ESTIMATES OF GENETIC PARAMETERS OF SEVERAL PRODUCTIVE TRAITS IN A COLOMBIAN CATTLE BREED, BLANCO OREJINEGRO (BON) AND ITS CROSSES WITH ZEBU, CHAROLAIS AND SANTA GERTRUDIS

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CHAPTER I

INTRODUCTION

The need to increase animal protein for the world's population requires no discussion. World demand for food is increasing rapidly and parallel to production costs. These changes have made cattle producers interested in determining which breeds and breeding systems will result in maximum profits for a particular production situation.

Dickerson (1969) pointed out that breed differences are an important source of genetic improvement in the efficiency of human food production from livestock through: (1) grading up to superior breeds, (2) heterosis from systematic crossbreeding, and (3) development of new breeds. Consequently, a primary objective of beef cattle genetic research is to evaluate breeds and breeding systems for productive efficiency under various climatic and management conditions.

Dickerson (1969) indicated that evaluation of breeds for production efficiency required reliable estimates of relative performance for the more promising purebreds, three-breed crosses from crossbred dams and the F1, F2 and F3 generations of two-breed crosses. Most research facilities and the number of adapted breeds to tropical conditions, are not large enough to provide a complete set of data. Thus, most studies in the tropics have involved only crosses with Zebu, Criollos, and in a few studies exotic breeds, such as Charolais and Santa Gertrudis were used.

The purpose of this study was to evaluate some genetic factors, such as, heritability and genetic correlations for several productive traits in Blanco Orejinegro (BON) cattle. Individual and maternal heterosis was measured with all possible combinations from the mating of BON, Zebu, Charolais and Santa Gertrudis bulls with BON, Zebu and crossbred (F1), BON x Zebu and Zebu x BON cows. This should provide valuable information for the formulation of efficient breeding programs to increase beef production.

CHAPTER II

LITERATURE REVIEW

Brief history of Blanco Orejinegro

The first cattle brought to the New World arrived with the landing of Christopher Colombus on the Hispaniola Island in November of 1493. Two decades later cattle were brought to Puerto Rico, Jamaica, Cuba and the mainland. These cattle formed the foundation of the Criollo (native cattle) of the southern North America, Central America and South America (Rouse, 1977; Salazar and Cardozo, 1981; Pinzon, 1984).

Santa Marta and Cartagena, were the ports from which cattle colonization of northern Colombia proceeded. These cattle became well established in Santa Marta and Cartagena settlements and began to move inland into the country.

Western Colombia was colonized from the Pacific ocean by Sebastian the Belalcazar who trailed a shipment of cattle through Panama. On the good grasses of the upper Cauca Valley (Western Colombia), cattle did exceptionally well and within a few years had spread and increased in number. Antioquia (Western Colombia) received 500 head in 1573, and the number was reported to have increased rapidly. (Rouse, 1977; Pinzon, 1984).

There is a controversy about the origin of BON. The White Park and Wild White breeds of Britain, the white cattle of Italy, the Swedish Mountain and Berrenda from Spain, as well as crosses are most frequently mentioned as possible ancestors of the BON (Rouse, 1977; Pinzon, 1984).

Since the only evidence of cattle importations in the early years was from Spain, the most plausible hypothesis for the genesis of the BON is the Berrenda breed of Spain, which posseses the same external characteristics of BON (Rouse, 1977).

Whatever the origin of BON, this breed has experienced good genetic adaptation to the wide range of environment and varied levels of management in the difficult tropical conditions of the coffee-growing region of the Andes of Colombia.

Description of the Breed

In South America the black-eared white pattern body is confined to the Blanco Orejinegro (BON), which inhabit the Andean region of Colombia, especially along the foothills of the western and central cordillera that rises from the Cauca Valley. (Pearson, 1968).

The BON coat is white, but black flecks occur in some individuals, especially on the lower neck and flanks. The skin is heavily pigmented, however the calves are born with pink skin, which turns black by action of external stimuli, mainly solar radiation. The pigmentation process is usually completed at 24 months of age. Apart from black ears, the breed has black mucosae, feet and horn tips. A recessive variant exists called Blanco Orejimono (BOM), in which the markings are red instead of black (Salazar, 1971).

Conformation is quite variable, but in general BON is typically a dual purpose milk-beef breed. The thin tail, drooping rump, high tail stock and concave dorsum are typical of BON. According to Pinzon (1984) the high tail stock increases the vertical diameter of the pelvis which facilitates parturition; the low rump and concave dorsum are typical of mountain breeds and these characteristics give them the ability to walk in the abrupt topography of the Andean region of Colombia.

Of special economic importance is their extraordinary rusticity, grazing ability and their resistance to Dermatobia hominis ("Nuche") and ticks. According to Mateus (1967) the low level of damage that "Nuche" produces on BON cattle is due to the following factors: The thickness of the skin which acts as a barrier; the strong pigmentation of the skin, which produces a repellent odor for the vector flies of "Nuche"; white coat color, (colored cattle is highly susceptible), since it is believed that vector flies are blind for white color, and finally to congenital inmunity.

Reproductive Performance

Rate of reproduction in beef cattle is the most important trait influencing the economy of beef production. Differences in calving, weaning and survival rate from different breeds of beef cattle in several regions of the world, are abundant in the literature.

Tropical regions of Latin America, especially low lands, have been associated with low reproductive rate and, consequently, with low cattle production. Undernutrition is commmonly accepted to be the most important limitation to obtain an acceptable reproductive rate. (McDowel et al., 1975; Stonaker, 1975).

Raun (1976), documented the low animal productivity in the low land tropics of Latin America. He gave an average calving rate of 40 to 50 percent; animals slaughtered at 3 to 5 years of age at weights of 350 to 450 kg.; an extraction rate of 13 percent and total animal production of carcass beef from the total beef herd of 25 kg.

Salazar (1977), reported some statistics of the reproductive performance of the Colombian herd. He gave, averaging over all the various ecological regions of the country, 53 percent of calving rate; 33 months for first estrus; 22 months for calving interval and a total of 5 calves per cow during its productive life.

Breed cow groups represented in the present study are: the Colombian native Criollo Blanco Orejinegro (BON), Zebu (Brahman), and their reciprocal crosses. A few studies involving these or similar cow groups in tropical regions are summarized in Table I. Breed types not used in this study are occasionally referred to for comparison purposes.

Calf Preweaning Traits

Calf birth weights, preweaning daily gains, and weaning weights for some Criollos, Zebu and crosses from Latin American tropics are presented in Table II. For most of the studies summarized in Table II, year fluctuations in environmental conditions and variation in quantity

TABLE I

CHARACTERIZATION OF SOME TROPICAL CRIOLLO CATTLE BREEDS AND CROSSES: REPRODUCTIVE AND PRODUCTIVE PERFORMANCE

Reference	Dam Breed	Sire Breed	Cow Weight Kg.	Calf Weaning Weight/Cow Weight Kg	Kg of Calf/ Cow in Breeding Herd	Calving Rate	Weaning Rate	Survival Rate	Age at 1st Cal-ing (Yr.)
Pearson et al (1968)	BON-Jersey	Jersey							3.3
	BON	Jersey							3.4
Lemka et al (1973)	BON	BON							3.4
	Hariana	Hariana							4.3
	Deshi	Deshi							3.9
	CCC	CCC							3.3
Botero (1975)	BON	BON				70			
Hernandez (1975)	Romo	Romo				82	77	96	
	Brahman	Brahman				75	72	96	
	Romo-Brahman	Charolais				83	79	95	
Rubio (1975)	CCC	CCC				74			
Gonzalez (1975)	San Martinero	San Martinero				67			
Hernandez (1981)	BON	BON				52	50	98	
	Romo	Romo				67	59	88	
	Zebu	Zebu				49	46	95	
	Romo-Zebu	Charolais				80	78	97	
	St.Martinero-Zebu	San Martinero				60	56	93	
	Zebu					59	54	92	
	St.Martinero					55	51	93	
	Zebu					76	72	94	
	BON-Zebu					59	56	95	

TABLE I (CONTINUED)

Reference	Dam Breed	Sire Breed	Cow Weight Kg.	Calf Weaning Weight/Cow Weight Kg	Kg of Calf/ Cow in Breed- ing Herd	Calving Rate	Weaning Rate	Survival Rate	Age at 1st Cal- ing (Yr.)
Trail and Gregory (1981)	Sahival		418	.41	159	94		96	3.3
	Boran		414	.41	140	88		94	3.4
Plasse et al (1981)	Criollo	Brahman				83			
	Zebu	St. Gertrudis				79			
	Zebu-Criollo	Brown Swiss				88			
Martinez & Laredo (1983)	BON	BON	396			78			2.8
Martinez (1983)	BON	BON				65		93	
	BON-Zebu	Charolais				65		94	
	Zebu	Zebu				53		91	
Gregory et al (1985a)	Zebu	Red Polled	298	.55	95	69		95	
	Ankole	Angus	341	.51	108	65		92	
	Boran	Boran	332	.53	106	71		93	
Gregory et al (1985b)	Ankole	Friesian	322	.48	66	69		80	
	Boran	Brown Swiss	312	.53	98	72		92	
	Zebu	Simmental	246	.59	64	66		84	
	Boran-Zebu		298	.53	101	76		96	
	Boran-Ankole		323	.54	102	73		90	

and quality of available food for animals, resulted in either gain or losses of weight of calves.

The year effect on birth weight of calves varied; however, most studies reported significant effect of year on the birth weight of calves. For preweaning daily gains and weaning weights year effect was a significant (P<.01) source of variation either in tropical studies (Hernández, 1976; Ocanto et al., 1981; Bauer et al., 1981 and Martinez and Hernandez, 1983), or in studies conducted in temperate areas of the United States (Roberson et al., 1986; McElhenney et al., 1985, 1986; Frahm and Marshall, 1985). The only exception was a study conducted in Louisiana by Reynolds et al., (1980).

Birth Weight

Effect of Season of Birth

Season and/or month of birth has also been reported to be an important source of variation (P<.01) on birth weight of calves. In three studies conducted at Texas (Roberson et al., 1986 and McElhenney et al., 1985, 1986) it was found that spring born calves were heavier at birth than winter, fall and/or summer born calves. Season of birth also had signifficant effect (P<.01) on the birth weight of calves in a study conducted with Guzera calves in the tropics of Brazil. Calves born during the dry season were heavier than calves born during the wet season. (Oliveira et al., 1983).

TABLE II

CHARACTERIZATION OF SOME TROPICAL CRIOLLO CATTLE
BREEDS AND CROSSES: CALF BIRTH WEIGHT
PREWEANING DAILY GAIN AND
WEANING WEIGHT

					Calf Weaning Weight	
Reference	Calf Sire a Breed	Cow Type a Group	Calf Birth Weight Kg	Calf Pre-Weaning Daily Gain Kg/d	Calf Age Adjustment Days	Adjusted Weight KG
Muller-Haye et al., (1968)	Br	Br	27.3			
	Br	CL	31.3			
	CL	Br	25.3			
	CL	CL	25.3			
Munoz & Martin	SG	SG	32.5		240	207.7
	SG	Br	27.5			205.8
	SG	C	31.3			212.8
	Br	Br	27.5			190.3
	Br	SG	36.5			228.5
	Br	C	35.6			230.1
	C	C	29.1			203.7
	C	SG	30.7			213.2
	C	Br	25.4			204.3
Stonaker (1971)	BON	BON	27.6		270	199.0
	Br	BON	34.0			222.5
	Ch	BON	30.2			231.0

TABLE II (CONTINUED)

Reference	Calf Sire[a] Breed	Cow Type[a] Group	Calf Birth Weight Kg	Calf Pre-Weaning Daily Gain Kg/d	Calf Weaning Weight: Calf Age Adjustment Days	Calf Weaning Weight: Adjusted Weight Kg
Hernandez (1976, 1981)	Romo	Romo	29.6	0.548	270	177.8
	Romo	Br [c]	29.3	0.707		220.3
	Romo	Romo x Br	29.5	0.708		220.8
	Br	Romo	31.8	0.671		213.2
	Br	Br [c]	29.0	0.665		208.6
	Br	Romo x Br	30.2	0.710		222.1
	Ch	Romo	33.4	0.647		208.1
	Ch	Br [c]	29.2	0.747		231.0
	Ch	Romo x Br	35.2	0.778		243.5
Botero (1976)	BON	BON	27.0		270	188
	Br	Br				185
	Ch	BON	33.0			221
	Br	BON [c]	33.0			218
	Ch	BON x Br				243
Gonzalez (1976)	SM	SM	29.0		270	175
	Z(Br)	Z	26.0			179

In studies conducted in Colombia (Hernandez, 1970; Martinez and Hernandez, 1983), Venezuela (Ocanto et al., 1981), and in Oklahoma (Bolton et al., 1986) season of birth did not affect the birth weight of calves.

Effect of Sex

In all the studies reviewed from research, conducted in tropical Latin America and in temperate areas of North America, sex of calf was found to be a significant ($P<.01$) source of variation for the birth weight of calves.

In tropical Latin American studies in which different types of Criollo breeds, Brahman, Santa Gertrudis, Charolais, and their crosses have been involved, the average (range) advantage of males over females reported was 1.86 kg (0.55 - 3.28) (Munoz and Martin, 1969; Muller-Haye et al., 1968; Hernandez, 1976; Arboleda, 1977; De Oliveira and Barbosa, 1983; Martinez and Hernandez, 1983).

Similar sex differences have been reported from studies conducted in temperate areas of North America with Brahman type cattle and Bos taurus breeds, (Comeford et al., 1987; Roberson et al., 1986; McElhenney et al., 1985 and 1986; Williamson and Humes, 1985; Gregory et al.; 1985; Belcher and Frahm, 1979; Crockett et al., 1978 and Bailey and Moore, 1980). Overall, differences between sexes averaged 2.2 kg (0.55 - 3.3).

