ecologist, geologist, and pedologist).

b Climatic conditions will be described for the underdeveloped land areas.

hase 2 Adaptive research - introducing and testing of grasses and legumes for total and seasonal growth, longevity, competition, and herbage acceptability.

a Response interactions with modified environments such as burning, seedbed preparation, cultivating, draining, irrigating, soil amendments, herbicides, insecticides, and defoliation intensities will be evaluated with small plot clipping trials that are occasionally grazed.

b. To find adapted tropical legumes that fix nitrogen efficiently for themselves and grass associates and that are readily consumed by ruminants for the improvement of animal performance and reproduction.

i. <u>Rhizobia</u> strains and companionability in grass associations will be investigated

ii. Collections of legume and <u>Rhizobia</u> variants will be obtained from the extensive exploitations and plant introductions by C.S.I.R.O. in Australia and introductions by the U.S.D.A. and other forage programs. Germplasm legume and <u>Rhizobia</u> variants will be maintained.

iii Cooperate in regional testing of tropical legumes.

c. To investigate possible symbiotic nitrogen fixing relationship with tropical grasses and its practical exploitation.

ase 3. To test selected species and varieties of pasture plants for total and seasonal yields, persistence, aggressiveness, acceptability to ruminants fed ad libitum or grazed, and for quality of herbage.

a Grasses and legumes will be grown in monocultures and mixtures of the best adapted and compatable species with treatment variables such as fertilization, defoliation intensity and frequency (stage of growth), and irrigation under intermittent grazing or alternate grazing and cutting

b. Preliminary data on herbage quality will be evaluated by chemical analyses (Van Soest and other methods) and in vitro or in vivo (nylon bag) techniques. For the more promising species data on nutritive value indices (digestibility coefficients and consumption) will be obtained at several morphological stages of growth by ad libitum feeding green chop or as hay.

c. Pilot experiments will be initiated to investigate cultural and management practices and grazing sequences for obtaining year-around grazing.

Phase 4. Advanced Pasture - Animal Program.

To disclose the potential output of animal products per hectare and per beast from selected grasses and legumes grown alone and in mixtures. Adapted and promising species will be evaluated with animals in grazing experiments. Data will be obtained on the influence of pasture species on animal nutrition and on the quality and quantity of animal products. The effects of the animal on soil-plant interrelationships will be studied so as to characterize changes in production potentials which might result from the cycling of animal excreta (animal to soil to plant to animal) over a period of years. In order to make wise compromises between outputs per animal and per hectare the mixtures and species being grazed will be evaluated at two or three stocking pressures based on herbage available per animal.

It is very important to make thorough economic evaluations of all grazing trials. The economist should be a team collaborator at the time of planning the grazing and other experiments.

i. Some variables to be evaluated with simple factorial combinations are rotational vs. continuous grazing, soil fertility levels, irrigation, leguminous effects. Supplementary feeding will be practiced only to avoid animal losses at high stocking pressures.

ii. Herbage availability, through selective grazing, influences nutritional aspects; hence, diagnostic samplings of forage produced and consumed should be made monthly.

iii. Intake and digestibility and chemical and botanical compositions of pasturage may be obtained during seasonal periods when distinct differences occur in herbage quality

iv In addition to animal products and their characteristics, supplementary data will be taken on liver, blood, and rumen samples.

v Investigations should include a study of methods of animal management and control of diseases and parasites; the effects of animal concentrations (stocking pressures) on diseases and parasite infestations and the influence of pasture nutritional differences on animal tolerance to diseases and parasites should be studied

b To develop dependable pasturage of suitable nutritional quality for year-around grazing through the manipulation of soil, plant, and animal factors when disease and parasite controls are employed with all variables.

i Soil factors include the manipulation of irrigation and fertility to aid in obtaining more uniform plant growth at various seasons.

ii Plant factors include grazing intensity, sequence of species within and among pastures, and periodic resting to accumulate growth that may be grazed <u>in situ</u>.

iii. Animal factors include their numbers on a land area (farm) by manipulating the breeding, calving, marketing, and lactating curves to coincide with seasonal undulations in nutrition (quality and amount of pasturage).

c To develop a 12-month feed program(s) through flexible utilization of pasture for grazing and for hay and silage. Forage harvested and stored during periods of excess growth will be fed during periods of slow rates of dry matter production. Arrested grazing offers an opportunity to study the influence on parasite populations.

i. Such feed programs may be arranged by using a single species or a series of species or mixtures in different pastures.

ii Species and mixtures will need to be evaluated for yield, quality and losses with methods of conservation at morphological stages of growth as well as for ease of conservation

iii. Flexible management of animals which considers their nutritional requirements and the undulating yield and quality of pasture and forage.

d. Supplementary feedstuffs.

i. To investigate the production of supplemental crops to be fed as greenchop, silage, hay or grazed <u>in situ</u> when pasturage is low.

ii. To evaluate the utilization of cellulosic by-products.

iii. To study the usefulness of cheap urea supplementation with molasses or other organic compounds as a means of improving animal performance.

Phase 5. To conduct related investigations for the establishment of methods for controlling or alleviating any serious deterrent(s) that may interfere with efficient animal production from pastures and forages as they appear during the research investigations or may be encountered by cattle producers.

a. Factors that may require special research are:

i. Nutrition. This will include research on nutrient content and utilization in ruminants, supplementation of pastures, or other forages for maximum efficiency and causes and control of metabolic disturbances.

ii. Physiology of reproduction in males and females. Research will be directed toward uncovering the causes of reproductive failures and studying preventative measures.

iii. Parasites and diseases. Effects of livestock-pasture management and certain anthelmentics on internal parasitism will be investigated. The effectiveness of various drugs in controlling external parasites will be studied. . Disease prevention will consist of using sound management and immunization against prevalent diseases. If other diseases or toxicities arise, these will be investigated.

iv. Soil problems as interrelated with physiological plant disturbances.

v. Nematodes and insects that alter plant growth.

vi. Plant diseases.

vii. Control measures for severe weed infestations.

hase 6. To develop methods of producing, processing, storing, and marketing abundant viable seed supplies of desirable grasses and legumes. Phenological characteristics as related to factors that affect seed production will be studied for species.

a. Some treatment variables to be investigated are row vs. sod sowing; fertilization; defoliation management; water, insect, disease, and herbicide control; disking or cultivating old sods; methods of harvesting; processing; and storing seeds.

b Commercial seed production by qualified persons will be encouraged as information becomes available

hase 7 To intensify plant exploration and international distribution and to improve grasses and legumes through breeding, selection, and genetical studies.

a. Collections of introductions and accessions.

i. To identify species and develop genotypes that furnish feed during periods of low production. Early evaluations will be made with animals by intermittent grazing and <u>in vivo</u>, <u>in vitro</u>, and chemical evaluations.

ii. Maintenance and distribution of vegetative and seed germplasm.

b. To conduct basic genetic research and to develop techniques which support breeding investigations of various plant species.

i. Modes of reproduction, floral biology, pollen production and receptibility, incompatabilities, seed formation and dormancy, apomictic reproduction, dehiscence and shattering, etc

c. To participate in international programs of grass and legume improvement:

i. For allocating breeding responsibilities with species so as to concentrate efforts,

ii For participating in the establishing of standards for evaluating species and varieties,

iii For developing varieties adapted to sizeable ecological regions, and

iv. For production and distribution of foundation seed stock.

<u>Utilization and Improvement of Natural Grasslands</u>

1. To investigate the yield and nutritional value of various botanical components

of natural grasslands in different environments.

a. Output of animal products per ruminant and per acre at different stocking pressures will be obtained as outlined in Phases 3 and 4.

i. Variables to be investigated include fencing, controlled burning, mowing, drainage, arrested grazing, and supplements based on nutritional factors such as energy feeds, urea-protein, and minerals.

2. To develop simple low cost methods of establishing higher quality and more productive grasses and legumes by judicious stocking in combinations with practices such as burning and draining, seedbed preparation and aerial applications of seeds, fertilizers and pesticides.

3. To develop a 12-month grazing system(s) for producing beef cattle through the manipulation of animals, and natural pastures in combination with seeded pastures and supplemental forages.

a. Supplementary soil, plant, and animal data as outlined in Phase 4-a should be obtained to aid in explaining the results.

4. Data are to be evaluated economically and an economist should cooperate in designing grazing and other experiments.

Animal Environmental Control

1. To evaluate under laboratory controls the significance of tropical conditions such as high temperature and humidity on animal production.

a. This area should be investigated if animal performance is suboptimal when nutrition and other biological input factors are controlled.

Animal Breeding

1. To improve the rate of reproduction, longevity, and productivity of ruminants through breeding in humid tropics under normal stresses of temperatures, humidity, diseases, insects, and nutrition.

a. The main breeding scheme will be to cross native cattle with high producing imported cattle with the objective of retaining the adaptive characteristics of the native stock and the high production rate of the imported stock. Also, selection may be directed toward using a given strain or type of [illegible]

and meat production.

Training and Educational Program

1. To develop an international educational and training program for [illegible]

of pasture-animal programs.

a. Research personnel

i. Postgraduate and postdoctorate in-service experience and training [illegible] ment basic training.

b. Extension personnel.

i. In-service training at one or more locations and special training [illegible] workshops.

ii. Involvement for short periods with research projects.

iii. Methods for accumulating and disseminating information.

c. To aid in training of technicians for managing pastures and animals.

i. In-service short course and training programs.

ii. Brief involvement with research pursuits.

iii. Repeat short courses.

d. Special educational programs.

i. Short courses, work shops, symposia, conferences, and seminars directed at specific audiences.

e. Accumulation, review and dissemination of information pertinent to pasture and animal research workers.

NCEPTS OF PASTURE IMPROVEMENT FOR LIVESTOCK PRODUCTION

here are two primary concepts of pasture improvement: (1) Utilization of the natur- sslands through better management of such pastures and animals. (2) Destruction of grasslands by fire or other ways and growing of seeded species after changing the vironment. Both of these concepts have merit and universal acceptance of either alone is untenable. For example, there should be endeavors to maintain and improve the production of native species in environments where there is a drastic shortage or a very erratic distribution of moisture and where irrigation is not available as in the short prairie grass region of U.S.A. and in some climatic zones of all continents. Also, very infertile, droughty, or flooded soil environments should remain in the natural vegetation. When yearly rainfall is reasonably high and reliable for a period of six months (more or less), it is usually preferable to destroy the native vegetation, if the soil environment can be altered at low costs, so as to grow more productive and nutritious seeded pasture plants. It is quite possible that the very low nutritional value of native species in many natural grazing lands is attributable to natural selection processes because palatable and heavy grazed species have gradually disappeared from sods.

The value of native species are strongly influenced by the fertility status of soils. In temperate arid and low rainfall regions soils are usually shallow but high in bases and fair in organic matter. Pastures on such soils are nutritious, but total production would not justify the use of seeded species. The native vegetation in humid tropical areas is generally of very poor quality because of the extremely infertile soils. Furthermore, as mentioned above, the more desirable species have been eliminated leaving those which are tolerant of low fertility conditions.

The concept of replacing native species on alluvial or reasonably fertile soils in tropical areas is unquestionably desirable. The destruction of indigenous sods on lateritic soils, and the seeding improved pastures may be questionable and should be pursued with caution. Lateritic soils, as in the Llanos of Colombia, may have very desirable physical or structural features, but they are usually extremely infertile. The highest fertility of such soils is near the surface where there is limited organic matter. Lateritic soils are characteristicly very low in base exchange capacity (3 to 10 me.), and often are only 5 per cent base saturation. They are extremely acid; the availability of calcium, magnesium, and potassium are often no more than 0.5 me. per 100 grams of soil. Lateritic soils are low in minerals, except aluminum and iron. The buffering capacities of aluminum compounds are extremely high, making it difficult to alter the pH. Phosphate fixation is usually very high. For such infertile soils, longtime experiments are necessary to ascertain the feasibility of using seeded species when soil fertility has been changed Growing species that are better "miners" of soil nutrients and concentrating cattle on smaller areas will only aggravate soil depletion. For such soils, the availability of lime and low cost fertilizers are very important considerations. Supplying calcium and phosphorus as mineral supplements to the cattle on natural pastures may be an economical way of avoiding further mineral deficiencies and permit the profitable raising of cattle

A. Development of the Pasture-Livestock Program in Florida and Australia

The development and improvement of the beef cattle industry during the twentieth century in subtropical Florida may serve to indicate potentialities in tropical regions.[1/] The small adapted cattle, able to survive the harsh nutritional, parasite, disease, and insect stresses, were remnants of Spanish cattle introductions that had crossed with other breeds. During the third to fourth decades, mature cows normally weighed about 550 lbs. and averaged a raised calf about every third year. There were few fences and sparse cattle populations and they grazed natural pastures. One beast averaged ranging over five to twenty acres. The native grasses on the sandy, acid, infertile soils were low in essential macro- and micro-mineral nutrients and low in protein. Broken pelvis and other bones caused by calcium and phosphorus deficiencies, other nutritional disturbances and insufficient trace minerals, such as copper and cobalt, occurred but at first were the unknown deterrents. Native grasses were very low in protein, since soil nitrogen and organic matter remained low because of the high oxidation on sandy soils. Legumes which fix nitrogen were absent from these natural savanahs. The utilizable energy and protein found in the native grasses remained below daily cattle requirements during much of the year. Burning the range was an excellent practice as this concurrently destroyed some parasites and the woody, mature, indigestible grass sods. The young regrowth, improved

---

1/ Observations of various investigations by R. E. Blaser during 1937-46 while associated with the University of Florida.

somewhat by the ash after burning, was nutritious for several weeks or months--during this period cattle grew and gained weight rapidly. Young cattle usually encountered severe nutritional stress; many died; others reached breeding condition at an age when today's Florida cattle are grandparents. It was common to sell late weaned calves to butchers because of severe nutritional stresses. Poor herd management, Texas fever, low nutrition, and severe screw fly infestations of unattended cattle caused high mortality. During the third and fourth decades in this century, many cattle died during the winters because of starvation due to the lack of energy and protein or mineral malnutrition on native pastures (quality rather than availability). Mineral supplements on natural pastures gave decided improvements in animal growth and reproduction, but spectacular progress occurred later by changing the soil environment and seeding improved pastures.

Today, Florida is a cattle empire--all problems are not solved (Appendix A). Applying needed nutrients to soils, establishing adapted grasses and legumes to replace native grasses, employing judicious grazing practices, exercising good herd management and hygiene, using better and adapted cattle breeds, better control of pests and supplementing deficient mineral nutrients are all links in this chain of success. The foundation of the Florida animal production program is improved pastures. Improved pastures depend on initial characteristics of soils and their amendments; total and seasonal yield and quality of pasturage; adapted species; available supplies of good seeds; irrigation where practical, and good animal grazing management. Pasture quality has profound effects on ruminants--research in Florida and Australia shows better calving and animal growth when legumes and grasses occur in pastures as compared to nitrogen fertilized grasses.

With natural unimproved pastures on the sandy acid soils in Florida (savannah vegetation) and poor cattle management during the first decades of this century there was about a 30 per cent calf crop and 5 to 20 lbs. of liveweight gain per acre with 5 to 10 acres required per head. Now with changed soil environments and introduced pasture plants, along with good herd management, calf crops average 80 per cent for the better herds. Stocking rates have increased sharply; realistic liveweight gains per acre for adapted species under natural rainfall are around 350 lbs. per acre as compared with 2 to 4 fold increases with nitrogen and irrigation.

The rapid development of the cattle industry in the humid tropics of Queensland, Australia,[1/] is similar to Florida developments. Cattle on natural unimproved savannahs (grass-tree vegetation) require 5 to 40 acres per beast. Under such nutritional stresses, calf crops average less than 50 per cent and steers are often 5 to 7 years old when they attain suitable fleshiness for marketing.

The dynamic development of the cattle industry now underway in tropical Australia starts with selected areas with favorable rainfall and where soil nutrient deficiencies can be corrected for growing adapted grasses and legumes of good nutritional value. All of the grasses and legumes for the improved pastures are plant introductions from other countries. Introduced species are studied in various environments with and without altering soil environments and promising pasture plants are soon evaluated with cattle. Adapted and semiadapted species are further improved through natural selection pressures from the new environments and by objective plant breeding programs.

Practices directed toward improving the natural savannahs per se in the above mentioned tropical and subtropical regions have not resulted in dramatic changes. These natural grasslands, however, made large contributions when used in combination with improved species for developing reliable feed programs. Animal and acre outputs from extensive operations on native vegetation have been improved by mineral supplements and good total management. Indeed, initial improvements in meat production per animal and per acre on extensive operations on the better natural grasslands may be most easily and economically attained by implementing simple managements as fencing and controlled burning, supplementing minerals that are deficient in soils and herbage, urea or urea-protein supplementation at critical periods, and good herd and breeding management.

The very significant natural adaptation of cattle to disease, insect, and nutritional stresses that are common in tropical regions should not be overlooked. The

---

1/ Personal observations and communications in Australia.

natural selection pressures that have improved the productivity and adaptation of native cattle have been substantially augmented by introducing new germplasm. For example, cross breeding with Brahma bulls has aided in developing cattle races that are especially adapted to tropical environments.

Although the aforementioned improvements in soil-plant-animal interrelationships were slow, the potentials for beef cattle production from improved pastures in the tropics appear excellent. The principles that have been established may stimulate spectacular developments if they are used in adaptive research and directed toward meat production in many undeveloped biological complexes in the tropics. Such adaptive research should not be done to obtain original information for publications; initially, research will serve best where practical experiments and demonstrations furnish information for increased animal production on farms. For example, the research principles established from the studies of a biological complex of infertile sandy acid soils, woody native grasses of low nutritional value, and cattle adapted to pest stresses in humid warm Florida should have application to the Llanos regions of Colombia and Venezuela and to the "Campo cerrado" of Brazil. Research principles for improved species in Australia and other tropical zones may be "transplanted" with some modification to other tropical areas for improved pasture and animal production.

All phases of beef cattle production, from year-around grazing of improved seeded pastures or from well managed combinations of seeded and natural pastures, have been attainable without supplements. The possibilities with dairy cattle without supplements in the tropics have not been fully explored and appear less promising than with beef cattle production.

IV. SITUATION AND SCOPE OF SOIL-PASTURE-LIVESTOCK PROGRAM

Land suitable for crops that are consumed directly by humans should not generally be used for livestock production. This is so because the production of nutritious high protein animal products for human consumption is very inefficient as compared with the production of grass and leguminous cereals, fruits, and vegetables for direct human consumption. Grain consuming simple stomached animals (poultry and swine) convert concentrate feeds into animal products more efficiently than do ruminants. The conversion efficiency of consumed pasture and forage feeds (dry matter) into liveweight gain ranges from 6 to 15 per cent for ruminants; the values for dressed carcass weights are lower, ranging from 4 to 9 per cent. Thus, the production of human foods through ruminants are luxury enterprises unless abundant supplies of low cost feeds are used as efficiently as possible. This low efficiency of energy conversion to usable human foods makes it clear that the economic foundation of ruminant livestock enterprises depends on low cost feeds that are produced on soils not suitable for crops to be used for direct human consumption. Feeds for ruminants must be reasonably high in digestibility and consumed in large quantities to maintain the nutrition requirements above that for maintenance; otherwise, the efficiency of production would be even lower than previously mentioned. On the other hand, ruminants utilize "woody" low protein pastures and feedstuffs that would otherwise be wasted. By supplementing with urea, very fiberous feeds may be converted into high quality protein products for human consumption.

Low cost feed for the production of livestock products can be most economically obtained from pastures in environments with long grazing seasons where there is high solar energy, favorable moisture with good distribution, and favorable temperatures for high rates of dry matter accumulation. In such environments meat, wool, and milk products produced at low costs can be highly competitive commodities in world trade. Examples are the exports of livestock products from ruminants from New Zealand and Australia. The favorable cost-price production relationships in these countries are associated with land values, labor, mechanization, and other low input costs for feed primarily from pastures.

The production of livestock products by ruminants from yearlong grazing seasons using judicious pasture utilization and practices in tropical environments have potential economic advantages. The rapid development of the beef cattle industry in humid tropical Queensland is indicative of potentialities. Many interrelating factors have contributed to the economical production and development of the livestock industry in tropical Ausalia: (1) Favorable temperatures - frostfree to light frosts, high rainfall (but distribution is often a problem), high light intensity and favorable photoperiods. (2) Adapted and improved tropical grasses and legumes with high economic dry matter yield potentials reasonably nutritious pasturage. (3) Information on soil and plant management for obtaining economical dry matter yields from plants. (4) Management programs of cattle adapted to the nutritional, disease, parasite, insect, and environmental stresses. (5) Integrated research directed toward judicious manipulating and compromising the soil-plant-animal interrelationships. Nonetheless, the business of producing livestock is and will continue to be faced with unsolved and unexpected temporary deterrents in Australia as well as in other humid tropical regions.

