PROBLEMS RELATED TO THE BREEDING IMPROVEMENT OF CATTLE IN TROPICAL REGIONS

by

SERGIO ULISES MOLINA

Agronomo., Escuela Agricola Panamericana, 1963

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Husbandry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1966

Approved by:

Major Professor

TABLE OF CONTENTS

INTRODUCTION

From day to day increasing concern is voiced in the popular press, in learned journals, and other communication media, regarding the rapidly expanding population of the world. Dramatic as the increase itself is, even more important and awesome is the fact that the increment rate is lopsided. Precisely in those nations where population is already pressing severely against food supply is where the largest population increase is expected. Latin America, where human population now approximates one quarter of a billion, is expected to exceed the half billion mark by the year 2000. One of the latest estimates (96) places the number of mouths in Latin America at 630 million by the year 2000; a remarkable 157% increment from their estimate of the actual population.

Throughout the world, in varying proportions, a high percentage of total human beings cannot be adequately fed or clothed without sufficient livestock products. In this age, more than ever, human welfare demands that livestock function with maximum efficiency.

Livestock improvement, in the scale demanded even by the present requirements, makes imperative a profound and sustained national effort.

Achievement of progress in a nation's animal industry is like farming itself. The "soil" must be prepared, and the right "fertilizer" used. Instantaneous results cannot be expected, for the process of growth and development can be speeded up only gradually. The best "soil" for national livestock improvement is the opportunity afforded the cattlemen, large and small, to work toward a better living standard for themselves. The best "fertilizer" for sustained and healthy growth of the industry is the continuous education of the producers themselves, a process which requires special institutions and time for those institutions to yield effective results.

Although not always recognized, progress must be simultaneous in many fronts. It is unreasonable to expect miraculous transformations from the introduction of power-driven machinery. Effective utilization of mechanical equipment in the livestock industry must be accompanied by simultaneous changes in other aspects of the industry. Too often, little consideration is given to making the conditions of the cattle-breeding community favorable to change and improvement.

Citizens of countries whose animal industry is barely beginning to scratch the surface of development look upon the tremendous feats already accomplished, and the giant strides now being made, in the animal science field by such countries as the United States and those of Western Europe. Little thought is given to the conditions which made the accomplishments possible.

Agricultural experiment stations alone would never have brought about animal improvement in the countries where a modernized husbandry is a conspicuous part of the economy. The speed of the improvement has been governed, not so much by the rate of acquisition of new knowledge by dedicated research workers in superbly equipped modern laboratories, as by the rapidity and constancy with which this newly acquired knowledge has been and is continually being passed on to the people directly responsible for the industry's growth.

Countries which have not yet modernized their agriculture to any great extent have the advantage of the great accumulation of knowledge in animal science derived from research and practice in other lands. Nevertheless, it should be mentioned that the adaptation of such knowledge is difficult and takes time. It should also be mentioned that widespread application of scientific knowledge to a nation's animal industry can be achieved only when the industry's community generally realizes the practical value of the scientific method, and when there are a large number of scientifically trained people in the country engaged in developing and spreading the knowledge particularly suitable to each segment of the industry. For these reasons, the animal industry in the less developed countries cannot avoid at least some of the intermediate stages of improvement through which other countries have passed to reach their present stage of relative advancement in this field.

The application of knowledge, new and old, to a nation's animal industry not only takes time, but it is also an endeavor for which there is no end in sight. Once improvement in animal production efficiency has been initiated, no final goal can reasonably and conclusively be set. This can be observed in precisely those countries that have the longest history of applying science to animal industry, where improvement is proceeding most rapidly at present.

AGRICULTURAL REGIONS OF NICARAGUA

Since an attempt will be made in this paper to make suggestions for the improvement of animal husbandry in Nicaragua--which if not immediately applicable hopefully at least should provoke some thought--it seems desirable to present certain relevant facts about the country.

Nicaragua's geographical situation is wholly within the Equator and the Tropic of Cancer, as are its sister republics of the Central American Isthmus. It comprises an area of roughly 57,000 sq. mi., holding a population of about 1¼ million people. Agriculturally, it can be divided into four spearate regions: the western plains region, the Managua-Carazo uplands or Sierras, the central mountain region, and the eastern plains region.

THE WESTERN PLAINS REGION. This region is made up almost exclusively of volcanic plains ranging from sea level to several hundred feet elevation. The rainy season usually begins in May and normally ends in October. There are only a limited number of precipitation scores, but from the figures available (32) one can appreciate the considerable variation in rainfall within this area.

Managua (inland--200 feet elevation)			
	1932-1948	mean	45.20"
		range	16.02"-70.36"
Granada (on Lake Nicaragua--196 feet elevation)			
	1877, 1883-1884, 1897-1949	mean	58.57"
		range	15.35"-93.67"
San Antonio (western)			
	1903-1949	mean	82.58"
		range	41.87"-187.73"

Rivas (between sea and Lake Nicaragua--160 feet elevation)

1932-1948	mean	59.39"
	range	31.14"-89.91"

The volcanic ash soils of this region are naturally fertile. FAO (28) reports that heavily cropped soils near Managua were found to be "extremely low" (2 ppm) in nitrate; "high" in available phosphate (100-150 ppm), soluble potash (400 kg./ha.), and replaceable calcium (700 ppm). On the average the pH ranges from 6.0 to 7.0; it goes up to 8.0 in limited areas near Rivas and on western Ometepe where the soil contains calcareous material.

The better farming areas are in the Departments of Leon, Chinandega, and Rivas. Sixty per cent of the population of the country is concentrated in these areas. Except where African Jaragua grass (*Hyparrhenia rufa*) grows, or other grasses have been planted, the grazing is of relatively poor quality. Despite this, a considerable number of livestock, principally cattle are produced in the Departments of Chinandega, Leon, Rivas and Chontales.

Agricultural production is concentrated on corn, sorghum, rice, beans, cotton, sugar and livestock. While examples of good farming can be found, the general average of crop agriculture and animal husbandry, especially, is mediocre to very poor. Relatively little land is irrigated in this region.

The main communications are limited to the railway running from Managua to Granada on the one side and from Managua to Corinto, Puerto Morazan, and El Sauce on the other; and to the Inter-American Highway extending from Managua to Rivas on the south, and northward to Sebaco and the border with Honduras. The main new road constructed outward from Managua goes to Chinandega and Granada. Lateral or feeder roads are poor, many of them being dust paths in the dry season and mud-and-water streams during the wet season.

THE MANAGUA-CARAZO UPLANDS OR SIERRAS. This comparatively small sierra and upland plateau region ranges in elevation from about 1300 to 4000 feet. In the Department of Managua coffee is grown from approximately 1300 to 3500 feet, while in the Department of Carazo the range is about 1600 to 2300 feet.

On the whole, the climate is cooler and somewhat more humid than that of the western plains region, as might be expected from the elevation.

Despite the fact that some regions have been planted to coffee since about 1860, and many others for at least nearly 50 years, the soils still show comparatively high fertility. It seems clear, however, that there must have been some loss of both depth and fertility where the steeper slopes have been cultivated, especially where systematic removal of all weed growth under coffee has taken place over a number of decades. Leaching of nutrients and erosion of surface soil have clearly occurred and must still be taking place.

This is essentially coffee producing country. The industry has gradually grown over the last 90 years. Elevation, climate, and soil are all suitable for the production of coffee. About 2/3 of the Nicaraguan coffee is produced in this region.

The labor supply is reported to be barely sufficient (32) for coffee harvesting because of competing crops in other regions; however, the workers are reasonably competent owing to their long experience with the production of coffee.

While a few staple crops are grown, and some cattle are kept on the estates and by the small landowners, coffee is likely to continue to be almost the only local industry.

THE CENTRAL MOUNTAINS REGION. This region includes the Departments of Matagalpa, Jinotega, Madriz, Nueva Segovia and part of Esteli, in northeastern Nicaragua. As the region is situated in the range of mountains forming the continental divide, most of the streams and rivers flow into the Caribbean Sea and there are numerous small but swift-flowing mountain streams. The elevation ranges from about 1500 feet to about 5500 feet. Coffee, which up to the present is the chief industry, can be grown at about 2000 to 5000 feet, preferably from 2200 to 3500 feet.

The topography is rugged. Mountain peaks attain heights of 4500 to 5500 feet, alternating with comparatively small lowland valleys and plateaus. Fairly extensive "llanos" or plains exist in the Department of Matagalpa, commencing some 25 miles east and southeast of the town. Climate, soil, and elevation are conducive to coffee production. Similar plain areas are found in the Department of Jinotega.

The climate is typical of highland country in the tropics, that is, of country known locally as "tierra templada": cool, humid to very humid, with little seasonal range in temperature but quite marked diurnal change. No meteorological records are available, but from personal experience the following description of the area should be reasonably accurate.

Rainfall is somewhat greater than in the Managua-Carazo Sierras but the rains are usually of lesser intensity. Heavy downpours of a torrential nature occur occasionally. The rainy season commences about mid-May but toward the northern portions of the region light rains may occur in February, March and April.

No temperature, humidity or evaporation data are available, but on the basis of a drop of about three degrees per every 1000 feet increase in elevation, the mean annual temperature may range from 69°F. to about 77°F. At about 4000 feet the night temperature may be as low as 50°F. Frost never occurs.

In addition to coffee, which amounts to about 1/3 of the country's total production, scattered annual crops and some cattle are raised in this region, particularly at the lower elevations. Torsale or Nuche (*Dermatobia hominis*) are an abundant source of damage to the cattle of the region.

THE EASTERN PLAINS REGION. This region comprises over half the total area of the country and is made up of the low slopes and plains which are bounded by the Atlantic Ocean. The region has a wide range of soils, from alluvial types along the numerous rivers, to shallow gravely soils and clay-loams of low natural fertility.

The region is dissected by numerous rivers--some of them of appreciable length, width and volume--and countless streams. The prevailing vegetation is tropical evergreen hardwood forest of very mixed composition. These forests are estimated to cover nearly 20 million acres of which about ¼ is believed to be of a superior type (32).

The Eastern plains have never been thoroughly explored. Apart from the five main rivers which permit a certain degree of navigation--the San Juan, the Escondido, the Rio Grande, the Prinzapolca, and the Rio Coco--and some local roads built by private enterprise in the vicinity of Puerto Cabezas, there are at present few means of transportation. At present agricultural activity exists within several miles of the main rivers; beyond this there is little or no human inhabitation. The human population is the lowest per unit area in Nicaragua.

The rain is heavier here than elsewhere in the country, with the fall extending over 9 to 12 months of the year. Examples of two centers (28) gives some impression of the amount and distribution of the fall:

Bluefields (coastal):

1926-1932, 1934-1949	mean	151.68"
	range	61.19"-200.11"

Cukra Hill Experimental Station on the Rio Escondido:

1945-1950	range	132.05"-155.71"

Temperature, humidity and evaporation data are not available, but it may be stated that there is little range in temperature between the drier and the wetter months; the humidity range is slightly more marked, the values being somewhat less in the months of February, March and April, in years when the rainfall is markedly reduced.

Up to the present the principal activity in this great region has been the exploitation of hardwood timber, principally Mahogany (*Swietenia macrophylla*). This has been carried on within reasonable distance of some of the principal rivers, which have been used for floating the logs down to the Atlantic. More recently there has been some exploitation of the *Pinus caribea* in the Department of Zelaya.

There has been some production of rice, beans, and other staple foods. At one time bananas grew quite abundantly but hurricane and disease have caused the production and export of bananas to fall off almost completely.

From this brief description of the principal regions of the country it is possible to infer that the country can be neatly divided into two more or less definite cattle regions, with some overlapping. The western plains region, almost exclusively encompassing the main population centers and possessing the best communications network in the country, seems predominantly suitable for dairy cattle and intensive forms of beef cattle production. The eastern coastal plains, with abundant rainfall throughout most of the year, seems capable of providing year-round pastures and thus eminently suitable for extensive production of beef cattle; although one must recognize that the lack of suitable roads and otherwise means of communication definitely reduces the attractiveness of the region.

There are no data available as to the number of different types of livestock within the country, or within any one of the regions described. Nevertheless, it is safe to state that the prediction made 15 years ago by the International Bank of Reconstruction and Development when it said that "cattle raising and the production of dairy products, meats, hides and other by-products, will be the most important future activity of Nicaragua," has definitely come true. Large animal husbandry is (32) not only the biggest single agricultural industry in the country, but is also the fastest growing.

BREEDING CATTLE FOR ADAPTABILITY AND PRODUCTION

GENERAL. It is widely known that animal species differ in their ability to thrive and to perform efficiently under a given set of conditions. Some species are adapted to cold climates, others to temperate climates, and still others are more suited to tropical conditions.

Not so widely realized is that among the large domestic animals, whose distribution is world-wide, differences in adaptive ability to different extremes of climate also exist. Still narrower, within a given species, there are less conspicuous but still detectable differences. Variations in grazing ability is an example. Some can obtain a satisfactory living while grazing over extensive range lands, while others require lush pastures and supplementary feeding, if they are to perform efficiently. Those who are able to utilize areas of sparse grazing and are there able to harvest extensive areas of land that would otherwise be of little use to man are often limited in their productivity when placed under excellent environmental conditions. Though they may be able to live and reproduce quite satisfactorily, one must remember that they have been developed under conditions where natural selection eliminated the weaklings, and where there was relatively little opportunity for expression of, let alone selection for, superior milk, or meat production. Their production may, under improved managerial conditions, leave much to be desired. Under good environmental conditions, it is necessary to select stock that has the inherent capacity to utilize efficiently large amounts of good quality feed, if that feed is to be transformed most efficiently into products for human consumption.

Variations in adaptability are important in selecting stock for a given set of conditions. This point has been frequently overlooked in attempts to improve the quality or productivity of stock in a given area. This has been particularly true in underdeveloped countries or regions where rigorous environmental conditions prevail, and as a result much time, effort, and money have been expended, often with very disappointing results.