Effect of Age of Dam

In most studies conducted in tropical Latin America and temperate areas of North America with several types of breeds and their crosses, age of dam has been reported to be a significant (P<.01) source of variation for birth weight of calves. (Hernandez,1976; Martinez and Hernandez, 1983; Roberson et al., 1986; Gregory et al., 1985; Williamson and Humes, 1985; Reynolds et al., 1980; and Crockett et al., 1978). In general, all these studies agree that cows from 6 to 8 years of age had the heaviest calves at birth with cows from 3 to 4 years and older than 8 years having the lightest.

Hernandez (1970) working with Romo cattle in Colombia, found significant age of dam effects on birth weight of calves in a period of five years (1959-1963) but not in another period of three years. Thrift et al., (1986) working with Longhorn, Red Poll and Senepol bulls mated to Angus, Charolais, Brahman and Hereford cows found a highly significant (P<.01) age of dam effect on birth weight of calves in Louisiana but not in in Kentucky. Oliveira et al (1983) working with Guzera cattle in Brazil did not find statistical differences on birth weight of calves due to dam age.

In general, the previous results indicate that birth weight increases with age of cows until a certain point and then decreases.

Effect of Sire Breed

Hernandez (1976) working with Criollo, Brahman and Charolais sires mated to Criollo, Brahman and crossbred (F1) Criollo-Brahman cows reported significant effect on birth weight of calves due to breed of sire. He found that Charolais sired calves (32.3 kg) were 1.7 and 2.8 kg heavier than Brahman and Romo sired calves, respectively.

The same author (1981) reported significant sire breed effect (P<.01) on birth weight of Charolais, Brahman and Criollo sired calves in three different localities of Colombia. Charolais bulls produced the heaviest calves at birth and Criollo bulls the lightest. The difference in birth weight between the average of the Criollo sired calves (27.4 kg) and that of Charolais (30.1 kg) in the three localities was 3.6 kg. Among the Criollos, the lowest birth weight (26.0 kg) corresponded to San Martinero, the highest to Romosinuano (29.6 kg) with BON being intermediate (26.7 kg). At El Nus the birth weight for Charolais, Brahman and BON sired calves were: 31.4, 30.8 and 26.7 kg., respectively.

In Venezuela Muller-Haye (1968) found that Brahamn bulls produced calves (29.3 kg) 4.0 kg heavier than Criollo bulls (25.3 kg).

Gregory et al., (1985) in Africa reported that Simmental sired calves were the heaviest at birth (30.8 kg) and Red Poll sired calves the lightest (25.8 kg).

Differences on birth weight due to sire breed were highly significant (P<.01) in the studies conducted by Thrift et al., (1986) in Louisiana and Kentucky. In Kentucky they found that Senepol bulls produced calves 1.3 kg heavier than Hereford bulls, while in the Louisiana study Longhorn calves (23.4 kg) were 5.9 kg lighter (P<.01) at birth than Red Poll sired calves. Comeford et al., (1987) in Georgia, found that Brahman bulls sired the heaviest calves (36.49 kg) and Polled Hereford the lightest calves (33.03 kg).

Williamson and Humes (1985) in Louisiana, found that Chianina bulls produced the heaviest calves at birth (33.7 kg), followed by Brahamn bulls (32.9 kg) and with the lightest calves from Simmental bulls (31.8 kg), Crockett et al., (1978) in Florida also found significant effect due to sire breed on birth weight of calves. The exception to the above findings was a study conducted in Oklahoma by Belcher and Frahm (1979).

From these studies it can be stated that breed of sire is an important source of variation for birth weight. Charolais, Simmental and Brahman bulls produced heavy calves and Angus, and Criollo bulls, including Longhorn produced light calves.

Effect of Dam Breed

Muller-Haye et al., (1968) reported that birth weight of calves from Brahman cows (26.3 kg) were 2.0 kg lighter than those from Criollo cows. Hernandez (1976) studying Romosinuano cattle and their crosses with Brahman and Charolais, found that Romosinuano dams produced heavier calves (31.7 kg) than Brahman cows (29.18 kg). The same author (1981) working at three different localities of Colombia with Brahman, Criollo dams (Romosinuano, San Martinero and BON) and crossbred F1 Brahman-Criollo cows, reported highly significant effects ($P<0.01$) of dam breed on birth weight of calves. Criollo dams produced the heaviest calves (30.5 kg) at birth and Brahman cows produced the lightest calves (27.0 kg) with crossbred (F1) cows being intermediate (29.7 kg). At El Nus, the average birth weight of calves from BON, Brahman and crossbred cows were: 31.1, 26.6 and 29.0 kg., respectively.

In the United States breed of dam has also been found to be a significant (P<0.01) source of variation for calf birth weight. In Georgia Comeford et al., (1987) found that calves from Limousin dams were 7.0 kg heavier than calves from Brahman cows. Thrift et al., (1986) in Louisiana found that Brahman cows produced the lightest calves (23.2 kg) and Charolais cows the heaviest (29.0 kg).

McElhenney (1986) in Texas reported 30.0, 33.8 and 32.0 kg for calves from Brahman, Hereford and Brahman x Hereford cows, respectively.

Summarizing these results, breed of dam has a significant effect on birth weight of calves. Criollo cows, in the tropics studies, consistently produce the heaviest calves while Brahman cows produced the lightest calves, while crossbred cows are intermediate. In the temperate areas of North America, Brahman cows also tend to produce light calves at birth and Charolais and Hereford cows tend to produce the heaviest.

Sire x Dam Breed Interaction

Muller-Haye et al. (1968) in Venezuela reported a significant sire x dam breed interaction for birth weight of calves. Brahman x Criollo calves were the heaviest at birth, averaging 31.3 kg and weighing 6.0 kg more than Criollo calves.

In a three-breed diallel study in Costa Rica Munoz and Martin (1969) reported significant (P<.01) sire x dam breed interaction on birth weight of calves. Brahman x Santa Gertrudis calves were the heaviest at birth, averaging 11.1 kg more than the lightest calves, Criollo x Brahman.

Hernandez (1976) working in Colombia with Romo cattle and their crosses with Brahman and Charolais found a significant (P< 0.01) sire x dam breed interaction on birth weight of calves. Charolais x crossbred F1 cows produced the heaviest calves at birth, averaging 34.1 kg; 5 kg more than the lightest, Brahman calves.

An evaluation of the Criollo breeds of Colombia (Hernandez, 1981), indicated that the effect of sire x dam breed interaction was significant (P<.01) in all three localities where the study was conducted. At Turipana, the heaviest calves at birth were the triple crosses consisting of Charolais bulls bred to crossbred (F1) Brahman x Romo cows (38.1 kg) with the lightest calves being the purebred Brahman calves (28.9 kg). At La Libertad, calves from Charolais bulls and crossbred (F1) cows from San Martinero x Brahman were the heaviest (31.1 kg) and the lightest were the straightbred Brahman calves (24.6 kg). At El Nus the same pattern was true with Charolais sired calves from crossbred (F1) BON x Brahman cows being the heaviest (34.0 kg) and Brahman calves the lightest (25.7 kg).

Cevallos et al. (1981) working with two different type of Criollo cows from Venezuela, and with Brahman and crossbred (F1) Brahman-Criollo cows mated to Brahman, Santa Gertrudis, Charolais and Brown Swiss bulls, reported a superiority of 11% from crossbred calves compared to purebreds.

In Texas, Comeford et al. (1986), reported a significant (P<.01) sire x dam breed interaction. Brahman x Limousin were the heaviest calves (39.2 kg) and Hereford x Brahman (29.3 kg) the lightest. Bailey and Moore (1980) in Nevada also reported significant sire x dam breed interaction. Brahman x Hereford calves were the heaviest (38.4 kg) and Angus x Hereford calves the lightest (33.7 kg). In general, there is a tendency to increase the birth weight of calves with specific mating of different breeds, specially when the cross involves the paternal lines from Charolais and/or Brahman cattle.

Average Daily Gain Before Weaning

Effect of Season of Birth

In three studies conducted at Texas by Roberson et al., (1986) and by McElhenney et al. (1985, 1986), and in one study in Oklahoma by Bolton et al., (1986), season of birth significantly (P<.01) influenced the preweaning gain of calves. In these studies winter and spring born calves gained faster than summer and fall born calves.

Season of birth also had a significant effect (P<.01) on the preweaning gain of calves in studies conducted in the tropics of Latin America (Garrido and Koger, 1981; Bauer et al., 1981; Martinez and Hernandez, 1983 and Ocanto et al., 1981). In all these studies, calves born during the dry season, before the seasonal rains, gained faster than those born during the wet season.

Effect of Sex

In all studies reviewed here, conducted either in tropical or temperate areas, sex of calf has significantly (P<0.01) influenced the preweaning daily gains of calves (Ocanto et al., 1981; Hernandez, 1976; Martinez and Hernandez, 1983; Reynolds et al., 1982; McElhenney et al., 1985, 1986; Roberson et al., 1986; Belcher and Frahm, 1979; Frahm and Marshall, 1981 and Bailey, 1981).

Average differences (with range) in tropical studies were: 0.076 kg/d (0.072- 0.079) with males gaining faster than females. Average differences between sexes, in all studies, were 0.075 kg ranging from 0.068 (Reynolds et, 1982) to 0.085 (McElhenney, 1985, 1986).

Effects of Age of Dam

Significant effects (P<.01) for age of dam on preweaning daily gain were found in all studies reviwed here, either in tropical or temperate areas.

Working with Romo, Brahman, Charolais and their crosses, Hernandez (1976) found that cows less than 3 years of age had the calves with the lowest daily gains. Cows from 3 to 9 years of age did not differ greatly. Martinez and Hernandez (1983) working in Colombia with BON cattle, found significant age of dam effects (P<.01) on preweaning daily gain of calves, among four years studied. They reported that cows between 4 and 9 years of age had calves with the greatest preweaning daily gains. Ocanto et al., (1981) in Venezuela, and Bauer et al., (1981) in Bolivia have also reported significant (P<0.01) effects of age of dam on the preweaning daily gain of calves.

In Texas, Roberson et al., (1986), working with Brahman, Hereford and Brahman-Hereford, reported that the smallest preweaning gains for calves was out of 2-year-olds, with maternal ability of dams increasing with dam age through 9 years. In Louisiana, Reynolds et al., (1980) working with Angus, Brahman, Africander-Angus and Brahman-Angus cross cattle reported that as age of dam increased, average daily gain before weaning increased.

According to the previous results, it can be concluded that age of dam is an important source of variation for average daily gain from birth to weaning. In general, preweaning daily gain increases with age of cows until a certain age and then decreases.

Effects of Sire Breed

Hernandez (1976), working with Romo, Brahamn and Charolais bulls mated to Romo, Brahman, and Romo-Brahman cows reported significant effect for breed of sire on preweaning gain of calves. He found that Charolais bulls produced the fastest growing progeny (0.708 kg), Romo produced the slowest growing progeny (0.630 kg) and Brahman bulls were intermediate (0.664 kg/day). The same author conducted to evaluated some of the Criollo breeds that exist in Colombia. He reported that sire breed, with only one exception at La Libertad in the eastern plains of Colombia, had a significant influence ($P<.01$) in the preweaning gain of calves. The study indicates that the Criollo and Charolais sires, averaged over all regions where the study was conducted produced the slowest and fastest growing calves, respectively (0.641 and 0.685 kg/d). Among the Criollos, the slowest growing calves were those sired by San Martinero bulls in the eastern plains (0.579 kg/d); the fastest were Romo sired calves (0.691 kg/d) with BON sired calves being intermediate (0.652 kg/d). At El Nus, the preweaning daily gains of Charolais, Brahman and BON sired calves were: 0.707, 0.673 and 0.652 kg/d, respectively. Frahm and Marshall (1985) in a study where Charolais and Brahman bulls were included reported significant effect of breed of sire on preweaning gain of calves, however, they did not show the trend of sire breed in influencing daily gains.

Effect of Dam Breed

Hernandez (1976) reported highly significant effects of breed of dam on preweaning daily gain of calves. He found that crossbred cows Brahman and Romo cows produced calves with the highest rate of growth (0.714 kg), Brahman cows ranked second (0.686 kg) and Romo dams last with 0.603 kg. The same author, evaluating some of the Criollo breeds of Colombia, found a significant breed of dam effect on average daily gain of calves from birth to weaning. Crossbred cows produced the calves with the highest rate of growth (0.723 kg) Brahman cows ranked second (0.660 kg) and Criollo dams (0.599 kg) produced the calves with slowest growth rate. At El Nus, the preweaning daily gains of calves from BON, Brahman and crossbred cows were: 0.631, 0.677 and 0.729 kg/d., respectively.

In Texas, McElhenney (1986), used a five-breed diallel study in which included milking and beef breeds. Among purebred beef cows, that Brahman dams produced the fastest growing calves from birth to weaning (0.846 kg), Hereford dams produced the slowest growing calves (0.752

kg), with Angus cows being intermediate (0.806 kg). Among crossbred beef cows, the highest rate in growth of calves was obtained from Brahman-Hereford (0.921 kg) and the slowest from Angus-Hereford cows (0.843 kg/d).

Summarizing these results, it can be said that breed of dam has an important effect on calf preweaning gain. In the tropics studies, crossbred cows consistently produced calves with the highest rate of gain, Criollo cows produced the calves with slowest rate of gain and Brahman cows were intermediate. In the temperate areas of North America, Crossbred, Brahman, Angus and Charolais cows tend to produce calves with fastest growth rate and Hereford cows the calves with slowest growth rate.

Sire x Dam Breed Interaction

Hernandez (1976) working in Colombia with Romo cattle and its cross with Brahman and Charolais reported significant (P<.01) sire x dam breed interaction on preweaning daily gain of calves. Charolais bulls mated to crossbred (F1) Romo-Brahamn cows produced the calves with the fastest growing rate,(0.772 kg) and Romo calves had the slowest growing rate (0.521 kg).