There are potentially serious deterrents for economical production of livestock products from ruminants in the tropics. Most forage and pasture plants are lower in nutritional value than temperate plants. This may retard conversion efficiency to animal products. Infertility of soils affects the nutritional status of pastures and forages. High temperatures may reduce protein content and enhance carbonaceousness of herbage. The incidence of animal diseases, insect and parasite pests is more severe in tropical as compared with temperate environments. Conversion efficiency of fibrous feeds may be inhibited by climatic factors such as high temperatures and humidity. Other deterrents are high capitalization and lack of trained farmers and personnel to manage the biological complex. The development of the livestock industry in Florida (tropical and subtropical) during this century encountered these complex problems and hinderances, but the solution of them serves as an exhibit of possibilities in tropical environments. The advancement of knowledge through experiences and research in Florida, Australia, and other tropical areas have established principles that may now be used in adaptive research and demonstrations for rapid progress in similar environments.

There are huge tracts of land in the tropics that appear to be suitable only for economical production of pastures and forages (Appendix B). Large grassland areas are used for the production of forage grasses and legumes alone or in combinations and often with other herbage plants for grazing hay, silage, or greenchop. Acreage in grasslands exceeds the combined area for wheat, corn, oats, hay, rye, soybean, sugar beets, rice, flax, peanuts, potatoes, and tobacco - approximately 30% of the land area of the globe is covered by grass. Over 60 per cent of the worlds agricultural land is non-arable and suitable only for grazing. One survey of 7.7 million square miles in 20 Latin American countries classified land use as being 20 per cent grasslands, 5 per cent cultivated (arable plus perennial crops), 50 per cent forest (with limited grazing), and 25 per cent waste lands.

In terms of livestock feed supplies, grasslands furnish over one-half of the total in many temperate areas and 85 to 90 per cent in tropical regions. Grassland provides the environment and "grass" is the sustenance of the ruminant. Latin America is endowed with abundant land resources for pasture and livestock production. Its agricultural land area approximates that of the United States (511 and 504 million hectares, respectively). There are almost twice as many livestock units in Latin America as in the United States and Canada combined (213.7 and 114.7 million head, respectively). Nonetheless, only about one-half as much meat, one-third as much milk, and one-fourth as many eggs are produced in Latin America as in North America.

A. Natural Grasslands

Natural grasslands, with various indigenous species and different soil and micro-environmental conditions, make up most of the grazing areas in the tropics. Of 1,139,.5 km^2 of land in Colombia, approximately 40 million hectares are covered with naturalized or native grasses and there are only 4 million of improved (sown) pastures and forages. Estimated hectares of grasslands and per cent classified as "natural" in various countries are Brazil, 125 million hectares, 93%; Peru, 27,600,000 hectares, 93%; Ecuador, 4,656,000 hectares, 90%; Bolivia, 11.3 million hectares, 90%; Venezuela, 16.7 million hectares, 90%; and Africa, 696 million hectares, 90% plus.[1/]

Animal output from natural grasslands is low; estimates of carrying capacity are not certain but range from one beast per 5 to 25 hectares. Marked seasonal variations in growth and quality of herbage occur because of dry seasons, when the vegetation dries out to form coarse fodder of poor quality for browsing. Scarcity of water often causes poor herbage utilization because stock concentrates and overgrazes the plants near watering places, while pasturage some distance from water may not be utilized. In general, the vast regions of natural grasslands support only a fraction of the cattle in a country - e.g. about 8% of the cattle in Colombia are found in the Orinoco Basin which has [illegible]0% of the total grassland (approximately 16.5 million hectares).

1 Availability and nutritional problems

Utilization of natural grasslands is conditioned by seasonal distribution of herbage caused largely by soil moisture and partially by infertility. An abundance of herbage is generally present during the rainy season as new shoots or new seedlings develop and grow rapidly. Such young, leafy herbage is usually consumed in large amounts and is more digestible as compared to mature plants. The crude protein content of some indigenous grasses may reach 8-10% on a dry matter basis. Bunch-type grasses make up much of the sward and stem elongation and flowering begins before the onset of dry periods. As physiological maturity proceeds, the leaf-stem ratio widens and nutritive value declines. The plants become progressively lower in protein, minerals, palatability and intake, digestibility, and higher in fiber and lignin. The energy and protein utilized by ruminants declines sharply because of intake and digestibility reductions. Tropical grasses are generally lower in minerals, digestibility coefficients, crude protein and energy utilized by ruminants than are temperate grasses. Digestibilities of tropical species seldom reach 65%; values of 50-60% are common (versus 55-78% for temperate climate species). Mature tropical grass may drop to 25% less as compared to 45% for temperate grasses.

In the mature tropical grasses crude protein may fall to a critical level of 5% or

---

1/ Figures for Bolivia, Venezuela, and Africa are taken from the FAO 1966 Yearbook and represent permanent pastures and meadows and probably do not include all of the natural grasslands; other figures are estimates made by Daves, Wm. 1960. Temperate (Tropical) grasslands. Proc. 8th Int. Grass. Congress 1-7.

lower. Below 7% crude protein, voluntary intake of the poor quality grass is limited so that the requirements of the rumen flora cannot be satisfied. This also has a marked effect on intake by decreasing the rate of digestion. A possible deficiency of certain minerals in the forage may accentuate the problem. For example, a phosphorus or cobalt deficiency has a profound effect of lowering feed intake in ruminants. During dry seasons, the further decreases in digestibility of grasses may occur due to losses of soluble mineral, energy and protein constituents from respiration, leaching and microbial fermenting. With low intake and digestibility, as during drought, cattle go hungry for lengthy periods. Nutritional requirements drop below that needed for maintenance; hence cattle lose weight, may have low and delayed conception, and maturity is prolonged so that slaughter occurs when animals are 6 to 7 years old. Under such nutritional stresses, there are often breaks in breeding cycles so that yearly calving percentages are unduly low, making it difficult to maintain herd replacements and provide cattle for slaughter. While breeding, control of diseases, and other input factors are important under such conditions, first attention must be given to the problem of adequate nutrition throughout the life of the animal. It is important to examine the problem of a year-round feed supply of an adequate nutrition level so as to support a given livestock enterprise. Provision of supplementary feedstuff might be an expediency; the growing of special crops for silage or green chop, the utilization of plant refuse byproducts, or urea supplements during nutritional stresses are feasible solutions. For instance, feeding supplemental protein to very low protein diets usually increases the rate of digestion and hence intake of low quality roughage. Crude protein and minerals should be supplemented, if deficient. A low level of supplement containing a high urea level would be satisfactory for animals at low production, such as pregnant beef cows. The minerals could be supplied in the protein supplement or by allowing the cows access to a mixture containing the deficient minerals mixed with salt. Under extensive grazing schemes, other alternatives such as providing off-season pasturage from sown species may be implemented. It may be more practical to irrigate sown species for off-season production than to conserve forage

Immature and actively growing pasture plants will more nearly provide the mineral needs of ruminants than mature plants. Plant constituency varies with the mineral content of soils and of pasture species for given stages of growth. A survey of several commonly occurring native grasses and legumes in Colombia showed a prevalence of low phosphorus content in many regions, but calcium was generally adequate. Mineral supplementation (indirectly pasture improvement) may be the initial step toward animal improvement on the low fertility natural grasslends. In fact, data obtained by ICA with salt supplements in the Llanos Orientalis of Colombia indicate a yearly per head increase of [illegible] kg of San Martinero cattle stocked at one beast per 5 hectares.[1/] Thus, a simple management practice resulted in decided increases in animal outputs and permitted a carrying capacity almost three times that normally used in the region. Other practices such as judicious mowing, controlled burning or a scheme of intensive grazing coupled with resting or rotational grazing might permit further increases in stocking rates. Alternatives mentioned earlier in this section should be examined by the Pasture-Animal Program of CIAT. After all, the application of man's knowledge has altered the development and maintenance of grasslands more than any other factor. Most grasslands are unstable vegetative sub-climaxes with dynamic natural shifts of species. The cattleman's aim for many tropical grasslands must be to improve the natural sward by encouraging the development and spread of more valuable species components at low costs and with simple methods. Research must aid in resolving the economic exploitation of this biological complex.

2. Burning influence

Use of fire, ignited by man and lightning, has probably been the most ancient and important influence on vegetation. The morphology and growth patterns of perennial grasses are aids in the resistance to burning injury: perennating organs are close to or protected by the soil, seeds ripen and fall to the soil before the advent of hot and

---

1/ Personal communication with Instituto Colombiano Agropecuaria (ICA) Animal Scientists.

ry weather and only one seasons growth is destroyed. The effects of fire are contra-
ictory because of many interacting factors and difficulty of experimentation; hence many conclusions are based on historical evidence without precise measurements. Burning ay be deliberately used for bush control, to rid land of coarse, unpalatable herbage and to reduce the encroachment of undesirable species. Burning of mature woody grasses de-troys inedible and dead plant refuse and encourages new palatable herbage because of ess light competition. Indiscriminant burning when regrowth will not occur is too often the practice. Without judicious fire management the "harsh" grass species may be favored the expense of the "soft" species which do not survive when burned (e.g. molasses grass). Additional research is needed to evaluate burning practices (particularly in Latin America nce most of the available data are from the U.S., Africa, and Australia). The effects grazing and burning are interrelated and must be studied together - e.g. in Queensland, grazing of annually burned pastures promoted the dominance of the undesirable spear grass (eteropogon contortus) but in protected areas the preferred kangaroo grass (Themeda australis) predominated. Other factors to be considered include season of the year, amount o inflammable material, frequency of burning, weather condition before and after burning, a resistance of the plant species to fire.

Burning often and at critical times, concurrently with fertilization and grazing, h been an inexpensive method of establishing sown species by attaining reduced competion from natural grassland species.

3. Grasses

A number of ecological surveys show an abundance of grass species in the tropics. More than 1000 have been classified in Mexico, over 800 in Brazil, 600 in Colombia, and 30 in Costa Rica. These surveys are floristic in nature and do not provide information on seasonal distribution, yield, and nutritive value. The CIAT Program should include re earch to evaluate the contribution of various dominating species in swards with graz-in animals. This can be done by seasonal sampling, chemical analyses, in vitro or in vivo digestibility studies, and by grazing trials. Other information could be obtained as an adjunct to grazing trials, e.g. botanical composition, plant nutrient content, and digestibilities from on-going grazing experiments.

Species replacement and succession are important factors in improving natural grasslands for more intensive management (efficient production) and improved nutrition. Thus, introduction, testing, and evaluation of species must be carried out under varying ecological conditions. It has been shown that introduced superior species permit higher grazing intensities than for indigenous plants - e.g. one beast per hectare on unfertilized molasses grass (Melinis minutiflora) in the Llanos Orientalis of Colombia, 1.5 - 2.0 head per fertilized hectare of Brachiaria decumbens and Hyparrhenia rufa vs. one head on 5 to 20 hectares of natural pasture[1/]. As rapidly as better pasture species are identified, animal evaluation studies (intake and digestibility trials with later grazing experiments) should follow along with agronomic aspects of establishment, forage production management, maintenance. In some areas species replacement may be accomplished without tillage, e.g. close grazing, mowing or burning, and sowing seed of Melinis minutiflora (molasses), Hyparrhenia rufa or Panicum maximum (guinea grass) or transplanting vegetative pieces of Digitaria decumbens (pangola), Brachiaria spp. or Axonopus micay, etc. Combinations of these practices coupled with soil amendments may be an economical way to establish other improved pasture plants.

4 Legumes

Legumes are scarce and make no significant contribution to grazing under natural grasslands on acid and low fertility conditions. Assuredly they will become important as improved pasture management practices are adopted. (See Section on Legumes under Sown Pastures)

5 Fertilization and liming

Natural pasture species on acid, low fertility soils that have become adapted through principles of the "survival of the fittest" during many years, will rarely give an econo-

---

1/ Personal communication with ICA Pasture and Forage researchers.

...ical response in terms of increased animal products. The ash constituents for lime or fertilizer nutrients that have been added would usually increase, but the utilizable energy and protein may be expected to remain low. On the other hand, liming and fertilizing should be implemented concurrently with introduced pasture species evaluations. A knowledge of soil nutrient status and fertilizer responses become increasingly important as artificial pastures (higher yielding and more nutritious) replace the natural grasslands. (See Fertilizing and Liming under Sown Pastures, Section B-3, below).

B. Sown Pastures

The best possibilities for improving livestock products per animal and per land unit are with sown pastures. Sown tropical pasture and forage species possess potentials for high rates of dry matter accumulation and nutritious herbage as compared with natural grassland species. Nutritious forage from desirable species interacts to reduce the harmful influences from diseases, parasites and other stresses of ruminant animals.

Sown pastures (improved and artificial) comprise only a small percentage of the total land area used for animal production in the tropics. Because of poor grazing management, choosing unadapted or nutritionally poor species, and/or low soil fertility, animal output from seeded pastures may be no better than for natural grasslands. On the other hand, with favorable management of the soil-plant-animal factors, one hectare often supports two or more beasts during wet seasons and about one beast during dry seasons. Carrying capacity and animal output have been sharply increased by fertilization (particularly with nitrogen and phosphorus), good grazing management, and by irrigation of adapted and nutritious species.

Sown pasture regimes require more capital outlay per unit of land than for natural pastures; thus, the manipulation of the interrelated factors for high outputs are profoundly important. Much technical skill is needed for the management of sown pasture enterprises, but the simplest and least costly operations for obtaining high production per acre and per animal should be the goal.

1. Animal evaluation

Pastures and forages *per se* are of no value except in terms of animal uses and products. Some improved grasses have been characterized by agronomic studies such as yield and persistence. Limited animal performance trials have been conducted for short periods but usually with methods that did not realize the per animal and hectare output potentials. The general lack of progress in animal production in the tropics may be attributed to isolated attitudes and research efforts; the resources already available have not been exploited to advance animal production. Research is especially needed on developing alternative pasture and forage management systems that furnish reliable nutritious feed supplies at low costs for the longest possible part of each year. Ruminants cannot hibernate, they must have feed; however, animal breeding cycles should be manipulated and timed to fit the expected flush growth curves and seasonal nutritional undulations.

As soon as feasible, CIAT should sponsor animal evaluation trials to explore nutritional and productive potentialities of grass species. Some of the more important grasses ready for pasture evaluation with ruminants include: guinea (*Panicum maximum*), para (*P. purpurascens*: syn. *Brachiaria mutica*), puntero or jaragua (*Hyparrhenia rufa*), pangola (*Digitaria decumbens*), molasses (*Melinis minutiflora*), *Brachiaria decumbens* and *B. ruziziensis*, and elephant (*Pennisetum purpureum*). As programs develop, other promising species should be investigated with grazing experiments. Initial investigations should be conducted without energy and protein supplements. In grazing trials three critical periods for growth of grasses which reproduce from seed and not vegetatively should be considered: (a) the flowering period, (b) the change from seminal to a coronal rooting system (generally occurring about one month after seedlings emerge), and (c) the period of major transfer of carbohydrates from aerial to storage organs, which usually occurs at the onset of the dry season.

Corollary studies of forage intake and digestibility along with *in vivo* and *in vitro* and chemical determinations can provide supplemental and substantiating evidence on the value of species, selections, or varieties of grasses and legumes. Investigations should be made under several soil fertility levels, at different times of the year, and with plants in various stages of growth.

2. Conservation and supplemental feed

Supplies of adequate quality and quantity of feed with year around pastures for ruminants should be a target as conservation and supplementing feeds complicate feed production systems. For environments where plants are dormant, woody and of little nutritional value over prolonged periods, however, forage must be conserved during periods of flush growth for feeding to cattle when shortages or low quality of pasturage are problems. Forage conservation demands breadth in management ability and higher costs in additional structures, mechanization, and labor. The feeding value of conserved forages are almost always inferior to freshly grazed forages due to losses in minerals, protein, vitamins, and highly utilizable energy materials. Dry matter is lost by mechanical means, respiration and fermentation. The concurrently high temperatures and humidities in tropical areas may aggravate storage losses of conserved forages.

The lack of year-round plant growth often limits full exploitation of sown pastures and forage crops. Plant growth patterns are cyclic because of available moisture, generally with an excess of forage during the rainy season but a scarcity during the dry period. As plants become mature quality diminishes since they are low in utilizable protein and energy, and are high in fiber. Under these conditions, a grazing scheme can be programmed for a cow-calf operation, but for effective and efficient animal performance some type of supplementation is required. There is a paucity of information throughout the tropics to provide for alternative feeding systems. Some studies show that timely fertilization with rational herbage utilization extends the grazing period; forage accumulation *in situ* provides available fodder but is usually of low quality; ensilage, hay making, and irrigation offer a possibility but costs inputs may be prohibitive; annual crops such as forage sorghum and *Dolichos lablab* and perennials such as kudzu (*Pueraria phaseoloides*), *Leucaena leucocephala* and *Cajanus cajan* for greenchop or rational grazing could be used but management may be too demanding and costs too high, plants may be selected for browsing but little is known of this potentiality.

Waste plant products from fruit, vegetable, and sugar cane industries should be investigated as potential feed supplements, especially with dairy cattle. This is virtually an unexplored area but is one needing attention and a solution could make a tremendous impact on animal production in the tropics.

3 <u>Fertilization and liming</u>

The best improved sown pastures occur on the river valleys on alluvial soils where soil pH and fertility are rather favorable. As such areas are used for intensive cropping, pastures will be grown on the less fertile more acid soils.

There is a need for characterizing the differential and potential responses of grasses and legumes alone and in associations when grown on different soils. The fertility status on lateritic soils is a deterrent because of the acidity, phosphate fixation, and unfavorable chemical characteristics for correcting these adverse properties. Available data on some of the more fertile soils show quite high yields and sharp increases in plant growth with added increments of fertilizers.

There is strong evidence that the production of certain grasses is sharply increased by some sort of a symbiotic interplay. Observations in humid Northern Colombia indicated decided improvement in color, possibly protein content, and yields of elephant and guinea grass strains.[1] This mechanism should be fully explored.

Wide differences occur among grasses in adaptation to the inherent soil nutrient status - e.g. molasses grass (<u>Melinis minutiflora</u>) and <u>Axonopus micay</u> are generally considered low fertility requiring grasses and do not markedly respond to added plant nutrients. <u>Paspalum plicatulum</u> (brown seeded paspalum), which occurs naturally in some areas (<u>Llanos Orientalis</u>) and becomes more prevalent with rudimentary management, remains low in crude protein content, even with elevated doses of nitrogen. Still, it is superior to some other native species. Conversely, many tropical grasses readily respond to applied

---

[1] Personal observations in Colombia.

nitrogen, which increases the quantity of herbage and the percentage of crude protein, e.g. pangola grass at the Palmira Experiment Station in the Cauca Valley with no nitrogen, produced 3.0 tons dry forage per year and contained 6.0% crude protein; but with 400 pounds of nitrogen the yield was about 24 tons of dry matter with up to 16% crude protein. Grasses differ in their requirements and utilization of phosphorus: molasses grass has low and buffel grass (*Cenchrus ciliaris* syn. *Pennisetum ciliare*) has high requirements. They also differ in their need for potassium; molasses grass has low requirements as compared with guinea, pangola, and Rhodes grass (*Chloris gayana*). These grasses grow well on soils high in sodium which substitutes in part for potassium. All legumes are lower in sodium requirements than grasses; hence, grasses low in potassium and high in sodium might be especially compatible with legumes.

Sulphur or minor elements may limit growth and persistence in certain localities. Tropical legumes differ in soil nutrient requirements - e.g. Townsville lucerne (*Stylosanthes humilis*), used extensively in the Australian drylands, can thrive on extremely low phosphorus soils (plant tissue may contain less than 0.10% phosphorus which is below the approximate 0.14% minimum needed by grazing animals); whereas perennial soybean (*Glycine javanica*) requires a high level of phosphorus. The latter is also sensitive to magnesium shortages. In many areas, especially soils low in lime, molybdenum is needed for legumes.[1/]

As a corollary to plant-soil nutrient relationships plant mineral constituency should be investigated. This often reflects the nutrient status of the soil, and serves as a guide to needed fertilizer for yield responses. Mineral composition of pasture plant tissues is useful for diagnosing adequate mineral levels for livestock. Lime and plant nutrient requirements will interact with methods of pasture utilization; more fertilization will be required under cultural practices where all herbage is removed as compared with grazing. Grazing experiments with fertility levels should be conducted over a period of years to establish production patterns through the dung-urine to soil to

---

1/ Personal communication with pasture research workers in CSIRO, Australia.

plant seedlings

- *Tropical legumes*

Tropical legumes are potentially very important in pasture mixtures for two reasons: (1) low soil nitrogen in tropical soils limits the growth rate potentials and applying fertilizer nitrogen is often not economical for producing livestock products because of low feed conversion efficiency. Tropical legumes are estimated to fix 100 to 350 lbs/N per acre yearly when properly inoculated and cultured. (2) Legumes have decided effects on animals, causing improved calving percentages and growth rates of calves and larger cattle. In Australia dramatic success with tropical pasture legumes in different micro-environments has been attributed to adaptive cultural research with many introduced legumes, adequate plant nutrients, *Rhizobium* strains that fix nitrogen efficiently, objective plant breeding for animal utilization and suitable grazing management. Annual legumes are used in "harsh" environments with long periods of drought; whereas, perennials are used in favorable rainfall areas. Tropical legume strains also make significant contributions in humid environments in Hawaii.