Relatively little attention has been given to variations in animal adaptability. The reason is, partially, in the way higher education and experimentation in Animal Husbandry have developed. Animal Husbandry and other branches of agriculture have naturally grown most rapidly in countries having optimum conditions for agricultural development. Such countries, have been in the best position, financially, to promote agricultural research and teaching, and their outstanding institutions have generally developed in regions adapted to intensive agriculture. It has naturally followed that the majority of leaders in Animal Husbandry have devoted their attention to areas where adaptability to rigorous conditions is of minor importance. These leaders have taught most of the students from underdeveloped countries, which for the most part, are without adequate institutions of their own. These students have rarely had their attention called to the problems of animal adaptability that must be dealt with in their own countries; in few cases have they been given any real appreciation of how to deal with these problems. It is not surprising, then, to find many instances in which these students returning to their own countries as leaders, have imported stock that was nearly ideal in the area where they received their training, but which was ill-suited or entirely unadapted to the conditions into which it was taken.

In any country, improving the efficiency of livestock production is an important task. In countries where the need for animal products is greatest, which unfortunately happens to be in those in which the efficiency of animal production is lowest, improvement is of paramount importance. Adaptability of animals to the environment under which they live and produce must be given careful consideration in all attempts to expand and improve livestock production.

Obviously, animal productivity can also be improved by providing a better environment, for the performance of any animal is determined partially by its heredity and partially by the conditions under which it is developed and maintained. Nonetheless, in many areas, limitations are laid down by nature. The livestock producer can progress only to a certain point in improving his animals within economic limits, the supply of feed and other environmental factors. In areas where many of the conditions under which cattle must be produced are determined by nature, if a producer's cattle are to perform profitably, he must select and breed animals that are particularly adapted to such environment.

ADAPTABILITY AND PRODUCTION IN TROPICAL AMERICA. Only limited effort has been made to develop livestock breeds or utilize hybrids especially adapted to tropical conditions in the Americas. Most of the highly productive breeds have originated and evolved in the temperate zones, under conditions, especially nutritional, that are unsuitable and generally unprofitable under tropical conditions. Personal experience of the livestock producers, information obtained through breeding investigations, and a number of indications of genetic-environmental interactions have shown the need for harmonizing the genetic adaptability of animals and their environment if economic production of meat and other animal products is to be achieved in the tropics.

If this coadaptation can be effected, the tropics may well replace the temperate zones as the principal sources of animal products to supply the needs of the expanding world population, thus mitigating their own pressing needs. It is becoming increasingly imperative to expand scientific investigations in animal breeding, nutrition, climatology, feed production, and the adaptation of these disciplines into production of livestock in the tropics.

It must be recognized that the genetic improvement of farm animals is a slow process. Rapid changes cannot be made to correct mistakes in forecasting the characteristics needed in genetic stocks or the conditions under which they will be used. Since maximum efficiency requires that animals be adapted to their destined use and to their environment, an intelligent prognosis must be made in planning long-term breeding projects and developing and promoting breeds and strains of cattle. For example, valuable time can be lost in selecting for tolerance to high ambient temperatures when the basic consideration may be tolerance to high solar radiation. Likewise, there is no point in selecting beef cattle for efficiency in converting large amounts of concentrates when they will be finished on pasture during the foreseeable future. Unwarranted and ill-founded assumptions about environment and adaptive mechanisms should be avoided.

The requirements of beef cattle for the tropics are distinctly foreign to the improved European beef breeds. The more essential requirements for tropical beef cattle are: ability to utilize fibrous roughages; tolerance to high solar radiation, high temperatures and high humidity; and adaptation to the microbiological organisms and insects of the tropics, especially to the several tick species and the Nuche fly (*Dermatobia hominis*).

The European breeds are deficient in all these characteristics, and their only apparent potential in most of tropical America is for crossbreeding or combining with native cattle or the Zebu to form crossbred foundations for new selections. Zebu-type cattle possess the desired adaptive traits for the tropics but are in general of slow growth and late maturity.

The genetic stocks of greatest potential usefulness to the American tropics very possibly are to be found among the native or "criollo" cattle which have descended from Spanish introductions. Unfortunately, the general tendency has been to underestimate their genetic worth. This evaluation is understandable in that most native cattle are small in size, and generally present a degenerate appearance. The introduction of outside blood, particularly the Zebu, has resulted in hybrid vigor, the advantages of which frequently have been attributed to the breed characteristics of the introduced stock. This unwarranted attribution has added to the general downgrading of the merits of the native cattle.

Two of the principal characteristics that make native cattle extremely valuable in tropical American beef cattle production must be mentioned. First, natural selection has endowed these cattle with adaptation to the disease and climatic stresses of the area. Few other cattle in the world, except the Zebu, possess this characteristic. This limits the opportunity for introduction of outside breeding for improvement or for crossbreeding. Secondly, they have shown good combining ability with the Zebu, the only other beast that has proved its utility in the tropics. Thus, if hybrid vigor is as important for the American tropics as it presently appears to be, perpetuation of native stocks is essential to have available bulls that can be used in crossbreeding with the Zebu or its derivatives. Selection in native populations for performance under improved management and nutrition also merits vigorous investigation. Thus, action should be taken to assure the continuance of native populations before potentially valuable genetic material is dissipated by top-crossing with other stock.

BREEDING FOR ADAPTATION TO THE AMERICAN TROPICS. A well adapted animal is one in perfect harmony with its environment. Of all the interrelated factors influencing the environment, climate is probably the most important, affecting not only the vegetation and parasitical fauna but likewise the density of human population, its needs and culture.

The climatology with which the animal breeder is concerned aims at establishing the influence of climate, with its constantly recurring phases, upon the animal (in this case the bovine), for the reaction of any animal to a particular external environmental stimulus is closely correlated with the animal's efficiency of production in that environment.

As a result of differences in hereditary characteristics the various breeds and even types within a breed react differently to environmental stimuli. The reaction of different types of cattle, even within a given breed, to external stimuli is intimately associated with anatomical and physiological characteristics which have developed as the result of natural selection.

If removed from their original environment to a new environment, certain individuals within the breed succeed better than others in adapting themselves to new conditions, the degree of successful adaptation of such animals being very accurately reflected in their ability to grow, to reproduce regularly and to produce, whether it be milk, meat or other animal product.

The manner in which animals react to meteorological conditions--the rise and fall in air temperatures, wind velocity, rainfall distribution and intensity, and the duration and intensity of sunlight--is information of value to the cattle breeder as a guide to the selection of cattle possessing those attributes which promote or facilitate their adaptability. The interpretation of the reactions of animals to climatic conditions gives a good indication of the morphological functional differences existing between breeds and even between individuals within a breed. The animal which is well adapted to a certain environment often possesses distinctive breed characteristics indicative of adaptability, and if these qualities are known, then the cattle breeder is able to select accordingly; the process of natural selection is thereby accelerated and the danger of introducing unadaptable types into a new environment can be avoided.

In order to determine what anatomical physiological characteristics are coupled with adaptability it is necessary to study the effects of specific environmental factors on special organs or parts of the body, and the animal breeder in tropical regions must in the first place determine what effect radiation, temperature, and humidity have on cattle. Further, it is necessary to find out whether differences exist between different breeds and types of cattle in their ability to find feed in a certain environment and in their ability to utilize such feed. Likewise animals must possess qualities which increase their powers of resistance against prevailing diseases and parasites.

There is every indication, therefore, that by the careful selection of certain qualities, it is possible to develop cattle breeds, and types within breeds, possessing hereditary characteristics that will ensure their adaptability to tropical climatic conditions. Such animals are endowed with resistance against intense radiation, high temperatures, and parasites; furthermore, they can make the most effective use of the variable feed conditions typical of the semi-arid tropics, and can be economically produced under these conditions. On this basis, therefore, it is possible to subdivide a country into climatic zones in each of which a breed or type can be found--or developed--which is in harmony with the prevailing environment. The environment, and the animal and its production potential will determine the most adequate breeding policy to follow.

ADAPTABILITY TO DIRECT SOLAR RADIATION. Solar radiation includes rays of three different wavelengths, namely: (1) long-wave rays--the infrared or heat rays; (2) rays of medium wave-length--the light or white rays to which the eye is sensitive; and (3) the short-wave or ultraviolet rays, invisible to the naked eye.

Radiation is a variable factor, fluctuating during the day and with seasonal changes in humidity; it is likewise modified both by latitude and altitude. The nature of the radiation received near the earth's surface is largely determined by the penetration of the sun's rays through the atmospheric strata which act as filters, admitting or excluding long--or short-wave rays in particular. At low latitudes there is a higher degree of radiation, both of heat rays and of short-wave rays, than in temperate regions; in those parts of the world near the Equator the intense radiation may have a most injurious effect upon animals.

Some animals which are not resistant to intense radiation may be adversely affected--with resultant skin irritation, or injury to the mucous membranes--if the intensity and nature of the radiation exceed certain limits. Consequently, indigenous cattle are frequently endowed with hair and hide color and other attributes (such as hair characteristics) evolved to give the animal protection against the injurious effects of excessive radiation.

Thus, both the infra-red rays of long wave-length and the light rays, are effectively reflected by white, yellow or reddish brown hair, but not by black hair (10,27,66). The short-wave or ultra-violet rays in turn are effectively resisted by yellow, reddish brown and black hide colors. It is apparent, therefore, that a white, yellow or red coat with a dark hide is the ideal combination to render an animal resistant to the temperature and intense radiation of the heat and short-wave rays. It is moreover, this hair and hide colors which are found among the native or "criollo" cattle of tropical America.

White hair color and a hide without pigmentation often result in injuries to the skin due to irritation caused by the short-wave rays; in contrast, black hair and black hide is a good combination for elimination rays of short-wave length. As long as an animal is not exposed to the sun, a dark heat-radiating color is advantageous in disposing of surplus heat acquired during exposure and through metabolic processes. Black cattle breeds are therefore the best suited to those regions where short-wave radiation is intense, at high altitudes and where mist frequently occurs--shade or cloudiness is an essential condition for dark colors to operate efficiently.

It can therefore be seen how important it is that breeders in tropical America give adequate attention to the selection of appropriate hair and hide color, with a view to breeding animals which are well adapted; this should replace the indiscriminate breeding of animals of certain colors because of prejudice or taste.

ADAPTATION TO HIGH ATMOSPHERIC TEMPERATURES. In climatic regions where cattle breeds have to contend with high atmospheric termperatures, various reactions occur which maintain the animal in a condition of thermostability. Apart from the alteration in the metabolism of the animals, other physical phenomena, such as the latent heat of vaporization of water from the lungs, play an important part in the dispersion of superfluous heat.

Likewise, both evaporation of moisture from the hide's surface and radiation of heat are effective in cooling the animal's body, and both processes are dependent upon the quality of the coat cover (9,65).

Smooth coated animals which have mainly primary hair follicles--from which straight hair emerges--have better developed sweat and sebaceous glands, and it can be accepted that they lose more moisture from the hide as a result of evaporation. Animals with furry coats have hides with two kinds of hair follicles, primary and secondary--from which curly or semi-curly hair emerges--; the thin curly hair form a mat on the animal's skin, and little evaporation of moisture from the skin takes place. Thus furry coated cattle with their heat-retaining layer and external protective cover cannot dispose of heat effectively through radiation, and these are animals which in hot weather readily become hyperthermic.

In tropical regions the hides of smooth coated animals--animals which have mainly primary follicles in the hide--are usually thicker than those of the woolly types; they have a better flow of blood to the hair follicles, consequently radiation of heat in these types is more effective. In order, therefore, to develop types which will radiate heat effectively in the tropics, smooth-coated animals should be used for breeding purposes.

ADAPTATION TO HIGH HUMIDITY. Seath and Miller (80) have indicated that the part played by humidity in the reactions of the animals is of little importance, for it was found that, within the temperature range from 50°F. to 90°F., a rise in 1°F. in air temperature was responsible for 13 to 15 times as great a rise in body temperature as was a rise in 1% in the relative humidity.

ADAPTATION TO FEEDING CONDITIONS. In consequence of the irregular rainfall and high temperatures of the tropics, natural grazing is deficient in protein and high in crude fibre during a considerable part of the year. The higher the animals have developed from the animal husbandry point of view, the more difficult will it be for them to utilize such poor grazing.

Owing to the annual droughts the animal must also have the ability to search for food, and if much walking is required to reach the feed or watering places, as is usually the case in tropical American ranches, the animal which does not move with ease will have difficulty in obtaining its maintenance needs, let alone its requirements for production.

Adequate nutrition affords considerable but by no means complete solution to the problem of adaptation to tropical America. In the economic production of stock it is essential that the most effective use be made of the vegetation available in the region. Thus while in cool temperate regions the problem of adaptation and environment is easily solved by feeding and shelter, a system of supplementary feeding in the tropics, where the necessary fodder is supplied to the animals in sufficient quantities, may be neither a practical nor an economic proposition.

In other words, it is possible for a breed adapted to a warm region to develop normally in a temperate climate, provided it received adequate feed and shelter, especially during the winter. The maintenance requirements of such an animal will, as a result of a greater power of radiating heat, be greater than those of an animal possessing a coat of heat-retaining properties, and provided it is healthy, it can maintain a normal body temperature.

The converse, however, is not true. A cattle breed developed in a cool temperate region will not thrive in the tropics, notwithstanding good feeding. Such animals tend to become hyperthermic as a result of high environmental temperatures and lack of adaptability; they automatically eat less and the whole process of normal metabolism is disturbed.

Thus, to breed animals which will effectively utilize the available feed resources in the American tropics, it is necessary to select those which are in thermal equilibrium with the environment, which can move with ease and which can make effective use of coarse fodders.

An effective utilization of roughage is fundamental to an economic cattle breeding industry in the American tropics. Thus if an endeavor be made to locate each breed in those regions which most closely resemble its original habitat, then for the hot tropical zones those breeds should be selected and bred which can advantageously utilize bulky feed and which are able to do relatively well without concentrates. The basis of selection should, then, be ability to thrive on native pasture.

ADAPTATION AND REPRODUCTION. The function of growth is to a large extent determined by the animal's efficiency of utilization of feed, closely correlated in turn with the ability of the animal to maintain thermal equilibrium. There is every indication that if the animal is not in thermal equilibrium with its environment then its metabolism is not normal either, and apparently no amount of feeding will stimulate growth. All animals, therefore, so constituted as to be unable to adapt themselves suffer from chronic undernourishment, owing to the fact that they cannot effectively utilize the available forage.