In a study conducted to evaluate the Criollo breeds from Colombia (Hernandez, 1981), found that the effect of sire x dam breed interaction on preweaning daily gain of calves was significant (P<.01) in all three localities where the study was conducted. At Turipana he found that the fastest and slowest growing calves from birth to weaning were the triple crosses of Charolais bulls with crossbred (F1)

Brahman-Romo cows and the purebred Romo calves, with 0.781 and 0.575 kg, respectively. At La libertad, calves from Brahman bulls and crossbred San Martinero-Brahman cows had the fastest growing rate (0.698 kg) and the slowest growing calves with 0.508 kg/d were the purebred Brahman calves. At El Nus the highest rate of growth was obtained in calves from Charolais bulls and crossbred BON-Brahman cows with 0.781 and BON (0.567 kg) were the calves with slowest rate of growth.

Ocanto et al., (1981) reported significant (P<0.01) sire x dam breed interaction on preweaning daily gain of calves. They studied the preweaning daily gain of calves resulted from the mating of two types of Criollo cows from Venezuela, and pure Brahman cows to Brahman, Santa Gertrudis, Charolais and Brown Swiss bulls. The overall average daily gain from birth to weaning was 0.665 kg and all the crossbred groups gained faster than the purebred control groups.

Bauer et al., (1981) reported a significant (P<0.01) sire x dam breed interaction on weaning weight. They studied the preweaning daily gain of calves resulted from the mating of Criollo and Brahman cows and their F1 crosses to Criollo, Brahman, Charolais and Charolais-Zebu-Criollo bulls. The overall preweaning daily gain was 0.558 kg. Crossbred bulls mated to F1 crossbred cows produced the calves with the highest rate of gain.

In Texas, McElhenney et al., (1985) in a five-breed diallel study which included beef and milking breeds, found that Brahman were the fastest growing calves (0.740 kg/d) and Herefords the slowest (0.668 kg) among straightbreed beef cattle breeds. Angus were intermediate with (0.717 kg). Among crossbred beef groups Brahman-

Hereford combinations produced the calves with the greatest rate of gain (0.812 kg/d) and Angus-Hereford the calves with slowest growing rate (0.755 kg).

Reynolds et al., (1982) working in Louisiana with Angus, Brahman, Brangus, Angus-Brahman and Angus-Africander crosses, found that Angus-Brahman calves had the greatest daily gains (0.812 kg/d) and Angus calves the lowest (0.614 kg/d). In Texas, Roberson et al., (1986), found direct heterosis in crosses Brahman and that Brahman cows produced calves with greater preweaning gains than Hereford dams when mated to either F1 or Hereford sires; however, Brahman dams had calves with lower preweaning gains than did Hereford dams. Bailey (1981) in Nevada also reported significant sire x dam breed interaction with Angus x Charolais calves with the largest daily gains and with Brahman x Hereford with the lowest preweaning gains.

Belcher and Frahm (1979) and Frahm and Marshall (1985) in Oklahoma, comparing two-breed crossbred cows producing three breed calves did not find differences due to sire breed by cow breed interaction.

Most of the references reported significant ($P<0.01$) sire breed by dam breed interaction on the preweaning daily gain of calves. The only exceptions were found in the studies conducted in Oklahoma, in which all cow groups were crossbred. Crosses involving Charolais sires and Brahman cows showed the highest rate of growth on their calves.

Weaning Weight

Effect of Season of Birth

In the studies conducted at Texas by Roberson et al., (1986) and by McElhenney et al. (1985, 1986), season of birth was an important source of variation (P<.01) on weaning weight of calves. In these studies winter and spring born calves were heavier at weaning than summer and fall born calves.

Season of birth also had significant effect (P<.01) on the weaning weight of calves in the studies conducted in the tropics of Africa and Latin America (Trail and Gregory, 1981; Garrido and Koger, 1981; Bauer et al., 1981; Martinez and Hernandez, 1983; Hernandez 1970; Ocanto et al., 1981 and Bastidas et al., 1981). In all these studies calves born during the dry season, before the long rains, were heavier at weaning than those born during the wet season.

Effect of Sex

In all studies reviewed here, either in tropical (Bastidas et al., 1981; Ocanto et al., 1981; Munoz and Martin, 1969; Bauer et al., 1981; Garrido and Koger, 1981; Hernandez, 1976; Arboleda, 1977; Martinez and Hernandez, 1983; Gregory et al., (1985) or temperate areas (Roberson et al., 1986; McElhenney et al., 1985, 1986; Thrift et al., 1986; Williamson and Humes, 1985; Peacock et al., 1981 and Crockett et al., 1978 and Bailey, 1981) sex differences in weaning weight have been found to be significant (P<0.01) with males being heavier than females.

Effect of Age of Dam

Research has shown that mothering ability increases with age of dam until a certain age and then decreases, thus affecting the weaning weight of calves. In studies conducted in tropical areas with different breeds all researchers have indicated that age of dam significantly affected the weaning weight of calves ($P<0.01$), (Gregory et al., 1985; Martinez and Hernandez, 1983; Garrido and Koger, 1981; Bastidas et al., 1981; Ocanto et al., 1981; and Bauer et al., 1981). Hernandez (1970) working with Romo cattle in Colombia, found significant effects ($P<.05$) for age of dam on weaning weight of male and females calves in a period of five years but not on male calves in another period of three years.

Most of the studies, conducted in the United States, reported that age of dam was a significant source of variation for weaning weight of calves (Roberson et al., 1986; Reynolds et al., 1980; Crockett et al., 1978; Peacock et al., 1981; and Thrift et al., 1986).

Most studies agree in that cows from 4 to 8 years had the heaviest calves at weaning.

Effect of Sire Breed

Hernandez (1981), working with Charolais, Brahman and Romo sires mated to Brahman, Romo and crossbred (F1) Brahman-Romo dams reported highly significant effect of sire breed on the weaning weight of calves. He found that Charolais sired calves were 13.5 and 24.1 kg heavier than Brahman and Romo sired calves, respectively.

Hernandez (1981), in a study that was conducted to evaluate the Criollo breeds that exist in Colombia, reported, with one exception at La Libertad experimental farm in the eastern plains of Colombia, that the breed of sire significantly ($P<0.01$) affected the weaning weight of calves. He reported that Criollo bulls produced the lightest calves at weaning (200.4 kg) and Charolais bulls the heaviest (234.5 kg). The difference in weaning weight between the average of the Criollo sired calves and that of Charolais in the three localities was 34.0 kg. Among the Criollos the lowest value (188.3 kg) corresponded to San Martinero, the highest to Romo (216.2 kg) with BON being intermediate (202.9 kg). At El Nus, Charolais, Brahman and BON sired calves weighed: 223.1, 213.4 and 202.9 kg., respectively.

In Africa, Gregory et al., (1985) found that Simmental and Friesin bulls sired the heaviest calves at weaning (182.0 kg) and Boran bulls sired the lightest calves (155.0 kg). Koger et al., (1975b) working in Florida with Shorthorn and Brahman sires bred to females varying in proportion of Brahman and Shorthorn, reported significant ($P<.01$) effect of sire. Brahman sired calves exceeded those sired by Shorthorn by an average of 7 kg. Weight differences due to sire breed for weaning weight were highly significant ($P<.01$) in the studies conducted by Thrift et al., (1986) in Louisiana but not in Kentucky. In Louisiana Longhorn calves were 20.0 kg lighter ($P<.01$) at weaning than the average weaning weight of calves sired by Red Poll and Senepol bulls.

Peacock et al., (1978) in Florida in a three breed diallel study reported significant ($P<0.05$) effects for breed of sires, among Angus (225.1 kg), Brahman (214.8 kg) and Charolais (227.3 kg) sires.

Williamson and Humes (1985) in Louisiana, did not find differences on weaning weight of calves sired by Simmental, Chianina, Brahman and Maine Anjou bred to Angus and Hereford dams. Average weaning weight was 203.5 kg with the largest difference being between Chianina and Maine Anjou measuring only 3 kg. From these studies it can be stated that breed of sire is an important source of variation for weaning weigth of calves. Charolais, Simmental and Brahman bulls produced heavy calves and African and Criollo bulls, including Longhorn produced light calves.

Effect of Dam Breed

Hernandez (1976) reported a significant effect for breed of dam on weaning weight of calves. In his studies crossbred cows between Brahman and Romo produced the heaviest calves at weaning with 9.8 and 29.8 kg difference over Brahman and Romo dams, respectively. In a different study, Hernandez (1981) reported that Criollo breeds of Colombia showed significant effects ($P<0.01$) for breed of dam on weaning weight of calves. Criollo dams (192.5 kg) produced the lightest calves at weaning. Crossbred cows produced the heaviest (225.2 kg) and Brahman cows were intermediate (205.6 kg). At El Nus, the weaning weight of calves from BON, Brahman and crossbred cows were: 202.1, 210.2 and 226.0 kg., respectively.

Peacock et al. (1978), in Florida, reported that Angus cows produced calves with weaning weights that were higher ($P<0.01$) than those of Charolais and Brahman cows by 10.0 and 11.7 kg, respectively. Thrift et al. (1986) in Louisiana found that Hereford cows produced the lightest calves at weaning (152.0 kg) and Brahman cows the heaviest (204.0 kg). In Kentucky, grade Charolais cows (188.3 kg) had the heaviest calves at weaning compared with grade Angus cows (176.3 kg).

Among purebred beef cows in Texas, McElhenney (1986), reported that Brahman dams produced the heaviest calves at weaning (201.5 kg) and Hereford dams produced the lightest calves (185.9 kg). Among crossbred cows the heaviest calves were those from Hereford-Brahman, being 18 kg heavier than the lightest from Angus-Hereford dams. Williamson and Humes (1985) in Louisiana found significant effects ($P<.01$) for breed of dam on weaning weight of calves with Angus dams weaning heavier calves (20.8 kg) than Herefords.

Summarizing these results, it is clear that breed of dam has a substantial effect on weaning weight of the calves. In tropical studies, crossbred cows consistently produced the heaviest calves while Criollo cows produced the lightest calves. Brahman cows were intermediate. In the temperate areas of North America, Brahman, Angus, Charolais and crossbred cows tend to produce heavy calves at weaning while Hereford cows tend to produce lightest calves.

Sire x Dam Breed Interaction

In Costa Rica, Munoz and Martin (1969), in a three-breed diallel study reported significant ($P<.01$) sire x dam breed interaction on weaning weight of calves. Brahman-Criollo calves were the heaviest at weaning. Weaning weight for Brahman-Criollo calves averaged 230.5 kg with Brahman calves being the lightest (190.3 kg).

Hernandez (1976) working in Colombia with Romo cattle and crosses with Brahman and Charolais, reported significant (P<.01) sire x dam breed interaction on weaning weight of calves. Charolais bulls mated to F1 crossbred Romo-Brahamn cows produced the heaviest calves at weaning, with (242.6 kg) Romo calves being the lightest.

In a study conducted to evaluate the Criollo breeds from Colombia, Hernandez, (1981), found that the effect of sire x dam breed interaction on weaning weight was significant (P<.01) in all three localities where the study was conducted. At Turipana, he found that the heaviest and lightest calves at birth were the triple crosses of Charolais bulls with crossbred Brahman-Romo cows and the purebred Romo calves, averaging 247.8 and 185.0 kg, respectively. At La libertad, calves from Brahman bulls and crossbred (F1) Martinero-Brahman cows were the heaviest (216.1 kg) with the Brahman calves (162.1 kg) the lightest. At El Nus the same was true with Charolais sired calves with crossbred (F1) BON-Brahamn calves being the heaviest (241.7 kg) and purebred BON calves (180.7 kg) the lightest.

Ocanto et al. (1981) reported significant (P<0.01) sire x dam breed interaction on weaning weight. They studied the weaning weight of calves which resulted from the mating of two types of Criollo cows from Venezuela, compared to grade and purebred Brahman cows mated to Brahman, Santa Gertrudis, Charolais and Brown Swiss bulls. The overall adjusted 205 day weight was 174.8 kg with all the crossbred groups being heavier than the purebred controls. Bauer et al., (1981) reported significant (P<0.01) sire x dam breed interaction on weaning weight. They studied the weaning weight of calves resulted from the mating of Criollo and Brahman cows and their F1 crosses to Criollo, Brahman, Charolais and Charolais-Zebu-Criollo bulls. The overall adjusted 205 day weight was 143.5 kg. Crossbred bulls mated to F1 crossbred cows produced the heaviest calves (164.4 kg) and the upgraded 15/16 Zebu-Criollo calves were the lightest (133.1 kg).

McElhenney et al., (1985), in a five-breed diallel study in Texas which included beef and milking breeds, found that among pure beef breeds, Brahman calves (180.6 kg) surpassed Angus and Hereford calves by 4.9 and 13.4 kg., respectively. The heaviest and lightest calves in their study were: Brahman-Hereford (198.0 kg) and straightbreds Hereford calves (167.2 kg).

Reynolds et al., (1982), working in Louisiana with Angus, Brahman, Brangus and Africander x Angus breed groups, found significant sire breed x dam breed interaction. The heaviest calves were the Brahman - Brangus (193.6 kg) and the lightest the Angus calves (152.1 kg).

Peacock et al., (1978), in Florida, did not find differences between the mating of Brahman, Angus, Charolais and F1 crosses of these breeds. Angus calves were the lightest (177.0 kg) and Charolais the heaviest (235.5 kg).

Calf Postweaning Traits

Calf postweaning daily gains and weights for some Criollos, Zebu, and crosses from the Latin American tropics appear in Table III.

Most studies agree that year fluctuactions in forage quality and quantity results in cyclic weight losses or gains in livestock. This effect has been demonstrated to produce significant ($P<0.01$) differences in the postweaning weights of Zebu (Bos indicus) and

Criollo breeds (Bos taurus) and their crosses in tropical Latin America (Hernandez, 1976; Plasse et al., 1981 and Hoogestijn et al., 1981, and in temperate areas of North America for European, British breeds (Bos tauros) and their crosses. (Belcher and Frahm, 1979 and Denise and Ray, 1987).

Average Daily Gain After Weaning

Effect of Season of Birth

In studies conducted in the Latin American tropics, seasonal fluctuations in environmental conditions have been reported as a significant ($P < 0.01$) source of variation on postweaning daily gain of livestock with the greatest postweaning gains occurring during the seasons of abundant food. (Plasse et al., 1981; Verde et al., and Hoogestijn et al., 1981).