A number of tropical legume species occur in sown pastures in South America - *Desmodium*, *Stylosanthes*, *Centrosema*, *Phaseolus*, *Clitoria*, *Calopogonium*, *Teramnus*, etc. Generally, legumes in pasture swards appear sporadically and erratically. A number of other legumes appear promising, but have not been fully evaluated: *Glycine javanica*, *Pueraria phaseoloides*, *Leucaena leucocephala* (syn. *L. glauca*) *Vigna* spp., etc. The findings in Australia suggest that the culturing of tropical legumes must be re-evaluated in various micro-environments in tropical South America. This could have a very decided economic and nutritional influence on cattle production.

In the CIAT program special attention should be given to legume bacteriology since tropical species have higher degrees of *Rhizobium* specificity than most temperate legumes. One point of importance is that many of the *Rhizobia* infecting tropical legumes are alkali producers and can thus grow in acid soils as contrasted to acid producing bacteria infecting most temperate legumes. Other factors to be considered are: (a) date of sowing to avoid high soil nitrate level caused by mineralization of organic matter at the beginning of the rainy season, (b) length of time for establishment - the Australians found that it requires as long as two years for certain species of tropical legumes to be fully established, (c) defoliation management to permit regeneration - most of the tropical legumes grow from the tips of the stems (terminal growth) and produce some axillary branches, but generally do not regenerate from stolons or crowns as do many temperate legumes, (d) assurance that deficient plant nutrients are provided either through natural soil fertility or by fertilizer amendments and (e) competition from companion grasses.

5. Plant protection and weed control

Pests including weeds, insects, and diseases are almost untouched investigations in tropical pastures and forages. Suppression of weeds (herbaceous and woody species) is generally done by hand labor and on limited areas; ravages of insects are usually unheeded and only a few surveys have been made on prevalence and damage by plant diseases. In the development of a CIAT Pasture-Livestock Program, attention should be given to these disciplines, but in cooperation with the allied scientists.

6. Improved selections of tropical pasture and forage plants

The few improved tropical pasture and forage species have been developed by selections among natural variants from phenotypes which appeared superior in forage yield, tiller production, leafiness, color, disease tolerance, and persistence. Varietal names have been given to some introduced accessions after limited testing, generally without selection but mass selection may have been imposed. The more sophisticated breeding procedures have not been employed, nor should they be until natural variation has been adequately sampled. Most of the tropical grasses are highly apomictic but generally sufficient sexual reproduction occurs to allow diversity of types among segregating progenies.

Recently, several clones of Imperial grass (Axonopus scoparius) with resistance to "gummosis" (a bacterial disease caused by Xanthomonas axonoperis) were found among na-

...rally occurring variants and released to Colombian farmers. At the Palmira Experiment Station in the Cauca Valley, an improved selection of forage sorghum with high forage yields and tolerance to certain diseases was developed by hybridization and selection among segregating generations. A similar improvement program of this species is carried on in Australia [1/]

An intensive tropical legume breeding program in Australia led to the release, multiplication, and seed distribution of Siratro, created by the hybridization of two introductions of *Phaseolus atropurpureus* and selection under heavy grazing into the F_5 generation. Two varieties of *Desmodium* - "greenleaf" (*D. intortum*) and "silverleaf" (*D. uncinatum*) - were developed after mass selection among direct introductions; three improved varieties of perennial soybean (*Glycine javanica*) - "Cooper," "Clarence," and "Tinaroo" - came after several generations of adaptation; Townsville lucerne (*Stylosanthes humilis*) arose after many years of natural selection in northern Queensland. Seeds of these improved strains are commercially available in Australia.

7. Collections and introductions

Grass-legume introduction gardens form a part of the "visitor circuit" on most experimental stations and School of Agronomy campuses in Latin America. In many instances they have existed for unrecorded years - to the degree that origin has been lost with antiquity. Some exchange of material occurs but viable and useful information generally cannot be found, nor is there an organized scheme for coordinated evaluation and subsequent use by farms. This is not always true, as pangola grass (*Digitaria decumbens*), a vegetatively propagated pasture plant, was introduced into Latin America in the early 1950's and promptly spread over a larger area in a shorter period of time than any other tropical species. In reality, dissemination proceeded too rapidly, as some farmers destroyed excellent stands of guinea grass to establish the "novel" pasture crop. Much to their dismay, it was discovered that pangola required more careful management and a higher soil fertility than many of the presently used species.

1/ Personal communication with ICA and CaRo forage and pasture workers.

Introductions and collections of exotic materials often become the instrument for [illegible] pasture and forage improvement. Certainly, diverse germplasm forms the basic foundation for a breeding program. CSIRO in Australia through its plant introduction organization acquired several thousand tropical and subtropical grasses and legumes during the past thirty years. Screening and assessment involved the close collaboration of several specialists in different environments. Plants that appeared promising for a particular environment were advanced to a cooperating group for further testing, commonly under grazing, and for seed production and distribution. Some 18 new grasses and legumes have been developed to the stage of commercial exploitation by such a cooperative effort in Australia. A number of these plant introductions came originally from Latin America and are presently being re-introduced.

A centralized and coordinated forage and pasture plant introduction organization is needed in Latin America. At present there is no such organization. Beginning in the late 1950's and with added impetus in the early 1960's the IRI Institute sponsored an extensive grass-legume collection expedition in Brazil. As a consequence one of the largest collections of plant materials in South America exists at Matao in Sao Paulo. Much potentially valuable plant material entered into independent exchange programs, but an adequate evaluation system failed to materialize - largely because of inadequate funds and a lack of a unified Interamerican Plant Introduction and Testing Program. CIAT should give purposeful consideration in assuming a leadership role in promoting such an organization.

One requisite to pasture and forage improvement in the tropics will be the accumulation and evaluation of germplasm. Later, plant breeding and genetic investigations must be actively pursued in developing superior varieties. The role of CIAT may be that of providing the impulse and supplementation for national programs rather than actual engagement.

8. Seed production of tropical pastures and forage plants

Seed and planting stocks of tropical grasses and legumes on a commercial basis do [illegible], except for a small number in Australia. Multiplication of improved seed [illegible] that continent is limited and distribution to the outside is generally re[illegible] a few pounds of seed at exorbitant prices (as compared with temperate pri[illegible] compared with temperate zone grasses and legumes. One small seed plant in Costa Ri[illegible], near San Jose, processes several grasses but only for local consumption. The ministry of Agriculture in most countries provides limited quantities of [illegible] stocks but for the most part, seed movements are from farm to farm. With [illegible] seed goes from an experiment station to the more aggressive cattle[illegible] ranch to ranch. For some species, such as guinea grass, molasses grass and [illegible] (*Hyparrhenia rufa*), cattlemen use hand labor to collect their own seed. Occasionally [illegible] seed is marketed locally, but viability and germination, and vitality of [illegible] is extremely low - e.g. local seed of guinea grass in the Cauca Valley showed [illegible] less than 1.0%.[1]

[illegible] for producing pure seed of good quality is a complex enterprise - crop [illegible] seed harvesting, processing, storing, and distributing. A lack of such a [illegible] and marketing service is a deterrent in the tropics. Seed deteriorates [illegible] of high humidity and temperatures which encourage microbial activity. [illegible] is needed to apply the techniques, methods, and procedures from the [illegible] regions. The Australians have made a beginning and other seed research or[illegible] look to them for leadership. The role of CIAT may motivate and stimu[illegible] activity. It will be necessary for the CIAT Program to engage in basic [illegible] research on phenological investigations and other factors that influence [illegible] and the production of high yields of quality seed.

[illegible] analysis of livestock production from pastures

[illegible] impossible to find concrete and valid economic information based on [illegible] various input factors and final products. Projections have been made [illegible], but the basis for their compilation have been derived from rather meager

---

[1] [illegible] with ICA forage workers

[illegible]

... is the poor performance due to malnutrition, parasitism, disease, or climate (temperature and humidity)? Undoubtedly, any one or more of these could interfere with the estrus cycle, semen quality, conception, implantation, and embryo survival. It is likely that a combination of these factors are involved under present grazing and management procedures in the tropics.

After the cause(s) of the poor reproductive performance is established, preventative measures will be tested. This may include good animal management procedures, nutrient supplementation, use of drugs and medication, and appropriate breeding systems.

3. Disease and parasite control

There has been a complacent attitude by livestock men in tropical environments that the cost of losses caused by disease and parasites is one over which they have little or no control. Deaths from diseases such as foot and mouth, anaplasmosis, rabies, anthrax, and various infections are very high. Incidious losses from diseases and parasites in the form of unthriftiness, low rate of gain, poor milk production, and poor reproductive performance, although less striking, cause tremendous losses in productivity and efficiency. The parasite and disease problem, although serious in beef animals, is accentuated in dairy cattle as a result of more intensified production.

In all the research and demonstrations sound management systems should be followed. Also, immunization against such diseases as blackleg, anthrax, and anaplasmosis should become routine procedure.

Research should be conducted concerning the effect of livestock-pasture management on internal parasitism. For example, rotational or strip grazing should be compared to continuous grazing. Also, anthelmintics, such as phenothiazine and thiabendazole, should be tested. The use of various drugs and method of application for controlling external parasites should be tested also.

4. Genetics

Undoubtedly, livestock indigenous to the tropics are more resistant to the para-

n— exist, except for a small number in Australia. Multiplication of improved seed s— in that continent is limited and distribution to the outside is generally re- st— to a few pounds of seed at exorbitant prices (as compared with temperate pri- ces as compared with temperate zone grasses and legumes. One small seed plant in Costa Rica, near San Jose, processes several grasses but only for local consump- tion. The ministry of Agriculture in most countries provides limited quantities of seed of stocks but for the most part, seed movements are from farm to farm. With certain introductions, seed goes from an experiment station to the more aggressive cattle- men and then from ranch to ranch. For some species, such as guinea grass, molasses grass and jaragua (*Hyparrhenia rufa*), cattlemen use hand labor to collect their own seed. Occa- sionally the excess seed is marketed locally, but viability and germination, and vitality of seed is extremely low - e.g. local seed of guinea grass in the Cauca Valley showed germination of less than 1.0%.[1/]

Technology for producing pure seed of good quality is a complex enterprise - crop production, seed harvesting, processing, storing, and distributing. A lack of such a seed producing and marketing service is a deterrent in the tropics. Seed deteriorates rapidly because of high humidity and temperatures which encourage microbial activity. Adaptive research is needed to apply the techniques, methods, and procedures from the temperate regions. The Australians have made a beginning and other seed research or- ganizations can look to them for leadership. The role of CIAT may motivate and stimu- late this activity. It will be necessary for the CIAT Program to engage in basic seed research on phenological investigations and other factors that influence seed development and the production of high yields of quality seed.

9. Economic analysis of livestock production from pastures

It is almost impossible to find concrete and valid economic information based on the costs of various input factors and final products. Projections have been made elsewhere, but the basis for their compilation have been derived from rather meager

1/ Personal contact with ICA forage worker

Initially, research should be directed toward uncovering the cause(s) of the low calving percentage. In other words, is the poor performance due to malnutrition, parasitism, disease, or climate (temperature and humidity)? Undoubtedly, any one or more of these could interfere with the estrus cycle, semen quality, conception, implantation, and embryo survival. It is likely that a combination of these factors are involved under present grazing and management procedures in the tropics.

After the cause(s) of the poor reproductive performance is established, preventative measures will be tested. This may include good animal management procedures, nutrient supplementation, use of drugs and medication, and appropriate breeding systems.

3. Disease and parasite control

There has been a complacent attitude by livestock men in tropical environments that most of losses caused by disease and parasites is one over which they have little or no control. Deaths from diseases such as foot and mouth, anaplasmosis, rabies, anthrax, and various infections are very high. Incidious losses from diseases and parasites in the form of unthriftiness, low rate of gain, poor milk production, and poor reproductive performance, although less striking, cause tremendous losses in productivity and efficiency. The parasite and disease problem, although serious in beef animals, is accentuated in dairy cattle as a result of more intensified production.

In all the research and demonstrations sound management systems should be followed. Also, immunization against such diseases as blackleg, anthrax, and anaplasmosis should become routine procedure.

Research should be conducted concerning the effect of livestock-pasture management on internal parasitism. For example, rotational or strip grazing should be compared to continuous grazing. Also, anthelmintics, such as phenothiazine and thiabendazole, should be tested The use of various drugs and method of application for controlling external parasites should be tested also.

4. Genetics

Undoubtedly, livestock indigenous to the tropics are more resistant to the para-

tions. In the development and organization of the CIAT Pasture-Animal Program, ... ents should be designed in consultation with economists so that reliable cost ... may be ... ned.

... Management, Nutrition, Physiology, Parasites and Diseases, and Genetics

... mentioned previously, the primary objective of the program is to provide addi- ... quality animal protein for human consumption by utilizing pasture and forage ... rather than as low protein feeds. More meat and other animal products are need- ... the ... problem of human nutrition, protein deficiency. However, ... products must be produced efficiently.

... the major deterrents to efficient livestock production in the humid tropics, ... Latin America, is the low animal reproductive rate. In some areas, calving per- ... as low as 30 to 40 per cent. Increasing the percentage to a respectable 80 ... cent would at least ... meat production in such areas even if the other ... levels remained the same. Unthriftiness and poor growth of the offspring ... rather than the exception. Many new-born calves do survive or gain weight ... slow rate that it may require five to six years for them to reach acceptable market grades as compared to 15-18 months in the United States. High death losses are ... frequently reaching 20 to 40 per cent. Generally, milk production in the tropics ... dously low. The low reproductive rates, unthriftiness, poor growth, and low ... production are due to a number of factors including malnutrition, internal and ex- ... parasites, disease, poor animal management, and probably temperature and humidity.

... to remove deterrents and to attain a high rate of animal production from ... forages with maximum efficiency, research will need to be conducted in ru- ... nutrition, parasite control, disease prevention and control, reproductive physio- ... genetics.

... Ruminant nutrition

... regions where pastures and other forages thrive, usually maximum economy of pro- ... can be achieved by using high levels of them in rations of ruminants. Certain [illegible] stages of maturity contain sufficient energy to support high levels of [illegible]. Pasturage, especially natural grasslands, is often deficient in pro- [illegible] in certain minerals, even with lush growth. As the plants mature, the problem [illegible] critical. Not only will the levels of protein and certain minerals drop, [illegible] will increase in crude fiber and hence, lower the energy levels for ru- [illegible]. Therefore, to properly nourish cattle for given levels of production, the [illegible] will need to be mapped and corrected. Of course, a flexible manage- [illegible] would be in order to make maximum use of the forages at various seasons with [illegible] supplementation. For example, dairy cows at peak production, beef cows with [illegible], and fattening cattle could be grazed on the lush, young, leafy, high energy [illegible]. On the other hand, dry cows, pregnant beef cows, and stocker cattle could uti- [illegible] high fiber, low protein, and low energy forages.

[illegible] anticipated that studies would be conducted on nutrient requirements. [illegible] requirements) are obtainable from accepted feeding standards. Rather, studies [illegible] conducted to ascertain the levels of the various nutrients in the forages and [illegible] with which they are utilized. From these studies, supplementary levels [illegible] formulated and tested.

[illegible] areas of the world with good nutrition, along with disease and parasite [illegible] and good animal management, certain metabolic disturbances are encountered. [illegible] grass tetany, muscular dystrophy, ketosis, milk fever, and tympanites [illegible]. Although the cause(s) of these is not clear in all cases, they can usually be [illegible] by the use of proper management or supplementation. Initially, precautions [illegible] be followed to guard against such possible disturbances. If any of these [illegible] serious problems, research will need to be directed to finding the cause(s) and [illegible] measures.

2. Reproductive physiology

[illegible] poor reproductive performance is one of the main problems hampering efficiency [illegible] production in the tropics, research will need to be directed in this direction.

Initially, research should be directed toward uncovering the cause(s) of the low calving percentage. In other words, is the poor performance due to malnutrition, parasitism, disease, or climate (temperature and humidity)? Undoubtedly, any one or more of these could interfere with the estrus cycle, semen quality, conception, implantation, and embryo survival. It is likely that a combination of these factors are involved under present grazing and management procedures in the tropics.

After the cause(s) of the poor reproductive performance is established, preventative measures will be tested. This may include good animal management procedures, nutrient supplementation, use of drugs and medication, and appropriate breeding systems.

3. Disease and parasite control

There has been a complacent attitude by livestock men in tropical environments that cost of losses caused by disease and parasites is one over which they have little or no control. Deaths from diseases such as foot and mouth, anaplasmosis, rabies, anthrax, and various infections are very high. Incidious losses from diseases and parasites in the form of unthriftiness, low rate of gain, poor milk production, and poor reproductive performance, although less striking, cause tremendous losses in productivity and efficiency. The parasite and disease problem, although serious in beef animals, is accentuated in dairy cattle as a result of more intensified production.

In all the research and demonstrations sound management systems should be followed. Also, immunization against such diseases as blackleg, anthrax, and anaplasmosis should become routine procedure.

Research should be conducted concerning the effect of livestock-pasture management on internal parasitism. For example, rotational or strip grazing should be compared to continuous grazing. Also, anthelmintics, such as phenothiazine and thiabendazole, should be tested The use of various drugs and method of application for controlling external parasites should be tested also.

4. Genetics

Undoubtedly, livestock indigenous to the tropics are more resistant to the para-

[illegible] and certain diseases prevalent in the areas. These are often not very efficient [illegible] of meat or milk, however. Therefore, in order to remove the deterrents to [illegible] production and efficiency, it would be desirable to develop breeding plans which [illegible] retain the resistant or adaptive characteristics of the native cattle and improve [illegible]. Results obtained in Colombia indicate that by certain crosses, the re-[illegible] of the native cattle and the high milk producing ability of the Holstein can [illegible].

[illegible] be desirable, perhaps, if two different classes of cattle, one for meat production and one for milk production, would not have to be maintained. There is evi-[illegible] Holstein steers are efficient producers of quite desirable carcasses. Thus, [illegible] research should be aimed in this direction rather than toward developing separ-[illegible] systems for meat and milk production. Dual purpose cattle for meat and [illegible] been efficient for many years in European countries. Holstein feeder steers [illegible] premium in the United Kingdom. The cow-calf herd, solely for meat production, [illegible] much less efficient than milk-meat enterprises.

[illegible], it is very important for one or more professionals in the following disciplines to be on the CIAT Staff: animal management specialist, veterinarian, nu-[illegible], reproductive physiologist, and biochemist. This will make it possible to exercise all possible known controls in management, diseases, parasitism, insects, and [illegible] to maximize pasture-animal outputs and simultaneously diagnose any limiting [illegible] of factors. There must also be an opportunity for each investigator to [illegible] independent research.

[illegible] Program, Dissemination of Information, and Collaboration with National [illegible]tions

[illegible] of the Pasture-Livestock Program of CIAT will finally be determined by [illegible] increases of livestock products in countries in tropical environments [illegible]. Such increases in production must be economically profitable - i.e. [illegible] subsidization. Meaningful success depends on professional and technical skills [illegible] research pursuits and trained personnel for adult education and technical skills at the farm level. Excellence restricted to research and development will cause the pro- [illegible] stagnate unless extension-promotional programs are encouraged through trained [illegible]. Programs may fail at the farm level, unless training of technicians and [illegible] educational programs are envisioned. CIAT should take leadership in the necessary [illegible] [illegible]ining (experience and education) program(s). It is envisioned that CIAT could develop a training program to advance pasture-animal production patterned after that of [illegible]. This training and educational venture could be carried on very effectively within the [illegible]ated method of proceeding as given in this proposal.

The advancement of principles to improve production of livestock commodities depends on the competency of the staff of National Programs. Within the corps of research [illegible] who occupy positions in the National Programs are individuals with advanced de- [illegible] outside the region and others with local training that lack in experience [illegible] or both. Too often the scope of research does not extend beyond the nation- [illegible] and projections are limited to a narrow outlook within the confines of a [illegible] station. Additional training and experience outside sectional environments [illegible] benefit many of the researchers by up-dating ideas (new principles, methods, tech- [illegible], and procedures) and motivating the new "crop" of research personnel.

[illegible] from CIAT could form the operating team for coordinated regional activi- ties. It is anticipated that the CIAT Project Leader(s) will aggressively participate in the coordination, collaboration, complementation, and supplementation of on-going [illegible] Programs. This must be initiated before the products of a training course [illegible]. The basis for a continuing and lasting International Pasture-Animal [illegible] Program depends on training of future scientists and technicians.

The integrated research approach should be especially suitable for on-the-job experience by research and extension personnel and by technicians trained for servicing and conducting practical programs.

A considerable amount of literature exists for the agronomic aspects of this CIAT [illegible], but published information on pasture-animal investigations is meager. Information [illegible] in local publications which do not receive wide distribution. A series [illegible] Abstracts reviews many of the lesser known Journals but even they do not [illegible] many libraries in the tropical regions. Productive research and extension may [illegible] by exchange of ideas and information. This CIAT project, in collaboration with the library science Program, should consider means for accumulating and [illegible] pertinent literature.