Under-feeding results in retardation of growth. Since the function of reproduction is intimately associated with growth, all the animals whose growth has been considerably retarded reveal repressed sexual activity.

The reproductive ability of a poorly adapted animal is low, and selection on a fecundity basis is, consequently, a most effective method of breeding for adaptability.

ADAPTATION AND PRODUCTION. Production of meat, fat, milk, etc., are nothing more than functions of growth, and if the animal does not grow normally, its productive capacity will be considerably reduced.

If an animal in the tropics is adequately fed but is not in thermal equilibrium with its environment, efforts are made by it to evaporate as much moisture as possible from the lungs by accelerated respiration and by panting or slavering, after the first recourse, decrease feed intake and cessation of rumination, have been exhausted. Besides the adverse effects on growth brought about by inadequate nutrition, the animal's distress is compounded by possible respiratory alkalosis due to increased respiration rate and loss of mineral salts drained from the body, either from the body tissues or from the blood, accompanying drivling (8).

In the tropics, therefore, retarded growth is usually the result of food restriction owing to the inability of the animal, because of hyperthermia, to metabolize properly sufficient food for normal existence. Conceivably, during periods of scarcity, retarded growth in the tropics may be partially due to lack of feed.

In hot areas, where animals experience great difficulty eliminating surplus heat, the development of protein tissue, which is the most important tissue associated with the weight increases in the early stages of growth, becomes rather difficult. In such areas, additional protein in the diet may fail to stimulate growth, unless methods are adopted at the same time to facilitate the expulsion of surplus heat.

Fat, a tissue almost devoid of moisture, is developed during the later stages of growth of the animal. The growth of unadapted cattle is such that muscle tissue, but not fatty tissue, shows signs of suppressed growth. There is, however, another cause for this phenomenon, namely, that the adaptation of the unsuitable animal is much lower in the first two years of life, when protein tissue should be developed, than in the succeeding years.

The function of milk production is also a function of growth. If an animal is well adapted to its environment, it can utilize effectively the available forage and grow normally. It enables the animal to reproduce at an early age, which in turn stimulates the growth of mammary tissue and potential milk production. The cow which has high inherent milk production will, however, not produce efficiently if inadequately fed to supply her needs for maintenance and milk production. An animal may, however, receive enough feed and yet be undernourished if the climatic conditions do not permit the effective conversion of the feed. This, then, is one of the reasons why the European dairy breeds do not succeed in giving good milk yields in the tropics.

ADAPTATION TO PARASITES AND DISEASES. Two parasites, of extreme economic importance to the beef cattle industry in the American tropics are the Torsalo or Nuche (Dermatobia hominis) and the tick species, vectors of such diseases as Anaplasmosis and Piroplasmosis.

Zebu-type cattle are known to be much more resistant than European breeds to tick-borne protozoan infections, particularly the two mentioned above (93). This valuable attribute is not restricted to Zebu breeds, for it has been found also in the "criollo" cattle of Nicaragua and Honduras (84).

If this characteristic resistance to tick-borne disease is genetically transmitted, as seems to be the case from the works of Bonsma (11), Ulloa and deAlba (84), and that of Zuravok (93), the utilization of this fact should be remarkably useful in the extensive tick-infested areas of tropical America.

The manner in which this resistance is expressed is obscure, though Bonsma (11) attributes this in large measure to the fact that resistant animals have a comparatively thick skin, which is less attractive to ticks. Proof of this is seen in the fact that his tick counts were highest for the comparatively thin-skinned animals and lowest for those with thick skin.

Management measures such as the regular use of dipping to reduce infestation by ticks hamper any breeding program for resistance to tick-borne diseases, since regular dipping prevents the expression of natural resistance. In other words, genetically susceptible calves are protected by the regular dippings that remove the ticks. In an exposed herd, that is not dipped, presumably the non-resistant calves are eliminated early by natural selection. Though it may prove less expensive and more practical to utilize dipping vats regularly as a preventive measure, than to develop tick resistant herds, undoubtedly there are some areas in which the converse is true.

Nothing is known regarding resistance to infestation by the Nuche fly, though in some regions its importance is much greater than that of the tick species.

ADAPTATION AND MORTALITY. Bonsma (11) remarked that there is a marked difference in the mortality rate of different breeds and types of cattle under subtropical conditions. Mortality among cattle undeniably is associated with their adaptability. The animal adapted to a region has not only a greater resistance to infection, but it is also better able to survive disease caused by such infections.

BREEDING FOR PRODUCTION IN THE AMERICAN TROPICS.

GENERAL. The whole matter of underdevelopment of beef cattle in tropical America may be summed up as being due to the inability of the animal to adapt itself to environmental conditions under which it is impossible to attain normal development unless it has the ability to rid its body of heat in excess of that required for its normal function.

Selecting in accordance to a European or North American standard of excellence is obviously not desirable. A type must be evolved that will suit the ranching conditions prevalent in the American tropics.

It must be recognized that in most tropical areas substantial improvement in the efficiency of livestock production can be obtained by improving the environment. The extent to which the environment is improved must, of course, be examined in relation to the cost and the value of the increased products that would result. Restrictions laid down by nature place definite limitations on the extent to which such improvements are economically sound. Nevertheless, the possibility of improving the environment, coincident to improving the livestock of an area, must be considered in long-range livestock breeding programs.

Many factors must be considered in any attempt to improve the conditions under which livestock is maintained. For the most economical production in the American tropics, maximum use must be made of pasture lands. Management practices should be so designed that the maximum yield of animal products is obtained per unit of land area.

In view of the limitations placed on livestock production by the environmental conditions prevailing in tropical America, it is essential, when plans are made for the improvement of livestock, that careful consideration be given to the appropriate environmental modifications to be effected concurrently with the breeding policy.

Overall heat load is the main purely environmental factor to consider. Lower heat production would obviously decrease heat load. This could occur through increased efficiency in the performance of work, lowered metabolic cost of growth and milk production, decreased expenditure of energy in alimentation, decreased thyroid activity, or increased habits of rest. On the other hand, man's requirements from his domestic animals--more milk, meat, etc.--are such that they increase the animal's heat production. Increases in the plane of nutrition has a similar effect.

For the most effective animal production the nutritional level should be optimal for maximum production, the fibre content should be as low as is practicable, and the provision of protein should not exceed optimal requirements. In practice, the standard of management of tropical pastures is poor and it is unlikely that the majority of animals receive more protein than they need, but they can easily receive excessive fibre (63).

If the feeding of concentrates is contemplated, it seems reasonable not to feed large amounts in the daytime, as this would raise heat production at a time when rising ambient temperature is rapidly increasing the heat load of the animal. The experimental work that has been done on the effect of daytime feeding of dairy cattle in the tropics seems to confirm this (80). Concentrates could best be fed in the relatively cooler period in the early evening, when ambient air temperatures are falling, or early in the morning before the ambient air temperature raises.

Water should always be freely available wherever the animal may be. Ittner, Kelly and Guilbert (33) have measured the effect of cooling the water consumed by Hereford and Brahman cattle on their productivity in terms of growth, during a period of 83 days in the California summer. They show that cooling the water from 88°F. to 65°F. decreased water consumption slightly, but decreased respiration rates and improved the daily live weight gain. Granted that cooling of the drinking water offered to beef cattle may not be of general applicability, but clearly, under certain circumstances it does merit consideration.

It is an accepted practice in temperate zones to protect cattle against climatic extremes by the provision of shelter, but the same attention is not being paid to their protection in the tropics.

Rhoad (65) reported that the time spent by cattle in the shade is associated with their heat tolerance, the animals with low heat tolerance spend much more time in the shade than do those with high heat tolerance. Again, therefore, sheltering beef cattle as a mangement measure is not one of general applicability, but one that, on economic grounds does merit consideration.

The main effect of shelter, obviously, on the heat load of an animal is to minimize heat gain by radiation. The effect of different types of shelter and details of design have been studied extensively in California (35,36,79). That work has shown that in general ambient air temperature will not be lower under a shelter unless there is a local cooling due to the evaporation of water.

Obviously, the amount and kind of attention that should be given to these and any other management measures will vary with the particular climatic and economic conditions of a region.

BREEDING PLANS. The methods of breeding that can be applied in the American tropics fall into three categories: (1) selection within the "criollo" cattle population, (2) grading-up with already improved breeds from other countries, and (3) development of new types out of animals that are graded only part of the way up to the improved type.

It must be recognized, before improvement programs are begun, that some of the existing types in the American tropics are meeting the needs of the people reasonably well. Others may need improvement in some or most of their economically important characteristics. Granting that improvement may be needed, it must be recognized further that adaptability to the environment is specially important in these areas and should not be overlooked.

Selection within native types has certain advantages. The native types are already adapted to the local environment, which may not be true of types brought in from other countries, and there is no problem of selection and importation of foreign stock. The disadvantage is that progress is much slower than grading-up with already improved types, provided the improved types meet local needs and are adapted to the environment.

Some important native types and strains of cattle are in danger of being lost or diluted through the mass introduction of other blood. It seems imperative that steps should be taken to insure that such important local types are not lost. This applies even though in some cases the animals may not be economic, for their potential value in breeding experiments and practical use in livestock improvement programs, may be sufficient to justify their maintenance in at least limited numbers.

Careful consideration should be given to native types and to their productivity in the prevailing conditions before deciding to discard selection within them as a basis for improvement, particularly where the environment places severe limitations on the possibility of introducing exotic breeds.

The quickest way to improve the productivity of commercial cattle in the tropics is to exploit hybrid vigor through systematic crossbreeding. In areas where bulls of European breeds cannot be used, the most workable plan would be to begin with the cows on hand and alternate the use of Zebu and native bulls in a systematic manner. Thus, if crossbreeding in the tropics is to be practiced in any scale during the next few years, the continual production of native bulls appears to be a practical necessity.

Grading-up has the obvious advantage of rapid improvement through the use of improved males on large numbers of native females. It is the logical method in all cases where there are existing types in other countries that meet a country's needs and which are apt to perform satisfactorily under the conditions in question. If this method proves satisfactory, foreign breeds or other improved herds need be maintained only as sources of males to continue the grading-up program, while the bulk of the animals in the area or country would become high grades as the program progressed.

Most of the work which has been carried out in the American tropics on the introduction of exotic breeds for use either as purebreds or for grading up has been carried out on a commercial and sometimes haphazard basis and has not been so designed as to be amenable to statistical analysis, or for comparison with adequate controls.

While crossbreeding may have advantages for commercial production, straightbred stocks will be needed for commercial production on operations where crossbreeding is not practical, and as sources of breeding stock for crossbreeding purposes. In the long run, improvement of beef cattle for the tropics depends on improvement through selection of straightbred stock. Further, this improvement must come through selection of cattle for performance in the areas in which they are to be used. Periodic introduction of genetic material from outside sources is to be commended, but selection in the environment in which animals are to bs used is essential for maximum ecological adaptation.

In many cases, it may be found that imported purebred animals cannot perform satisfactorily under existing environmental conditions. Grades with a certain amount of improved breeding may withstand the environment satisfactorily and produce at higher levels than the native stock. In such cases, the obvious procedure is to determine the extent to which improved breeding can be introduced, then develop a new type from animals with this breeding background.

The development of a new breed is not a task to be undertaken lightly. A definite need for a new type should be clearly evident before such a project is started. Facilities should be available to handle a large number of animals and to continue the project for many years, so that a new type can be well established. Since the special requirements imposed by tropical conditions are almost entirely of a physiological nature, to obtain animals which will give optimum returns, it is necessary to concentrate in those animals, not only with inherent high rates of production in the desired qualities, but also with the ability to maintain these high rates under the conditions prevailing in such areas.

The relative importance of variations in adaptability may increase as infectious diseases and parasitic agents come under control, pastures are improved, and innate potentialities for production are increased.

Those planning and supervising the work should obviously have a clear understanding of the genetic principles involved. Work like this is necessarily limited to government experiment stations and to a limited number of private breeders who have unusual facilities and are willing to venture afield from established breeding practices in tropical America.

Improvement of the inherent productive capacity of livestock must be accompanied by improvement in the environment, including better feeding, management, and disease and parasite control if the benefits of better breeding are to be fully realized.

National or area-wide improvement in the production capacity of any given type of livestock will in most cases be based on males produced from a very small percentage of the population and in relatively few herds maintained either by private breeders or at government owned studs.

Granting this, it must be recognized that any improvement which may be possible in productive capacity of commercial stock is, in the long run dependent upon continued genetic improvement of the stud stock. Without continued improvement in the stud stock, commercial stock can be raised within a few generations to a level where further improvement by grading up is infinitesimal.

Further, it should be recognized that stud breeding must be directed toward real improvement in producing capacity if the product of the breeding is to benefit the commercial livestock producer.

The opportunity for genetically improving traits of economic value, thus, rests primarily with the purebred breeder or in seedstock herds. Most of the opportunity for selection in beef cattle is among bulls. The level of performance in commercial beef cattle populations is determined primarily by the bulls available to commercial herds from the purebred segment of the industry. For the purebred breeder to discharge his responsibility to the other segment of the beef cattle industry with maximum effectiveness, an understanding of the function of all segments is essential. The purebred breeder should possess an appreciation of all traits of economic importance to the industry, and enough responsibility and appreciation of the importance of his breeding policy to the other segments of the industry. In addition, he should understand the procedures for measuring or evaluating differences in those traits and be able to develop effective breeding policies for making genetic improvement in all traits that affect efficiency of production in beef cattle.

SELECTION CRITERIA. It is important that the breeder has an effective yardstick of merit, regardless of the selection procedure and breeding system used.

Reasonably accurate measurement of an animal's ability to produce is essential for any real improvement in the genetic merit of livestock. Animal husbandmen have long used visual evaluation of livestock as one of their main measures of performance. Certain things about an animal's producing capacity can be ascertained by merely looking at the exterior, but characteristics such as milk production, growth rate, efficiency of feed utilization, and reproductive efficiency cannot be determined by visual inspection. Therein lies one of the chief weaknesses of show ring or visual methods of measuring merit in livestock. The show ring serves as a place where breeders can exhibit and advertise their wares, where the feeder and fitter of livestock can demonstrate his skill, and where the public can see something of the livestock producer's workmanship. Recognizing these advantages one should at the same time recognize its limitations. In addition to the fact that many important characteristics cannot be evaluated accurately in the show ring, it has become common practice to consider many so-called fine points in judging animals. These fine points have little or no practical significance and each of these points considered reduces the degree of which effective selection can be practiced for more important characteristics. The usefulness of the show ring is further reduced by the showing of animals, fed under highly artificial conditions, often to a level of fitness far beyond that desired in breeding animals or even in animals intended for slaughter. Assuming that the show ring gives a useful measure of merit at least for certain characteristics, the proportion of animals that can be fitted and shown is so small that it cannot serve as a basis for selecting more than a small portion of the breeding animals, and the breeder must make most of his selection under more practical circumstances.