Effect of Sex

In studies conducted with Zebu and Criollo cattle and their crosses with Charolais and Santa Gertrudis, in the tropics of South America, sex of calf was found to have a significant ($P<0.01$) effect on the postweaning daily gain of calves (Plasse et al., 1981; Hoogestijn et al., 1981 and Verde et al., 1981). Hernandez (1976) working with Romo, Brahman, Charolais and their crosses reported postweaning daily gain of 0.331 kg/d for all male and 0.291 kg/d for all female animals.

Preston and Willis (1975) summarized genetic statistics for final live daily gain of young beef cattle. They reported an average difference for daily gain of 0.145 kg/d. between males (bulls and steers) and heifers.

Effects of Age of Dam

Significant effects (P<.01) of age of dam on postweaning daily gain of animals was reported in studies conducted in Latin American tropics with Criollo, Brahman and their crosses (Plasse et al., 1981; Verde et al., 1981).

Hernandez (1976) working with Romo, Brahman and their crosses with Charolais, and Hoogestijn et al. (1981), working with Zebu cattle (Brahman, Guzera and Nelore) did not find differences on postweaning daily gain of animals influenced by age of dam.

According to Petty and Cartwright (1966) the maternal effect on daily gain of animals disminish with the postweaning months until it disappears.

Effect of Sire Breed

Hernandez (1976), working with Romo, Brahamn and Charolais bulls mated to Romo, Brahman, and Romo-Brahman cows reported a significant effect for breed of sire on postweaning average daily gain. He found that Brahman bulls produced the calves with the highest rate of postweaning daily gain; with their progeny averaging 0.340 kg/d.

Charolais bulls ranked second (0.302 kg/d) and Romo bulls were last (0.291 kg/d).

Hernandez (1981) reported that breed of sire, with only one exception at La Libertad in the eastern plains of Colombia, significantly influenced ($P<0.01$) the postweaning average daily gain. He found that Criollo bulls produced calves with the slowest rate of gain and Brahman bulls, produce calves with the highest rate of gain. The difference between the average of Criollo sired animals (0.230 kg) and Brahman sired calves (0.250 kg) was 0.020 kg/d. The average daily gain of Charolais sired calves was close to that of Criollo sired calves (0.229 kg/d). Among the Criollo breeds, the slowest growing calves after weaning were those sired by BON bulls (0.217 kg) with the daily gain of Romo sired calves being 0.250 kg and the San Martinero sired animals intermediate (0.219 kg).

<u>Effect of Dam Breed</u>

Hernandez (1976), working with Romo, Brahman and crossbred Romo-Brahman cows mated to Romo, Brahman and Charolais bulls, reported a significant effect for breed of dam on postweaning average daily gain. He found that Brahman cows produced the calves with the highest postweaning average daily gain (0.347 kg), crossbred Romo-Brahman cows had the slowest growing calves after weaning (0.262 kg) and Romo dams produce calves which gained 0.325 kg/d. The same author evaluated some of the Criollo breeds of Colombia in three different localities, found significant effect of breed of dam on postweaning average daily gain of animals. Averaging the results of the three localities where the study was conducted it was found that Brahman cows produced the fastest growing animals after weaning, 0.262 kg/d.; Criollo dams averaged 0.253 kg. and crossbred (F1) dams 0.205 kg/d. Among the Criollo breeds Romo cows ranked first (0.283 kg/d) San Martinero dams were second (0.239 kg/d) and in the last place BON cows (0.237 kg/d). At El Nus, the postweaning average daily gain from BON, Brahman and crossbred cows were: 0.237, 0.237 and 0.193 kg/d., respectively. From these results it seems that breed of dam has an important effect on postweaning daily gain of animals.

Sire x Dam Breed Interaction

Munoz and Martin (1969), working in Costa Rica, with Santa Gertrudis, Brahman and Criollo and their crosses reported significant (P<0.01) sire breed x dam breed interaction effect on postweaning weight. Criollo x Brahman calves had greater postweaning daily gains (0.489 kg/d), 0.120 more than Criollo calves.

Hernandez (1976), working in Colombia with Romo cattle and its crosses with Brahman and Charolais reported significant (P<.01) sire x dam breed interaction on postweaning average daily gain. Brahman bulls mated to Romo cows produced calves with a high rate of daily gain after weaning, averaging 0.421 kg/d. Charolais x crossbred dams progeny had the slowest daily gain of 0.262 kg.

Hernandez, (1981), found that the effect of sire x dam breed interaction on postweaning average daily gain was significant (P<.01) in three localities where a study was conducted to evaluated three of the Colombian Criollo breeds. At Turipana, he found that the fastest and slowest growing postweaning animals were the F1 crosses of Brahman bulls with Romo cows and the Charolais-Romo-Zebu measuring 0.365 kg/d and 0.194 kg/d, respectively. At La Libertad, animals from crossbred F1 cows out of Brahamn bulls and F1 San Martinero-Zebu calves were the slowest and fastest growing animals measuring 0.153 and 0.283 kg/d., respectively. At El Nus, the greatest daily gain was obtained in animals sired by Brahman bulls from BON cows (0.276 kg/d) and with 3/4 Charolais 1/4 BON having the lowest daily gain 0.162 kg/d.

Plasse et al., (1981), reported a significant (P<0.01) sire x dam breed interaction on average daily gain. They studied the postweaning average daily gain of animals which resulted from the mating of two types of Criollo cows from Venezuela, and grade and pure Brahman cows mated to Brahman, Santa Gertrudis, Charolais and Brown Swiss bulls. The fastest growing animals, Brahman x Brown Swiss, gained 0.102 kg/d more than Criollo calves. Verde et al., (1981), reported significant (P<0.01) sire x dam breed interaction on postweaning average daily gain. They studied the postweaning daily gain of animals which resulted from the mating of Criollo and Brahman cows and their F1 crosses to Criollo, Brahman, Charolais and Charolais-Zebu-Criollo bulls. The overall postweaning average daily gain was 0.356 kg/d. Crossbred bulls mated to F1 crossbred cows produced the calves with the highest daily gain having an 8% advantage over Zebu.

16 Month Weight

Effect of Season of Birth

In studies conducted in the Latin American tropics, seasonal fluctuations in environmental conditions have also been reported as an important source of variation on postweaning weight of livestock (Plasse et al., 1981; Ordonez et al., 1981 and Hoogestijn et al., 1981). Hernandez (1970) reported significant effect of season of birth on 18 month weight of Romo heifers during one period of three years, when the year was divided in four different seasons, but not in a second period of two years, when only three seasons were considered; however for both reports, heifers born during dry season and weighed at 18 months of age during the wet season which is characterized by abundant food, were heavier than those born during wet season and weighed at 18 months during the dry season.

Effect of Sex

In studies, conducted with Zebu and Criollo cattle and their crosses with Charolais and Santa Gertrudis, in the tropics of South America, sex of calf significantly ($P<0.01$) influenced the postweaning weight of livestock (Plasse et al., 1981; Ordonez et al,1981 and Hoogestijn et al., 1981). They did not report the differences between sexes. Hernandez (1976) working with Romo, Brahman, Charolais and their crosses reported 18 month weight of 313.9 kg. for all male animals and 280.1 kg for all female animals. Difference between sexes

TABLE III

CHARACTERIZATION OF SOME TROPICAL CRIOLLO CATTLE BREEDS AND CROSSES: CALF POSTWEANING DAILY GAINS AND WEIGHTS

Reference	Calf Sire Breed [a]	Cow Type Group [a]	Calf Post-Weaning Daily Gain Kg/d	Calf Postweaning Weight: Calf Age Adjust-ment Days	Calf Postweaning Weight: Adjusted Weight Kg
Munoz and Martin (1969)	SG	SG	0.406	380	263.9
	SG	Br	0.477		271.7
	SG	C	0.384		264.9
	Br	Br	0.401		246.2
	Br	SG	0.458		295.7
	Br	C	0.464		296.4
	C	C	0.369		253.4
	C	SG	0.403		270.3
	C	Br	0.490		273.3
Hernandez (1976,1981)[b]	Romo	Romo	0.258	540	245.7
	Romo	Br	0.317		305.8
	Romo	Romo x Br[c]	0.252		290.0
	Br	Romo	0.363		310.3
	Br	Br	0.354		295.5
	Br	Romo x Br[c]	0.247		300.8
	Ch	Romo	0.262		278.0
	Ch	Br	0.318		319.6
	Ch	Romo x Br[c]	0.244		312.4
Botero (1979)	BON	BON		540	242.0
	Br	Br			266.0
	Ch	BON			283.3
	Br	BON			296.8
	Ch	Br x BON[c]			301.0
Gonzalez (1976)	SM	SM			222.0
	Br	Br			224.0
	Br	SM			253.0
	SM	Br		540	262.0
	Ch	SM			221.0
	Ch	Br x SM[c]			263.0
Hernandez (1981)	SM	SM	0.197	540	215.1
	SM	Z	0.286		257.5
	Z	Z	0.211		219.0
	Z	SM	0.291		259.7

TABLE III (Continued)

Reference	Calf Sire Breed [a]	Cow Type Group [a]	Calf Post-Weaning Daily Gain Kg/d	Calf Postweaning Weight: Calf Age Adjust-ment Days	Calf Postweaning Weight: Adjusted Weight Kg
	Z	SM x Z[c]	0.153		250.8
	Ch	SM	0.230		228.8
	Ch	Z	0.276		276.0
	Ch	SM x Z[c]	0.218		263.0
Hernandez (1981)	BON	BON	0.216		240.0
	BON	Z	0.268		283.6
	Z	Z	0.226		260.0
	Z	BON	0.276		285.3
	Z	BON x Z[c]	0.192		271.7
	Ch	BON	0.220		274.0
	Ch	BON x Z[c]	0.196		295.7

was 33.8 kg. Gregory et al., (1985), in Africa reported significant (P<0.01) differences between sexes on 18 month weight, males (230.0 kg) weighed 9 kg more than females. Preston and Willis (1975) summarized genetic statistics for final live weight of beef cattle. They reported an average difference for final weight of 15.4 kg. between males (bulls and steers) and heifers.

Effect of Age of Dam

Significant effect (P<.01) for age of dam on postweaning weight of animals was reported in studies conducted in Latin American tropics by Plasse et al. (1981), working with Criollo, Brahman and their crosses.

Gregory et al., (1985), in Africa, working with Zebu and Bos tauros breeds, Hoogestijn et al., (1981) in Venezuela working with Zebu cattle (Brahman, Guzera and Nelore), and Hernandez (1976), in Colombia working with Romo, Brahman and their crosses with Charolais did not find differences on postweaning weight of animals as affected by age of dam.

According to Petty and Cartwright (1966) the maternal effect on weight of animals disminish with the postweaning months.

Effect of Sire Breed

Gregory et al., (1985), in Africa working with Boran, Red Poll, Friesian, Brown Swiss and Simmental sires mated to crossbred cows resulting from the mating of Boran and Red Poll bulls to Ankole, Boran and African Zebu cows, found a significant (P<0.01) breed of sire effect on the 18 month weight of animals. Progeny from Friesian bulls (236 kg) were 18 kg heavier than progeny from Brown Swiss bulls.

Hernandez (1976) in Colombia working with Romo, Brahamn and Charolais bulls mated to Romo, Brahmän, and crossbred (F1) Romo-Brahman cows reported highly significant (P<0.01) effect of breed of sire on 18 month weight of animals. He found that Charolais bulls produced the heaviest progeny (308.2 kg), Brahman bulls produced progeny that were intermediate (303.2 kg) with Romo producing the lightest progeny (279.6 kg).

In a study (Hernandez, 1981) that was conducted to evaluate some of the Criollo breeds that exist in Colombia, breed of sire significantly (P<0.01) influenced the 18 month weight of animals Criollo bulls produced the lightest animals and Charolais bulls, with only one exception at El Nus, the heaviest. The difference between the average of Criollo sired animals (261.4 kg) and Charolais sired animals (278.5 kg) was 17.1 kg.

Among the Criollo breeds, the lightest animals at 18 months of age were those sired by San Martinero bulls (240.0 kg); the heaviest those sired by Romo bulls (283.4 kg) with BON sired animals being intermediate (278.3 kg) (Hernandez, 1981).

From these studies it can be stated that breed of sire is an important source of variation on postweaning weight of animals. With only one exception, all other studies reported significant effect of sire on postweaning weight of animals.

Effect of Dam Breed

Trail et al., (1985), in Africa, working with crossbred native breeds cows mated to Boran, Red Poll, Friesian, Brown Swiss, and Simmental sires found significant effect (P<0.01) for breed of dam on 18 month weight of calves. The progeny of crossbred dams weighed 9.2 kg more than the progeny of straightbred dams.

Hernandez (1976), working with Romo, Brahman and crossbred Romo-Brahman cows mated to Romo, Brahman and Charolais bulls, reported significant effect of breed of dam on 18 month weight of animals. He found that Brahman cows produced calves with the highest 18 month weight (309.4 kg), with crossbred Romo-Brahman cows having calves that weighed 298.3 kg and Romo dams calves weighing 283.3 kg.

The same author (1981) evaluating some of the Criollo breeds of Colombia found significant effect of breed of dam on 18 month weight of calves. Averaging the results from three localities where the study was conducted it was observed that crossbred cows produced calves with the greatest weight (282.1 kg) compared to Brahman cows which averaged 276.6 kg and Criollo dams weighing 260.1 kg. Among the Criollo breeds, Romo cows ranked first (279.3 kg), BON dams second (266.5 kg San Martinero cows last (234.6 kg) in 18 month weight. At El Nus, the 18 month weight from BON, Brahman and crossbred cows were: 266.5, 274.4 and 278.1 kg/d., respectively. From these results it appears that breed of dam has an important effect on postweaning weight of animals.