[illegible] FOR DEVELOPING AN INTEGRATED PASTURE-LIVESTOCK PROGRAM

[illegible] objectives given in Section II suggest that these broad research and training [illegible] efficient production of animal products from pastures, embodying soil, plant, animal and climatic input factors, and their interplay may be developed in stages [illegible] a complete program. The costs and efforts in research investigations to improve animal production efficiency will be three to six fold more for meat and milk livestock [illegible] than for a total single crop (rice) investigational program. Because of the [illegible] interplay of soil-plant-animal factors, progress will be slow as compared to [illegible] crop program. Thus, the need to conduct investigations for additional years [illegible] the costs.

[illegible] with animal production are very costly as compared with single [illegible] because of larger land areas; more facilities; much more professional, [illegible], and labor personnel for herd management; and attentive animal care during [illegible] year. For example, the land area needed to evaluate four variables in terms [illegible] liveweight gains (output per animal and land area) would be 1000 to 1500-fold [illegible] that needed to compare the yield and quality of two crop varieties. The four-[illegible] treatment comparisons would not produce very useful data unless two or more [illegible] were imposed concurrently, thereby requiring eight variables to evaluate [illegible]. Furthermore, the liveweight data would apply only in a general way to milk production and animal reproduction. Such land costs make up only a small fraction of the [illegible]. Other costs include all specialties of single crop cultures plus animals;

... water; facilities for weighing, milking, and carcass evaluations; animal para-... disease, and insect controls and investigations; and the conduct of experiments ... several animal generations in reproduction investigations.

... soil-plant investigational complex with a single crop is much less costly be-... fewer investigations and less time is required when compared with a pasture-... k complex. This is attributed to the many grasses and legumes in seeded pas-... and natural grasslands that must be studied within pasture evaluation programs. ... research, breeding and genetics for improvements, fertility and soils re-..., and cultural and management information is scarce as compared with wheat, maize, and .... Also, investigations with pasture perennials that are eventually used in ... mixtures require more time and space than for annual crops. Finally, such ... investigations may be of speculative value unless evaluations are made ... animals.

... ess of this project will be measured primarily by the output of livestock ... ities in subsequent years. To obtain rapid and applicable results, it is most ... to use an integrated approach, involving a team of cooperating specialists, ... ll individuals are concerned and dedicated to the task of producing livestock ... through the complex input factors and their interactions. Extreme departmen-talization, symbolic of many land grant universities and federal projects, is a con-... administrative device, but it often deters livestock production because it iso-... the specialists from the important interrelated factors. The business of animal ... ion is not departmentalized, it is a symphony of an ecological interplay of in-... tors. Thus, the administrative setup for livestock production from pastures ... have a director that encourages individual specialists to contribute to the eco-... symphony. In such team efforts minds meet on the planning and debating table; ... ity is maintained as minds are not to be amalgamated. Each scientist may ... ntributions in a dual manner, i.e. team responsibility and other or individual ... h. The unit may be small or large, but it should be objectively coordinated make an impact. Such programs with coordinated efforts of team members for augmenting the production of animal products have had tremendous impacts on animal agriculture in New Zealand and Australia.

Because the complete pasture-animal program cannot be initiated at one time, the ... in Section II are generally given in order of priority for "growing into" the pasture-livestock investigational program. The tentative arrangement of the priorities should not be misconstrued as relative significance of scientific endeavors, since no specialization is more important than another. During the investigations, as ... of special potentialities become apparent, the order of investigational ... should be altered.

A successful livestock program that will survive economic cycles must have ample supplies of pasture or other low cost feed that is sufficiently nutritious to attain optimum growth and reproduction rates of ruminants. Other factors such as diseases ... nullify responses, but high nutritional standards usually interact to reduce ... impacts from certain diseases, parasites, conception deterrants, or environments. The research philosophy for success must be one to utilize the solar flow of energy to plants and the subsequently elaborated compounds by plants and ruminants as efficiently as possible in terms of animal products by manipulating soil, plant, and animal input factors.

Why are cattle enterprises not now "booming" in the humid tropics? The favorable temperatures all year, along with high light intensities and favorable photoperiods, suggest tremendous potentialities for harnessing the flow of radiant energy through the plant to ruminants. The fact that this potential has not been exploited to any degree of efficiency is strongly attributed to "fragmented" research that has not ... nor solved the practical interplay of problems of raising livestock. Today the reasons for suboptimum animal performance remain unknown. For example, low calf-crop rates may occur because of nutrition, diseases, parasites, physiological, or genetic factors. An integrated team effort would pinpoint production deterrents and desig-

[illegible] need for special investigations. This is the time for a team of specialists [illegible] their talents with dedications to attain the primary objective.

[illegible] of initial costs, development, procurement of personnel, and facilities, [illegible] some of the pasture-livestock phases may need to be staggered (Section II) [illegible] investigations may be done with steers at low costs when compared to a herd [illegible] production investigations. When considering steer performances, the data may [illegible] as a rough index for possibilities with animal herds. A livestock business [illegible] be successful without raising calves efficiently. Thus, a beef herd should [illegible] as soon as feasible to study and manipulate the factors that influence [illegible], conception, calving (per cent raised and rate of growth), longevity and re- [illegible] life histories. A competent animal ecologist should manage the herd. Re- [illegible] principles in beef cattle apply directly to dairy herds. Work with dairy [illegible] be delayed; however, milk production potentials cannot be projected without [illegible] lactating cows.

[illegible] employment of dual purpose herds (meat and milk production) for improved pas- [illegible] and efficiency may be an important objective in the future.

[illegible] programs should obviously be started after a sizeable research program has been developed. Research staffs, data, and soil-plant-animal facilities are necess- ary for the implementation of various training programs.

Staffing, and physical facilities will depend on the magnitude of the program.

[illegible] STAFF AND FACILITIES

[illegible] Professional Staff for the Pasture-Animal Program

The following list includes minimum specialization and dual responsibilities are included in several of the position categories. The professional staff should have training and experience to qualify as associate or as senior research officers and should accept dual responsibilities in research and training agendas. Several special- ists would be needed initially in certain categories such as pasture agronomists (soil-plant-animal interrelationships). Some professional categories could be initially served through consultantships varying in length of service.

Pasture Agronomist (3)

Soil Chemist (Plant Nutritionist) (1)

Soil and Legume Bacteriologist (1)

Biochemist (1)

Chemist (Organic and Inorganic) (2)

Weed Ecologist (1)

Climatologist (1)

Entomologist (1)

Animal Nutritionist

Rumen Nutritionist

Animal Ecologist

Veterinarian

Animal Physiologist

Reproduction Physiologist

Animal Parasitologist

Animal Pathologist

Animal Breeder

Food Scientist (meat and milk processing)

Plant Physiologist (1)

Soil Physicist (Irrigation) (1)

Plant Breeder (Grass and Legume) (2)

Seed Physiologist (Production) (1)

Plant Pathologist (Nematologist) (2)

Statistician (1) CIAT

Economist (1) CIAT

Agricultural Engineer (Construction, Machinery) (2) CIAT

Electronic Specialist (1) CIAT

Journalist (Editor) (1) CIAT

Plant Ecologist (Consultant)

Geologist (Consultant)

Pedologist (Consultant)

B. Educational and Training Programs for Technicians, Extension, and Research Personnel

Objective research for the advancement of practical production of animal products in tropical regions will stagnate at the research level unless farm and industrial technicians and extension personnel are trained to extend research principles. But again as with research in the soil-plant-animal complex, training programs involve many input factors and areas of specialization as compared with a "cash" crop. This will add costs and time to training programs. Advanced training programs that allow for specialization and additional experience, to augment research and teaching proficiencies, should be available opportunities.

1. Initial Personnel

   a. Journalist and editor -- research and education, CIAT

   b. Informational specialists and lecturers -- coordinate educational and training programs, accumulate and arrange information, and handle guests.

C. Physical Facilities - Office, Laboratory, Teaching, Housing

1. Research and Education Programs

   a. Offices and specialized or other laboratories for all professional staff listed (see VI A).

   b. Other physical facilities:

      Secretary offices

      Small offices for in-training scientists

      Seminar rooms -- (small) -- CIAT

      General tea and coffee room -- serve as meeting and discussion area

Auditorium for lecture - CIAT

Central library - CIAT

Accounting office - CIAT

Photographic and duplicating laboratory - CIAT

Housing dormitory for trainees and single CIAT technicians

Central Dining facilities - CIAT

Cottages for resident married technicians that look after animals.

2. Supporting Facilities

Machine and repair shop and storage - CIAT

Woodwork and painting shop and storage - CIAT

Machine storage -- several sheds - CIAT

Electronics shop and storage - CIAT

Environmental control building for seed and animal investigations

Isolation barns -- diseases and parasites

Quarantine building

Dairy research center - open housing, milking parlor, maternity space

Hay driers and storage building

Upright silos (8 x 25 ft.) and bunker silos

Pole barn roof cover for feeding and handling animals to obtain data on digestibility coefficients and nutritive value indicies.

Weather recording station and equipment

Feed storage and mixing

Equipment for land preparation, fertilizing, seeding, pasture maintenance, silage and hay making, green chop, weed control

Fencing

Heat drying of small pasture and forage samples.

Equipment for small plot investigations

Pick-ups and tractors

Greenhouse space - CIAT

Phytotron (Controlled chambers) - CIAT

Statistical laboratory - CIAT

VII. REVIEW OF SELECTED INVESTIGATIONS AND SUBSTANTIATING INFORMATION

A. Year-round Pasture and Forage Systems - Animal Evaluation of Pastures and Supplementary Feeds

Pasture and forage crops research in the initial phases of CIAT should focus on the development of year-round feeding systems for cattle on sown (improved) pastures. As cattle numbers are concentrated on the most productive pasture lands the immediate impact would be an intensification of the better grazing areas (i.e. regions where more than one beast is carried per hectare -- in the four departments of the northern coastal plains of Colombia: Atlantico, Bolivar, Cordoba, and Magdalena, about 5.85 million hectares of pasture land support 6.86 million head of cattle). These partially developed grazing lands are readily accessible to urban centers; generally, improved grasses which are responsive to applied plant nutrients have already been established; agricultural experiment stations are located within the region and available research should be directly applicable.

Information exists to show that a number of the tropical grasses are highly responsive to applied nitrogen. Forage yields increased linearly with additions of nitrogen up to 1000 lbs./acre (Appendix C-1, C-2) when grass herbage was removed. Under grazing it would appear that less nitrogen was needed. Studies in Brazil (Appendix D-1, D-2, D-3), in Colombia (Appendix E-1, E-2) and in Australia (Appendix E-3) suggested that from 30 to 50 lbs./acre of nitrogen would be sufficient for high yields when applied at intervals of 6 to 8 weeks. Timely applications of nitrogen stimulated pasture output. Under rotational grazing nitrogen topdressings were made after each resting period (Appendix E-1, E-2) or after each second rest period (Appendix E-3). With continuous grazing a seasonal topdressing generally corresponds to the rhythmical growth cycle of the grass, rainfall distribution or temperature effects (Appendix D-1, D-2, D-3, E-4).

Fertilized grass is capable of producing more than 2000 pounds of liveweight gain per acre as shown by data from Colombia (Appendix E-1, E-2), and Australia (Appendix E-3). In Brazil (Appendix D-1) cattle on fertilized grass could be marketed at 2 to 3 years of age as compared to 4 to 6 years under normal range conditions; nitrogen at 200 kg./hect. more than doubled yield over no nitrogen in terms of Total Digestible Nutrients/hect., steers/hect and liveweight gain/hect., but did not affect age of finish; use of 200 kg./hect. of nitrogen, 100 kg of P_2O_5 and 60 kg. of S gave an annual net return of about $45 (U.S.) over the no fertilizer control. In Puerto Rico (Appendix E-4) use of 1800 lbs./acre of 14-14-10 fertilizer as compared to 600 lbs. increased yearly beef gains from 570 to 1072 lbs./acre; carrying capacity was almost doubled from 1.4 to 2.2 600 pound steers/acre; the forage protein was increased from 8.1 to 15.9 per cent.

These results reflect the animal performance potential which may be expected with tropical grasses. They do not adequately characterize the differences among grasses or pastures nor is there sufficient information to compare different management systems of selected pasture plants. The cost returns are based on present prices of nitrogen fertilizer. It is anticipated that nitrogen costs will decline, as has occurred in the United States, thus reducing pasture production costs. Since tropical soils are generally low in nitrogen content and favorably respond to amendments, the practical potentials might reach sizeable magnitude.

Animal trials should be designed to provide knowledge of feeding (pasturing) systems, stocking rates, and forage conservation (or supplementation) practices. Type of design depends to a great extent on the purpose of the pasture, whether it is the main or sole source of feed throughout the year or is to provide feed for only a season of the year. In the former instance, the off-season becomes critical and may determine the over-all stocking rate; alternatively, conservation of feed (or provision of supplementation) during scarce pasturage is required. In the latter cases maximum grazing intensity consistent with plant survival and sound pasture management can be used. In view of the present need to improve the animal nutritional status in the tropics the first priority is to measure the performance of grasses (in pure stand and later as mixtures) throughout the year and then evaluate potential animal performance. Grazing (feeding) systems cannot be judged alone but must be considered in relation to farm management as a whole.

Productivity of grazing animals in the tropics is limited by the low feeding value of the pasture. Tropical grasses are strikingly less digestible at all stages of growth than the cool season grasses (Appendix F-1). Studies in southeast Queensland and data from the United Kingdom showed that the maximum dry matter digestibility of orchard grass was 76%, perennial ryegrass 80%, Paspalum commersonii (a common Australian grass) 74% and Urachloa pullulans (also Australian) 57%; minimum digestibilities dropped to 48, 60, 31, and 34 percents, respectively.

As plants mature animal intakes for most tropical grasses are reduced (Appendix F-2), e.g. with immature buffel grass (30 days of age) the daily intake reached 70 gm. dry weight of forage per kg.$^{0.73}$ of animal liveweight, but when more mature (250 days of age) dropped to 22 gm. Intake of pangola grass declined from 67 gm. at 30 days to 24 gm. at 150 days. Physiological condition of the forage plant also affects intake. Cutting and feeding Paspalum plicatulum (Appendix F-3) in the early seeding stage, but lush plant growth, gave a daily dry matter intake of 916 gm. per head with sheep; with frosted leaves, but succulent stems, intake declined to 677 gm.; with leaves and some frosted stems it dropped to 582 gms.; when the entire plant was severely frosted it decreased to 359 gm.

Differences in voluntary intake appear to be related with rumen distension which depends to a great extent on feedstuff break-down and how long the undigested material remains in the rumen (Appendix F-4). In Venezuela elephant grass harvested after 30 days of regrowth required 45 hours to pass through the ruminant digestive tract and when cut after 70 days of regrowth, 65 hours.

Results with temperate grasses suggests that rumen bacterial activity may be depressed if the percentage of crude protein drops below 8.5. For tropical grasses intake declines markedly when the crude protein percentage falls below 7. This indicates that the low feeding values of many mature tropical grasses are due to low consumption caused by suboptimum crude protein for the rumen flora. To improve animal production when eating such forage (especially during the dry seasons) it is necessary to increase the amount of feed ingested. Since soil moisture usually limits plant growth, other management practices must be investigated. Irrigation, forage conservation, supplementation of urea and energy feeds or the growing of special arable crops could furnish good quality feed when pasturage is unavailable or of low quality. Such information is not generally available nor is it put into practical use.

Inferences can be drawn from present knowledge that suggest more intensive studies: Feeding values of legumes do not decline rapidly with maturity (Appendix F-2). Daily animal intake (gm. dry matter/kg.$^{0.73}$ liveweight) for perennial soybean (*Glycine javanica*) remained at 80 and 92 gm. when plants were 150 and 250 days old; for Siratro (*Phaseolus atropurpureus*) it was 72 and 75 gm., respectively. Thus, forage quality may be realized by accumulation *in situ* such legumes as *Pueraria phaseoloides* (tropical kudzu), *Dolichos lablab*, *Cajanus cajan*, *Desmodium* spp., *Leucaena leucocephala*, etc. Accumulated growth of legumes would be utilized by rational grazing. Forage sorghums and sudangrasses perenniate in the tropics and with adequate soil moisture and plant nutrients they can be harvested at intervals of 6 wks., yielding 40-60 tons of fresh material per hectare per year. They could be ensiled, fed as greenchop forage, or grazed. A host of other crops such as maize, elephant grass, etc. can also be ensiled. Pasturage may be accumulated *in situ* by restricting grazing or by timely cutting when combined with fertilizer application. Irrigation stimulates plant growth during dry seasons, but its potential use and economic value in the tropics awaits investigation. Feed supplements such as molasses and other byproducts may enhance intake of low quality forage. Urea supplementation of low protein grasses has notable potentiality since from 20 to 40% of the ruminant protein requirement may be urea.

f. Tropical Legumes Re-evaluated

Grasses thrive when nitrogen is available. It is supplied through the decomposition of organic matter (particularly the mineralization of nitrogen with the onset of the rains after dry periods in the tropics), through release from N captured by associated legumes, through N-carrying fertilizers, and a small amount by lightening and rainfall. Tropical legumes can provide the cheapest source of nitrogen but their use has generally been disappointing because of short plant duration. Success with legumes in the tropics begins with the concept that they are tropical in origin. Invasion into the temperate regions resulted from the differentiation and progressive changes in genotypes. Experimentation with these modified types led to erroneous ideas about growing legumes in the tropics. Legume bacteriology may be the key to success in the re-examination of tropical legumes. Calcium supply influences the formation and functioning of nodules, but Australian work shows that bacteria are not calcium - sensitive. They require calcium in trace amounts only and it is the host legume plant which requires quantities of this element. Tropical legumes are capable of extracting calcium under acid soil conditions where there is low calcium availability, as contrasted to temperate legumes. Also, tropical legumes and nodulating Rhizobia are more tolerant of soluble aluminium and manganese in acid soils than are temperate legumes. Furthermore, many tropical Rhizobia produce alkali buffers to counterbalance acid soil situations. Lime responses may be attributed to the release of molybdenum, which is required in the nitrogen fixing function of nodules, rather than changes in direct calcium supplies. Investigation in Australia showed that other elements such as sulphur and cobalt may be influencing factors but such information is lacking for Latin America and most of the other tropical regions.

The specificity of bacteria-host legume relationship is very important. Many tropical legumes nodulate successfully without inoculation but nitrogen-fixation may be ineffective or even parasitic. For example, Lotononis bainesii reached a height of about 6 inches in Colombian trials and never flourished; it responded similarly in Australia until a strain of Rhizobium found among introductions from Africa proved to be specific and exceptionally efficient in symbiotic nitrogen fixation. As a consequence this tropical legume is becoming of commercial significance and may obtain as great importance as some temperate legumes. In Australian plot trials and under field conditions the plants grew luxuriantly, provided excellent ground cover and produced a sward 30-36 inches in height. The legume is compatible when mixed with pangola, guinea, and other grasses and plants have begun escaping into adjacent roadsides and waste places.[1/]

Tropical legumes generally produce few crown regenerative shoots but grow from the tips and axillary branches. Many are trailing and vine like and do not readily root at the nodes. Thus, grazing management differs from that of temperate legumes. Most tropical legumes develop enlarged tap roots but secondary roots arise further below the soil surface as compared to temperate species. This suggests a modified scheme for maintenance fertilization. Seedling aggressiveness of many species is poor, thus the establishmental period is prolonged and faster growing grasses may predominate. Tropical legume species differ in water requirements, plant culture, soil requirements, etc. The investigations with tropical legumes in Latin America are meager and special Rhizobia strains have not been considered. Most of the available information came from introduction garden observations, where management regimes similar to those for grasses and temperate zone legumes were used. Re-evaluations must include recent cultural information and agronomic and animal uses may be studied concurrently, first in pure stand and later in combination with grasses. Programming experiments with tropical legumes will require the collaboration of a "team" with representatives from several disciplines.

Not only do legume species provide nitrogen for an associated grass but their presence in a pasture sward usually sustains the nutritive value of the pasturage.

1/ Personal communications with ICA and CSIRO forage research workers.

Limited research shows that the ingestion of tropical legume plants does not decline with maturity as with grasses (Appendix F-2). Furthermore, digestibility remains at a high level and may increase with those which produce large amounts of high protein seeds.