Unfortunately, unimportant superficial characteristics have a way of becoming the principal criteria by which cattle are selected in tropical America. There is always the desire for distinctive breed characteristics. Preconceived notions about attributes which are thought to be correlated with adaptive mechanisms, performance, or utilize combine to dominate selection standards to the extent that little room is left for performance. Inclusion of such selection criteria imposes an almost unsurmountable obstacle to progress in selecting beef cattle for new or unfavorable conditions.

It is to be highly recommended, then, that selection criteria be confined to the essentials of reproductive efficiency and the ability of the animal to thrive and grow in its environment. Merit of the individual animal should be determined by its performance rather than by superficial traits such as the color of the nuzzle, or the presence or absence of white hairs in the switch. If high reproductive efficiency is not achieved, one may never be able to apply sufficient selection pressure to achieve any significant improvement in production.

Simultaneous improvement of management and nutrition along with genetic potential is essential. The process of natural selection conceivably has largely fixed, in native cattle, the genotypes best suited to the conditions under which they have evolved. With the limited variability available very little genetic improvement can be accomplished, unless nutrition and management improvements provide the opportunity for detecting important differences, which would conceivably be greater under modified conditions.

MAJOR PERFORMANCE TRAITS FOR BEEF CATTLE IN TROPICAL AMERICA. _Breeding efficiency and fertility_. Although efficient reproduction is essential to the beef cattle industry of any country, the evidence to date indicates that reproductive efficiency is very low in heritability. However, there may be various phenomena affecting reproductive processes which are sufficiently highly heritable to be of importance in a beef cattle breeding program.

Several studies have indicated that there are specific genes which may cause complete sterility in the female (29,38). In both cases the condition was reported to be caused by a single sex-limited, autosomal recessive gene. Other reproductive abnormalities reported to be inherited as simple autosomal recessives are prolonged gestation (30) and double cervix (83).

Warnick (90) investigated the interval from parturition to first estrus in beef cows. Line of breeding, breed, and age of cow had little effect on the length of the interval, and the length of the interval apparently had little effect on subsequent fertility. Christian et al. (21) reported that vitamin A deficiency did not affect materially the interval from calving to involution of the uterus, but that the interval from calving to first post partum ovulation was longer in vitamin A deficient cows. They also reported that early weaning of calves (2 weeks of age) shortened the post partum interval to first ovulation of a little over 2 weeks but not the interval to involution of the uterus.

The level of winter nutrition was reported to affect both the percentage calf crop and the pounds of calf per cow at weaning time (31). They reported that feeding only a limited amount of hay during the winter feeding period of 4 months resulted in a lower percentage calf crop and fewer pounds of calf per cow at weaning than feeding adequate amounts of hay or hay plus concentrates.

An analysis of the components of variation in length of the calving interval in a herd of range beef cattle where year round calving was practiced revealed that the length of calving interval was not heritable (13). Also, they failed to find a correlation between the length of successive calving intervals for the same cow, which indicates that the length of calving interval is not repeatable.

The word fertility is used in a broad sense to mean an animal's ability to produce normal, healthy young that are capable of surviving. Fertility is only moderately heritable, but the level of fertility in a herd affects the possibilities for selection of other traits. The economic importance of fertility is undeniable. Unfortunately, a breeder may fail to recognize the importance of this difference in fertility among individuals and may keep a son from the cow that is of lower fertility because it is a better calf otherwise.

A high level of reproductive performance on fertility is basic to an efficient beef industry in tropical America. It is fundamental for making genetic improvement because increased calf crop decreases the percentage that must be saved for replacement and thus increases the selection differential. Efficient cow-calf operations are fundamental to an efficient industry, and no single factor in commercial cow operations has a greater bearing on production costs than the calf crop. With a higher percentage of the total beef cattle population composed of cows, fertility is an increasingly important trait from the standpoint of total industry efficiency. Both the male and female, should be considered in selecting for fertility, as reduced calf crop can be the result of sterility or partial sterility of either.

A calf crop that is uniform in age is important. If the breeding season is limited to not more than 90 days, a great deal can be done to have a calf crop fairly uniform in age. Also, this will contribute to increased fertility of the herd because those cows that fail to settle in the 90-day breeding season can be promptly marketed for beef.

Because of the importance of reproductive performance or fertility to efficient production, it must command some attention in a breeding improvement program, even though research results indicate that heritability is low and rate of improvement will be slow. In purebred herds, consideration should be given to culling open cows if they are below average in previous production and all cows open in successive years regardless of production. This assumes that no reproductive disease problem exist. Herd bulls should be selected from cows with good fertility records, be sired by bulls of high fertility, and show high fertility themselves as measured by their ability to settle cows.

Upon initiation of a program of culling for low fertility, one may seem to market some good cows, but generally any nice-looking cows which are among those culled will prove to have been merely "boarders."

In herds where reduced calf crops are a problem, close attention to feeding, disease control, and management practices are definitely indicated. Reproductive disease markedly influence fertility. Level of feeding--particularly level of energy, vitamin A, and phosphorus--is important. Management of bulls, size of pastures, and distribution of water may be related to whether cows conceive during the normal breeding season. In tropical America the cost of barbed wire is so high that it may render uneconomical the use of small pastures for breeding purposes. Nevertheless, breeders and commercial producers can profitably give greater attention to these items in increasing calf crops.

All the discussion on fertility is based on the assumption that conditions will permit a cow to raise a calf every year. One may find it necessary to make adjustments if the conditions are so severe that a cow cannot raise a calf each year without depleting her to such an extent that she may not survive. Pasture improvement and supplemental feeding should be considered if this situation exists.

Preweaning growth. Prenatal growth is generally related to postnatal growth, but not to such traits as feed efficiency. There are apparently no negative associations of birth weight with economically important traits. Woodward and Rice (94) found a positive relation between birth weight and length of body within given weights.

More mature cows give birth to larger calves than younger, less mature cows (42,78). Also, larger cows have larger calves than smaller cows of comparable ages. In a series of papers, Koch and Clark (42,43,44,45) emphasize the importance of maternal effects on birth weight. Male calves are larger at birth than females (42).

Gains of calves during the suckling period, or weaning weights adjusted to a constant-age basis, are larger from more mature cows than from younger, less mature cows and, also, larger cows wean heavier calves than smaller cows of comparable ages (4,42,55,59,70,77). Bull calves are heavier at weaning than heifers or steers, and steers are heavier than heifers where feed conditions are adequate for sex differences to be expressed (59,60,61,70), while under more adverse conditions little difference between weaning weights of steers and heifers is present (77). Pahnish et al. (58) found that factors for adjusting calves to a constant weaning age of 270 days were considerably higher for bull calves than for heifer calves.

Weaning weights or gains during the suckling period are not highly heritable (5,40,43,44,45,39,50,60,71,72,74,81,82,89). Repeatability estimates of weaning weights are higher than heritability estimates (72).

Heavier calves at birth, calves born within a season of the year that permits the nursing cows to be under better pasture conditions, and those reared during more favorable years gain more during the nursing period and reach heavier weaning weights (7,22,43,55,70).

Lindholm and Stonaker (49,50) considered weaning weight of the calf as one of the most important traits influencing net income to the rancher. Consequently, it is an important trait to include in the selection program. However, because of the negative genetic correlation of milking ability with postweaning growth (45), selection for weaning weight alone would be less desirable than combining selection for both preweaning and postweaning rates of gain.

It appears evident, also (71), that selection for increasing weaning weights would be much more effective under optimum conditions than under suboptimum conditions, particularly if the latter were quite adverse.

Rollins et al. (69) conclude that the growth mechanism and genetic factors from birth to four months of age are different from and independent of the mechanism and genetic factors operating for the period from four months to weaning age.

Weaning weight of calf is used as a measure of mothering ability. The calf's own genetic impulse for growth is confounded with mothering ability by this procedure, but this is not a serious handicap since half of the growth impulse of the calf is transmitted by the dam. The ability to wean heavy, vigorous calves is necessary for efficient cow-calf operations. With the trend of marketing cattle at younger ages, weaning age represents a higher proportion of total age at market time and increases the relative importance of weaning weight. Increasing the pounds of calf produced per cow increases efficiency because certain fixed costs such as veterinary, labor, and bull service are on a per head basis. Feed costs for cows seem to be rather closely related to size of cow, but faster gains of calves decrease feed requirements per unit of gain.

It is emphasized that the objective is to increase weaning weight relative to mature cow size. Thus pounds of calf achieved for each unit of cow weight maintained is a good measure of efficiency of operations from the standpoint of returns per unit of feed.

Selection of bulls and replacement heifers that have heavy weaning weights relative to the herd average will lead to genetic improvement in mothering ability. In selecting for increased weaning weight, selection is being practiced not only for mothering ability but for the calf's own ability to grow. Research information indicates that selection among cows for mothering ability should be reasonably effective. This can be accomplished by selecting cows on the basis of the weaning weights of their calves, since cows that wean calves heavier than the herd average in one year are more apt to produce calves heavier than average in succeeding years.

Adjusting for differences in age of dam, sex of calf, and age of calf is necessary since these factors influence weaning weight. In adjusting for differences in age of calf, it is recommended that average daily gain from birth to weaning be used for each calf.

Mothering ability of cows may be compared within groups of the same sex of calf and within ages of cows if numbers are large. This avoids an adjustment for differences in sex of calf and age of dam. The most accurate adjustment factors for sex of calf and age of dam are those developed in the herd in which they are used, provided the data are not biases and the herd is large enough for reliable results to be obtained. Adjustment factors for smaller herds should be developed from herds with similar management regimes. Records are more accurate where the calving season is relatively restricted so that major differences in age and seasonal influences are avoided. Since weaning weight is used as a measure of mothering ability, it is important that all calves be treated the same, so that the major variable is difference in nursing ability of the cows.

<u>Postweaning growth</u>. Bulls gain more rapidly than steers and steers gain

more rapidly than heifers (6,25). Mason et al. (51) have shown that males vary more than females in rate of gain.

Many studies have been made on factors that influence postweaning rate of gain. Large calves at birth generally gain more rapidly than smaller ones (92,93,94). However, gains during the suckling period, or weaning weights, are not so consistently related to postweaning gains (75). Apparently, two conflicting forces are operating which influence postweaning gains. Calves that do not have a sufficient supply of milk during the nursing period, and consequently have lower suckling gains, will tend to compensate during the postweaning period by making more rapid gains (26,46). On the other hand, inheritance of rapid growth would tend to be expressed both prior to and following weaning. One of these influences would tend to create a negative relation between preweaning and postweaning gains, while the other would create a positive relation (4,25,41,64,91,93). Thus, weight for age at the time calves are put on test, or age when calves are put on test at a constant weight, may or may not be related to test gains, depending upon the relative influence of preweaning genetic and environmental influences. Cobb et al. (23) found positive relationships among weights of cattle at various ages, although there were negative relationships between suckling and postweaning rates of gain. Blackwell et al. (4) found that the relation of age of dam to postweaning gains is opposite to the relation between age of dam and preweaning gains. Younger and very old cows wean lighter calves than cows in the age range in which they are at the peak of their productive life, but these smaller calves at weaning from younger and older cows gain more rapidly following weaning. Castle et al. (20) found that although calves compensate in gains made on the range for lower rates of winter feeding, an optimum rate of winter feeding to allow gains between 1½ and 2 pounds per day results in greatest production at the lowest cost under the conditions of the experiment.

Koch and Clark (45) state that selecting for gain to weaning will increase genic value for growth response, and to a slight extent increase genic value for maternal environment. This may be partly nullified by the negative genetic correlation between maternal environment and postweaning growth response. Selecting cows on the basis of weaning weight of their calves may increase genic value for milking ability but decrease genic value for growth. Selecting for gains from weaning to slaughter may increase genic value for growth but decrease genic value for milking ability.

There is some evidence that longer-bodied animals gain more rapidly than those that are larger in heart girth and shorter in body. Blackwell et al. (5) found that individual differences in growth and body size are highly heritable when cattle are under uniform conditions. Genetic correlations were generally high among traits involving size and growth rate.

Brinks et al. (12) found that mature body size of cows is highly heritable and that larger cows tend to produce calves that gain more rapidly throughout the growth period. Feed efficiency is closely related to rate of postweaning gain, and the factors that are related to rate of gain are generally also related to feed efficiency (25,48,64,93). Bulls are more efficient in converting feed into gains than heifers (53), even though they eat no more per unit of body weight (2). Heavier calves at birth are more efficient than lighter calves at birth, and younger calves of the same weight are more efficient than older ones. Much of the variation in feed efficiency determined on a weight-to-weight feed test can be accounted for by variations in birth weight, rate of gain during the feed test, and weight for age at the time the feed test starts (53,64).

The research that has been done on interrelationships of traits points clearly to the necessity for considering carefully all economically important traits in a selection program, because selection for only one trait might lead to improvement or to degeneration of another. Implications of these studies point to the necessity of selecting on the basis of an index in which each trait is properly weighted so that over-all improvement of beef cattle can be accomplished.

It would appear logical that if animals vary in rate and efficiency of gain, these variations would be a reflection of their ability to digest feed. No relationship has been established between digestibility coefficients and rate or efficiency of gains (52,54). It should be pointed out that all methods of determining digestibility of feed are inaccurate. The failure to establish a relationship between digestibility and rate and efficiency of gains merely demonstrates, therefore, that this relationship, if it exists, cannot be established without more refined techniques for determining digestibility. It clearly does not demonstrate the nonexistence of such a relationship.