Sire x Dam Breed Interaction

Munoz and Martin (1968) in Costa Rica working with Santa Gertrudis, Brahman and Criollo breeds reported significant ($P<0.01$) sire x dam breed interaction on postweaning weight of animals. Brahman x Santa Gertrudis surpassed Criollo animals by 42.3 kg.

Hernandez (1976), working in Colombia with Romo cattle and its crosses with Brahman and Charolais reported significant ($P<.01$) sire x dam breed interaction on 18 month weight of animals. Charolais bulls mated to Brahman cows and Brahman bulls to Romo cows produced animals with similar weight at 18 months of age, (326.1 kg) surpassing Romo animals by 81.4 kg.

In a study conducted to evaluate the Criollo breeds from Colombia, Hernandez (1981), found that the effect of sire x dam breed interaction on 18 month weight was significant ($P<.01$) in all three localities where the study was conducted. At Turipana he found that the heaviest and lightest animals at 18 months of age were the F1 crosses of Brahman bulls with Romo cows and the purebred Romo animals, weighing 314.5 and 246.7 kg, respectively. At La libertad, calves from Charolais bulls and Brahman cows were the heaviest at 18 months of age weighing 276.0 kg with the lightest calves (215.0 kg) were the San Martinero calves. At El Nus the highest weight was obtained in animals sired by Charolais bulls with crossbred BON-Brahman cows (295.7 kg) and BON the lightest (240.0 kg).

Conformation Score

The system used in this study to record muscularity and, thus, muscle to bone ratio from the relative width through the hind quarters to length of hind leg (Fig. 1) was introduced in the beef cattle program of the INSTITUTO COLOMBIANO AGROPECUARIO (ICA), Colombia, by Stonaker (1971). No studies were found which reported similar procedure to record muscling score as was done in this experiment. However, references on similar type of systems are numerous and are used for comparison purposes.

Effect of Sex

Sex of calf was found to be an important source of variation on the muscling score of calves at weaning time in several studies (Crockett et al., 1978; Peacock et al., 1978, 1981; Williamson and Humes, 1985; Reynolds et al., 1982; Frahm and Marshall, 1985). Thrift et al., (1986) did not find a significant effect year of calf birth on the weaning score of calves. Researchers agree that males receive the highest scores.

Effect of Age of Dam

Age of dam varies on its effect on weaning score of calves. Highly significant effect at 1% level of statistical probability was reported in four studies (Crockett et al., 1978; Peacock et al., 1978, 1981 and Reynolds et al., 1982); at 5 % level of statistical

MUSCULARITY OF HIND QUARTERS

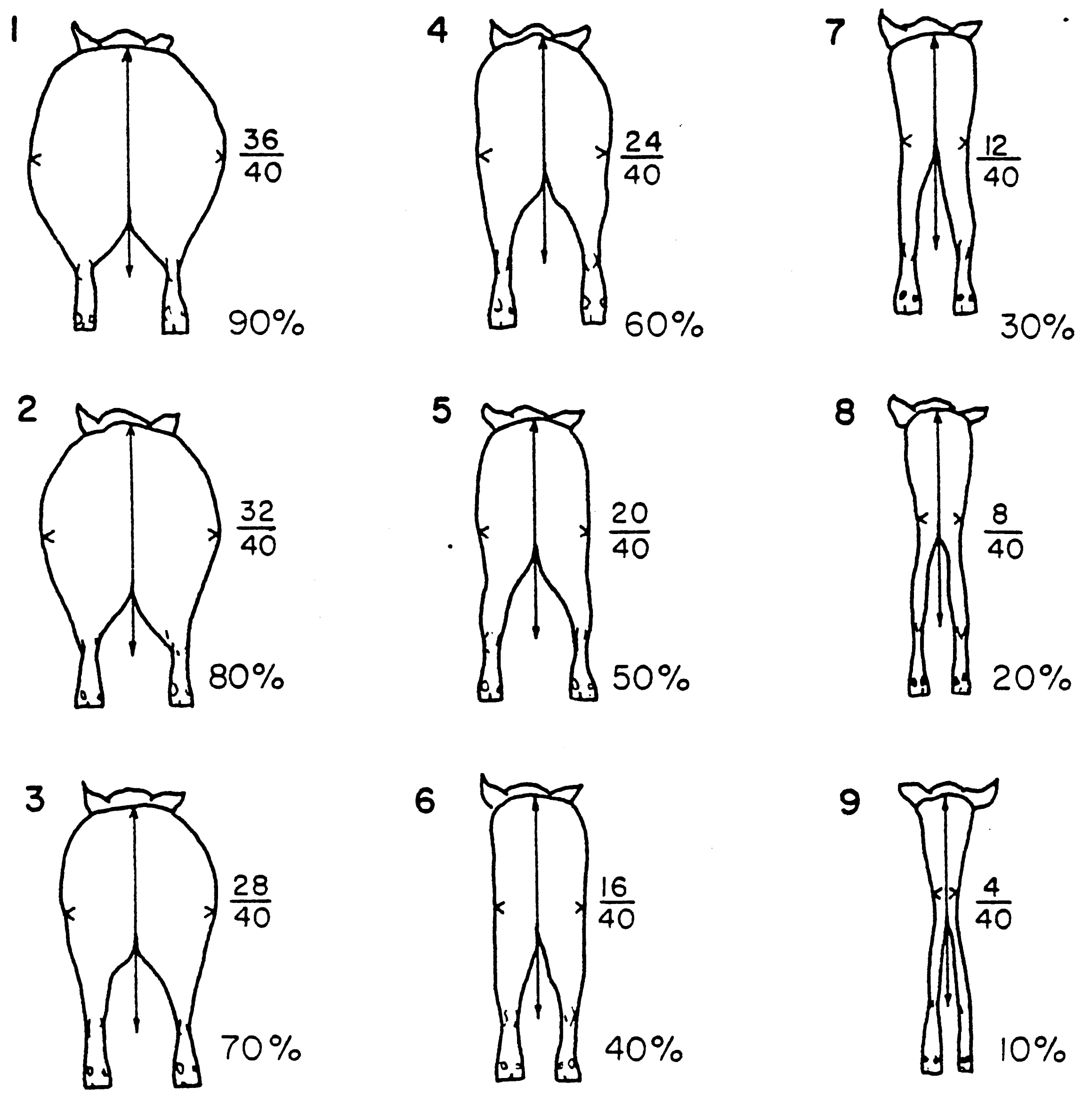

Figure 1. Ratio width through quarters halfway from tailhead to point of hocks to the height from tailhead to hock.

probability was reported in one study (Thrift et al., 1986) and not significance in one study (Frahm and Marshall, 1985).

In general, researchers agree that weaning score changes in the same fashion as weaning weight: as age of dam increases, weaning weight and conformation or muscling score increases.

Effect of Sire Breed

Breed of sire is a significant ($P<0.01$) source of variation for weaning score (Koger et al., 1975; Crockett et al., 1978; Peacock et al., 1978; Williamson and Humes, 1985, and Thrift et al., 1986). It did not have effect in three studies in Oklahoma (Dhuyvetter et al., 1985; Frahm and Marshall, 1985). In general, Angus and Charolais sired calves received the highest scores and Longhorn and Brahman sired calves the lowest.

Effect of Dam Breed

Breed of dam was also found to have an important effect on the weaning score of calves (Koger et al., 1975; Williamson and Humes, 1985, and Thrift et al., 1986); Frahm and Marshall, (1985). Peacock et al., (1978), did not find significant effect. In general, calves out of Angus and crossbred dams received the highest scores and calves out of Shorthorn and Hereford dams the lowest.

Sire by Dam Breed Interaction

Sire by dam breed interaction effect on weaning score of calves was reported to be a significant source (P< 0.01) of variation on the weaning score of calves. (Bolton et al., 1986; Crockett et al., 1978; Peacock et al., 1978, 1981 and Reynolds et al., 1982). Crossbred, Charolais, and Angus calves tend to receive the highest scores, and Shorthorn and Hereford the lowest.

Genetic Parameters in Beef Cattle

Heritability Estimates

Estimates of heritability and genetic correlations are numerous in the literature. Some of the published estimates of the heritability of birth weight, preweaning gain, weaning weight, postweaning gain and weight and weaning and yearling conformation scores appear in Tables IV-X.

Average values (range) for the above seven traits are: birth weight, .28(-.27,.85); preweaning gain, .22(.07,.41); weaning weight, .26(-.03,.64); weaning conformation score, .51(.28,.94); postweaning gain, .41(.00,.90); yearling weight, .39(.18,.71); yearling conformation score, .59(.13,.1.70).

Because of the high number of reports, the genetic, phenotypic and environmental correlations are presented in tabular method in Table XI.

TABLE IV

ESTIMATES OF THE HERITABILITY OF BIRTH WEIGHT IN BEEF CATTLE

Reference	h^2 ± SE[a]		Breed(s)	Comments
Miguel and Cartwright (1963)	.15		Hereford	
	.16		Brahman	
	.55		Hereford x Brahman	
	.50		Brahman x Hereford	
	.26		Hereford F1	
	.20		Brahman F1	
Brinks et al (1964)	.38	.06	Hereford	Females
Dunn et al (1970)	.85		Hereford-Angus-Shorthorn	Straightbreeds
	.46			Crosses
Plasse (1972)	.48	.10	Brahman	Average 2 herds
Koger et al (1975)	.72		Angus	Average 2 trials
	.08	.15	Hereford	
	-.27	.06	Brahman	
	.14		Angus x Hereford	Average British cross
	.21		Brahman-Angus-Hereford	Average Brahman cross
	.26			Combined
Hernandez (1976)	.19	.07	Romo-Brahman-Charolais	Crosses combined

TABLE IV (CONTINUED)

Reference	h^2 ±	SE[a]	Breed(s)	Comments
Burfening et al (1978)	.31	.02	Simmental	Field data
Nelsen and Kress	.54	.10	Hereford	Bulls
Buchanan et al (1982)	.34	.03	Hereford	Bulls
	.36	.03	Hereford	Heifers
De Olivera et al (1983)	.11	.08	Guzera	Males
	.07	.08	Guzera	Females
	.07	.05	Guzera	Combined
Avila et al (1984)	.04	.09	Angus	
Ledic et al (1985)	.24	.07	Tabapua	

TABLE V

ESTIMATES OF THE HERITABILITY OF PREWEANING GAIN IN BEEF CATTLE

Reference	$h^2 \pm SE^a$	Breed(s)	Comments
Buchanan, D. (1982)	.09 .01	Hereford	Bulls
	.16 .01	Hereford	Heifers
Hernandez, G. (1976)	.17 .08	Romo-Brahman-Charolais	Combined
Plasse, D. (1972)	.07 .05	Brahman	Field data
Burfening, et al (1978)	.16 .02	Simmental	Field data
Nelsen and Kress (1979)	.38 .04	Angus	Field data
	.41 .08	Hereford	Field data

TABLE VI

ESTIMATES OF THE HERITABILITY OF WEANING WEIGHT IN BEEF CATTLE

Reference	h^2	$\pm$ SE	Breed(s)	Comments
Miguel and Cartwright (1963)	.24		Hereford	
	.44		Brahman	
	.25		Hereford x Brahman	
	.22		Brahman x Hereford	
	.19		B F1	
	.07		H F1	
Dunn et al (1970)	.18		Angus-Hereford	Bulls straight
			Shorthorn	
	.34		Crosses	Combined
Plasse (1972)	.06	.05	Brahman	
Koger et al (1975)	.64		Angus	Average two trials
	.01		Hereford	
	-.03		Brahman	
	.56		Angus-Hereford	Average British cross
	.38		Brahman-Angus-Hereford	Average Brahman cross
	.45			Combined
Hernandez (1976)	.18	.08	Romo-Brahman-Charolaiss	Combined
Burfening et al (1978)	.22	.02	Simmental	Field data

TABLE VI (CONTINUED)

Reference	h^2	± SE	Breed(s)	Comments
Nelsen and Kress (1979)	.43	.09	Hereford	Bulls
	.35	.06	Angus	Field records
Buchanan et al (1982)	.18	.01	Hereford	Heifers
	.23	.02	Hereford	Bulls
Avila et (1984)	.21	.29	Angus	
Ledic et al (1985)	.15	.05	Tabapua	

TABLE VII

ESTIMATES OF THE HERITABILITY OF WEANING SCORE IN BEEF CATTLE

Reference	h^2	± SE^a	Breed(s)	Comments
Brinks et al (1964)	.28	.09	Hereford	Heifers
Dunn et al (1970)	.42		Angus - Hereford - Shorthorn	Straightbreeds
	.47		Angus x Hereford X Shorthorn	Crosses
Francoise et al (1973)	.43	.39	Hereford	Bulls
	.94	.53	Hereford	Heifers
	.68	.33	Hereford	Combined
	.58	.16	Angus	Bulls
	.47	.13	Angus	Heifers
	.51	.10	Angus	Combined
	.53	.10	Angus	Pooled
Koger et al (1975)	.58		Angus	Average 2 trials
	.37		Hereford	1 trial
	.35		Brahman	1 trial
	.67		Angus x Hereford	British crosses
	.42		Brahman x Angus x Hereford	Brahman crosses
	.38		All breeds	Combined

TABLE VIII

ESTIMATES OF THE HERITABILITY OF POSTWEANING GAIN IN BEEF CATTLE

Reference	h^2	± SE	Breed(s)	Comments
Miguel and Cartwright (1963)	.74		Hereford	
	.23		Brahamn	
	.00		Hereford x Brahman	
	.90		Brahman x Hereford	
	.42		H F1	
	.70		B F1	
Hernandez (1976)	.07	.06	Romo-Brahman-Charolais	Combined
Nelsen and Kress (1979)	.30	.06	Angus	
	.26	.26	Hereford	
Buchanan et al (1982)	.35	.03	Hereford	Bulls
	.49	.04	Hereford	Heifers