Addition of a legume to available feedstuffs improves the unit area carrying capacity, increases liveweight gain per animal, and enhances calving percentage (Appendix G). Overseeding native (natural) grasslands in Australia with Townsville lucerne (Stylosanthes humilis) and using 100 cwt. of superphosphate per acre dramatically changed carrying capacity from one animal per 15 to 25 acres to one animal per 1.5 to 3.0 acres. Furthermore, steers gained as much as 300 lbs./head/year, maintained body weight during the dry season and weighed 950 pounds at 2 3/4 years of age. At this same location pastures of Kangaroo grass (Themeda australis) and spear grass (Heteropogon contortus) never gave gains of more than 100 lbs./head/year; much of this was lost during the dry season; cattle were marketed at 6 to 8 years with a carcas weight of 550 lbs. It is significant to note that grazing one steer per acre of Townsville lucerne was equivalent to feeding 2.0 lbs./head/day of a high protein supplement. Also, brood cows on native pasture had a calving rate of less than 45% as compared to 68% and more when grazed on Townsville lucerne.[1/]

Townsville lucerne is an annual legume that produces 6000 lbs./acre or more of dry matter, plus a seed crop of nearly 1000 lbs./acre during a 3-month rainy period in northern Australia. It is grazed in situ during the remainder of the year and seeds are actually licked from the soil. This legume has helped to revolutionize the cattle raising industry in Australia. It came originally from Brazil. This suggests the unexploited potential of other legumes found in the tropics.

C. Improvement of Natural Grasslands

Pasture and forage research with natural (native) grasslands in the tropics is essentially unexplored. If the projected animal protein needs (as based on expected

1/ Personal communication with M.J.T. Norman, Division of Land Research, CSIRO, data from the Katherine Experiment Station, Northern Territory.

population increases) can be accepted as a target (Appendix H) parts of these immense areas must be more effectively utilized. Their development will be slow and arduous but inroads have been made and man's quest for expansion pushes still forward and further into the hinterland (See Appendix I for locations and descriptions of the natural grasslands in Latin America). Cattle numbers in Latin America have increased in recent years (Appendix B), and even greater numbers are projected for the future, as shown by the anticipated 1975 estimate in Colombia (Appendix J).

Problems encountered in pasture and forage improvement in the partially developed regions (e.g. Bolivar savannahs of Colombia and Costa Rica) can be compounded for the more remote and undeveloped areas. Research should lead the way and several developments suggest that improved production is feasible. At the "La Libertad" Experiment Station divisions into smaller grazing blocks, control of brush, and occasional mowing increased the carrying capacity - approximately 2.0 hectares per beast as compared to 15.0. The modified pasture and grazing management caused some of the more desirable grass species to increase and eliminated some taller growing, less consumed types. Increasing the stocking rate alone may not always give significant improvement as demonstrated by work in the Northern Territory of Australia. Replacement of native (naturalized) species with more nutritive grasses (still rustic but productive on the low fertility soils - e.g. molasses grass (Melinis minutiflora), Axonopus micay, Hyparrhenia rufa) can increase the carrying capacity and elevate pasture output. At the "El Pinal" Ranch near Orocue in the Llanos Orientalis, a molasses grass pasture supported one 300 kg steer per hectare and gave a liveweight gain of 150 kg in 10 months. Normal stocking on this ranch was 10 hectares per animal. An example of the possibilities has also been demonstrated on a ranch in the Lake Maracaibo region 10° north of the equator where, without irrigation but on improved and well-managed pastures, 1800 cattle were carried on 2,000 hectares.

Improvement of natural grasslands should proceed along an evolutionary pattern from simple to more intensive management practices. During the process improvements such as the following should be considered: introduction of more productive and nutritive grasses and legumes, use of fertilizers (Appendix K), improved grazing management and use of supplemental feedstuffs.

A study of dry matter digestibility of natural pasture forage in Australia was considerably lower than introduced (improved) grasses (Appendix F-3). The reduced dry matter intake was striking, being about 1/3 that of the improved grass.

Studies in North Queensland, Australia illustrated some of the improvements which can be made with native pastures (Appendix I-1). An undeveloped native range carried one animal on 50 acres with a yearly output of 2.0 lbs. dressed meat. Clearing and developing the area with sown pastures lowered the stocking rate to 3.0 acres per animal, give a yearly gain of 189 lbs. or 63.0 lbs./acre/year. There was a cost of $13.00 per acre (Australian) for clearing, fencing, seeding, fertilizing, establishing facilities for water, dipping and animal handling. At the current price of $20.00 (Australian) per 100 lbs. of meat expenses were defrayed during the first year of operation (Appendix I-2). Such phenomenal results are not to be expected with all underdeveloped grassland areas, but they do suggest tremendous potentials.

D. Pasture and Forage Crops Introductions and Regional Testing

In the development of a Pasture and Forage Program one must take inventory of the present situation which suggests the evaluation and utilization of those grasses and legumes currently in use. Introductions and assessments of pasture and forage crops are continually done by research workers at the experimental stations and Colleges of Agriculture and by ranchers but additional knowledge is needed. Species and varietal trials have been conducted in a number of locations in Colombia since 1955. Information is available to indicate adaptation, forage yield, and response to fertilizer. Similar evaluations are available from other countries, but not always conveniently found in published form.

Considering the extreme climatical, edaphical, and ecological conditions in Latin America a regional screening and testing program should be instituted in collaboration with other National programs. Information is needed about 1) adaptation, 2) seasonal production, 3) quantity of herbage on a seasonal basis, 4) quality - nutritive value at various times of the year, 5) flowering and seeding, 6) prevalence of diseases, insects and other pests, and 7) persistency. Agronomic evaluation should be carried out under at least two levels of fertility. Such trials can be handled similarly to the International Cereals Uniformity Tests. These testing sites should not be "show places" but designed to evaluate the species under conditions comparable to those under which they will be used (Appendix M). Since seed and propagating materials are not generally available, CIAT headquarters can serve as a focal point for early screening, maintaining, and distributing of materials, and in the accumulating and disseminating of information.

F. Laboratory Techniques for Nutritive Value

After the initial screening of forage and pasture crops, preliminary evaluation of their nutritive value and ingestion with animals becomes imminent. It should be kept in mind that ecological factors may influence nutritive value. Intake and digestibility data for most pasture and forage crops have been obtained by cutting and feeding to individually penned cattle or sheep. Descriptions of these techniques may be found in the literature. The quantity of forage needed to measure intake and digestibility with steers and with sheep (approximately 2.0 tons and 250 pounds of dry hay, respectively) preclude the use of these methods to screen the many tropical grasses and legumes. Suitable laboratory techniques can be used to advantage: 1) Small herbivorous animals, such as the rabbit (which is not suitable because of low digestive efficiency for roughage) and the small marsupial Setonis brachyurus which has a ruminant-like digestion. 2) Chemical analyses for determinations of protein and crude fiber, but relationships with digestibility are highly variable; soluble sugars which are related to digestibility and perhaps to intake; silica which is positively associated with crude fiber and negatively related to protein, sugar, moisture, and digestibility; and moisture which is related to intake and digestibility. 3) *In vitro* digestion in which samples of feedstuffs are incubated with rumen liquor and a proteolytic enzyme (pepsin). 4) Nylon bag dry-matter digestibility in which samples of feedstuff are submerged in the rumen of a fistulated animal. The latter two techniques are simple, rapid, inexpensive to conduct, reproducible under controlled conditions and require small samples of forage (Appendix N). Several studies have shown that they are comparable to results obtained by <u>in vivo</u> trials.

These methods cannot reproduce the effects of selective grazing in the field where forage quality is measured and described in terms of animal performance. Animal evaluation trials provide information for the forage agronomist and the animal scientist and they must be collaboratively carried out.

F. <u>Pasture and Forage Crop Improvement through Breeding and Genetics</u>

Little work has been done on breeding and genetical research aimed at pasture and forage crop improvement in the tropics. Most of the plant breeding effort in the tropical regions is directed toward crops such as corn, rice, oil seed, pulses, cotton, cocao, coffee, etc. as shown by the FAO World List of Plant Breeders. Grass and legume breeding in the tropics and subtropics remains in the pioneering stage with work done mainly in Australia and in the U.S.A. - Georgia, Texas and Florida. Simple mass selection has been carried out at Kitale, Kenya and specific hybridization (mainly with elephant grass) was accomplished in India. Most of the improvement has been achieved by selection among naturally occurring types. A wealth of material exists in the tropics and the array of diversity is generally unknown. In most tropical countries a vast storehouse of native grasses and legumes await genetical investigation. Only a fraction of the available gene pool has been assembled. Invasion of agricultural enterprises into uncleared regions may result in the loss of valuable material needed for continued progress in pasture and forage plant improvement.

The characteristics sought in the selection and breeding of tropical grasses and legumes are as follows: increased and prolonged herbage production, high quality forage which implies leafiness and high nutritive value, high palatability (especially in grasses - a medium level of legume acceptability could be an advantage for persistency), rapid regeneration after defoliation, tolerance of pests and diseases, compatability with other species, uniformity of flowering, adequate seed formation, ease of establishment, and efficient Rhizobium symbiosis for legumes. This broad spectrum cannot be explored concurrently. Investigation has shown that improvement can be attained with many of the characteristics: bermuda grasses (Cynodon dactylon) have been bred for increased forage yield, a higher percentage of leafiness, extended period of vegetative growth, improved animal acceptibility and recently, using the nylon bag technique to measure digestibility, a variety was developed with superior nutritive value. Rhodes grass (Chloris gayana) selections were made for the following: leafiness during the summer (rainy season), uniform seeding in the autumn (cool, dry season), drought tolerance, improved stoloniferous habit, and more dense swards. Variation in palatability has been encountered among types of Setaria sphacelata. Differences occur in crude protein values of guinea (Panicum maximum) and Paspalum plicatulum. Increased persistency was noted among types of Sorghum almum. Increased forage production, intensified stoloniferous habit, improved persistency under dry conditions and less seed pod shattering developed with Siratro, a variety of Phaseolus atropurpureus. Differences in such characters as time of maturity, rate of growth, forage yield, stolon development, size and shape of leaf were found among varieties of perennial soybean (Glycine javanica). Studies have shown that nutritive differences occurred among selections of Paspalum plicatulum (Appendix O).

Mode of reproduction in a species determines the extent of variability in its plant populations. Diversity is wide in cross-pollinated types but little or none exists within closely self-pollinated ecotypes. Phenotypic and genotypic differences do occur among species found in different regions. Apomictic strains usually have some degree of sexuality and variability. The manner of reproduction is known for many tropical and subtropical pasture and forage species but certain processes may be altered by environmental conditions - e.g. more than 50% crossing may occur in forage sorghums in the tropics as compared to 6% in the temperate regions; guinea grasses (and others) may flower rhythmically in areas with distinct wet and dry seasons but throughout the year in localities with intermittent rains. Before launching a breeding program a detailed knowledge of floral biology is needed, such as the factors influencing flower initiation, season of year when flowering occurs, time of anthesis, interval for pollen tube development and rate of growth down the stigma to the ovule, and mode of embryo development where apomixis is suspected.

It is possible that CIAT will not initiate breeding programs with a host of species (or even one) because of the vast array of pasture and forage crops available. The role of CIAT might be that of coordinating and supplementing work of the National Programs. Some of the more basic investigation with floral biology and genetical studies might be conducted at the CIAT headquarters.

G. Seed Production and Distribution

An improved variety or selection has no commercial value without an effective scheme for seed increase and marketing - this does not exist in Latin America nor in Africa. A substantial improvement in seed production technology must develop in the tropics so seed of useful tropical pasture and forage species flow freely in national and international trade channels as occurs for the temperate species. The system used in temperate regions embodies an immense reservoir of production and merchandising resources and skills. Through years of development, seed production and mechanization has become highly specialized enterprise in temperate zones. Somehow a pasture seed industry must be developed rapidly in the tropics. It will require the mobilization of knowledge from the temperate zone and adaptive research in the tropics and subtropics. Determined ingenuity, persistence and capital will be required to produce large supplies of quality seed of tropical grasses and legumes. Tropical species are often bulky vines, towering tussocks and woody shrubs with low seed set and have readily shattering pods and/or inflorescenses with non-uniformity in seed maturity. Hot and humid environments heap added problems onto the task of harvesting, storing and producing high quality seed. Thus, scarcity of seed of good germination, purity and viability is a critical problem.

In the early 1960's the state departments of agriculture in New South Wales and Queensland, the Universities of the two states, the Division of Plant Industry, the Division of Tropical Pastures, and several private seed companies launched a coordinated program to devise means for seed multiplication, processing, and distribution of tropical grasses and legumes in Australia. By application of available knowledge and through modifications of techniques and procedures, seeds of named varieties of several species are produced commercially - "Silverleaf Desmodium" (Desmodium uncinatum), "Greenleaf Desmodium" (D. intortum), "Cooper" and "Clarence Glycine" (G. javanica), "Nandi" and "Kazungula" Setaria (S. sphacelata), "Rodds Bay" and "Hartleys" Paspalum (P. plicatulum), "Coloniao" and "Green Panic" guinea grasses (Panicum maximum), "Siratro" (Phaseolus atropurpureus) "Miles Lotononis" (L. bainesii), "Oxley" and "Schofield" Stylo (Stylosanthes guyanensis: syn. S. gracilis), "Townsville" lucerne (Stylosanthes humilis). It has been demonstrated that seeds can be mechanically harvested from grasses heretofore never considered - e.g. in North Queensland 1.0 ton of para grass seed was direct combined from 100 acres and 100-300 pounds per acre from Brachiaria ruziziensis.[1/]

Development of a seed industry is an immense task with many unknowns thus it is recommended that CIAT consider employing a Seed Specialist (production and processing) to coordinate efforts in this discipline.

1/ Personal communication with Bela Grof, Tropical Agricultural Research Station, South Johnstone, Australia.

VIII. CENTERS OF RESEARCH AND WORK IN PROGRESS

Colombia

1. Palmira, Cauca Valley

    a. Staff - 2 pasture agronomists, animal scientists.

    b. Areas of research -

    1) Introduction and testing, species and varietal evaluation.

    2) Advanced testing with selected species using animals as integral part of evaluation.

        a) Crop rotations with pastures and forage crops.

    3) Animal evaluation of chosen species - some investigation conducted in past and more projected.

        a) Digestibility studies of pasture and forage species.

    4) Breeding of forage sorghum and Desmodium species.

2. "Turipana", near Monteria, Sinu Valley.

    a. Staff - 1 pasture agronomist, animal scientists.

    b. Areas of research -

    1) Research in various aspects of introduction and strain testing, fertility trials, limited animal evaluation of pasture species.

    2) Regional testing projected, using animals.

3. "La Libertad", near Villavicencio, Llanos Orientalis.

    a. Staff - 1 pasture agronomist, animal scientists.

    b. Areas of research -

    1) Introduction and species testing, agronomic studies at "La Libertad" station and in Regional tests at Orecue and San Martin,

    2) Limited aspects of animal evaluation of pastures at "La Libertad" and projected at Orecue and San Martin.

4. "Naitaima", El Espinal, Tolima Valley.

    a. Staff - 1 pasture agronomist (part time) supervision and direction from

ICA headquarters at "Tibaitata", Savannah of Bogota.

b. Areas of research -

1) Introductions and species testing and some agronomic evaluations of pasture species, crop rotations with pastures and forage plants.

5. "El Nus", near Medellin

a. Staff - 1 pasture agronomist (part time), animal scientists.

b. Areas of research - Limited introductions, agronomic and animal trials.

Note: For the immediate future it would appear that ICA would offer the greatest opportunity as a collaborating institution within the near future. Throughout the country there are 12 pasture agronomists, three of whom have Ph.D's in plant breeding, pasture management and crop ecology, plant and soil nutrition; one has a M.S. in pasture management and animal nutrition and another in pasture management; several will be obtaining advanced degrees in the near future.

Ecuador

1. Instituto Nacional de Investigaciones Agropecuarias (INIAP), Pichilingue.

a. Staff - 1 pasture agronomist, animal scientist.

b. Areas of research -

1) Introduction gardens and species testing.

2) Limited trials of agronomic evaluations.

3) Projected aspects of animal studies with pasture plants.

4) Limited multiplication and distribution of seed (largely vegetative).

2. INIAP, Santo Domingo.

a. Staff - 1 pasture agronomist.

b. Areas of research -

1) Introductions, limited agronomic evaluations of species.

Note: Immediate collaboration could begin with INIAP, moving into animal grazing trials at the Pichilingue Station and expansion of agronomic studies (including, re-evaluation of legume work) at Santo Domingo.

Peru

1. Estacion Experimental Agricola de La Molina, Lima.

   a. Staff - 1 pasture agronomist.

   b. Area of research -

      1) Introduction garden, limited species evaluation and agronomic studies.

2. Universidad Agraria Facultad de Agronomia, La Molina, Peru.

   a. Staff - 3 pasture agronomists (teaching and research), animal scientists.

   b. Areas of research -

      1) Introductions and species evaluations, limited agronomic studies.

      2) Limited breeding (selection) with alfalfa.

3. Estacion Experimental de Tingo Maria.

   a. Staff - ?

   b. Areas of research -

      1) Introductions and aspects, agronomic evaluations; preliminary species trials under grazing some 10 years ago; limited to the former two at present.

4. Universidad de la Amazonia - Iquitos.

   a. Staff - 2 pasture agronomists (teaching and research).

   b. Area of research - Introductions and species testing.

Note: With the discontinuous guidance from the North Carolina Project up to 10 or 12 people have been trained in pasture and forage crops development and management. Presently most of them are dispersed into other disciplines. A recent move by North Carolina to establish Commodity Programs should create a favorable environment for cooperation among the experimental stations and Schools of Agronomy. It is anticipated that three N.C. employees will staff the Pasture and Forage Commodity Program. Since those who hold pasture and forage positions in the Schools of Agronomy were formerly associated with SIPA, Venezuela

1. Centro de Investigaciones Agronomicas, Maracay (Facultad de Agronomía also situated at Maracay)

   a. Staff - ?

   b. Areas of research -

      1) Introductions and species testing, limited aspects of agronomic and animal evaluations with pasture species; in late 50's and early 60's digestibility studies with native pastures.

2. Estacion Experimental de Calabozo (situated in the Llanos), reported work with introductions, agronomic and animal trials with pasture species.

3. Estacion Experimental de Aracue - reported observations of grasses and legumes in collection and grain sorghum breeding.

4. Estacion Experimental de Zona Arida, El Cuji, State of Lara - collection of grasses and legumes.

5. Estacion Experimental del Zuila (Facultad de Agronomia also at Zuila) - collection of grasses and legumes.

Note: Most of the above information came from the literature so it would be advisable to survey the work underway and explore possibilities of collaboration.

Bolivia

1. Estacion Experimental Agricola "Los Llanos", General Saavedra, 65 km. from Norte de Santa Cruz (   ).

   a. Staff - 1 pasture agronomist.

   b. Area of research - reported grass - legume collection and 22 experiments with forages in 1966.

      1) Collaboration with USAID and British Mission.

Note: The Bolivian tropics according to reports of those who have collected and worked there have an untapped potential in regard to pasture and forage species and undoubtedly animal development.

Puerto Rico

1. College of Agriculture, Mayaguez.
   a. Staff - 1 part time grass ecologist.
   b. Area of research - grass collection (of significant size).
2. Agricultural Experiment Station, Rio Piedras.
   a. Staff - 1 pasture agronomist full time, 2 soil agronomists (USDA) part time.
   b. Area of research -
      1) Introductions and species testing.
      2) Agronomic and animal trials (limited but excellent work) on a private farm near Orocovis, 30 km. from San Juan; economic evaluations.
3. Corozal Experiment Station.
   a. Staff - 1 pasture agronomist (part time) and 1 forage crops breeder (part time), animal scientist.
   b. Areas of research - Introductions, some agronomic studies, limited animal trials, preliminary breeding of Digitaria (collaboration with Schank of Florida).
4. Gurabo Experiment Station.
   a. Staff - 1 pasture agronomist (part time), animal scientist.
   b. Area of research - Small pasture and forage collection, limited agronomic and animal trials (Animal Science Department).
5. Isabela Experiment Station.
   a. Staff - 1 forage breeder (part time), animal scientist.
   b. Research - Breeding of pigeon pea and limited animal evaluation of pastures and forages (Animal Husbandry Section).
6. Las Lajas Experiment Station.
   a. Staff - 1 pasture agronomist, animal scientist.
   b. Research - Limited introductions and agronomic studies.

Note: Animal evaluation trials with associated economic analysis on improved grasses have contributed significantly to the advance of pasture development and should have application in Latin America. It is suggested that a feasibility study be made to survey the possibility of locating a Latin American Pasture and Forage Crops Introduction Station in Puerto Rico (perhaps as a consortium of the USDA, CIAT, several U.S. Universities and other institutions).

Brazil

1. Departamento de Pesquisas e Experimentacao Agropecuarias (DPEA), Ministerio da Agricultura, Rio de Janeiro - Regional Experimental stations as follows:
   a. Instituto Pesquisas Experimentacao Agropecuarias (IPEA) do Norte, Belem, Para.
   b. IPEA do Nordest, Recife, Pernambuco.
   c. IPEA do Leste, Cruz das Almas, Bahia.
   d. IPEA do Centro-Oeste, Sete Lagoas, Minas Gerais.
   e. IPEA do Centro-Sul, Km. 47, Campo Grande (near Rio de Janeiro).

Note: The Regional centers are being developed by the Ministry of Agriculture in collaboration with the IRI Institute. At each of the above named 5 sites plus the experiment station being established near Brazilia, introductions, agronomic and pasture trials are underway or projected. Undoubtedly, these centers represent sites where cooperative research could be done but further details are needed. In addition, there are a number of state experiment stations where limited research in pastures and forages is carried out. It is recommended, however, that the feasibility of regional collaboration be explored through DPEA.