Growth rate is important because of its high association with economy of gain and its relation to fixed costs, such as veterinary, equipment, and labor, that tend to be on a per head or per unit of time basis. In most instances, differences in growth rate have been measured in time-constant, postweaning feeding tests. Results indicate that differences in growth rate can be appraised rather accurately in this manner. A postweaning period of at least 140 days is required to measure differences in growth rate. This minimum length is based on rather uniform initial weights, condition, ages, and previous treatments. Final weight at 12 to 18 months (standardized for age differences) is probably a better measure of genetic differences in growth rate than any individual component of final weight (that is, birth weight, preweaning gains, and postweaning gains).

Final weight at a standard age of 18 months seems to be a good measure of growth rate, and it may fit the management programs of some purebred breeders in Latin America, where bulls are fed a relatively low level of concentrates during their first dry season and fed at a higher level on grass during the following rainy season. By this procedure, bulls are developed at a high enough level of feeding and over a long-enough period for genetic differences in growth rate to be expressed, and a good appraisal of growth can be made. Bulls handled in this manner are in good sale condition at a desirable age.

The use of postweaning gain alone as a measure of growth could foster poor milking ability because of compensatory gains, in that a poor feed supply in one period tends to be followed by a period of increased rate of gain.

Research results indicate that a reasonably high level of feeding is desirable to appraise differences in growth rate most accurately. If a lower level of feeding is used, the period for measuring growth rate should be extended. Because of the high percentage of heifers that must be kept for replacements, there is not much opportunity to select among heifers for differences in growth rate. Hence, from this standpoint, very little can be gained from the test feeding of heifers.

Economy of gain is one of the most important traits of beef cattle. Economy of gain is difficult to estimate because it requires individual feeding and adjustment for differences in weight, since increased weight is associated with higher feed requirements per unit of gain.

Present information indicates that genetic improvement can be made in economy of gain by selecting for it through rate of gain. It is therefore recommended that breeders depend on differences in rate of gain as an indicator of economy of gain rather than incur the added expense of individual feeding.

Longevity. The longer animals remain productive in a herd, the fewer replacements will be needed and thus the costs of growing out replacements to productive age will be reduced. However, the longer an animal remains in a herd, the longer will be the generation interval, which may reduce the rate of genetic improvement from selection. Breeders of purebred cattle or seed-stock herds in tropical America should be concerned with making genetic improvement in longevity so that the commercial beef cattle populations will be productive at older ages. Yet, a fairly rapid turnover of generations in purebred herds is desirable for making a maximum rate of genetic improvement in other traits of economic value.

RECORDS AND BEEF CATTLE IMPROVEMENT. To attain the maximum rate of genetic improvement in all traits of economic value in beef cattle requires a clear perspective of objectives and a planned breeding program to accomplish them. Objectives should include all traits that are of economic importance to the beef cattle industry. While the traits in which the different segments of the industry are interested vary, the purebred breeder especially must be interested in and aware of the demands of all segments of the industry. In tropical America the commercial producer is interested in cows that have long productive life and should be interested in those that wean a high percentage of their calves with heavy weights. The feeder should demand cattle able to make fast and efficient gains on pasture, and the packer should be interested in animals that yield a high percentage of marketable product.

The heritability, genetic association with other traits, and relative economic importance determine the attention each trait should receive in selection. Traits vary in heritability and economic value. The greater the number of traits selected for, the smaller the selection differential will be for any one trait. Traits of low heritability respond less to selection than do traits of high heritability. The opportunity for selection should be used for traits that will result in the maximum genetic progress for the traits of greatest economic value. Obviously, little can be gained and much can be lost by paying too much attention to traits of little economic value and traits of low heritability.

The rate of improvement in most economically important traits of beef cattle will be relatively slow primarily because of the inherently low reproductive rate, the large number of traits of economic value, and the long generation interval. The low reproductive rate, which makes it necessary to keep a high percentage of the offspring, especially females, as replacements, and the large number of traits limit the selection that can be practiced for any one trait. However, most of the economically important traits have reasonably high heritability, fertility being the most important exception. Even though improvement is slow, it tends to be permanent, accumulates from year to year, and is transmitted to future generations.

Traits of economic value are commonly referred to as performance traits and include all traits that contribute to both efficiency and production and desirability of product. The record of performance is the systematic measurement of traits of economic importance and the use of these records in selection. The function of records of performance is to help find the genetically superior individuals in all economically important traits so that they may be used for breeding purposes.

The objective of any system of measurement is to make possible the evaluation of differences between animals. The preferred measurements are those that give the most accurate estimate of the breeding value or genetic merit of an animal relative to the others in a herd. Records increase a breeder's knowledge of differences between animals and thus increases the accuracy of his selections.

Research in beef cattle breeding has demonstrated that appreciable genetic improvement can be made in most traits of economic value by selection on the basis of differences in individual performance.

The systematic measurement of differences among animals in the traits of economic value, the recording of these measurements, and the use of the records in selection will increase the rate of genetic improvement.

Performance records of animals should be adjusted to eliminate known differences between animals so that genetic differences will be a larger part of the total differences measured or observed. Adjustments should be made for differences in age, sex, age of dam, and other environmental variables that can be measured or evaluated. Because any increase in environmental variation tends to obscure genetic differences and decrease the effectiveness of selection, every precaution should be taken to measure economically important traits as accurately as possible.

Records of performance are useful primarily to provide a basis for comparing cattle handled alike within a herd and not for comparing differences between herds. This is because large environmental differences due to location, management, and nutrition are likely to exist between herds. It is difficult to adjust accurately for these differences. Genetic differences between herds do exist, but large environmental differences make the evaluation of genetic differences extremely difficult.

Average weaning weights of 500 pounds may be realistic in some environments and in some production programs, whereas 350-pound weaning weight may be reasonable under more adverse conditions. Yet, beef cattle may provide the most desirable means of utilizing the land under both conditions. Furthermore, the genetic merit of a herd weaning 350-pound calves may be equal or even superior to that of a herd weaning 500-pound calves. Standards of performance expressed as deviations from individual herd or group averages are advisable for making comparisons within a herd, but comparison between herds based on minimum standards of performance can be undesirable and misleading.

Minimum standards of performance for the various production traits have been considered in some records of performance programs. Because of the variation in environmental conditions and production programs, standards involving between-herd comparisons may lead to give recognition to herds carried under superior environmental conditions rather than those that are genetically superior.

All economically important traits that are heritable should be evaluated for all animals in a herd. An effective record of performance program should be compatible with practical management regimes. Cattle should be evaluated under the approximate environmental conditions in which their progeny are expected to perform.

The relative emphasis put on the different traits may vary in different herds, but the attention that each trait receives should be based primarily on its heritability and economic importance to the entire beef cattle industry. Keeping records does not change what an animal will transmit, but records must be used to locate and use the genetically superior individuals if improvement is to be accomplished.

A systematic record of performance program with selection based on differences in records is basic to any planned breeding program. The choice of breeding plans and the details relating to them involve many considerations. Pedigree, individual performance, and progeny test information all have a place in a constructive breeding program. Certainly, young sires should be initially selected on the basis of pedigree and individual performance data. The extent that they are used will depend on their rank with other sires based on progeny test information.

Since generation interval affects rate of improvement from selection, consideration should be given to keeping it relatively short. If a sire is truly superior, he should sire sons that have genetic merit which surpasses his own when he is bred to cows that have comparable genetic merit to the population that produced him. The problem is one of devising an evaluation program based on use of records that aid in locating such sons. Perhaps one handicap to continued improvement in some herds is the extensive use of an old sire without sufficient attention to locating sons to replace him. When the old bull passes out of the picture, the herd is left without sires that are superior to him. Continued improvement depends on the use of herd bulls that are superior to the ones used in the previous generation.

In tropical America, a wide gap exists between the production of and the need for superior breeding males. Therefore, governments should, where practicable, employ Artificial Insemination as a means of increasing the number of superior breeding males and of accelerating the pace of livestock improvement. In order to insure that this practice is soundly carried out it is necessary that as far as possible only sires of known breeding value be used, superior to the quality of the stock to be improved, and whose genetic capacity is in harmony with the environmental conditions present in the area where it is to be used.

Before a bull is used extensively in a region, as would be the case with artificial insemination, it may be desirable to progeny test him for genetic defects on several of his daughters. There are many genetic defects in livestock (most of them unknown in the American tropics because of a lack of knowledge about their existence, adequate preparation for their identification, or even absence of written records attesting their existence when accidentally discovered), and it is obviously desirable to keep herds as clean as possible of such defects. The purebred segment of the industry carries the greatest part of the responsibility for keeping such defects at a low level so that they will not become a problem to the commercial segment of the industry.

The breeding of cattle of truly superior merit is a great challenge. Many decisions must be made on breeding plans, and selecting herd bulls and replacement females, and on the continued use of herd bulls after some information is obtained on the performance of their progeny. One very difficult decision among tropical American breeders seems to be dropping a bull that is not contributing to the accomplishment of his goals, and may even be inferior to others in his herd, but for whom the breeder has developed an attachment for no special reason other than he is a "nice" bull.

The more a breeder knows about the animals in his herd and the more clearly he understands his objectives, the more frequently he should make correct decisions. Success in breeding superior beef cattle, like success in any other venture, depends primarily on the utility of the goals and the accuracy of the decisions made while working toward the goals. A complete record of performance program provides the basis for making correct decisons.

Goals can be attained only by those who have the objectivity to keep them in perspective and the dedication to remain steadfast in achieving them. They can be accomplished only by planned breeding programs based on the systematic use of records for selection on all traits of economic importance.

Progress in beef cattle breeding is relatively slow at best. The life of many purebred herds is not long enough to make appreciable improvement even though the goals of the breeder are sound and his program systematic. Continuity of operation with practical-sized herds and a well-planned breeding program with utility objectives is essential. Sound judgment with the minimum of bias and prejudice is required in evaluating records and in making selections. Breeding beef cattle, like any other business, is highly competitive. To meet competition successfully, a superior product must be produced at a reasonable cost. Real merit is necessary to keep a product in demand.

THE IMPORTANCE OF PASTURES AND THEIR MANAGEMENT IN TROPICAL AMERICA

GENERAL. The first step in an attempt to increase the livestock output of a region must be to find the chief factors limiting production. They may be a combination of heredity, nutrition, disease or management. It is also necessary to ascertain to what extent the total production of a breed under definite conditions can be increased by breeding, better feeding, disease control and improved management.

Though infrequently stressed, good animal productivity is dependent upon the soil because it contains those minerals that the plants take up, and from which the animal bone, muscle and the animal products used by man are synthesized. The animal, in transforming plant material into products useable by man, must use some of the original material for skeletal growth, for maintenance, etc. Thus, animal products are relatively expensive, and while they are generally highly valued because of their nutritional values as well as their taste, they must compete with less expensive foods from plant sources, especially in tropical regions. In these circumstances, the animal husbandman must constantly seek ways for increasing the efficiency of livestock.

The heavy prolonged rainfall areas of tropical America are low in those soluble minerals so necessary to a good frame in cattle and horses. In these regions, even in those parts underlaid by limestone, the animals may be smaller than what one would expect. The Caribbean slope of the continent, for the most part, lacks the recent volcanic eruptive material so common to the Pacific slopes of these countries, where the soils are much deeper and richer in plant nutrients. Yet, though many factors have some effect on the composition of a plant, the mineral content of the soil is at times one of the less important. Thus, improvement in soil fertility may have a much greater effect upon plant growth through increased yields than through changes in plant composition. It follows, then, that the major result of differences in soil fertility, so far as the ability of the soil to furnish feed for livestock is concerned, may be the amount of growth or other animal product produced per unit of land area rather than any marked or measurable effect upon the composition of the gains of the animal or other animal product.

Since the productivity of a unit of land area is intimately associated with the efficiency of the labor used in producing the animal goods, which in turn is obviously one of the main factors which determine the standard of living, it may be stated as being broadly true, then, that only by raising the efficiency of their labor can the animal producer of tropical America raise his standard of living.

Regardless of all other factors, the fundamental problem of animal husbandry in the tropics is one of feed and nutrition in general, coupled with management. Adequate nutrition, with good care and management, I believe, could easily effect a 40-50% improvement.

Too often, cattle rearing in tropical America, is done in a most haphazard basis by people with little knowledge of commercial cattle husbandry, much less of how to rear animals for a specific market.

In regions with seasonal distribution of rainfall, grasses grow quickly when the rainy season ("winter") begins, and usually get beyond their best grazing stage, because stock cannot eat them quickly enough. Large areas grow to maturity, dry off in situ as the dry season ("summer") advances, and are eaten during the dry season. The long dry season enforces a dormant period and growth is confined to the rainy season. Close rotational grazing is not practiced, and though the stock numbers are inadequate to keep down the "winter" growth of grass, the dry season grazing is often overstocked.

The first step in the improvement of local cattle must be that of encouraging the owners to manage the grazing better, to reserve areas for use in the dry season, to limit stock numbers to the carrying capacity of the land, and to make him realize that one good animal is better than several poor ones.

Once the grazing has been improved and the people have been educated to appreciate good stock, great improvement can be effected in the local animals. Not only can the economic value be enhanced but the native stock possess those hidden attributes of drought-resistance, tolerance or resistance to many tick-borne diseases and ability to withstand high temperatures, which fit them so well to our hard conditions.

The growing of suitable forage crops appropriate for feeding livestock constitutes a very essential phase of animal husbandry which is worthy of serious consideration. High quality stock demand an adequate and constant supply of good and nutritious feeding stuffs for their maintenance and health, and their development. While it is true that judicious breeding, rigid selection, and proper management are necessary and are contributing agencies in whatever success may be attained in stock raising, yet it is an undeniable fact that all of these factors amount to nothing if the question of suitable feeds is not considered. This problem is particularly evident in places where the vegetation turns dry and unpalable during certain months of the year. At this time livestock loose flesh considerably for want of sufficient green feeds. The economic waste resulting from such an eventuality is rather obvious, and therefore, one should look forward to diminishing, if not totally avoiding, such an unnecessary but inevitable loss by instituting proper remedial measures.

Because of feed supply problems, feedlot ventures, with beef cattle, are not feasible nor profitable due to the high cost of feed and the low selling price of the resulting product. Only with dairy cattle is such feeding profitable, largely because the selling price of the milk is high and so denied to a large part of the potential consumers.