TABLE IX

ESTIMATES OF THE HERITABILITY OF YEARLING WEIGHT IN BEEF CATTLE

Reference	h^2	± SE	Breed(s)	Comments
Dunn et al (1970)	.71		Hereford-Angus	
			Shorthorn	Straightbreeds
	.56		Shorthorn-Angus-Hereford	Crosses
Hernandez (1976)	.19	.08	Romo-Brahman-Charolais	Combined
Nelsen and Kress (1979)	.65		Angus	Bulls
	.36		Hereford	Bulls
Buchanan et al (1982)	.23	.02	Hereford	Bulls
	.37	.03	Hereford	Heifers
Avila (1984)	.27	.31	Angus	
Ordonez et al (1981)	.18	.08	Brahman	

TABLE X

ESTIMATES OF THE HERITABILITY OF YEARLING SCORE IN BEEF CATTLE

Reference	h^2	± SE	Breed(s)	Comments
Brinks et al (1964)	.13	.08	Hereford	Heifers
Dinkel and Bush (1973)	.45		Hereford	Steers
Francoise et al (1973)	.61	.53	Hereford	Bulls
	1.70	.83	Hereford	Heifers
	1.32	.50	Hereford	Combined
	.12	.15	Angus	Bulls
	.57	.16	Angus	Heifers
	.41	.11	Angus	Combined
	.56	.11	Hereford-Angus	Pooled
Buchanan et al (1982)	.24	.02	Hereford	Bulls
	.34	.03	Hereford	Heifers

TABLE XI

AVERAGE ESTIMATES OF GENETIC, PHENOTYPIC AND ENVIRONMENTAL CORRELATIONS AMONG GROWTH TRAITS AND CONFORMATION SCORE IN BEEF CATTLE 1/

Traits		Preweaning ADG	Weaning wt.	Weaning Score	Postweaning ADG	Yearling wt.	Yearling Score
Birth weight	G	.31[b,c,d,i]	.51[b,c,d,f,i]	.14[b,f]	.35[b,c,i]	.62[b,c,i]	.18[b,c]
	P	.21[b,c,i]	.38[b,c,f,i]	.10[b,f]	.22[b,c,i]	.42[b,c,f,i]	.12[b,c]
	E	.11[b,c]	.26[b,c]	.15[b]	.21[b,c]	.30[b,c]	.09[b,c]
Preweaning ADG	G		.97[b,c,d,h,i]	.30[b,f]	.16[b,c,i]	.68[b,c,h,i]	-.05[b,c]
	P		.98[b,c,h,i]	.51[b]	.06[b,c,i]	.68[b,c,h,i]	.25[b,c]
	E		.98[b,c,h,]	.58[b]	-.03[b,c]	.64[b,c,h]	.32[b,c]
Weaning weight	G			.38[b,f,g]	.09[b,c,e,g,i]	.55[b,c,e,f,g,h,i]	.16[b,c,e,g]
	P			.40[b,f,g]	.09[b,c,e,g,i]	.61[b,c,e,f,g,h,i]	.19[b,c,e,g]
	E			.59[b]	.07[b,c]	.67[b,c,h]	.33[b,c]
Weaning score	G				.006[b,g]	.003[b,f,g]	.39[b,g]
	P				-.03[b,g]	.26[b,f,g]	.26[b,g]
	E				.15[b]	.50[b]	.40[b]

TABLE XI (CONTINUED)

Traits		Preweaning ADG	Weaning wt.	Weaning Score	Postweaning ADG	Yearling wt.	Yearling Score
Postweaning ADG	G					.71[b,c,e,g,h,i]	-.25[b,c,e,g]
	P					.70[b,c,e,g,h,i]	.25[b,c,e,g]
	E					.58[b,c,h]	.38[b,c]
Yearling weight	G						.01[b,c,e,g]
	P						.39[b,c,e,g]
	E						.53[b,c]

1/ G= Genetic Correlation, P= Phenotypic Correlation, E = Environmental Correlation

a Gain to and weight and score at 12 to 18 months of age
b Brinks *et al.*, (1964)
c Buchanan *et al.*, (1982)
d Burfening *et al.*, (1978)
e Dinkel and Busch, (1973)
f Dunn *et al.*, (1970)
g Francoise *et al.*, (1973)
h Hernandez, (1976)
i Nelsen and Kress, (1979)

Heterosis Estimates

Results of research involving breed evaluation and crossbreeding programs in temperate areas have been summarized by Cundiff (1970), Franke (1980) and Long (1980), and data available from different breeding programs in Latin American tropics by Plasse (1983). Estimates of heterosis are numerous in the literature. Some of the published estimates of heterosis of birth weight, preweaning gain, weaning weight, weaning conformation score, postweaning gain and yearling weight appear in Tables XII-XVII.

Average values (range) for the above seven traits are: birth weight, 6.7(.5,15); preweaning gain, 11.0(3.0,25.0); weaning weight, 8.5(1.8,23.1); weaning conformation score, 8.0(3.0,11.0); postweaning gain, 16.1(3.6,41.7); yearling weight 11.0(3.6,19.1). No study with heterosis value for yearling conformatioon score was found in the literature reviewed. Maternal heterosis, which is the advantage (or disadvantage) of crossbred dam instead of purebred dams (Sheridan, 1981) has been shown to have an effect on nearly all traits examined in the literature. Maternal heterosis generally has positive effect on preweaning traits. Composite estimates indicate increases in calving rate (6.6 %), calf survival (2.0 %), birth weight (1.6 %) and in weaning weight (4.2 %) (Long, 1980).

Conversely, postweaning traits have been reported to be adversely affected by maternal heterosis. Postweaning average daily gain was decreased by 1.5 % and kg of TDN per kg gain was increased by 5.3 % (Olson et al., 1978a). Although maternal heterosis had these negative effects, steers and heifers from crossbred dams were still heavier at slaughter, 1.5 and .2 %, respectively. (Olson et al., 1978b).

TABLE XII

ESTIMATES OF HETEROSIS OF BIRTH WEIGHT IN BEEF CATTLE

Reference	Heterosis %	Breed(s)	Comments
Muller-Haye (et al) (1968)	7.6	Brahman-Criollo	
Munoz and Martin (1969)	6.6	St. Gertrudis-Brahman	Average all breeds 4.8
	0.5	St. Gertrudis-Criollo	
	7.6	Brahman-Criollo	
Cundiff (1970)	2.9	Hereford-Angus-Charolais	Average
Hernandez (1976)	4.7	Romo-Brahman	Average 2 trials 4.3
Hernandez (1981)	3.9	Romo-Brahman	(1976-1981)
Crockett et al (1978)	8.7	Brahman-Hereford-Angus	Brahman-Criollo 14.5
Reynolds et al (1980)	15.0	Angus-Brahman	
Long (1980)	4.0	Several Breeds	Range 1- 11 %
Hernandez (1981)	9.9	San Martinero-Brahman	
	12.7	BON-Brahman	Average 11.3 Criollo-Brahman
McElhenney et al (1985)	4.3	Angus-Hereford	Average all cross
McElhenney et al (1986)	4.7	Brahman-Holstein Jersey	Both years 4.5

TABLE XIII

ESTIMATES OF THE HETEROSIS OF PREWEANING GAIN IN BEEF CATTLE

Reference	Heterosis %	Breed(s)	Comments
Plasse et (1968)	10.0	Brahman-Criollo	
Hernandez (1976)	14.7	Romo-Brahman	Average 2 trials
Hernandez (1981)	12.6	Romo-Brahman	13.7 % (1976-1981)
Long (1980)	4.5	Several Breeds	Range 2-8
Hernandez (1981)	11.4	St.Martinero-Brahman	Criollo
Hernandez	11.4	BON-Brahman	Average 11.4
Bailey (1981)	3.0	Hereford-Red Polled Angus-Charolais Brahman	
Reynolds et al (1982)	25.2	Angus-Brahman	
McElhenney et al (1985)	9.3	Angus-Hereford	Average all cross
McElhenney et al (1986)	7.4	Holstein-Brahman Jersey	8.4

TABLE XIV

ESTIMATES OF HETEROSIS OF WEANING WEIGHT IN BEEF CATTLE

Reference	Heterosis %	Breed(s)	Comments
Munoz and Martin (1969)	3.7	St.Gertrudis-Criollo	
	10.6	Brahman-Criollo	
	9.1	St.Gertrudis-Brahman	Average 7.7
Cundiff (1970)	4.1	Bos taurus breeds	Range -2.8-8.8
Long (1980)	5.0	Several Breeds	Range 3.0-16.
Hernandez (1976)	13.1	Romo-Brahman	Average 2 trials
Hernandez (1981)	11.3	Romo-Brahman	12.2
	11.5	BON-Brahman	Average all trials
	11.1	St.Martinero-Brahman	Criollo-Brahman 11.3
Gregory et al (1985)	1.8	Boran-Ankole	
	6.2	Boran-Zebu	Average 4.0
McElhenney et al (1985)	8.4	Angus-Hereford	
		Holstein-Jersey	
McElhenney et al (1986)	7.1	Brahman	Average 7.8
Reynolds et al (1982)	23.1	Angus-Brahman	
Bailey (1981)	2.4	Hereford Red Polled	
Bailey		Angus-Charolais	Average all
		Brahman	Breeds
Peacock et al (1978)	7.1	Brahman-Charolais	Angus-Charolais 2.1
		Angus	Brahman-Angus 12.2

TABLE XV

ESTIMATES OF HETEROSIS OF WEANING CONFORMATION SCORE IN BEEF CATTLE

Reference	Heterosis %	Breed(s)	Comments
Koger et al (1975)	9.0	Brahman-Shorthorn	
Peacock et al (1978)	6.9	Angus-Brahman	
Crockett et al (1978)	11.0	Angus-Brahman	
	3.0	Angus-Hereford	
	10.0	Brahman-Hereford	Average 8.0

TABLE XVI

ESTIMATES OF HETEROSIS OF POSTWEANING GAIN IN BEEF CATTLE

Reference	Heterosis %	Breed(s)	Comments
Plasse et al (1968)	9.0	Criollo-Brahman	
Munoz and Martin (1969)	1.5	St. Gertrudis-Criollo	
	15.8	St. Gertrudis-Brahman	
	23.9	Brahman-Criollo	Average 13.70
Cundiff (1970)	3.6	British & European breeds	Range 2.2 6.5
Hernandez (1976)	22.7	Romo-Brahman	
Hernandez (1981)	21.6	Romo-Brahman	Average 22.2
	41.7	St.Martinero-Brahman	
	23.1	BON-Brahman	Average Criollo-Brahman 32.4
Long (1980)	6.0	Several Breeds	Range 2-11

TABLE XVII

ESTIMATES OF HETEROSIS OF YEARLING WEIGHT IN BEEF CATTLE

Reference	Heterosis %	Breed(s)	Comments
Munoz and Martin (1969)	3.6	St.Gertrudis-Criollo	
	10.1	St.Gertridis-Brahman	
	12.3	Brahman-Criollo	Average 8.7
Cundiff (1970)	5.1	Several Breeds	Average 5.0
Hernandez (1976)	16.7	Romo-Brahman	Average 2 trials
Hernandez (1981)	14.6	Romo-Brahman	16.5 (1976-1981)
	13.8	BON-Brahman	Average all Criollos 16.1
	19.1	St.Martinero-Brahman	
Long (1980)	4.0	Several Breeds	Range 2- 7

CHAPTER III

GENETIC PARAMETERS AND PRODUCTIVE PERFORMANCE FOR SEVERAL GROWTH TRAITS OF BLANCO OREJINEGRO (BON) CATTLE

Abstract

This study was conducted from 1977 to 1983 in a tropical region of the north central Andes of Colombia, South America, to evaluate the native breed, BON. The herd of approximately 230 cows was managed continuously on Puntero grass (*Hyparrenia rufa*) with a mineral mixture provided *at libitum*. Cows were randomly alloted to single sire breeding groups within age and physiological status categories. Calving, weaning, and liveability rates averaged 63.9, 59.6, and 93.4%, respectively. The traits studied with their respective means were: birth weight (BW), 26.6 kg.; daily gain from birth to weaning (WDG), .574 Kg/d; weaning weight adjusted to 240 days of age (WW), 169.2 kg;, weaning conformation score (WC), 50.1; daily gain from weaning to 16 months of age (YDG), 0.177 kg/d; 16 month weight (YW), 213.7 kg; and 16-month conformation score (YC), 50.7. Heritabilities (h^2) estimates for the above traits were: BW, .275; WDG, .091; WW, .091; WC, .134; YDG, .083; YW, .038 and YC, .104. Genetic (G) and phenotypic (P) correlations of BW with preweaning traits were low and positive and high and negative with postweaning traits. Genetic

correlation between WDG and WW was high (0.97) and positive, while the same correlation between WDG with postweaning traits were of lower magnitude. WW was negative correlated with YDG. YDG was highly (.91) genetically correlated with YW. Standard error for most genetic parameters were high.

Key words: Beef cattle, Blanco Orejinegro, heritability, genetic correlation.

Introduction

In Latin America, the Criollo cattle (Bos taurus) have been the basis of the cattle industry since their introduction to this continent by the Spanish conquistadores in the fifteenth century. The Criollo breed is now in the process of extinction due to the introduction and crosses to other breeds, especially Zebu cattle (Bos indicus). In most situations, they are being crossed with exotic breeds without any systematic plan for improvement, except for the hope that the introduced breeds would solve the production problems of the tropics, which usually have other causes. A high percentage of heterosis was obtained by crossing Criollo and Zebu breeds, however, these results were at first misinterpreted and the improvements were only attributed to the Zebu breeds, rather than to the non-additive effect of genes as was proved in recent years. The data available today show the extraordinary combining ability of the Criollo with other breeds, (Hernandez, 1981; Plasse, 1983) especially Zebu, which makes it necessary to further evaluate the potential and the rational use of these breeds in the tropics of Latin America.

The Colombian Criollo breeds were very numerous at the beginning of this century before the importation of other breeds began, especially Zebu. The Colombian government, knowing the importance that the Criollo germplasm had to offer for the future production of milk and meat, has maintained a herd of Blanco Orejinegro (BON) since 1940 at El Nus Research Station. At the beginning, the breed was selected for milk production, and was used in a crossbreeding program with Jersey. This experimental crossing program was abandoned. Since 1968, the breed has been selected for beef production and used in a beef crossbreeding program with Zebu, Charolais and later, Santa Gertrudis. The present study was undertaken in order to provide reliable estimates of heritability, genetic and phenotypic correlations for several productive traits as well as non-genetic fixed effects such as age of dam, sex of calf and month of birth, which may provide essential information for the formulation of efficient breeding schemes in future programs.