2. IRI Institute Research Station, Matao, Sao Paulo.
   a. Staff - 2 pasture agronomists, with additional staff located in Campinas and Rio de Janeiro.
   b. Areas of research - Introductions and various aspects of agronomic and animal evaluations of pasture species; legume bacteriology.

Note: The most productive and significant pasture and forage research for the "campos" region has been done by the IRI Institute at Matao and other sites (on ranches) in Sao Paulo. Results from these trials are directly applicable and are being moved into the IPEA programs.

Costa Rica

1. Interamerican Institute of Agricultural Sciences (IICA), Turrialba.
   a. Staff - 2 pasture agronomists, animal scientists.
   b. Area of research - Introductions and limited aspects of agronomic and animal trials.

Note: Pasture and forage investigation at Turrialba has been erratic and sporadic during the past decade, lacking orientation in the use of animals to evaluate pasture plants.

Trinidad

1. Imperial College of Agriculture, Trinidad.

   Some rather significant and informative papers have been published on investigation conducted in Trinidad. Much of it should have application to parts of the tropics. There apparently has been a lack of continuous orientation in the overall program.

Jamaica

1. Grove Place Agricultural Station, Jamaica.

   Investigation has been reported in areas of introductions, agronomic and animal studies.

Note: Before collaboration is anticipated in Costa Rica, Trinidad, and Jamaica a survey should be made of present work, facilities and staff.

IX. APPENDIX

A. The Range Cattle Industry In Florida

Quotations from Dr. W. G. Kirk, animal scientist,[1] on the development of the cattle industry and the importance of pastures along with good herd management are pertinent.

"The native cow gradually developed the characteristics that enabled her to exist and reproduce under extremely hard conditions. Starvation rations, mineral deficiencies, Texas fever, severe weather and complete freedom to roam weeded out all animals that had any inherent weakness. The result was an extremely hardy animal that has been the mainstay of the Florida cattle industry in the past and is today the foundation stock of the state's commercial herds.

"Purebred and grade cattle brought into the state by the settlers usually did not last long but the few calves sired by these importations and out of native cows were an improvement over their dams and a gradual upbuilding took place. The one permanent factor, however, was the Native cow. When it was proved that the failure of the imported animals was due to insufficient feed, deficiency diseases and ticks, and further demonstrated that these difficulties could be overcome by dipping, a continual alert for ticks, supplying phosphorus, copper, cobalt and iron, along with better feed, the situation began to improve and the native cow like the imported cattle, responded with a faster growth rate, greater size, more calves, and higher quality meat.

"One of the easiest ways to start cattle improvement was to provide cattle with the essential minerals deficient in the native pasture. Mineral boxes in most pastures were a novelty before 1935 but by 1940 there were few pastures that did not have one or more. Cattle at the Range Cattle Station on native range ate an average of 41.3 pounds complete mineral per year during a three-year period, beginning in

---

[1] Kirk, W. G. 1954. The range cattle industry in Florida. Meeting of the Grassland Farming Committee.

1948, while those on improved pasture ate an average of 11.8 pounds. Earlier records at the Station show that cows living entirely off native pasture have consumed an average of 94 pounds of complete mineral in a year.

"Cattlemen thought that most of their troubles were over with the disappearance of the Texas fever tick and the corrections of the mineral deficiencies of the feed. Purebred bulls of several beef breeds mated to the native cow gave considerable response in growthy claves, with the Brahman sires excelling in this respect. However, better cattle cost more and needed more attention than the native cow and it was this cost plus care that brought to light other requirements. It was not until the necessity for furnishing a more adequate feed supply throughout the year was recognized that there was rapid and continued improvement in the quality of beef cattle produced.

"It is estimated that over one-half of the land area of Florida is used for pasture. This land ranges from rolling sandy pine land to muck and marsh area with many intermediate types. Over 1,500,000 acres have been used for the establishment of improved pasture. The work "Improved" is a misnomer in many instances since with poor preparation before planting and little or no maintenance afterwards the results were disappointing, even though better types of grasses were planted.

"Overstocking pastures has always been and still is too prevalent. This practice has resulted in small cattle, lowered production and heavy losses under any severe conditions. It is estimated that on many ranches and farms disposal of from 10 to 25 per cent of the herd would result in greater total production with a lower cost per unit of production. Management of herds and pastures did not receive much attention until the lower cattle prices forced cattlemen to consider these factors if they were to remain in business.

"Cattle production is limited by the amount and quality of available feed. With improved pastures there has been a steady increase in beef cattle numbers until on January 1, 1954, there were 1,500,000 head. The average weight of the range cow 25 years ago was about 550 pounds while today it is 800 pounds, 250 pounds more. In addition to increased numbers and greater size, there are more calves which grow off faster. Improved feed, higher quality cattle, and changed management practices have been responsible for the tremendous increase in beef production and the potential of Florida pastures is just being discovered.

"A question in everyone's mind is the productivity of Florida pastures. Factors which affect the amount and quality of pasture have received much attention at the Range Cattle Station since it was established in 1941. Good pastures and good cattle cannot be separated.

"Grade cows having an average of 13.3 acres of native pasture per cow in a 5-year period produced 268 pounds calf gains per year which is 20 pounds per acre of pasture. These cows had a 65 per cent calf crop and the calves averaged 400 pounds when weaned at seven months with U.S. Low Good grade as slaughter animals. Another group of cows on the same kind of pasture and supplemented with 10 pounds grapefruit daily for 120 days during the winter produced 304 pounds calf gains per year and 23 pounds gain per acre of pasture. These results were obtained during winters when feed conditions on the range were good.

"Cows on a combination of one acre of improved pasture and 4.5 acres of native range per animal produced an average of 340 pounds calf gains per cow yearly. This is an estimated gain of 20 pounds per acre of native range and 218 pounds per acre of improved pasture. There was an 80 per cent calf crop, the calves averaged 425 pounds at weaning and graded U.S. Good. These cows obtained all of their feed from the pasture. Controlled and deferred grazing was practiced on the improved area but the cows had access to the native range at all times.

"A herd of 62 cows having 75 acres of pasture made up of one-third Pangola-White clover and two-thirds Pangola grass had 310 pounds calf gain per acre of pasture and 375 pounds per cow. The calf crop was 80 per cent, the calves weighed 450 pounds at weaning and graded U.S. High Good.

"There is a lack of personnel with training and experience to manage an intensive cattle production program."

Appendix B. Land Use, Human and Cattle Numbers, Animal Output, Energy and Protein per Caput 1/

Region & country	Total area	Arable	Grazing	Human pop. 1965	% Inc. since 1950	Catt. pop. 1966	% Inc. since 51/52	Animals slaught. 1965	Carcas wt. 1964	Milk per Cow 2/	Cal./caput/day 1965 Cereals	Pots., star. Foods	Milk	Available proteins 1965 Total	Animal
	1,000 hectares			000		000		000	kg.	kg.	no.	no.	no.	gm.	gm.
United States	936,339	185,152	256,214	194,572	27	108,862	35	33,158	265	3665	665	91	390	92.0	65.1
Bolivia	109,858	3,091	11,323	4,114	36	2,317	87	192	220	-	954	270	59	48.6	12.4
Brazil	851,196	29,760	107,274	81,451	56	90,692	76	7,843	191	430	1121	413	111	71.3	18.7
Colomb.	113,834	5,047	14,606	18,068	60	17,078	15	2,021	208	270	761	357	180	54.4	23.9
Ecuador	27,067	2,894	2,200	5,164	58	1.600	45	278	155	500	633	239	61	43.7	14.2
Peru	128,522	2,618	27,823	11,750	65	3,500	11	-	-	680	843	381	68	57.3	18.3
Venezuela	91,205	5,219	16,706	8,752	73	6,755	17	915	176	670	774	291	164	60.1	25.4

1/ FAO Yrbk. 1966 and USDA Agric. Statistics for 1967.

2/ No. of milking cows = U.S. 15,987,000, Colombia - 1,837,000, Venezuela - 3,300,000.

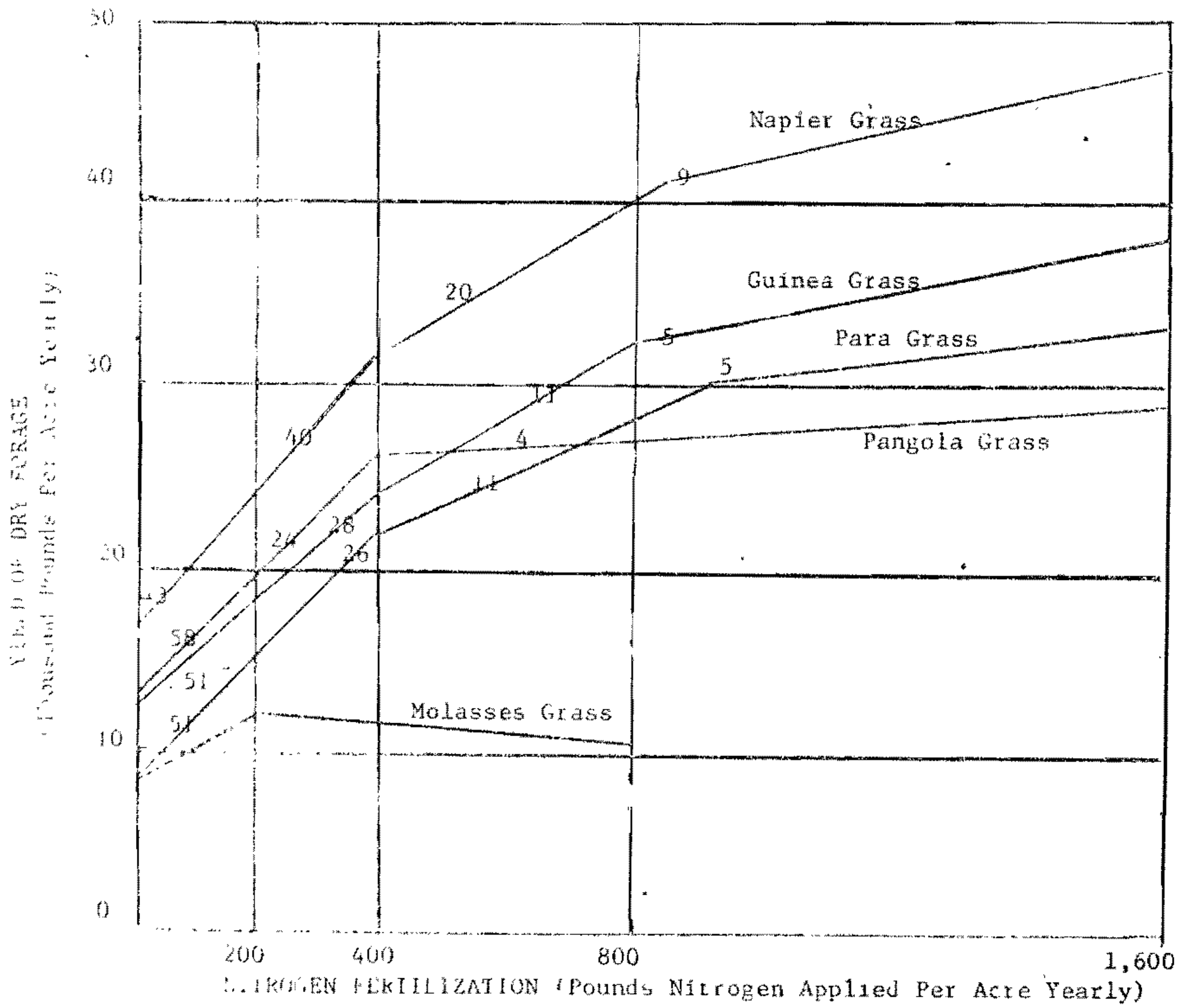
Appendix C. Increased Production of Dry Forage of Tropical Grasses with Added Increments of Nitrogen Fertilizer (Crowder, et al – Colombia)

1. Influence of rate and time of N application on forage yields of pangola grass.

Time of N Application	Tons/acre air-dry forage by rates of N (lbs./A)[a/] 0	150	300	600	900	1200
1) 1/6 after every harvest	1.40	2.85	6.15	14.95	20.80	24.20
2) 1/3 every 2nd harvest	1.45	3.60	7.05	13.75	18.80	22.60
3) 1/2 every 3rd harvest	1.45	4.15	9.50	12.35	17.90	21.00

a/ Data for dry forage yields are averages of 3 cycles (6 cuts per cycle) for a 3-year period; total N applied for a cycle of 6 harvests.

2. The effect of nitrogen fertilization on yields of five grasses harvested by cutting every 60 days (numbers show pounds of dry forage per pound of increment of N) (Vicente-Chandler, Puerto Rico)



[illegible] D. Effect of Nitrogen Fertilizer Applied to Grass Pastures on Cattle Output

[illegible] of nitrogen fertilization on the liveweight gain of Zebu cattle in [illegible], and [illegible] - Brazil.

[illegible] of N rates on Colonial guinea grass pastures[a].

[illegible]	[illegible]	Nitrogen Treatment-kg./hect.[b]			
		None	N-0	N-100	N-200
		[illegible] weight gain - kg/hect. and stocking rate - steers/hect. ( ).			
[illegible] 5[illegible]-58	168	[illegible]83(2.[illegible]3)	289(2.[illegible]9)	430(3.77)	612(6.12)
[illegible] 58	[illegible]68	42(0.86)	45(0.86)	44(1.48)	54(1.45)
[illegible] [illegible]8-59	[illegible]	2[illegible]3(1.69)	257(1.65)	474(3.10)	692(4.55)
[illegible] [illegible]9	[illegible]	34(0.68)	24(0.70)	41(0.98)	47(1.04)

[a] [illegible]

[b] 200 kg/hect. P_2O_5 and 40 kg [illegible] sulfur Oct. 1957 plus 20 kg. sulphur Oct. 1958.

Summary [illegible] Colonial Grass Trials:

1. [illegible] cattle [illegible] for market at 2-3 years of age as compared to 4-6 under range conditions in Brazil.
2. [illegible] 200 kg/hect. [illegible] than doubled yield over N-0 in terms of TDN/hect., steers per hect. and liveweight gain/hect., but did not affect age of finish.
3. Response and residual of winter-dry season applied N greater than summer-wet season applied N.
4. [illegible] response to S appeared during the second summer season.
5. The treatment of 200 kg/hect. of N, 100 kg P_2O_5 and 60 kg S gave an annual net return of about $45 over the no. fertilizer control pasture.

[illegible] Liveweight gains, stocking rates and protein contents of fertilized and unfertilized pastures during 168-day summer season - November 7, 1961 to April 24, 1962 (Quinn, et al -Brazil)

[illegible] and treatments		November 7, 1961 to April 24, 1962				
		Live wt. gain /steer		Crude protein in grass[1]	Stocking rate - steers /ha.	Live weight gain/ha. kg.
		Total kg	Daily gm.	%		
[illegible]	Fertilized	122.8	731	10.10	2.90	356.1
	Unfertilized	129.1	768	9.47	1.66	214.3
[illegible]	Fertilized	136.5	813	8.73	3.09	421.8
	Unfertilized	135.0	804	6.26	1.85	249.8
[illegible]	Fertilized	95.8	570	8.37	2.86	274.0
	Unfertilized	98.7	588	6.38	2.29	226.0
[illegible]	Fertilized	117.3	698	10.65	3.15	369.5
	Unfertilized	100.8	600	8.68	1.22	123.0
5. [illegible]sses grass	Fertilized	123.1	733	10.21	.98	120.6
	Unfertilized[2]	73.7	877	8.81	1.08	79.6
6. Coastal Bermuda	Fertilized	110.4	657	9.41	1.95	215.3
	Unfertilized	102.3	609	8.22	1.01	103.3

[1] [illegible] of 7 samplings.

[2] [illegible] for first 84 days of summer.

3. Liveweight gains, stocking rates and protein contents of fertilized and unfertilized pastures during 112-day winter season - July 18 to November 7, 1961 (Quinn, et al, Brazil)

Grasses and treatments		July 18 to November 7, 1961: Live wt. gain /steer, Total kg.	Live wt. gain /steer, Daily gm.	Crude protein in grass[1] %	Stocking rate steers /ha.	Live weight gain/ha. kg.
1. Colonião						
(*Panicum maximum*)	Fertilized	18.8	168	6.33	2.06	38.7
	Unfertilized	.4	4	5.41	2.23	.9
2. [illegible]						
P. [illegible]	Fertilized	14.8	132	4.67	1.75	25.9
[illegible]	Unfertilized	- .5	- 4	3.67	1.75	- .9
3. Pangola						
(*Digitaria*	Fertilized	19.6	175	4.72	2.63	51.5
decumbens)	Unfertilized	2.6	23	3.69	2.60	6.8
4. Tanganyika	Fertilized	8.6	77	6.94	1.17	10.1
(*P. maximum*)	Unfertilized	4.5	40	5.06	1.13	5.1
5. Molasses grass						
(*Melinis*	Fertilized	- 1.9	- 17	5.23	1.61	- 3.1
minutiflora)	Unfertilized	4.2	38	4.43	1.61	6.8
6. Coastal Bermuda						
(*Cynodon*	Fertilized	- 2.8	- 25	5.57	1.98	- 5.5
dactylon)	Unfertilized	-23.5	- 210	5.45	1.75	- 41.1

[1] Average of 8 samplings.

Appendix E. Increased Animal Performance with Added Nitrogen Fertilizer

I. Case History 1 (1963 data from Dr. R. Astralaga - Abonos Colombiano, S.A.) -

1. Location - Cauca Valley, Colombia - "La Chica" Ranch owned by Alfonso Jaramillo Arango.
2. Pasture and Grazing Scheme - 2 fanegadas (2/3 hect.) of pangola grass divided into 4 paddocks for rotational grazing (10 days pasturing and 30 days rest).
3. Fertilizer and Irrigation - 100 kg. of N/hect. first grazing period and 50 kg. thereafter; supplemental irrigation when needed.
4. Cattle and Liveweight Gain - 6 Cebu steers of approximately 2 yrs. age per fanegada (corresponds to 9.375 per hectare); daily livewt. gain 0.775 kg. per animal x 9.37 = 7.26 kg. per hect. or 2,652 kg. per year (estimated).
5. Cost inputs and return per hectare* -

a. Interest on value of 9.37 animals	-	937.50 (pesos)
b. Land investment (8% interest)	-	480.00
c. Value of N (urea)	-	1000.00
d. Irrigation equipment (5 yr. amortization)	-	400.00
e. Interest on irrigation equipment (5 yrs.)	-	120.00
f. Irrigation cost	-	200.00
	Total	3257.50
Gross return (2,652.45 kg. x $2.40 pesos/kg.)	-	6365.80
	Net	3108.30

* Pasture was already established - from 800 to 1500 pesos establishment cost.

2. Case History 2 (1963 data from Dr. R. Astralaga - Colombia) -

   1. Location - Cauca Valley, Colombia - Caucaria Ranch owned by Luis E. Sardi Garces.
   2. Pasture size and grazing schedule - 75 fanegadas of para grass divided into 12 paddocks for rotational grazing (9 days pasturing and 27 days rest).
   3. Fertilizer and irrigation (as above).
   4. Cattle and liveweight gains (Cebu with results similar to the above).

3. Case History 3, (1967 data from Mr. John Evans) -

   1. Location - Parada Research Station, Mareeba, Queensland, Australia.
   2. Pasture and grazing scheme - 1/3 acre paddocks for rotational grazing - on 2 weeks and off 4 weeks, with disking after each second grazing period to distribute droppings. (Protein peak of grass reached 25 days after applying N, yearly range from 10-20% on a dry weight basis).
   3. Fertilizer and irrigation - 300 lbs./A of N (6 appl./yr.), 200 lbs. superphosphate (22% P_2O_5), 100 lbs. K_2O; supplemental irrigation as needed.
   4. Cattle and liveweight gains - 3 steers (18-20 mo.) per acre, 5 groups turned-off per acre over 2 yr. period, approximately 1100 lbs./A/yr. dressed beef; average daily gain 1.85 lb./head/day.
   5. Cost inputs and return per hectare - Initial outlay of \$250/A on cattle; pasture cost of \$93/A/yr. (includes interest on land, \$43 fertilizer cost, 4A. feet of water at \$3.50/A ft. and \$25/A labor); return of about \$125/A from established pasture (approximately \$50/A establishment cost) as compared to about \$450/A from tobacco (grown in the same region.)

Note: Dr. B. Grof, Tropical Agricultural Research Station, South Johnstone, Queensland reported that 70 acres of Pangola grass, receiving 1000 lbs./A/yr. of ammonium sulphate, supports 3 steers per acre with total animal gains of about 2000 lbs. per acre.[1/]

[1/] Personal communication and visit.