Though Zebu blood has increased the size of the lowland cattle, the type of horse to handle these larger cattle, in general, has not changed. These horses, except where improved blood has been introduced, seldom exceed 14 hands, are full boned, rather narrow chested, and with rather straight back, but frequently with steep croups. The muscling is good, and the animals are sturdy, frequently possessing tremendous endurance as measured by long hours under the saddle in the deep mud of the rainy season and scorching sun of the dry season.

In the tropics, it is so far axiomatic that when improved animals become available, they should not be expected to find their maintenance and some of their production from grazing on tropical grasslands alone on a year-round basis.

For high quality cows in dairy development schemes, and probably also for good beef production, great emphasis should therefore be placed on the cultivated and fertilized grasses as a source of protein, phosphorus and calcium. Only in very limited areas does it appear that a grass-legume mixture is a feasible proposition, as the white clover of the tropics has not been found yet.

The object of intensive grazing management is to obtain the maximum yield of animal product per acre. It is a complex problem. In the first place it involves the maximum production of herbage during the wet or rainy season and the distribution of that herbage over the entire year in accordance with the needs of the animals. Secondly, the herbage must be of a suitable quality to fulfill the animal's requirements for optimum production. Thirdly, the maximum proportion of the herbage produced must be actually consumed by the animals. Finally, if a system of intensive grassland management is to be a practicable one it must maintain the health, productivity, and fertility of the livestock and the fertility of the soil with a reasonable expenditure of labor.

There are many intelligent animal breeders in tropical America, and where these gentlemen are operating, applying their knowledge and reasonable management and care, progress is being made. But on the whole, in spite of the many adverse conditions, above all is the human element that contributes so much to the absence of appropriate care and management. This is largely due to the lack of herdsmen who can apply intelligently the directions of the owner and even use his own judgement. Those who have been able to make progress have done so because they themselves are operating owners. It is these latter instances that show what can be done in the American tropics as far as efficiency in beef cattle production is concerned, but it will be many years before such a condition becomes general.

Feeding good quality forage throughout the year is one of the major managerial problems confronted by the beef cattle industry in the American tropics. Failing to do so, in Nicaragua, as in other tropical American countries, large amounts of concentrates would have to be fed in order to meet the deficiencies, which would increase the cost of beef cattle production and consequently the cost to the consumer. This would defer the low income families from consuming adequate amounts of this essential diet food.

Paladines and deAlba (57) found that forage consumption was only 72-82% of that which would be expected in temperate climates. They speculate that this low consumption may be a direct effect of climate upon the animals or an indirect effect through the types of pastures that develop under such climatic conditions. The fact that they found very large individual variations in amounts consumed offers interesting possibilities.

If the preliminary report made by Cabrera (14) proves to be a fair indication of the nutritive requirements of cattle in tropical America, the problem of adequate feed intake is further compounded. His work would seem to indicate that the energy requirements for growth, maintenance, and production of dairy cattle are about 1.5 to 2 times the requirements reported by Morrison.

Because of the intrinsic nature of soilage itself, it is difficult to increase the daily dry matter intake to a point where the grass itself will supply all of the dry matter required by an animal. Rivera (67) points out that the feeding of hay to dairy cows materially increases the dry matter intake.

The Pacific region of Nicaragua and other countries in Central and South America, has a very severe dry season of approximately 6 months duration, usually extending from the latter part of November through to the first part of May. Absence of rainfall and high temperatures completely stop vegetative growth. Lack of forage production and much deliberate and accidental burning seriously limit available forage during this season.

Weight losses of cattle during the dry season are very large and deaths are quite frequent. Because of this long period of limited feed supply, the practice has developed of keeping slaughter animals on the farm or ranch for as much as 3 to 5 years in order to attain the size and weight necessary for market. The low reproductive rates of cattle in this region undoubtedly can be attributed in part to extremely poor nutrition during the dry season.

The current system of dry-season feeding is that of "deferred grazing." Forage, particularly Jaragua grass (Hyparrhenia rufa) is allowed to accumulate during the latter part of the rainy season and is saved in the field for grazing. Analysis of grass forage from El Capulin Experimental Station in Costa Rica (1) for several years have shown that protein content on a dry weight basis usually decline to about 1.5% during the dry season. The extremely low protein content has been attributed primarily to dilution from the rapid increase in dry weight at florescence which occurs at the beginning of the dry season in November and December.

Supplementary forage of sufficient quality for animal maintenance is needed urgently. Ensilage has been made with some success, but heavy rains during September and October frequently have resulted in spoilage. It has been suggested that high quality hay can be made during the annual dry period of July and August (the "canicula"). However, the rainfall during these 2 months has been always an estimated 4 to 6 inches, and the short dry period appears to be unpredictable as to time and duration. Haymaking at the beginning of the extended dry season seems to offer a better possibility. After approximately November 15 there is very little rainfall. Field preparations, such as mowing and fertilization, would have to be started sufficiently before the dry season to insure time for forage growth.

The data presented by Adeniyi et al. (1) indicate clearly the necessity for properly timed harvest of forage produced for dry season feed. Regardless of its initial quality, the decline of protein concentration, and total protein produced per unit area renders the system of "deferred grazing" both inefficient and uneconomical. The decline in protein concentration probably is accompanied by reduced digestibility of what little remains.

Adeniyi's (1) data indicate that there are two points of primary consideration in obtaining quality forage for use during the dry season. These are date of field preparation and date of harvest. Whether or not fertilizer is used, all forage should be harvested by the middle of December. Slower growth of unfertilized grass will necessitate mowing early in October if maximum quality of forage is to be produced. Harvest of unfertilized grass should be completed as quickly as possible after rains have ceased in order to maintain protein concentrations at the highest possible level.

Where fertilizer is used, the system employed should be dependent on the length of time necessary to apply the fertilizers and to make hay on the land area used. The area should be mowed and fertilized during the first half of October. All fertilizer should be applied by approximately October 20. The hay-making operation should begin when rains cease during the last week of November and continue until all hay is made. The forage should be harvested in the same sequence as the fertilizer is applied. This technique will give the highest average percentage of protein in the forage and will sacrifice the least in terms of hay yield. A delay in time of fertilization or harvest will result in decreased forage production and forage quality (1).

Kemp et al. (37), working in British Honduras has found that continual clipping of Jaragua grass at a height of 2" gave 7% less dry matter per acre yearly than clipping at 5" from the ground. This difference was not significant, neither was there any deterioration of the pasture from the continual low clipping. He also shows that a fertilizer dressing of 20 lbs. of nitrogen per acre increases the yield of dry matter over the control as much as three-fold in six weeks, and raised the protein content to about 7%.

THREE IMPORTANT GRASSES IN TROPICAL AMERICA.

PANGOLA (*Digitaria decumbens*). Pangola thrives well over a rather wide range of soils and rainfall conditions. It possesses several desirable characteristics to make it a superior pasture grass in the American tropics at the lower elevations. Among these are its tolerance of a wide range of soil moisture, pH, and fertility; its ease of establishment, drought tolerance, aggressiveness and competitiveness against weeds. It is also noteworthy for its ability to withstand and recover rapidly from overgrazing.

Its habits of forming a dense mat or ground cover is probably a disadvantage in trying to grow it in combination with a legume, since it suppresses, under most conditions, herbaceous viny legumes which are commonly associated in varying degrees with other tropical pasture grasses. But this same growth habit and competitiveness enhances its ability to keep out pasture weeds, thus materially reducing the cost of pasture maintenance. Its success in competing with noxious pasture pests appears to outweight by far its unsuitability for a grass-legume combination.

Once established, Pangola is quite drought resistant, much more so than Guinea grass. Apparently 3/4 of the roots of Pangola are in the top foot of soil with less than 1/10 below two feet. Pangola does seem to have a higher proportion of very fine roots in addition to having a greater weight of roots than other tropical grasses, thus perhaps providing more absorption surface area than other grasses (56).

Pangola does not pose a serious threat to becoming a weed, as it can be eradicated by both herbicides (non-selective) and proper cultural practices, i.e. turning the sod to a shallow depth to expose the grass roots, followed by a disc harrow or other suitable tool to tear up the sod and remove the grass roots from the field. Such practices of eradication should be done in the dry season.

Obviously, cutting interval or frequency of grazing will have a very definite influence upon the forage yield. Vicente et al. (86) found that the highest yields were obtained when Pangola grass was cut every 60 days, but the forage was of lower quality as indicated by a higher lignin content and lower protein content. He concludes that it is probably best to harvest Pangola grass about every 45 days during seasons of fast growth and about every 60 days during seasons of slow growth.

Caro and Vicente (18) in studying the effect of two cutting heights upon the forage yield of Pangola grass, found that cutting close to the ground (0-3") increased the yields by 56% in comparison with cutting at 7-10" from the ground, at all seasons of the year. These investigators point out that the sharp differences caused by varying cutting heights are striking and that they show the importance of managing each grass in accordance with its requirements. When Molasses (Melinis minutiflora) and Pangola grasses were compared with high cutting (7-10") they produced similar yields; if with low cutting, Molasses grass yielded little and eventually disappeared; if both grasses were cut at the best height for the species (close for Pangola, high for Molasses), Pangola yielded twice as much forage as Molasses.

There are several experiments which point to the tremendous increase in production possible by proper fertilization of Pangola grass. Oakes et al.

(56) found that forage yield is increased by fertilizer applications, at least up to the level of 300 lbs. of nitrogen per acre yearly in split applications. Increased yields were obtained for each increment of nitrogen applied, though at the higher rates each increment produced less forage. Caro et al. (16) reported that with cutting management and 400 lbs. of nitrogen per acre annually Pangola yielded approximately 24,000 lbs. of dry matter per acre yearly, having approximately 8% protein. Vicente et al. (86) found that with a 60-day harvest interval and 400 lbs. of nitrogen per acre yearly, Pangola grass produced approximately 73 tons of green forage, or 29,763 lbs. of dry matter with approximately 8% protein. Rivera (73) reports an annual dry matter production of 20,600 lbs. per acre yearly with applications of 400 lbs. of nitrogen per acre yearly. Adeniyi and Wilson (1) found that applications of 1,200 lbs. per acre of Ammonium sulfate increased yields to an estimated 111 tons of fresh forage per acre. He speculated that higher applications of nitrogen might give even greater increases in yield of Pangola grass.

Crowder et al. (24) reported that although crude protein percent of harvested forage varied from cut to cut, an increase did occur with increasing rates of applied nitrogen: no nitrogen, 7.2%; 50 lbs./acre, 7.7%; 100 lbs./acre, 10%; 200 lbs./acre, 13%. The protein content declines unless nitrogen is added after every cut. The recovery of nitrogen, obtained in leaves and stems, was higher for the second and third years of the experiment, probably because of a more favorable soil nitrogen level. After the sixth cut, applications of 100 lbs./acre of nitrogen, or more, gave recovery rates of 50 to 75%.

Ultimately, the real value to beef cattle production of any grass is its ability to produce reasonable gains in weight. Caro et al. (19) reports that intensively cultivated and managed Pangola averaged, over a 4-year period, 1,058 lbs. of beef per year. Caro et al. (16) in another report, found a production of 1,063 lbs. of beef per acre per year.

GUINEA GRASS (Panicum maximum). Guinea grass is another tropical grass which offers a means of increasing livestock production in tropical America. In Central America, Guinea is used primarily for grazing. Productivity of Guinea grass pastures in these areas can be markedly increased by proper management alone. The pastures should not be overgrazed, especially toward the end of the wet season, and should be fenced to provide for proper rotation, particularly during the dry season. Otherwise, the animals will feed on the highly nutritious leaves during the beginning of the dry season and have only the less nutritious leaf sheaths and stems to graze on later. In order to obtain sufficient forage having a proper protein content for carry-over or "deferred grazing" during the dry season, nitrogen fertilizer should be applied to closely grazed or mown pastures during October or at the latest in very early November. These pastures should not be grazed again until forage becomes scarce during the dry season.

Vicente and Figarella (85) report that the carry-over forage provided by unfertilized Guinea pasture was only 88 animal-days of grazing during the dry season, as contrasted with 138 animal-days provided by the pasture receiving 100 lbs. of nitrogen per acre at the appropriate time.

Guinea grass produced its highest yields and recovered more of the fertilizer nitrogen when cut every 60 days (88). With 60 day harvest interval and 800 lbs. of nitrogen per acre yearly, Vicente et al. (88) found that Guinea grass produced approximately 73 tons of green forage or 32,733 lbs. of dry matter per acre yearly with 9.6% protein.

Caro et al. (19) found that Guinea averaged 1,058 lbs. of beef per acre yearly when well fertilized. In another experiment, Caro et al. (16) reports that well fertilized Guinea grass pastures produced approximately 1,200 lbs. gain in weight per acre yearly when grazed by young dairy heifers. In still another grazing experiment, Caro et al. (17) reports 1,300 lbs. of gain in weight from steers grazing well fertilized and managed Guinea pastures.

There would seem to be little room to doubt the superiority in yield and probably total nutritive value of Guinea grass, due possibly to a high percentage of leaves. Guinea grass should be recommended if properly managed, with adequate fertilization. Rotational grazing or mowing at least once a year seems rather important. This would keep bunches down to at least 8", enabling Guinea to benefit from the high percentage of leaves. At least one field should be left every year to reseed itself.

NAPIER GRASS (Pennisetum purpureum). Napier grass and the other Merker varieties are probably the standard soilage grass utilized in the American tropics. Its most appealing quality is its enormous yield of green forage.

Caro and Vicente (15) reported 23,652 lbs. of dry matter yield and 1,773 lbs. of crude protein per acre yearly from unfertilized Napier grass. Vicente et al. (88) found that with a 60-day harvest interval and 800 lbs. of nitrogen per acre yearly, which seemed to be the optimum combination, Napier grass yielded 44,561 lbs. of dry matter, or approximately 130 tons of green forage per acre yearly, containing 9.7% protein. Crude protein and protein yields increased with nitrogen fertilization up to the 2,000 lbs. level. More than 60% of the fertilizer nitrogen was recovered in the forage at all rates up to 1,200 lbs. per acre yearly, but efficiency of utilization in terms of dry matter produced per pound of nitrogen decreased beyond the 400 lbs. level.

According to the work of Caro et al. (18) the most appropriate cutting height for Napier is 0-3" from the ground. This cutting height increased yields over high cutting (7-10") by 27%.