Materials and Methods

Source of Data

Data used in this study were collected at the Instituto Colombiano Agropecuario Experimental Station at El Nus, Colombia, from 1977 through 1983, as part of an experiment in progress to evaluate the genetic potential of the native ("Criollo") breed Blanco Orejinegro (BON).

The station is located between 800 and 1200 meters above sea level in a mountainous region of the Colombian Andes, and is characterized by abrupt topography, poor and eroded soils. Temperature conditions at El Nus are warm to hot with a long wet or rainy season. Rainfall is bimodal and 70% of the annual precipitation occurs mainly from April to June and from August to October. Average rainfall during the years studied was 2155 mm. (Table XVIII).

TABLE XVIII

METEROLOGICAL DATA FOR EL NUS, COLOMBIA

	J	F	M	A	M	J	J	A	S	O	N	D
	El Nus (Latitude 6.5 N., longitude 74.8 W)											
Mean monthly temp. (C)	23	24	24	23	23	23	23	23	23	22	23	23
Precip.(mm)	47	64	100	251	271	230	205	211	258	311	155	71
Days of rain	9	10	13	19	21	21	17	19	21	23	19	13
Rel.hum.(%)	85	84	86	86	87	86	85	85	87	88	89	88

The topography at El Nus is varied: 64% ondulate, 32% abrupt and 4% flat with acid soils (pH 4.5) and deficient in nitrogen, calcium, zinc, phosphorus, and copper and has a high content of magnesium, iron, and potassium (Staffe, 1956).

Cattle

BON cattle, one of the several native breeds that exist in Colombia, was originated from the cattle brought by the Spanish conquistadores in the fifteenth century and have thrived in the Colombian Andes. Its spanish name means the "Black-eared white" breed, which accurately describes it. A note on their history and connection with other breeds and types of black-eared white cattle is given by Pearson (1968). Its basic color is white but can be lightly or heavily mottled with black, especially on the lower neck and flanks. The skin is strongly pigmented; the ears, muzzle, mucosae, distal part of feet, scrotum, vulva, udder, perinnee, and horn tips are black. There exists a recessive variant called Blanco Orejimono, which is identical except that black is replaced by a reddish color.

At the Experimental Station of El Nus, the Colombian government has maintained, since 1937, a closed herd of approximately 300 animals to preserve this germplasm avoiding the absorption by other breeds.

Management and Data Collection

This study was initiated with cattle produced from 1963 to 1976 in a continuous random mating management system in two separate herds that existed at the experimental station, in the low (800 m) and high altitude (1200 m) of the farm. These herds have been previously described by Martinez and Hernandez (1983). From 1979 through 1982, two bulls that were purchased out of the region were extensively used in order to avoid the high inbreeding that may exist, since the herd had remained closed to outside breeding for several years. In 1977, the two herds were joined and the continuous mating system changed to a 90 day breeding season.

Cattle were maintained in fenced pasture of Puntero grass (*Hyparrhenia rufa*) in the high altitude of the experimental farm (1000 m) with water and mineral mixture provided *ad libitum*. They did not receive supplemental feed. Heifers and bulls were selected for mating according to their weights at 16 and 24 months of age with some emphasis placed on weaning weight. Heifers were bred at 2 years of age to calve first at 3 years. Two year old and older bulls were used for two and in some cases up to three consecutive years, but avoiding the mating among close related animals such as full and half sibs; mother and son, and father and daughter.

Heifer replacement policy was based on both the availability of animals and forage. In 1979, available heifers for mating were used in different experiments. From 1980 through 1982, approximately the top 40% of the heifers were selected to replace cows that were culled because of age or reproductive failure.

Mating was made at random and the mating groups consisted of one bull and 25 cows. Each mating group had a heterogenous composition with females of all ages and physiological status (heifers, dry and lactating cows, Table XIX).

Cows, which varied in age between 3 and 14 years, were on a 90 days breeding season from May through July (rainy season). Heifers were also mated for a 90 day period but from April through June. The calving season, extended from January to April, which are the driest months of the year.

All animals received curative and preventive treatment against the common diseases in the region and were dehorned at approximately three months of age. In any event animals were culled before 16 months of age and no males were castrated before that age.

TABLE XIX

EXPERIMENTAL DESIGN

		Number of Cows By Reproductive Status						
Year of Calf Birth	Total No. of Cows	Lac.	%	Dry	%	Hef.	%	No.of Sires[a]
1978	55	44	80.0	7	12.7	4	7.3	3
1979	101	46	45.5	55	54.5	-	-	5(2)
1980	166	81	48.8	50	30.1	35	21.1	8(1)
1981	271	169	62.4	79	29.1	23	8.5	14(7)
1982	219	160	73.1	56	25.6	3	1.3	14(12)
1983	209	125	59.8	58	27.8	26	12.4	11(6)
TOTALS	1021	652	61.2	305	29.9	91	8.9	29

[a] First number is the total number of sires used by year and the number in parentheses is the number of new sires.

Birth weights were taken during the first 24 hours after birth. At an average age of 8 months, calves were weaned, weighed and assigned a subjective muscling conformation score as described by Stonaker (1971), by a pannel of at least three persons. After weaning males and females were placed in separate pastures. At 16 months of age, all animals were weighed and assigned a conformation score in the same manner as at weaning time. The weights were adjusted to a constant age of 240 and 480 days according to the following formulas:

$$\text{Adj. 240 day wt.} = \frac{\text{actual wn. wt. - birth wt.}}{\text{age at weaning}} * 240 + \text{birth wt.}$$

$$\text{Adj. 480 day wt.} = \frac{\text{actual 16 mo. wt.-actual wn. wt.}}{\text{days between weights}} * 240 + \text{Adj. wn. wt.}$$

Statistical Analysis

Reproductive Traits

Reproductive data are based on a binomial (pregnant vs. non-pregnant) rather than a normal distribution; thus two-way frequency tables were developed and tested for homegeneity by Chi-square. Tables were developed for year of calf birth (CY), and for reproductive status (RS) (lactating, open and heifers), by birth type (calf, no calf) and by weaning type (calf weaned, calf not weaned). Both birth type and weaning type were based on number of cows exposed to breeding.

Tables were also developed for survival rate for CY and RS, by liveability type (calf alive at weaning, calf died before weaning), based on the number of calves born.

Statistical evaluation of the data was made by least-squares mixed model procedures (Harvey, 1977, 1982). The effects of year and season of birth, sire within year sex of calf, age of dam and the interaction between year and season of birth were analyzed for growth and conformation traits. Significant sources of variation were determined from separate analysis of each trait using full models. The mean square for sires within year was used to test the effect of sire and the residual mean square was used to test all other effects. Least-square means were calculated from a reduced model in which non-significant effects were eliminated. The analysis of birth weight included 637 observations; the analysis of average daily gain from birth to weaning, weaning weight and weaning condition score included 607 observations; the analysis of average daily gain from weaning to 16 months included 587 observations; and, the analysis of condition score at 16 months included 530 observations.

To study the effect of season of birth, the calving season was divided in two periods: period 1 from January 1 to March 6, and period 2 from March 6 up to the end of the calving season on May 6. The first period corresponds to the middle of the driest season (December to March) and the second period corresponds to the end of the same dry season and to the beginning of the long wet season (April to July).

Cows were grouped in four age classes: less than 3.5 years, most of first calve heifers; 3.5 to 4.5 years, second calve cows; 4.5 to 9.5 year, third to sixth calve cows and the fourth group formed by cows older tan 9.5 years of age. The data of 29 sires were analyzed.

The statistical model was:

$$Y_{ijklm} = u + a_i + b_{ij} + c_k + d_l + f_m + (af)_{im} + e_{ijklm}$$

Where:

Y_{ijklm} is the dependent variable studied;

μ is the overall mean;

a_i is the fixed effect of the i^{th} year;

b_{ij} is the random effect of j^{th} sire within the i^{th} year;

c_k is the fixed effect of the k^{th} sex;

d_l is the fixed effect of the l^{th} age of dam;

f_m is the fixed effect of the m^{th} season of birth;

$(af)_{im}$ is the effect of the interaction of year of birth with season of birth; and,

e_{ijklm} the experimental error.

Heritabilities and Correlations

The heritabilities and genetic, phenotypic and environmental correlations were estimated from the components of variance and covariance for half sibs according to a mixed model with no interactions between random and fixed effects. (Harvey, 1977).

$$h^2 = \frac{1/NR1^* \ \sigma^2{}_s}{1\text{-}NW/Nr1^* \ \sigma^2{}_s + \sigma^2{}_e}$$

with $\sigma^2 s$ being the crossclasified or nested "family" variance component estimate and $\sigma^2 e$ with the sires variance component estimate, NR1 the decimal proportion of additive genetic variance σ^2 in

σ_s and NW the decimal proportion of additively genetic variance in σ_e. (In random mating populations NR1 = 0.25 and NW = 0.75).

Genetic correlations were computed in each case by simply dividing the "family" covariance component estimate for the two traits by the geometric mean of the two "family" variance component estimates:

$$r_g\ (hh') = \frac{\sigma_s\ (hh')}{\sigma^2_s\ (h) * \sigma^2_s\ (h')}$$

where h refers to the h th trait and h' refers to another trait.

Phenotypic and Environmental Correlations

$$r_p = \frac{\sigma_e\ (hh') + 1 - NW/NR1\ \ \sigma_s\ (hh'')}{\sigma^2\ (h) = 1 - NW/NR1\ \ \sigma_s\ (h)\ \ \sigma^2_e\ (h') + 1 - NW/NR1\ \ \sigma^2_s(h')}$$

$$r_e = \frac{\sigma e(hh') - NW/NR1\ \sigma s\ (hh')}{\sigma e(h) - NW/NR1\ \sigma s(h)\ \sigma e\ (h') - NW/NR1\ \sigma s(h')}$$

Results and Discussion

Cow Reproductive Performance

Cow group means for reproductive traits by year of calf birth and reproductive status are presented in Table XX. Calving rate over all years and reproductive status groups averaged 63.90; percentage of cows weaning a calf 59.6, and survival rate between birth and weaning was 93.4%.

These values are greater than the average (53.0%) estimated by Salazar (1977) for the Colombian herd and also above the average for the same breed (58.0%) in three previous reports (Botero, 1975; Arboleda, 1977 and Hernandez, 1981).

Differences for calving and weaning rates among years, and mortality rate from birth to weaning among years and reproductive status did not differ (P>.10), while differences for calving and weaning rates among reproductive status groups were significant (P<0.01).

Since cows that were open and dry during the breeding season do not have the stress of lactation they have the highest probability of becoming pregnant. This group of cows consistently produced a higher percentage of calves. Calving rate for this group of cows averaged 90.5%, which was 8.1 and 42.3% higher (P<.01) than the calving percent of heifers and lactating cows. The low probability of the lactating cow becoming pregnant has been pointed out in nearly all studies. In tropical conditions, in the eastern plains of Colombia, Stonaker et al., (1985), reported an average increase of 25% in calving rate in cows that were separated from their calves (72.5%) as compared with those lactating (47.5%) during the breeding season. The calving rate of heifers (82.5%) is above that reported by Martinez and Laredo (1983), 78.1% for two groups of heifers of the same breed under different mineral supplementation.

Cow Productivity and Calf Traits

Probabilities of attaining greater F-values from analyses of variance are presented in Table XXI. Year of calf birth and sex of calf significantly affected all traits except for the effect of sex of calf on cow weight and conformation score at 16 months of age. The effect of sire, nested within year, was significant for the ratio of calf weight to cow weight and weaning conformation score (P<.05) and for birth weight (P<.01). Age of dam affected (P<.01) most of the traits, except for average daily gain after weaning and conformation score at 16 months of age. Season of birth was significant for average daily gain (both before and after weaning) (P<.01), and for weaning weight (P<.05). Year of calf birth x season of birth interaction affected both average daily gain and also weight and conformation score at weaning, cow weight and approached significance for the ratio of calf weight to cow weight.

Cow weight

Age of dam, year of calf birth and its interaction with season of calf birth affected (P<.01) the weight of the cow at parturition. Least-squares means (Table XXII) indicates that BON cows reach their mature weight after 4.5 years of age. The average weight for cows above 4.5 years of age was about 422 kg. First calve heifers, those in the same group under 3.5 years of age, weighed 364.8 kg at calving which is 86% of the weight of mature BON cows. The corresponding values for cows in the second group, mostly second parity cows, were 406.6 kg and 96.4%. First calve heifers in this study were lighter than the average weight at first parturition for BON heifers, reported by Martinez and Laredo (1983).

Ratio of calf weight to cow weight has often been used as an estimator of efficiency (Trail and Gregory, 1981; Frahm and Marshall, 1985; Gregory et al 1985 a, 1985 b). Based on the ratio of 240 d calf weight to cow weight, first calf heifers weaned the greatest proportion of cow weight (.451), followed by second calf and mature cows (averaged .418). Cows older than 9.0 years decline in efficiency (averaged .406).

Cow efficiency was significantly affected by year of calf birth ($P<.01$) and since the variation of cow weight and calf weight was parallel among the years and cow efficiency depends on these values, its variation followed the same pattern.

Sex of calf did not affect weight of cow at weaning, but since weaning weight was greater for males, the efficiency of production was significantly ($P<.01$) affected by sex of calf. Cows raising a bull calf weaned the highest proportion of cow weight, (.448)), .050 units more than cows weaning a heifer calf. Season of birth was not a significant ($P>.10$) source of variation and the interaction of year x season of calf both approach significance.