4. Case History 4 - (Data from Jose Vicente-Chandler - Puerto Rico)

Grass pastures in Puerto Rico responded strongly to an increase in fertilization from 600 to 1800 lbs./A yearly of 14-4-10. Beef production increased from 570 to 1072 lbs./A yearly and total digestible nutrients from 4,300 to 6,700 while carrying capacity was almost doubled, from 1.4 to 2.2 600 pound steers per acre. Forage consumed by the cattle increased from 8,900 to 13,400 pounds of dry matter per acre yearly; its protein content from 8.1 to 15.9 per cent, which approaches that of legume herbage.

It was profitable to increase fertilization up to 1800 lbs./A yearly. The additional 500 pounds of liveweight produced was worth $110 compared with increased fertilizer costs of about $48 including application.

The effect of 3 fertilizer levels on the productivity of elephant grass pastures

14-4-10 per acre yearly lbs.	Weight gain per acre lbs.	Carrying Capacity 600 lb. steer no.	Dry forage Consumed Yearly a/ lbs.	T.D.N. Consumed per acre b/	Protein Content of Forage %
600	570	1.4	8,900	4,300	8.1
1,800	1,072	2.2	13,400	6,700	15.9
3,000	1,190	2.5	13,600	8,100	17.6

a/ Difference in forage harvested from paired strips cut before and after grazing.

b/ Calculated from body weights, days of grazing and gains - weight.

Appendix F. Feeding Value of Tropical Pastures

1. Maximum and minimum dry-matter digestibility of tropical and temperate pasture plants (Milford and Minson - Australia)

Pasture or species	Country	Maximum digestibility	Minimum digestibility
1. *Paspalum commersonii*	Australia	74	31
2. *Urochola pullulans*	Australia	57	34
3. *Bothriochloa insulpta*	Kenya	67	45
4. Orchard grass - var. S37	UK	76	48
5. Perennial ryegrass - var. S24	UK	80	60

2. Daily animal intake (gm/kg liveweight 0.73) of subtropical pasture plants when grown in S.E. Queensland in 1962-63. (Milford and Minson - Australia).

Grasses	Age of grass in days			
	30	80	150	250
1. Buffel - var. Molopo	79	55	42	22
2. *Sorghum almum* - var. Crooble	78	64	49	
3. Rhodes - var. Samford	42	40		
4. Rhodes - var. Callide	64	62	59	
5. Pangola	63	50	29	
6. *Glycine javanica* - var. Cooper			80	92
7. *Phaseolus atropurpureus* - var. Siratro			72	75

3. Differences in nutritional values of 3 subtropical grasses when fed to sheep (Milford - Australia).

Start of 10-day cutting period	Grass	D.M. digest. %	D.M. intake g/hd/day	Crude protein content %	Crude protein digestibility %	Remarks
1.4.57	1. *Cenchrus ciliaris* L. (Buffel grass West. Aust. var.)	48	1032	7.4	57	Full bloom, leafy.
	2. *Paspalum plicatulum* (C.P.I. 2741)	45	916	4.0	11	Ear. seeding, leaves drying.
	3. Natural pasture dominantly *Bothriochloa intermedia*	41	456	5.5	17	Mature, very dry.
13.5.57	4. *C. ciliaris*	44	769	8.0	43	Mature, leaves dying.
	5. *P. plicatulum*	43	677	3.4	10	Stems succulent leaves frosted.
	6. Natural pasture	35	333	2.5	-118	Mature, very dry.
10.6.57	7. *C. ciliaris*	44	910	7.2	44	Mature, badly frosted.
	8. *P. plicatulum*	40	582	3.5	- 9	Leaves and some stems frosted.
	9. Natural pasture	28	315	2.6	- 98	Dry and stemmy.
9.8.57	10. *C. ciliaris*	35	740	7.1	29	Frosted, very dry.
	11. *P. plicatulum*	38	359	3.4	- 4	Severely frosted
	12. Natural pasture	32	149	2.2	- 11	Dry and stemmy.

4. Nutritive value of elephant grass cut at various stages of growth (Butterworth and Arias - Venezuela)

Age of plants days	Dry matter %	Crude protein %	Crude fiber %	D.M. digest. %	D.M. intake gm/kg 0.75	Rate of passage hrs.
30	12	21	28	65	67	45
50	18	7	32	60	65	53
70	29	5	38	58	70	65

Appendix G. Effect of Pasture Forage on Reproductive Performance of Cross-bred Cows (1935-57) (A.C. Warnick - Florida)

	Grass	White Clover-grass
Stocking rate, acres/cow	2.00	1.25
Pregnancy per cent, lactating cows	47.00	79.00
Pregnancy per cent, nonlactating cows	95.00	100.00
Weaning per cent, all cows	64.00	83.00

Appendix H. Projected World Human Population and Animal Protein Need

1. Estimated human population and anticipated animal protein per person based on "low" population projections.[a/]

		1962-64		1980	
Region	Range	People 000,000	Protein gm/day	People 000,000	Protein gm/day
World[b/]	Low	3,162		4,071	20.9
	Medium		23.5		24.0
	High				29.2
North America	Low	208		248	66.2
	Medium		63.7		76.7
	High				97.1
Latin America	Low	229		352	21.2
	Medium		25.6		24.0
	High				31.8
Africa	Low	248		367	9.9
	Medium		11.6		11.3
	High				15.0

a/ The World Food Problem - A Report of the President's Advisory Committee, May 1967, Pages 263-264.

b/ Excluding Russia and China.

Appendix I. Locations and Descriptions of Natural Grasslands in Latin America (Roseveare - England)

1. Savannahs of Hot Climates.

a. Orinoco Flood Plains or Llanos of Venezuela and Colombia.

i. The Venezuelan Llanos lie to the north of the Orinoco River (2,580 km. in length) and occupies an area approximately 1,000 km. long and 325 km. wide. Roughly it forms a semicircle from the Guaviare River in Colombia (a tributary of the Orinoco) to the Atlantic coast of Venezuela. A gradual slope reaches from the base of the Andes, which extends into Venezuela, towards the Orinoco but altitude seldom exceeds 180 to 220 meters above sea level.

(a) The temperature curve at Cuidad Bolivar (eastern part of the Llanos) closely parallels that of Port of Spain, Trinidad. Variation in temperature during the course of the year is far from being uniform over the vast region, even at equal altitudes. At Calabazo in the central Llanos are found the widest monthly variations recorded in Venezuela.

(b) Mean annual rainfall fluctuates from 800 to 1,800 mm. and days of rainfall from 75 to 150. There are two seasons -- a rainy period which begins in April, reaches a maximum in June or July; continuing until October with occasional showers into November and December, and a dry period during January to March in which there is no rain. The rainy season is always accompanied by inundation of vast tracts of land, especially in the vicinity of the Orinoco.

ii. East of the Andean range and transecting Colombia from north to south lies the Colombian Llanos. It is divided by a western projection of the Giuana Highlands from the great Amazon Plains further south.

(a) In climatic and other environmental conditions the Colombian Llanos resemble that of Venezuela and indeed being continuation of them. Mean temperatures to about 500 m above sea level, range from 27 to 30°C.

(b) North of the Guaviare River and from the base of the Andes precipitation ranges from 1200 to 5600 mm. and occurs in 70 to 240 days. It is unevenly distributed, being interrupted twice during the year with one period during January - March being quite dry.

5. "Campos" of Central Brazil. The central grasslands region comprise parts of the states of Sao Paulo, Rio de Janeiro, Guanabara, Espirito Santos, Minas Gerais, Goias, Mato Grosso and the Federal District. Climatic conditions are variable but this huge region has a common pattern of rainfall distribution: frequent and heavy in the summer and very little in the winter - an annual range of 1,000 - 2,000 mm. Average annual temperatures fluctuate between 19° and 26°C.

i. The "Campos cerrados" are mixed formations of trees, shrubs and underneath grasses which occupy extensive areas on the central plateau of the states of Sao Paulo, Minas Gerais, Goias and Mato Grosso.

ii. The "Campos limpos" are open bunch grass formations with no trees. Both types extend into the northern region of Brazil and occupy parts of Amapa, Roraima, and Rio Branco of the State of Maranhao.

It is estimated that there are some 160 million hectares of vegetation of these types in Brazil.

6. Savannahs of Bolivia and the Gran Chaco.

i. Bolivia - The eastern Llanos or savannahs of the Department of Santa Cruz and part of the Department of Cochabamba form a part of the large area known as the Gran Chaco, which is shared by Bolivia, Paraguay, Brazil and Argentina.

The "wet savannahs", Llanos of Yacuma and Mojos, lie in the northern, riverine lands and remain inundated for much of the year.

ii. Gran Chaco - a region of scrub forest interspersed with patches of savannah, extending northward from about 30° latitude into Paraguay, eastern Bolivia and western Brazil - a lowland plain with few interruptions. Some of the highest temperatures recorded in any part of South America occur in the Chaco. During the summer rainy season vast areas are under water.

d. Savannahs of the Amazon Basin and the Guianas.

i. The great Amazon forest is generally regarded as one vast forest, but numerous grassy savannahs interrupt the thick cover of trees. The most important savannahs are situated in the northeast on the Rio Branco (towards the frontier of the Guianas and in the lower Amazon between the Rio Negro and Rio Xingu tributaries. Flooded savannahs are found along the littoral and in the lower Amazon, with little or no woody vegetation but a lush herbaceous cover in which grasses predominate. A non-flooded type is comprised of grass and legume species, dicotyledons of other families and interspersed with shrubs or small trees ("Campos cerrados" and "limpos"). One series of these "Campos" follows the Atlantic Coast (including the isle of Marajo - one of the most developed zones for cattle production); another lies along the course of the Lower Amazon in the State of Para; another is situated on the upper extremities of the rivers Branco, Trombetas and Jari; a fourth extends into the basin of the southern affluents of the Amazon, in the extreme south of the States of Para and Amazonas.

(a) Temperatures in the Amazon region are not excessively high, around 25°C with a low annual range. Rainfall for the whole region is abundant, in some instances over 3,000 mm. and a high degree of relative humidity. There is a so-called dry season or summer, July to December, in which there may be partial or entire absence of rain.

ii. Upland savannahs occupy an extensive area in southwestern Guiana and continue to the east in broken form into Surinam and French Guiana. With an elevation of 100-150 meters they have an undulating surface, broken with granite masses which are sometimes heavily forested. Rainfall does not exceed 1500 mm. annually and generally occurs within a four month period.

[illegible] Bolivar Savannahs of Colombia and Lowland Savannahs of Costa Rica. These regions occupy an unusual position among the grassy savannahs of Latin America in that they contain areas of improved pasturelands which are of vital importance in supplying the meat requirements of their countries.

i. The Bolivar savannahs stretch along the Magdalena River, covering a vast lowland that seldom exceeds 200 meters, and extend over the coastal region where elevations may reach 350 meters. Annual temperatures range from 27 to 30 C with comparatively small fluctuations. Rainfall is irregular and unevenly distributed, averaging 300 to 4350 mm. in 22 to 145 days. One period of drought lasts from 3 to 5 months.

ii. The savannahs of the Pacific lowlands of Costa Rica rise to 750 meters in the province of Guanacaste (which provides a high proportion of the country's beef). Tropical temperatures prevail but are of less significance than the two seasons: winter or wet, lasting from May to November, and the summer or dry from December to April. Annual precipitation ranges from 1040 to 3050 mm.

2. Semi-arid Grazing.

Northeastern Brazil is hot and mostly semi-arid. It includes the states of Bahia, Sergipe, Alagoas, Pernambuco, Paraiba, Rio Grande do Norte, Ceara and Piaui and the Territory of Fernando de Noronha. An equatorial climate prevails in about 15 per cent of the region and subtropical in the remainder. An average maxima of 36 C and a minima of 18.6° has been recorded. Two well-defined seasons - rainy and dry - are generally recognized. About 8 per cent of the region receives no more than 255 mm. of rain annually, about 25 per cent 255 to 635 mm. and the remainder over 635 mm. With regular or defined distribution the latter quantities would be satisfactory for pasture development but the entire monthly amount may [illegible] during violent storms of short duration. In some localities there may be rain in December and January but none afterwards; in some years none may fall between January and the end of March with downpours in April and May; and occasionally an entire year may pass without rainfall. In the typical dry zone called "Sertao", which makes up the greatest part of the region, extensive cattle raising is practiced, using local breeds of small size and low productivity.

Appendix J. Projected Increase in Cattle Numbers for Colombia.[a]

1958-60 Base	Projection A[b] 1965 000	Projection A[b] 1975 000	Projection B[b] 1965 000	Projection B[b] 1975 000
14,402	16,667	22,994	16,259	18,632
% Increase	16	60	13	29

a/ Based on a study made by Harold M. Riley, 1962.

b/ Projection A - 1.2% annual increase in per capita consumption and a 2.5% increase in per capita income.

Projection B - Same level of consumption continued as in 1958-60.

Note: The 1967 estimate is 17,078,000.

Appendix K. Productivity of Introduced Grasses in the Improvement of Natural Grasslands

A. Influence of fertilizer on the forage yield of introduced grasses.

Grass	Tons dry matter per hectare	
	No fertilizer	Fertilized[a/]
Axonopus scoparius	0.9	9.4
Digitaria decumbens	1.0	3.1
Hyparrhenia rufa	1.3	6.0
Axonopus micay	3.2	5.6
Panicum maximum	3.4	9.5
Brachiaria decumbens[b/]	3.5	12.3
Pennisetum purpureum	4.8	32.5

a/ Data from La Libertad Experiment Station, Llanos Orientalis, Colombia.

b/ Kg/hect. - N, 150 at establishment and 50 after each harvest; P_2O_5, 150; K_2O, 25.

Appendix L. Cattle Production from Native and Sown Pasture in the Fitzroy Basin Brigalow Region of North Queensland, Australia (Coaldrake and Smith - Australia)

1. Stocking rates and beef gains with native and improved pastures.

Experiment	Stocking rate acres/head	Dressed wt. of meat per head lbs/yr.	Dressed wt. of meat per acre lbs/yr.
Stage 1 (undeveloped)	50	100	2.0
Stage 2 (cleared & developed to sown pastures)	3	189	63.0
Stage 3 (20% of area cultivated for winter fattening)	1.5	210	140
Sorghum almum/green panic (*Panicum maximum*) pasture	2.0	240	120

a/ It is estimated that where experimental production is held at 1-2 acres per head an average good farmer will run 1.5-3 acres and the poor farmer 2-4.

2. Cost of clearing and establishing pastures in the Brigalow Region of Australia (5,000 acre unit).[a/]

	per acre
1. Clearing - pulling forest with chain and cable drawn between two crawler tractors	$ 3.00
2. Seed (mixture of Green panic, Rhodes and *Sorghum almum* and alfalfa	4.50
3. Seeding into ash from aircraft	.50
4. Fencing: 3 barb suspension fence built by contract at $300/mile for 640 acre units	1.50
5. Water: Farm dam or bore plus reticulation	2.50
6. Cattle yards and dipping facility	1.00
Cost of pasture ready for use	$ 13.00

a/ Add cost of house, farm shed and purchase of rental of land, plus interest, etc.

Note: Excerpt of letter from J. E. Coaldrake, Division of Tropical Pastures, who supplied the above information.

"If we take the figure of 60 lb. of meat/acre/year at the current price of $20.00 per 100 lb., then the gross return of $12.00 per acre per year allows a wide margin against which to charge interest, purchase price of store cattle or cost of breeding, etc. This is why there are up to 200 applicants for each new block of brigalow land that the government releases for development.

In the case of brigalow land regrowth of the leguminous tree often becomes a problem. If this is treated by aerial spraying with 2, 4, 5T in the first season, the cost is now $4.00 per acre for hormone and flying. If allowed to grow on past the first year then ploughing is, at present, the only sure control. This shallow ploughing currently costs $1.50 to $2.00 per acre per time. Two ploughings are generally needed to prepare for a crop such as forage oats. This gives a return of 300 lb. liveweight per acre (or upwards if rains are good) for the crop, i.e. roughly 200 lb. meat per acre per year. Ploughing plus cropping to eliminate regrowth can be a highly profitable business in brigalow country."

Appendix M. Adaptation and Yields of Some Tropical Legumes and Grasses in Hawaii[a/]

	Rainfall inches	Elevation feet (plus)	Soil fertility	Green yield, tons/acre Alone	Grass Assoc. Not Irrig.	Irrig.
1. Tropical legumes						
a. *Desmodium canum*	60 - 150	3000	v. low	-	-	-
b. *Desmodium intortum*	60 plus	2500		-	80	-
c. *Leucaena leucocephala*	20 - 60	1000	P	35	5-35	100
2. Tropical grasses						
a. *Brachiaria mutica*	moist	2000	heavy	60	-	-
b. *Digitaria decumbens*		4000	mod.		80	
c. *Pennisetum clandestinum*	35 plus	6000	mod.		4-100	
d. *Panicum maximum*	25-80	2000	mod.		100+	5-35
e. *Panicum maximum*	20-45	2500	mod.		4-8	
f. *Cynodon dactylon*	15-80	3000	heavy			40

a/ Data from Coop. Ext. Ser. Univ. of Hawaii, leaflets 101 through 107 and 110, 111 and 114.

Appendix N. Forage Needed and Precision of Methods Used to Estimate Forage Quality of Bermudagrass at Tifton, Georgia (Burton, et al)

Method	Forage Needed	CV
1. Daily gain of steers	14,500 kg	12.9 - 31.3
2. Dry matter intake of steers	2,700 kg	6.7 - 16.9
3. Dry matter digestibility (fed steers)	1,450 kg	2.5 - 3.2
4. Dry matter digestibility (nylon bag)	40 gm	1.7 - 3.1
5. Dry matter percentage	60 gm	4.5 - 6.4
6. Crude protein content	10 gm	5.0 - 5.4
7. Percent leaves (dry basis)	20 gm	6.7 - 13.0
8. Crude fiber content	10 gm	3.3 - 5.3
Dry forage needed for digestibility studies[1/]		
9. Dry matter digestibility (fed to sheep)	100 kg	-
10. Dry matter digestibility (*in vitro*)	8 gm	-

[1/] Personal communication forage research workers Cornell University.

Appendix O. Differences in Nutritional Values of Two Varieties of *Paspalum plicatulum* when Fed to Sheep

(Milford - Australia)

Start of 10-day cutting period	Variety	D.M. digest. %	D.M. intake g/hd/day	Crude protein content %	Crude protein digestibility %	Remarks
1. 21.11.55	a. C.P.I. 2741	57	1333	9.5	48	Young, leafy
	b. C.P.I. 11826	56	1509	10.3	60	Young, leafy
2. 28.5.56	a. C.P.I. 2741	42	521	3.0	- 10	Mature, stemmy, leaf dry.
	b. C.P.I. 11826	44	1019	5.3	39	Mature, some green leaf.
3. 9.9.57	a. C.P.I. 2741	40	457	3.8	9.2	Mature, leaves frosted, some stems green at base.
	b. C.P.I. 11826	50	818	4.4	20	Mature, leaves frosted, some stems green at base.

X. SELECTED REFERENCES

Al..., F. E.
1965. Aspects of the evaluation of herbage species and varieties in animal production experiments. Paper presented at the 9th Int. Grassld. Congr. Sao Paulo, Brazil, pp. 6, bibl. 5, Port. s., mimeo. (Grassld. Res. Inst., Hurley., Berks.).

Andrew, C. S. and Norris, D. O.
1961. Comparative responses to calcium of 5 tropical and 4 temperate pasture legume species. Austr. J. Agr. Res. 12:44-55.

Andrew, C. S. and Henzell, E. F.
1964. Mineral Nutrition of Plants. in "Some Concepts and Methods in Subtropical Pasture Research". Bul. 47, Commonw. Bur. Past. Fld. Crops, Hurley, England.

Andrew, C. S.
1965. Mineral nutrition of sub-tropical pasture species. C.S.I.R.O. Jour. of the Australian Institute of Agric. Sci. 31(1): 3-10.

Ar...o R., D. and Teunissen, H.
1964. Comparative study of meat production from five tropical grasses. (Span.) Tec. pec. Mex. No. 3, 15-19, bibl. 6, illus., Eng. s. (C.N.I.P., Cotaxtla, Veracruz, Mexico).

Astralaga M. S., R.
1962. (Rational management of fertilized grasslands.) (Spanish) Agric. trop. 18, No. 11, 645-9.

Balch, C. C. et al.
1951. Apparatus for the separate collection of faeces in urine from cows. Jour. Agr. Sci. 41:98-101.

Barnard, C.
1964. Grasses and Grasslands. Div. of Plant Industry, C.S.I.R.O., MacMillan & Co., Ltd., Melbourne.

Blaser, R. E., and N. C. Brady.
1950. Nutrient competition in plant associations. Agron. J. 42: 128-135.

Blaser, R. E., R. C. Hammes, Jr., H. T. Bryant, C. N. Kincaid, W. H. Skrdla, T. H. Taylor, and W. L. Griffeth.
1956. The value of forage species and mixtures for fattening steers. Agron. J. 48. 508-513.

Blaser, R. E., R. C. Hammes, Jr., H. T. Bryant, W. A. Hardison, J. P. Fontenot, and R. W. Engel.
1960. The effect of selective grazing on animal output. Proc. of 7th Inter. Grass. Cong. pp. 601-606.