Napier grass pastures averaged 1,058 lbs. of weight gain per acre yearly over a 4-year period, in one study (19), 950 in another (16), 1,300 lbs. in still another (17). One disadvantage of Napier grass seems to be its low TDN content. The work of Arroyo et al. (3) shows a 53.95% TDN content for Napier grass, compared with 66.07% reported for Pangola in the same work.

Information such as this presented above is of practical, commercial and economic value when one considers that in the American tropics gross production and energy values of grasses are low (24); crude protein content is 5% or less (1), especially if growth is allowed to accumulate; a shortage of other protein exists; and, an all-purpose legume is not available. The information discussed presents a means whereby grass production and protein values can be improved, provided that an economical supply of nitrogen fertilizer is available.

A high level of soil fertility is an important factor in the cultivation of these grasses. But, the results suggest that the increase in yield and feeding value obtained from heavy manuring amply justify the additional costs involved.

Fertilization after each harvest seems to be a necessary practice for maximum yields of these grasses. Soil texture is important in determining the number of applications to be made during the year. In deciding on which nitrogen source to use, availability, cost per pound of nitrogen, and efficiency of utilization must all be considered. In addition, the lime required to neutralize residual acidity must also be taken into consideration. Vicente and Figarella (87) showed that dry matter yield was unaffected by the nitrogen source. However, less protein was produced with urea and ammonium hydroxide than with ammonium sulfate, sodium nitrate, or ammonium nitrate, showing that the former are somewhat less efficient providers of nitrogen under the conditions of the experiment.

The larger variations in protein content of the forages according to cutting interval are important. Rodriguez (68) suggests that when nitrogen is applied there is a more or less rapid assimilation of the nitrogen by the grasses depending on the soil moisture, season of the year, and size of the plant, until a maximum content of the nitrogen is obtained. During this period the intake of nitrogen exceeds its utilization by the plant in forming new tissue. He states that the maximum content probably occurs when intake and utilization of nitrogen are in equilibrium. Thereafter, the rate of utilization of nitrogen exceeds its rate of absorption, with a consequent reduction as a percentage of dry matter. If enough time elapses, the nitrogen content as a percent of dry matter of the grasses fertilized with nitrogen may be reduced through growth to about the same level as that of unfertilized grasses.

If the protein content of these tropical grasses could be increased by management, while holding the forage yields at the levels already shown to be possible, it would mean a great deal to tropical American beef cattle breeders. A suggestion of how to accomplish precisely that comes from the work of Lewis (47). His results show that soluble fertilizers applied 7 to 20 days before mowing increases the protein content of hay. It may not be amiss to emphasize that these late dressings of nitrogen are given with intention of increasing the protein content of the hay. The need for early fertilization with nitrogen to increase the yield of hay still remains.

A NOTE ON THE NUCHE FLY AND TICKS

The Nuche fly (Dermatobia Hominis) and the cattle tick (Boophilus microplus) are the two most destructive parasites affecting livestock in tropical America.

The economic damage of the fly is difficult to measure. The larvae in the animal renders the hides useless for leather. Many animals die from the infestations as a result of arteries cut by the larvae, or where secondary infection takes place. It seems reasonable to suspect that the loss of blood and the irritation caused is sufficient to lower the resistance of the animals to disease and to lessen its ability to convert efficiently feedstuffs to milk or meat.

Death loss resulting from tick fever are only a part of the losses sustained by cattlemen because of ticks. As an ectoparasite, ticks can cause severe anemia and irritation leading to "tick worry." With a heavy infestation of these blood sucking parasites, the normal function of the skin may be impaired and resulting wounds are susceptible to secondary infection and possible worm infestation. These ill-effects from the tick have a direct effect upon milk production, growth, and the physical well-being of cattle.

Both the Nuche and the cattle tick are still a problem of tropical America for a number of reasons. There is a lack of sufficient dipping vats or spraying facilities, enforced quarantine, dipping regulations, and practically little or no control over ticks on cattle in transit. There is also the difficulty of convincing cattlemen accustomed to cattle ticks, of the economic importance of these pests. Only "all out" control measures will succeed in eradicating this serious cattle pests. Furthermore, there are certain tropical conditions that interfere with efficient control and regulation measures such as abundance of wild animals and extensive swamps, and areas without adequate means of transportation and communications.

Cattle dipping vats are not popular because cattlemen consider them too expensive. The expense is not so much in the construction costs of the vat but rather in operational expenses. Animals, with hoofs softened due to excessive humidity and water, or those having to cross through rocky volcanic terrain, are subject to injuries during the drives often becoming lame. Dipped animals must usually be rested before being returned to the pastures to avoid losses from overheating. Many of the difficultues encountered with the dipping of cattle, such as mechanical abortions, poisoning, death from injuries, etc., can be traced directly to the lack of experienced personnel and improperly designed cattle vats.

Spraying and bathing animals alone cannot be depended upon to effect a complete control of the Nuche fly and the cattle ticks. Good animal management must be practiced along with the control measures taken.

GOVERNMENTS AND CATTLE IMPROVEMENT

Experimentation and improvement programs with livestock are inherently long-term and relatively expensive in relation to other types of agricultural research and improvement activities; further, such work must be continuous and if it is to be effective, have adequate provisions for technical laboratories for serving the experimental and field work.

Livestock improvement and animal breeding centers occupy an important place in countries where effective livestock improvement schemes are already in operation. Such centers are essential parts of programs aimed at selection of superior animals and strains of livestock for distribution, and at demonstrating the advantages of maintaining livestock under improved conditions of husbandry. Governments in tropical America should give particular attention to the importance of closely linking the work carried out at such breeding centers with the problems of the stockowning population which they serve and to the importance of not maintaining standards of husbandry at the centers which are too far in advance of those which it is hoped to bring the stockowners themselves. In the locating and stocking of breeding centers, care should be taken to avoid confusing stockowners by carrying out work where they can observe it, which is not applicable to their areas or using types of animals that they should not be encouraged to use in their breeding operations.

If research is to yield good returns in increasing production it is important to get new information applied rapidly and effectively. Governments in tropical American countries should give careful consideration to the organization of methods of presenting scientific information to practical animal husbandmen, in such a way that the advantage of its application will be seen, and their cooperation obtained in improving livestock by the use of such methods.

Studies of selection indices under one set of circumstances provide useful leads for those working under different conditions, but actual indices should be developed for each set of environmental and economic conditions. This must be preceded by studies of the economic importance of each trait, development of practical and rapid methods of measuring variability in those traits (where they do not already exist), and developing indices which give reasonably good indication of each animal's breeding value.

While practical problems usually arise in the field, and the solution must be applicable in the field, experimental studies under deliberately limited and artificial conditions are often essential to the development of the solution. This is particularly the case when the problem involves interaction between two complicated and very variable sets of factors, such as the range of environmental conditions, and the physiological responses of the animal. For this reason, extensive experimental studies in the laboratory, and under controlled atmospheric conditions, are an indispensable part of any investigation of the problem of heat tolerance. Nevertheless, these experimental studies must be linked with parallel field studies, so that they shall remain oriented to the practical problem, and so that ideas shall be tested in the field as they become available.

There is need for studies of the heritability of the various traits which contribute to the adaptability to hot climates and to other adverse conditions. A knowledge of the phenotypic and genotypic correlations of these traits among themselves, as well as with those of more obvious productive importance, will facilitate the judicious implementation of improvement plans.

Perhaps one of the greatest single difficulties to be overcome in undertaking effective experimental and developmental work in the livestock field in tropical America is that of convincing both practical farmers and government administrators of the necessity for and advantages of such work. Progress in the animal breeding field has lagged far behind that in the plant field, both because progress in livestock breeding is necessarily slow, owing to the slow rate of reproduction, and because people do not see the real possibilities of improvement in livestock or do not understand the steps which are necessary to bring this improvement about. Often much money is wasted in establishing a government farm which is stocked with animals and operated very much as any good farm should be but which does not yield any return for the money expended because no provisions were made for the carrying out of experimental work or for developing a field improvement program based on such work.

The quantity of farm commodities that farmers can produce over and above their own needs depends in part on their willingness to work hard and to invest additional capital in their enterprise. To be willing to do this, the farmer must have incentives. In many countries agricultural programs are still impeded by obstacles which frustrate or suppress the farmer's normal urge to better his condition in life through increased production. Where this is true, one of the first steps in stimulating agricultural improvement is to remove the obstacles.

The removal of such faults may not by itself bring about progress, but their continuance will definitely restrict or prevent it. Education of the farm people--it cannot be overemphasized--is required for national agricultural improvement.

REFERENCES

1. Adeniyi, S. A., and Wilson, P. N. 1960. Studies on Pangola grass at I.C.T.A., Trinidad. I. Effect of fertilizer application at time of establishment, and cutting intervals on the yield of ungrazed Pangola grass. Trop. Agric., Trinidad, 38:271.

2. Ampy, F., and Bogart, R. 1962. Some physiological studies on growth and feed efficiency in beef cattle (Bos domesticus). Am. Zool., 2:170.

3. Arroyo, J. A., and Rivera, L. 1961. Digestibility studies on Napier grass (Pennisetum purpureum), Giant Pangola grass (Digitaria valida) and Signal grass (Brachiaria brizantha). J. Agr. Univ. P. R., 45:151.

4. Blackwell, R. L., Knox, J. H., and Hurt, P. W. 1958. Effect of age of dam on weaning weight, long yearling weight and postweaning gains of beef cattle. Proc. West. Sect. Am. Soc. An. Prod., 9:XLII.

5. Blackwell, R. L., Knox, J. H., Shleby, C. E., and Clark, R. T. 1962. Genetic analysis of economic characteristics of young Hereford cattle. J. Anim. Sci., 21:101.

6. Bogart, R., and Blackwell, R. L. 1950. More beef with less feed. Oreg. Exp. Agr. Sta. Bull. 488.

7. Bogart, R., Nelms, G. E., Price, D. A., Shelby, C. E., and Clark, R. T. 1956. Correlations involving body measurements, scores and certain productivity traits in beef cattle. Proc. West. Sect. Am. Soc. An. Prod., 7:XLII.

8. Bonsma, J. C. 1940. The influence of climatological factors on cattle. Observations on cattle in tropical regions. Fmg. So. Afr., 15:373.

9. Bonsma, J. C., and Pretorius, R. 1940. The influence of climate on cattle. Fertility and hardiness of certain breeds. Fmg. So. Afr., 15:7.

10. Bonsma, J. C. 1943. Influence of color and coat cover on adaptability of cattle. Fmg. So. Afr., 18:101.

11. Bonsma, J. C. 1944. The influence of climatological factors on cattle. Fmg. So. Afr., 19:71.

12. Brinks, J. S., Clark, R. T., Kieffer, N. M., and Quesenberry, J. R. 1962. Mature weight in Hereford range cows--heritability, repeatability, and relationship to calf performance. J. Anim. Sci., 21:501.

13. Brown, L. O., Durham, R. M., Cobb, E., and Knox, J. H. 1954. An analysis of the components of variance in calving intervals in a range herd of beef cattle. J. Anim. Sci., 13:511.

14. Cabrera, J. I. 1952. Minimum nutritive requirements of dairy cattle under tropical conditions. J. Agr. Univ. P. R., 36:102.

15. Caro, R., and Vicente, J. 1956. Comparative productivity of Merker grass and of Kudzy-Merker grass mixture as affected by season and cutting height. J. Agr. Univ. P. R., 40:144.

16. Caro, R., Vicente, J., and Figarella, J. 1960. The yields and composition of five tropical grasses growing in the humid mountains of Puerto Rico, as affected by nitrogen fertilization, season, and the harvest procedure. J. Agr. Univ. P. R., 44:107.

17. Caro, R., Vicente, J., and Burleigh, C. 1961. Beef production and carrying capacity of heavily fertilized, irrigated Guinea, Napier, and Pangola grass pastures on the semiarid south coast of Puerto Rico. J. Agr. Univ. P. R., 45:32.

18. Caro, R., and Vicente, J. 1961. Effects of two cutting heights on yield of five tropical grasses. J. Agr. Univ. P. R., 45:46.

19. Caro, R., Vicente, J., and Figarella, J. 1965. Productivity of intensively managed pastures of five grasses on steep slopes in the humid mountains of Puerto Rico. J. Agr. Univ. P. R., 49:99.

20. Castle, E. N., Wallace, J. D., and Bogart, R. 1961. Optimum feeding rates for wintering weaner calves. Oreg. Agr. Exp. Sta. Tech. Bull. 56.

21. Christian, R. E., Robert, W. K., and Dyer, I. A. 1956. The effect of vitamin A and energy deficiencies on some post partum reproductive phenomena in the cow. Prox. West. Sext. Am. Soc. An. Prod., 7:LV.

22. Clark, R. T., Shelby, C. E., Quesenberry, J. R., Woodward, R. R., and Willson, F. S. 1958. Production factors in range cattle under Northern Great Plains conditions. U.S.D.A. Tech. Bull. 1181.

23. Cobb, E. H., Wayman, O., and Arganosa, V. 1961. Phenotypic correlations between conformation scores and liveweights of 8, 12, and 20 months of age and rate of gain in beef cattle. Proc. West. Sect. Am. Soc. An. Prod., 12:XIX.

24. Crowder, L. V., Michelin, A., and Bastifas, A. 1964. The response of Pangola grass (Digitaria decumbens Stent.) to rate and time of nitrogen application in Colombia. Trop. Agric., Trinidad, 41:21.

25. Dahmen, J. J., and Bogart, R. 1952. Some factors affecting rate and economy of gain in beef cattle. Oreg. Agr. Exp. Sta. Tech. Bull. 26.

26. deBaca, R. C., Bogart, R., Sawyer, W. A., and Hubbert, F. 1959. The expression of growth for environmental influences affecting gains in steers. J. Anim. Sci., 18:1536.

27. Dowling, D. F. 1964. The significance of the thickness of cattle skin. J. Agric. Sci., 62:307.

28. F.A.O. Report of the FAO mission to Nicaragua. 1950. F.A.O., Rome, Italy.

29. Gregory, P. W., Mead, S. W., Regan, W. M., and Rollins, W. C. 1951. Further studies concerning sex-limited genetic infertility in cattle. J. Dairy Sci., 34:1047.

30. Gregory, P. W., Mead, S. W., and Regan, W. M. 1951. A genetic analysis of prolonged gestation in cattle. Portugaliae Acta Biologica, Series A., R. B. Goldschmidt Volume, p. 861.

31. Hubbert, F. Jr., and Sawyer, W. A. 1951. The influence of winter nutrition in range beef cattle production in eastern Oregon. Proc. West. Sect. Am. Soc. An. Prod., 2:109.

32. I.B.R.D. The Economic Development of Nicaragua. 1953. The John Hopkins Press, Baltimore.

33. Ittner, N. R., et al. 1951. Water consumption of Hereford and Brahman cattle and the effect of cooled drinking water in hot climates.

34. Ittner, N. R., et al. 1951. Cattle shades. J. Anim. Sci., 10:184.

35. Kelly, et al. 1948. Artificial shades for livestock in hot climates. Agric. Engng., 29:239.

36. Kelly, et al. 1950. Thermal design of livestock shades. Agric. Engng., 31:601.

37. Kemp, E. D. S., MacKenzie, R. M., and Romney, D. H. 1961. Productivity of pasture in British Honduras. III. Jaragua grass. Trop. Agric., Trinidad, 38:161.

38. Kidwell, J. F., LeGrand Walker, and McCormick, J. A. 1954. Hereditary female sterility in Holstein-Friesian cattle. J. Heredity, 45:142.

39. Knapp, B. Jr., and Nordskog, A. W. 1946. Heritability of growth and efficiency in beef cattle. J. Anim. Sci., 5:62.

40. Knapp, B. Jr., and Clark, R. T. 1950. Revised estimates of heritability of economic characteristics in beef cattle. J. Anim. Sci., 9:582.

41. Knapp, B. Jr., and Clark, R. T. 1951. Genetic and environmental correlations between weaning weight scores and subsequent gains in the feed lot with record of performance steers. J. Anim. Sci., 10:355.

42. Koch, R. M., and Clark, R. T. 1955. Influence of sex, season of birth and age of dam on economic traits in range beef cattle. J. Anim. Sci., 14:386.

43. Koch, R. M., and Clark, R. T. 1955. Genetic and environmental correlations among economic characters in beef cattle. I. Correlation among paternal and maternal half-sibs. J. Anim. Sci., 14:775.

44. Koch, R. M., and Clark R. T. 1955. Genetic and environmental relationships among economic characters in beef cattle. II. Correlations between offspring and dam and offspring and sire. J. Anim. Sci., 14:786.

45. Koch, R. M., and Clark, R. T. 1955. Genetic and environmental relationships among economic characters in beef cattle. III. Evaluating maternal environment. J. Anim. Sci., 14:979.

46. Koger, M., and Knox, J. H. 1951. The correlation between gains made at different periods by cattle. J. Anim. Sci., 10:760.

47. Lewis, A. H. 1941. Improving the quality of hay. Emp. J. Exper. Agr., 9:43.

48. Lickley, C. R., Stonaker, H. H., Sutherland, T. M., and Riddle, K. H. 1960. Relationship between mature size, daily gain, and efficiency of feed utilization in beef cattle. Proc. West. Sect. Am. Soc. An. Prod., 11:IX.

49. Lindholm, H. B., and Stonaker, H. H. 1956. Relative economic importance of traits affecting net income in beef cattle. Proc. West. Sect. Am. Soc. An. Prod., 7:LVIII.

50. Lindholm, H. B., and Stonaker, H. H. 1957. Economic importance of traits and selection indexes for beef cattle. J. Anim. Sci., 16:998.

51. Mason, R. W., Bogart, R., and Krueger, H. 1958. Methods of adjusting data for differences due to sex. Proc. West. Sect. Am. Soc. An. Prod., 9:XLI.

52. Nelms, G., Bogart, R., and Oldfield, J. E. 1954. Determination of digestibility in performance testing of beef cattle. Proc. West. Sect. Am. Soc. An. Prod., 5:123.

53. Nelms, G. E., and Bogart, R. 1955. Some factors affecting feed utilization in growing beef cattle. J. Anim. Sci., 14:970.

54. Nelms, G. E., Price, D. A., and Bogart, R. 1956. The relationship of some digestion coefficients to rate and efficiency of gains in growing beef cattle. Proc. West. Sect. Am. Soc. An. Prod., 6:217.

55. Nelms, G. E., and Bogart, R. 1956. The effect of birth weight, age of dam and time of birth and suckling gains of beef cattle. J. Anim. Sci., 15:662.

56. Oakes, A. J., Bond, R. M., and Skov, O. 1959. Pangola grass (Digitaria decumbens) in the United States Virgin Islands. Trop. Agric., Trinidad, 36:130.

57. Paladines, O. L., and deAlba, J. 1963. Aceptacion de forrajes tropicales por el ganado. Turrialba, 13:194.

58. Pahnish, O. F., Bogart, R., Stanley, E. B., Roubicek, C. B., and Shelby, C. E. 1958. Adjustment of weaning weights of range calves to a standard age of 270 days. Proc. West. Sect. Am. Soc. An. Prod., 9:XLVII.

59. Pahnish, O. F., Roubicek, C. B., Stanely, E. B., Bogart, R., and Shelby, C. E. 1958. The influence of age of dam on the 270-day weaning weight of bull and heifer calves. Proc. West. Sect. Am. Soc. An. Prod., 9:XLVIII.

60. Pahnish, O. F., Stanley, E. B., Bogart, R., and Roubicek, C. B. 1961. Influence of sex and sire on weaning weights of southwestern range calves. J. Anim. Sci., 20:454.

61. Pahnish, O. F., Brinks, J. S., Clark, R. T., and Quesenberry, J. R. 1961. Range performance of progeny of Miles City sires. J. Anim. Sci., 20:909 (Abstr.).

62. Patel, V. G., and Anderson, D. W. 1957. Variations of skin thickness in dairy cattle. Emp. J. Exper. Agric., 26:18.

63. Payne, W. J. A., and Laing, W. I. 1952. The limit set to tropical dairy production by nutritional factors. Proc. N. Z. Soc. Anim. Prod., 11th Ann. Conf., 1951:23.

64. Pierce, C. D., Avery, H. G., Burris, M., and Bogart, R. 1954. Rate and efficiency of gains in beef cattle. II. Some factors affecting performance testing. Oregon Agr. Exp. Sta. Tech. Bull. 33.

65. Rhoad, A. O. 1938. Some observations of the response of purebred Bos taurus and Bos indicus cattle and their crossbred types to certain conditions of the environment. Proc. Amer. Soc. An. Prod., 31st. Ann. Meet.: 284.

66. Riemerschmid, G., and Elder, S. S. 1945. The absorptivity for solar radiation of different coloured hairy coats of cattle. Onderstepoort J. Vet. Sci., 20:223.

67. Rivera, L. 1951. Forage consumption as soilage by Holstein, native and Holstein-native crossbred cows. J. Agric. Univ. P. R., 35:91.

68. Rodriguez, J. P. 1949. Effect of nitrogen applications on the yield and composition of forage crops. J. Agric. Univ. P. R., 23:98.

69. Rollins, W. C., Guilbert, H. R., and Gregory, P. W. 1952. Genetic and environmental factors affecting preweaning growth of Hereford cattle. J. Anim. Sci., 11:743 (Abstr.).

70. Rollins, W. C., and Guilbert, H. R. 1954. Factors affecting the growth of beef calves during the suckling period. J. Anim. Sci., 13:517.

71. Rollins, W. C., and Wagnon, K. A. 1955. A genetic analysis of weaning weights in a range beef herd operated under optimum and suboptimum nutritional regimes. Proc. West. Sect. Am. Soc. An. Prod., 6:35.

72. Rollins, W. C., and Wagnon, K. A. 1956. A genetic analysis of weaning weight in a range beef herd operated under optimum and suboptimum nutritional regimes. J. Anim. Sci., 15:529.

73. Romney, D. H. 1961. Productivity of pastures in British Honduras. II. Pangola pasture (as influenced by climate, soil type, and phosphate fertilizer). Trop. Agric., Trinidad, 38:39.

74. Romo, A., and Blackwell, R. L. 1954. Phenotypic and genetic correlations between type and weight of range cattle at different periods. Proc. West. Sect. Am. Soc. An. Prod., 5:205.

75. Sabin, S. W., Stratton, P. O., and Hilston, N. W. 1958. Growth from birth to weaning in beef calves as an indication of future performance. J. Anim. Sci., 17:1147 (Abstr.).

76. Samuels, G., and Gonzales, F. 1963. Influence of nitrogen source and time of cutting on yield and protein content of Napier (Merker) grass. J. Agric. Univ. P. R., 47:205.

77. Sawyer, W. A., Bogart, R., and Oloufa, M. M. 1948. Weaning weight of calves as related to age of dam, sex, and color. J. Anim. Sci., 7:514.

78. Sawyer, W. A., Li, J. C. R., and Bogart, R. 1949. The relative influence of age of dam, birth weight, and size of dam on weaning weight of calves. Proc. West. Sect. Am. Soc. An. Prod.

79. Seath, D. M. 1946. Effect of warm weather on grazing performance of milking cows. J. Dairy Sci., 19:199.

80. Seath, D. M., and Miller, G. D. 1947. Effect of hay feeding in summer on milk production and grazing performance of dairy cows. J. Dairy Sci., 30:921.

81. Shelby, C. E., Clark, R. T., and Woodward, R. R. 1955. The heritability of some economic characteristics of beef cattle. J. Anim. Sci., 14:372.

82. Shelby, C. E., Harvey, W. R., Clark, R. T., Quesenberry, J. R., and Woodward, R. R. 1963. Estimates of phenotypic and genetic parameters in ten years of Miles City R.O.P. steer data. J. Anim. Sci., 22:346.

83. Sittmann, K., Rollins, W. C., and Kendrick, J. W. 1961. A genetic analysis of the double cervix condition in cattle. J. Heredity, 52:26.

84. Ulloa, G., and deAlba, J. 1957. Resistencia a los parasitos externos en algunas razas de bovinos. Turrialba, 7:8.

85. Vicente, J., and Figarella, J. 1958. Growth characteristics of Guinea grass on the semiarid south coast of Puerto Rico and the effect of nitrogen fertilization on forage yields and protein content. J. Agr. Univ. P. R., 42:151.

86. Vicente, J., Silva, S., and Figarella, J. 1961. Effects of nitrogen fertilization and frequency of cutting on the yield and composition of Pangola grass in Puerto Rico. J. Agr. Univ. P. R., 45:37.

87. Vicente, J., and Figarella, J. 1962. Effect of five nitrogen sources on yield and composition of Napier grass. J. Agric. Univ. P. R., 46:102.

88. Vicente, J., Silva, S., and Figarella, J. 1962. Effect of frequency of application on response of Guinea grass to nitrogen fertilization. J. Agr. Univ. P. R., 46:342.

89. Wagnon, K. A., and Rollins, W. C. 1959. Heritability estimates of postweaning growth to long-yearling age of range beef heifers raised on grass. J. Anim. Sci., 18:918.

90. Warnick, A. C. 1955. Factos associated with the interval from parturition to first estrus in beef cattle. J. Anim. Sci., 14:1003.

91. Willson, F. S., Urick, J. J., and Flower, A. E. 1954. Genetic studies of steer progeny groups slaughtered following three successive feeding treatments. J. Anim. Sci., 13:965 (Abstr.).

92. Woodward, R. R., Quesenberry, J. R., Clark, R. T., Shelby, C. E., and Hankins, O. G. 1954. Relationships between preslaughter and postslaughter evaluations of beef cattle. U.S.D.A. Circ. No. 945.

93. Woodward, R. R., Quesenberry, J. R., and Willson, F. S. 1954. Production and carcass quality in beef cattle. Mont. Agr. Exp. Sta. Circ. 207.

94. Woodward, R. R., and Rice, F. J. 1958. Variation in weight-constant body length measurements of Hereford bulls. J. Anim. Sci., 17:1146.

95. Zurakov, I. S. 1939. Dokl. Akad. seljskohoz. Nauk, 20:30. Cited from An. Breed. Abstr., 8:353, 1940.

96. U. S. News & World Report, Nov. 7, 1965, p. 32.

PROBLEMS RELATED TO THE BREEDING IMPROVEMENT OF CATTLE IN TROPICAL REGIONS

by

SERGIO ULISES MOLINA

Agronomo., Escuela Agricola Panamericana, 1963

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Husbandry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1966

Throughout the world, in varying proportions, a high percentage of total human beings cannot be adequately fed or clothed without sufficient livestock products. In this age, more than ever, human welfare demands that livestock function with maximum efficiency.

The application of knowledge, new and old, to a nation's animal industry not only takes time, but it is also an endeavor for which there is no end in sight.

Since an attempt is made in this paper to make suggestions for the improvement of animal husbandry in Nicaragua, certain relevant facts about the country are presented.

The importance of variations in adaptability in selecting stock for a given set of conditions is stressed. This point has been frequently overlooked in attempts to improve the quality or productivity of stock in a given area, particularly in regions where rigorous environmental conditions prevail, resulting in a waste of time, effort, and money.

Adaptability in relation to solar radiation, temperature, and humidity, are discussed briefly. Reproduction, production, mortality, and parasites and diseases are also discussed from the adaptive point of view.

In view of the limitations placed on livestock production by the environmental conditions prevailing in tropical America, it is essential, when plans are made for the improvement of livestock, that careful consideration be given to the appropriate environmental modifications to be effected concurrently with the breeding policy.

It is highly recommended, that selection criteria be confined to the essentials of reproductive efficiency and the ability of the animal to thrive and grow in its environment, without losing sight of the fact that simultaneous improvement of management and nutrition, along with genetic potential, is essential.

Breeding efficiency and fertility, preweaning growth rate, postweaning growth rate, and longevity are discussed as the most important performance traits for beef cattle in tropical America. The importance of records in improvement programs is discussed at some length.

Grazing management is, perhaps, one of the most important factors limiting production in tropical America. Consequently, it is discussed at some length. As examples of the possibilities, three grasses (Pangola, Guinea, and Napier) are discussed.

A final note on the Nuche fly and ticks, and on the role of the government in animal husbandry improvement is made.