...ian, A. V.
...56. Plant introduction, selection, breeding and multiplication. in Tropical Pastures. ed. Davies, Wm. and Skidmore, C. L., Faber and Faber Ltd., London, ... 75-88.

Boudet, F. and Baeyens, F.
1963. A method for studying and mapping tropical pastures. (French) Rev. Elev. 16, No. 2, 191-219, bibl. 34, illus. Eng. & Span. summaries. (Inst. Elev. Med. Vet. Pays Tropicaux, Alfort, Seine, France).

Bruun, O.
1966. (Pastures of the wet tropical region of Bolivia.) (Span.) Exp. Bull. 31 Min. Agric. Bolivia (n.d.) pp. 21, bibl. 51.

Bryant, H. T., R. E. Blaser, R. C. Hammes, Jr.
1958. Low cost forage all year long. What's New in Crops and Soils, 10(9), Aug.-Sept.

Buckner, R. et al.
1967 Chemical composition, palatability, and digestibility of ryegrass-tall fescue hybrids, Kenwell and Ky. 31 tall fescue varieties. Agron. J. 59:345-349.

Burton, G. W. and Hart, R. H.
1967 Use of self-incompatibility to produce commercially seed propagated F_1 bermudagrass hybrids. Crop Sci. 7:524-527.

Butterworth, M. and Arias, P. J.
1965 Nutritional value of elephant grass cut at various ages. Proc. 9th Int. Grassld. Congr. 899-901.

Camargo, A. P. DE.
1965. (Climate of Brazil.) (Port.) Paper presented at the 9th int. Grassld. Congr., Sao Paulo, Brazil, pp. 11, bibl. 13, Eng. and Span. s., maps, mimeo. (Inst. Agron. Campinas, Sao Paulo, Brazil).

Carrera, M. C. and Ferrer, F. M.
1963. Zebu meat production from six species of tropical grasses. (Spanish). Agricultura tec., Mex. 2, No. 2, 81-6, bibl. 11, illus.

Chaverra, H. and Lotero, J.
1965. (Forages and livestock (in Colombia).) (Span.) Agric. trop. 21, No. 11, 713-27, bibl. 16, illus. (Cent. Nac. Invest. Agropec., Tibaitata, Bogota, Colombia)

Chaverra, H. and Lotero, J.
1966. Pastos y ganadaria. Agricultura Tropical 21, no. 11, 713-727.

Coaldrake, J. E. and Smith, C. A.
1967. Estimates of animal production from pastures on brigalow land in the Fitzroy Basin, Queensland. J. Aust. Inst. Agric. Sci. 33, No. 1, 52-4. (Bibl. 7; Cunningham Lab., St. Lucia, Brisbane, Qd. Aust.).

Cole, J. P.
1965. Latin America: an economic and social geography. London: Butterworth & Co. pp. 468. Tbls. Figs. App. Bibls.

Colman, R. L., Holder, J. M. and Swain, F. G.
1966. Production from dairy cattle on improved pasture in a sub-tropical environment. Proc. of X Intern. Grass. Cong. pp. 499-503.

Crowder, L. V.
1959. The adaptation and production of species and selections of grasses and clover in Colombia. Jour. of Range Management 12(5): 225-228.

Crowder, L. V.
1960. Gramineas y leguminosas forrajeros en Colombia. Boletin Tecnico no. 8, Ministerio de Agricultura de Colombia, Bogota.

Crowder, L. V., et al.
1964. The Response of pangola grass (Digitaria decumbens Stent.) to rate and time of nitrogen application in Colombia. Trop. Agric. 41, no. 1: 21-29.

Crowder, L. V.
1967. Grasslands of Colombia. Herbage Abstracts 37(4): 237-245.

Cunha, T. J., and Pace, J. E., Editors.
1967. Proc. of 1967 Beef Cattle Short Course on Pasture Fertilization and Irrigation. pp. 1-197.

Davies, Wm.
1960. Temperate (tropical) grasslands. Proc. 8th Int. Grass. Congr. 1-7.

Davies, J. G.
1965. Pasture improvement in the tropics. Proc. 9th Int. Grassld. Congr. 218-220.

Dobereiner, Johana
1966. Nitrogen-fixing bacteria of the genus Beijerinckia Derx in the rhizosphere of sugar cane. Plant Soil 15: 211-216.

Dobereiner, Johana
1966. Uma bacteria fixadora de nitrogeno na rizosfera de Paspalum. Pesquisa Agropecuaria Brasileria 1: 357-65.

Donaldson, L. E., Lucas, M. H., Johnston, L. A. Y., and Ritson, J. B.
1967. The reproductive efficiency of several North Queensland beef herds. 2. The influence of Vibriosis, Trichomoniasis, and Lesions of the reproductive tract. Aust. Veterinary Journ. 43: 41-44.

Dugand, A.
1942. On the vegetation and plant resources of Colombia. Chron. Bot. 7:71-75.

Edye, L. A., and Kiers, H. J.
1966. Variation in maturity, stolon development, and frost resistance of Glycine javanica. Aust. Jour. of Exp. Agric. and Animal Husbandry 6: 380-387.

Foreign Agricultural Service.
1953. Agricultural Geography of Latin America, USDA Misc. Bull. 743.

Grasslands.
1959. Symposium presented at the New York meeting of the American Association for the Advancement of Science.

Grassland Research Institute, Hurley.
1961. Research Techniques in Use At The Grasslands Research Inst., Hurley. Bul. 45, Commonw. Bur. Past. Fld. Crops, Farnham Royal.

Grossman, J., Aronovich, S., Campello, E. do C. B.
1965. Grasslands of Brazil. Proc. 9th Int. Grassld. Congr., 39-47.

Development in Tropical Latin America. ... State College of Agriculture, pp. 256-271.

... Jones, D. W., Davis, G. K., and Neller,

... response ... different phosphatic fertilizers on pangola- ... Exp. Stations, Univ. of Florida. pp. 1-28.

... Ruelke, O. C., Allen, R. J., Jr., ...

... Agr. Exp. Stations, Institute of Food & Agric. ... Florida, pp. 1-3...

... genetics. In Some Concepts and Methods in Subtropical ... Bur. Past. Fld. Crops, Hurley, England.

... of the breeding of legumes for tropical pastures. C.S.I.R.O. ... Institute of Agric. Sci. 31(2): 102-109.

... northern and southern development as an essential in Australia's future ... C.S.I.R.O. Jour. of Australian Institute of Agric. ...

... night grazing on the growth rates of Zebu cattle in East ... British Grassland Soc., 15(3): 212-215.

... paddock grazing under tropical conditions. J. Brit. ... 18, ... 69-73, bibl. 12. (Dep. Agric. Serere Exp. Sta., ...

... beef production per acre. Sheepfarming Annual 1966, pp. 77-92.

... response of ... Zebu milking stock to moderate levels of supplementary ... East African Agric. and Forestry Jour. 31(4): 368-374.

... Killinger, G. B., Greene, R. E. L., Harris, H. C., Myers, ... and Gammon, N.

... soil and forage analyses, and economic returns from eight ... north central Florida. Bull. 631 Florida agric. Exp. Sta., ... (Beef Res. Unit, Gainesville).

... a summer-growing, self-regenerating annual legume ... permanent pastures. Soil and Crop Sci. Soc. of Florida, ...

... self-regenerating annual legume for use in Florida pastures. ...

[illegible] B.
[illegible] Mesa redonda tenida sobre forrajes [illegible] IICA Turrialba, Costa Rica.

[illegible] M. J.
[illegible] of grazing method and stocking rate in the effi- [illegible] utilization by dairy cattle. J. Agric. Sci. 61, No. 2, [illegible] (Ruakura Anim. Res. Sta., New Zealand.).

[illegible] pasture plants. in Some Concepts and Methods in [illegible] Research, Bull. 47, Commonwealth Bureau of Pastures and [illegible] Berkshire, England. pp. 144-153.

[illegible] D.
[illegible] pasture species. 9th Int. Grassld. Congr. pp. 815-822.

[illegible] between the crude protein content and the digestible crude [illegible] tropical pasture plants. Jour. of British Grassland Soc. [illegible]

[illegible] Minson, D. J.
[illegible] feeding value of pasture and supplementary feed. Proceed. [illegible] Australian Society of Animal Production. 6: 319-329.

[illegible] feeding value of tropical pastures. in Tropical Pastures, ed. Davies, [illegible] Faber and Faber Ltd., London. pp. 106-114.

[illegible] Agricultura y Cria
[illegible] Presented by Minister of Agricultura Cria, Caracas, [illegible]

[illegible] Milford, R.
[illegible] values and nutritive value indices of Digitaria decumbens, [illegible] and Phaseolus atropurpureus. Aust. Jour. of Agric. Research. [illegible]

[illegible] E.
[illegible] distribution of grasslands. in Grasses and Grasslands, ed. C. Barnard. [illegible] Co., Ltd., London. pp. 182-205.

[illegible] and the measurement of pasture production. Proceed. of [illegible] pp. 606-611.

[illegible] M. J.
[illegible] studies in Jamaica. 5. Liveweight production from [illegible] used for rearing and fattening beef cattle and the [illegible] of the yields. J. agric. Sci. 62, No. 2, 187-97, bibl.

[illegible] M. J.
[illegible] investigation of pasture improvement using pangola grass [illegible] on beef farms in Jamaica. Paper presented at the [illegible] Sao Paulo, Brazil, pp. 6, bibl. 5, Span. s., mimeo.

... from the Far North Coast.

... native pasture at Katherine N.T. ... Exp. Agric. Anim. Husb. 5, No. 18, 227-31, bibl. 13.

... 1940-64: a review of published work. Div. Land ... and Ind. Res. Org., Australia.

... Some Concepts and Methods in Subtropical Research. ... England.

... Concept. Plant and Soil 22, no.

... Dijkman, M. J. and Wehlburg, C. ... Agriculture. McMillan Co., 1446 pp.

... Sao Paulo City, Philippines.

... techniques ... A.S.A., A.D.S.A., A.S.A.P., and A.S.R.M. Comstock ... New York

... agriculture and forestry in the tropics. Patterns, ... London, Faber and Faber, 2d ed. 221 pp. (Bibl. 8 pp.)

... de Colombia. Revista Academy Colombia ... 12, no. 47, 95-117

... fertilization on yields and composition of pangola ... Hawaii Agr. Exp. Sta. HAES Tech. Paper No. 708.

... economic development of tropical lands. Proc. 10th ... 1966. 1966, 818-23. (Bibl. 43; Univ. Coll.

... guinea grass pastures and a beef production with ... East

... grasses. IBEC Res. Inst. Bul. 28.

... Studies, no. 49.

[illegible]
1965. An approach to the commercial production of seed of tropical pasture plants. [illegible] 9th Int. Grassld. Congr. pp. 521-26.

[illegible], J. T.
1967. Indicator methods in herbage quality studies. in Pasture and Range Research Techniques. Comstock Pub. Assoc., Ithaca, N.Y., pp. 45-56.

[illegible], J. [illegible]
[illegible] [illegible] of Guinea grass (Panicum maximum). Paper presented at the [illegible] Grassld. Congr., Sao Paulo, Brazil, pp. 5, bibl. 4, Span. s., mimeo. [illegible] Centre, Bodles, Jamaica)

[illegible], [illegible] E.
[illegible] Use of the relationship of stocking rate to gain of cattle in an experimental design for grazing trials. Agron. J. 53, No. 5, 309-13, bibl. 12. (Texas Agric. Exp. Sta., Angleton).

[illegible], G. M.
[illegible]. The Grasslands of Latin America. Imp. Bur. of Past. and Field Crops Bul. 36.

Rotar, Peter P., and Ukio Urata.
1966. Some agronomic observations in Desmodium species: seed weights. Tech. Prog. Rpt No. 147. Hawaii Agr. Exp. Sta.

Rotar, Peter P., Soon Jai Park, Amara Bromdep, and Ukio Urata.
1967. Crossing and flowering behavior in Spanish clover, Desmodium sanwicense E. Mey., and other Desmodium species. Tech. Prog. Rpt. No. 164. Hawaii Agr. Exp. Sta.

Rotar, Peter P., and Ukio Urata.
1967. Cytological studies in the genus Desmodium; some chromosome counts. Amer. Jour. of Botany 54(1): 1-4.

Schaafhausen, R. V.
1965. Weight increase of Zebu cattle grazing on the legumes Dolichos lablab and Cajanus indicus. Paper presented at the 9th Int. Grassld. Congr., Sao Paulo, Brazil, pp. 5, bibl. 19, Port. s., mimeo. (Fazenda Esta. Val de Palmas, Bauru, Sao Paulo State, Brazil).

[illegible], [illegible] A. et al
[illegible]. The preparation and feeding value of pangola grass silage. Trop. Agr. [illegible]:251-256.

[illegible], A.
[illegible]. Studies on the Hyparrhenia veld. 6. The fertilizer value of cattle excreta. J. Agric. Sci., Camb. 64, No. 3, 403-6, bibl. 18. (Vet. Res. Stn., [illegible], Zambia).

[illegible], [illegible]
[illegible]. Studies on the Hyparrhenia veld of Zambia. 7. The effects of cattle grazing veld and dambo at different stocking rates. J. Agr. Sci. 66:41-56.

[illegible] Cunningham Laboratory, C S I R.O.
______ 1966-67 Annual Report. Division of Tropical Pastures. C.S I.R.O. pp. 1-[illegible]

[illegible] Cunningham and Townsville Laboratories. pp. 1-40. [illegible]

[illegible] javanica -- its strengths and weaknesses. Rural Res. [illegible]

[illegible] from tropical legumes. Rural Res. in C.S.I.R.O. pp. 29-32.

[illegible] C.
[illegible] and weed control for increased food production. in "Prospects of the World Food Supply." Nat. Acad. of Sci., pp. 72-71.

[illegible]
[illegible] from Uganda pastures containing Stylosanthes gracilis and [illegible]. Paper presented at the 9th Int. Grassld. Congr., Sao [illegible], Brazil, pp. 5, bibl 7, Port. s., mimeo. (Serere Res. Stn., Uganda.).

[illegible], T. H., and [illegible], A. D. H.
[illegible] The use of liveweight gain trials for pasture evaluation in the tropics. [illegible] An "[illegible]" latin-square design. Jour. of British Grassland Soc. 21(1): [illegible]-55.

[illegible], T. H., and Joblin, A. D. H.
[illegible]. The use of liveweight gain trials for pasture evaluation in the tropics. [illegible] Variable stocking rate designs. Jour. of British Grassland Soc. 21(2): [illegible]-155.

Sugar Manufacturers' Association (of Jamaica) Ltd.
1960. Pasture management. Rep. Sug. Manufact. Ass. (Jamaica) 58-9.

[illegible]shi, M., Mcomaw, J. C. and Ripperton, J. C.
[illegible]. Studies of Napier grass. III. Grazing Management. Bull. 128, Hawaii [illegible] Exp. Sta. pp. 5-4 .

[illegible] et al.
[illegible]. Estudio comparativo de produccion de carne en 5 zacates tropicales. II. (Comparative study of beef production on five tropical pasture grasses II.) [illegible] Mexico [illegible], p. 38-45.

[illegible], J. M. A. and Terry, R. A.
[illegible]. A two-stage technique for the in vitro digestion of forage crops. J. [illegible] Grassld. Soc. 18:104-111.

[illegible] States Department of Agriculture.
[illegible]. Notes on the agricultural economics of the twenty Latin American Republics. [illegible] U.S. Dept. Agr. pp. 86, maps 2.

[illegible], and [illegible], W. W
[illegible] grass-legume mixtures and grass under irrigation as pas[illegible]. Agron. J. 50:85-88.

[illegible]
[illegible] in the analysis of fibrous feeds. II. A rapid method [illegible] of fiber and lignin. Jour. of the A.E.A.C. 46(5): 829-835.

Van Soest, P. J., Wine, R. H. and Moore, L. A.
1966. Estimation of the true digestibility of forages by the in vitro digestion of cell walls. Proc. of X Int. Grass. Cong. pp. 438-441.

Van Soest, P. J.
1967. Development of a comprehensive system of feed analyses and its application to forages. Jour. Animal Sic. 26(1): 119-128.

Van Soest, P. J. and Jones, L. H. P.
196[illegible] The effect of silica in forages upon digestibility decline. Paper presented Am. Dairy Sci. Asso., Ithaca, N.Y.

Van Soest, P. J., and Wine, R. H.
196[illegible] Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell-wall constituents. Jour. of the A.O.A.C. 50(1): 50-55.

[illegible], V. [illegible]
1967. Minerales para el ganado de carne. in Pastos y Ganados para la Costa Atlantica. Boletin de Divulgacion no. 15. pp. 67-75.

Vicente-Chandler, J., et al.
1964. The intensive management of tropical forages in Puerto Rico. Agric. Exp. Sta. Bul. 187, Univ. P.R., Rio Piedras. pp. 152.

Webster, C. C. and Wilson, P. N.
1966. Agriculture in the Tropics. Longman, Greene & Co., Ltd., London. pp. 248-271.

[illegible], Mary.
196[illegible]. Clover boosts calf production. Res. Rept. 12(4): 4-5. University of Florida.

Williams, R. J.
[illegible]. Plant introduction. in Some Concepts and Methods in Subtropical Pasture Research. Bul. 47, Commonw. Bur. Past. Fld. Crops, Hurley, England.

Williams, W. A.
1967. The role of leguminosae in pasture and soil improvement in the neotropics. Trop. Agr. 44: 105-116.

[illegible], R. O.
[illegible]. Milk production in developing countries. London, Faber and Faber Ltd., [illegible] p. Tables. Graphs. Map. Refs.

[illegible], I. J., Edye, L. A., Davies, J. G. and Haydock, K. P.
1964. Animal production from a sorghum almum pasture in south-east Queensland. Aust. J. Exp. Agric. Anim. Husb. 4, No. 15, 326-35, bibl. 19. (Qd. Agric. Coll., [illegible])

[illegible], R., Plucknett, D. L. and Rotar, Peter P.
[illegible] [illegible] and yield performance of Desmodium intortum and D. Canum in Hawaii. Tech. Bull. No. [illegible] Hawaii Agric. Exp. Sta. University of Hawaii. pp. 1-22.

[illegible], [illegible] R. and Plucknett, D. L.
196[illegible]. Beef production with heavy phosphorus fertilization in infertile wetlands of Hawaii. Paper presented at the 9th Int. Grassld. Congr., Sao Paulo, Brazil, [illegible] 6, bibl. 7, Span. [illegible], mimeo. (Hawaii Agric. Exp. Stn., Honolulu).

[illegible]. ACKNOWLEDGEMENTS

1. For time consuming review of research in progress, for patient discussions of scientific endeavors and philosophies, for stimulating ideas and worthwhile suggestions, and for transportation the following people are to be recognized:

Colombia - Dr. Hernan Chaverra and associates in the Pastures and Forage Crops Program at the Instituto Colombiano Agropecuaria.

Australia - Drs. J. G. Davies and H. M. Hutton and their associates who staff the Division of Tropical Pastures at the Cunningham, Samford, Cooper and Townsville Laboratories.

Dr. B. Crof and others of the Queensland Department of Agriculture.

Dr. M. J. T. Norman and staff of the Division of Land Research, CSIRO.

Dr. F. H. W. Morley and staff of the Division of Plant Industry, CSIRO.

Dr. G. L. McClymont and staff of the University of New South Wales.

Dr. W. M. Willoughby and staff of the Pastoral Laboratory at Armidale, CSIRO.

New Zealand - Dr. L. R. Wallace and staff of the Plant and Animal Research Center at Rurakura.

Hawaii - Drs. D. L. Plucknett and P. Rotar of the University of Hawaii.

Puerto Rico - Mr. Jose Vicente-Chandler and associates of the Cooperative ARS Research Project located at Rio Piedras, and Dr. G. L. Spain of the Agricultural Experiment Station at Rio Piedras.

2. Special appreciation is extended to the following:

Dr. I. P. Fontonot, Professor of Animal Nutrition and Biochemistry, Virginia Polytechnic Institute for a critical review of the proposal and help in preparing Section IV-C.

Dr. J. Taylor, Animal Production Department, Grasslands Research Institute at Hurley, England for a review and critique of the manuscript.

Dr. N. S. Khan, A… Scientist with the Rockefeller Foundation for valuable exchange of ideas and fruitful suggestions while traveling in Colombia, Australia, New Zealand and Hawaii.

3. For initial orientation, which provided a tentative objective and a practical approach for preparing this proposal, acknowledgement is made to the following:

1. Staff of the Rockefeller Foundation:

Dr. L. M. Roberts, Assoc. Director for Agriculture.

Dr. U. J. Grant, Director of CIAT.

Dr. H. A. Rodenhiser, Consultant.

Dr. E. C. Stakman, Consultant.

Dr. R. Cummings, Assoc. Director for Agriculture.

2. Others:

Dr. G. W. Burton, Principle Geneticist, USDA, Tifton, Georgia.

Dr. A. A. Hanson, Section Head, Pastures and Forage, USDA, Beltsville Maryland.