TABLE XX

COW REPRODUCTIVE PERFORMANCE BY YEAR AND REPRODUCTIVE STATUS

	Total			Reproductive Status								
				Lactating			Dry			Heifers		
Year Calf Birth	% Born[c]	% Weaned[c]	% Survived[d]	% Born	% Weaned	% Survived	% Born	% Weaned	% Survived	% Born	% Weaned	% Survived
1978	69.1	67.3	97.4	63.6	61.4	96.4	100.0	100.0	100.0	75.0	75.0	100.0
1979	65.3	57.4	87.9	32.6	28.3	86.7	92.7	81.8	88.2	--	--	---
1980	68.1	62.7	92.0	46.9	44.4	94.7	90.0	84.0	93.3	85.7	74.3	86.7
1981	62.7	58.7	93.5	46.2	43.2	93.6	93.7	87.3	93.2	78.3	73.9	94.4
1982	58.4	55.3	94.5	47.5	44.4	93.4	89.3	85.7	96.0	66.7	66.7	100.0
1983	65.6	62.2	94.9	52.8	49.6	93.9	84.5	82.8	98.0	84.6	84.0	100.0
TOTAL	63.9	59.6	93.4	48.2	45.1	93.7	90.5	84.9	93.9	82.4	76.9	93.3
CHI-SQUARE	5.2[a]	4.6[a]	5.3[a]		169.06**[b]				147.22**[b]		0.026[b]	

a/ Chi-square values among years

b/ Chi-square values among reproductive status

c/ Based on number of cows exposed to breeding

d/ Based on number of calves born

** P<0.01

TABLE XXI

PROBABILITIES OF ATTAINING GREATER F-VALUES FROM ANALYSIS OF VARIANCE FOR COW WEIGHT, CALF WEIGHT TO COW WEIGHT RATION AND CALF GROWTH AND CONFORMATION TRAITS

				Calf Traits						
				Weights			Avg. Daily Gain		Conformation Scores	
Source	d.f.	Cow Wt.	Calf Wt/ Cow Wt.	Birth	Wean- ing	Year- ling	Pre- weaning	Post- weaning.	Weaning	Yearling
YEAR (Y)	5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SEX	1	0.99	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.68
SIRE/Y	51	0.39	0.04	0.01	0.13	0.32	0.13	0.18	0.05	0.36
COWAGE	3	0.01	0.01	0.01	0.01	0.01	0.02	0.72	0.01	0.22
SEASON (S)	1	0.58	0.15	0.64	0.02	0.99	0.01	0.01	0.36	0.19
Y*S	5	0.01	0.07	0.36	0.01	0.62	0.01	0.01	0.01	0.53
ERROR	636									

Postweaning daily gain is from weaning to 16-month of age.
Yearling is weight at 16-month of age.

TABLE XXII

LEAST-SQUARES ± STANDARD ERROR FOR MEASURES OF COW PRODUCTIVITY BY YEAR OF CALF BIRTH, SEX OF CALF AND AGE OF DAM

	No. of Cows Weighed	Cow Weight Kg	Calf Weaning Wt./Cow Weight Kg/Kg
Overall	593	403.6 ± 2.21	0.42 ± 0.004
Sex of Calf			
Males	293	403.5 ± 2.72	0.45 ± 0.005 a
Females	300	403.7 ± 2.63	0.40 ± 0.005 b
Cow age (years)			
Under 3.5	71	364.8 ± 4.64 c	0.45 ± 0.008 b
3.5-4.5	53	406.6 ± 5.12 b	0.42 ± 0.008 a
4.5-9.0	346	421.3 ± 2.34 a	0.42 ± 0.004 a
Over 9.0	123	421.7 ± 3.52 a	0.41 ± 0.006
Year			
1978	26	386.8 ± 7.05	0.43 ± 0.013
1979	57	396.2 ± 5.16	0.43 ± 0.009
1980	103	400.4 ± 4.29	0.45 ± 0.008
1981	158	406.8 ± 3.22	0.40 ± 0.006
1982	121	408.9 ± 3.90	0.41 ± 0.007
1983	128	422.3 ± 3.80	0.42 ± 0.007
Season			
1	415	404.6 ± 2.61	0.43 ± 0.005
2	178	402.6 ± 3.17	0.42 ± 0.006

abc = Means in the same column within same classification not sharing a common superscript differ ($P<0.05$)
d 1 = First part of the calving season
d 2 = Second part of the calving season

The average production efficiency of BON cows .423 is far below the average of .553 reported by Frahm and Marshall (1985) and by Gregory et al (1985 a, 1985 b) but above the average of .41 reported by Trail and Gregory (1981). The above studies, however, were conducted in different environments and with different breeds.

Birth Weight

The least-square means for birth weight for the different effects are shown in Table XXIII. Mean birth weight for the study was 26.58 kg. This value is within the range of previous reports of the same breed and for other Criollos, (including Texas Longhorn), 25.0 to 29.6 kg (Rodriguez et al, 1971; Stonaker, 1971; Botero, 1975; Arboleda, 1977; Hernandez, 1981; Martinez and Hernandez, 1983; Thrift et al, 1986).

The differences found among years were significant ($P<.01$). This is not consistent with the results of a previous report with the same breed when the herd was managed under continuous mating system with calves born all year round (Martinez and Hernandez, 1983). Differences in birth weight due to year are associated with environmental (nutritional) conditions previous to the calving season. During the last trimester of gestation, 70% of the fetal growth occurs. Thus, cow nutrition during these months is particularly important. Prenatal malnutrition may increase mortality of the newborns, reduce calf growth rate and reproductive activity of cows (Dunn and Kaltenbach, 1980).

Season of birth did not affect birth weight of calves. As was stated before, differences in birth weight are associated with previous environmental conditions and since the two seasons in which the calving season was divided are both related to similar previous environmental conditions, this result was as expected and in agreement with studies with the same breed in similar conditions (Martinez and Hernandez, 1983).

Season x year of calf birth interaction was not significant (P>.10). This result is in agreement with most studies in the literature but in disagreement with a previous report with the same breed (Martinez and Hernandez, 1983); however, in the latter report, seasons include both, rainy and dry seasons, while this study included only the dry season, beginning (season 1) and end (season 2).

Sex of calf affected birth weight (P<.01). All the studies in the review of literature reported a significant effect of sex on this trait. Males were heavier (1.47 kg) than females. This difference corresponds with the average difference found (1.63 kg) in four studies with the same breed. (Rodriguez et al., 1971; Botero, 1976; Arboleda, 1977; and Martinez and Hernandez, 1984).

Age of dam also had a significant effect on birth weight of calves (P<0.01). This result is in agreement with many other studies (Hernandez, 1976; Martinez and Hernandez, 1983; Roberson et al, 1986). A gradual increase of birth weight was found beginning with the youngest cows less than 3.5 years of age (25.09 kg) and ending with cows between 4.5 and 9.5 years of age (27.40 kg). There was a decrease in birth weight (26.9 kg) in cows older than 9.5 years but calves were still heavier than calves of the youngest group. This result agrees with Martinez and Hernandez (1983), who found that BON cows reached the peak of production in this trait between 6 to 8 years of age.

Sires within years had a significant (P<0.01) effect on birth weight of calves. This result agrees with most of the studies consulted and reported in the review of literature. Since the interest of the study were not the comparison of individual sire performance the equation that gives the individual sire mean birth weight was absorbed in the model, so these means cannot be presented.

Average Daily Gain From Birth to Weaning

Average daily gain from birth to weaning for male and female calves in this study was 594 g/d (Table XXIII). This value is above the average given in a previous study with the same breed (583 g/d) Martinez and Hernandez, (1983).

Year of calf birth had a significant effect (P<.01) on preweaning daily gain of calves. This result agrees with many other studies (Hernandez, 1976; Bauer, et al., 1981; Martinez and Hernandez, 1983). Interpretation of time trends is difficult because other effects such as health problems may have contributed to year variation.

Sex of calf was also an important source of variation (P<.01). Male calves (634 g/d) gained 81 g more per day than females (553 g/d). The difference between sexes found in this study is relatively close to 72 g/d found in previous studies with the same breed (Martinez and Hernandez, 1983) and that of 68 g/d reported by Patty and Cartwright (1966) in a summary of statistics for beef cattle.

Age of dam effects (P<.05) indicated smaller preweaning gains for calves out of the youngest cows; with maternal ability of dams increasing with dam age through 9.0 years and then decreasing with older cows (greater than 9.0 years) but without declining their production to the levels of young cows. This result is in accordance with Reynolds et al. (1980), Roberson et al., (1986), and Martinez and Hernandez (1983).

Calves born at the beginning of the dry season gained 608 g/d, 23 g more per day (P<.01) than calves born at the end of the dry season, presumably because of better pasture conditions either before birth, which benefits cow performance, and during the period when the calf is suckling and grazing. On the other hand, it seems that at El Nus, heavy rainfall is a stressor for all animals not only for the presumably higher expenditure of energy for walking in the slippery hills but also for the significant increment in disease problems, mainly those associated with parasites, especially ticks and nuche.

Martinez and Hernandez (1983) studied the effect of season of birth in BON cattle for the period 1973-1976 with birth occurring all year round. They reported that the dry season was the most favorable for the preweaning daily gains of animals; calves born during the driest months of the year gained 44 gr more per day than calves born during the wettest month of the year.

Season of birth x year interaction was a significant (P<.01) source of variation for the preweaning gain of calves, and this result could be due to differences in environmental conditions among and within years (Table XXIV). Only for the first two years, average daily gains of calves born at the beginning of the dry season were below the average of daily gains of those born in the second part of the calving season, (end of the dry season), confirming that the first part of the dry season is more beneficial for the birth of calves.

Sires nested within years did not differ (P>.10) for the preweaning weight of their calves. As was explained before, the sires within year solution was absorbed for in the model, thus the means were not estimated.

Weaning Weight

Least squares means for weaning weight for the different type of effects appears in Table XXIII. Mean weaning weight for male and females at 240 days of age was 169.23 kg. In the literature review, no studies conducted either in tropical or temperate regions with weaning at the same age (240 days) were found to compare with these results.

Year of calf birth was a significant (P<.01) source of variation. Since weaning weight is directly dependent on average daily gain before weaning, it is not surprising that the pattern found in weaning weight be similar to the pattern found for preweaning daily gain.

Season of birth was also a significant (P<.05) source of variation for the weaning weight of calves. Calves born at the beginning of the calving season (middle of dry season) were 5.31 kg heavier than calves born at the end of the dry season. Pasture conditions during the period when the calf is suckling and starts grazing are more favorable for calves born at the beginning of the calving season. This result agrees with previous results with the same breed in the same environment (Martinez and Hernandez, 1983).

Sex of calf was significant ($P<0.01$) source of variation for weaning weight. Male calves (179.70 kg) were 20.94 kg heavier than females ($P<.01$).

Age of dam was also a significant ($P<.01$) source of variation for weaning weight. Weaning weight least-square means increased with dam age for up to 9 year old dams and then decreased. Peak of production for this trait was found in the group of cows of 4.5 to 9 years old.

As stated before, season 1 was, in general, more appropriate for the birth of calves since greatest daily gains and, consequently, weaning weights were obtained. However, during the first two years, performance of calves born in the second part of the calving season were heavier at weaning than calves born during the first part of the birth season. The largest difference found was during 1979 (13.5 kg). This erratic and large difference resulted in the detected interaction ($P<0.01$). Factors responsible for the interaction could not be identified with certainty because physiological status and number of cows calving during each season were confounded. During 1979, the highest number of dry cows calved. These cows did not have the biological function of maintaining a previous lactation and thus had more opportunity to prepare for the present lactation.

Conformation score at weaning reflects not only the adaptability of the calf but also the maternal (milking) ability of the cow. Therefore the results, with only one exception, season of birth, were affected (P<.01) for the same sources of variation that affected weaning weight. Sires nested within year was significant (P<0.05). The least squares means are presented in Table XXIII. In accordance with the results of weaning weight the highest scores were found in 1979, 1980 and 1983. Conformation scores were also higher for males (2.3 units) than for females, from the third group of cows, and for calves born during the beginning of the calving season.

Although the same method of scoring was not found neither in tropical nor in temperate areas for comparison, there is general agreement that conformation score is affected by the same sources of variation that affect weaning weight since they are parallel to each other.

Williamson and Humes (1985), Peacock et al (1978, 1981); Crocket et al., (1978), and Reynolds et al., (1982) reported significant effects of year, season and age of dam on weaning score.

Average Daily Gain After Weaning

The average daily gain after weaning for the study was 177 g/d (Table XXV). This value is far below the average of Criollos from Latin America (256 g/d) and BON in previous studies (282) (Plasse, 1983; Hernandez, 1976; Martinez and Hernandez, 1983).

Least squares means for all type of effects appears in Table XXV. Year of calf birth was a significant (P<.01) source of variation for postweaning gain of calves and thus for their postweaning weight. This result agrees with many other studies (Hernandez, 1976; Plasse et al., 1981; Hoogestijn et al., 1981; Verde et al., 1981). Year fluctuations in environmental conditions influence forage quality and quantity resulting in cyclic weight losses and/or gains in livestock and, consequently, it could affect weights of animals at a given age.

Season of birth was also an important source of variation ($P<.01$) for both postweaning daily gain; however, 16 month weight was not affected. Calves born during the second part of the calving season gained more per day than calves born during the first part of the calving season. Tropical studies reported significant effect of season of birth on postweaning gain of calves (Hernandez, 1970, 1976). There is no correspondence of environmental conditions at birth, weaning and 16 months of age. Good environmental conditions for the first two weights do not correspond to the best conditions after weaning. Negative phenotypic and environmental correlations were found between postweaning gains with preweaning gain and weaning weight (Table XXVII).

Calf year x season of birth interaction also was a significant source of variation (Table XXVI). Contrary to the results reported for preweaning traits, during the first two years (1978-1979), calves born in the first part of the calving season were heavier than calves born in the second part of the calving season. During the remaining years of study, the pattern was opposite and thus contrary to the findings in preweaning traits. This erratic performance resulted in the significant interaction of year x season.

Age of dam did not have effect ($P>.10$) on postweaning gain of calves. This result is in accordance with the suggestions of Petty and Cartwright (1966) who pointed out that the maternal effects on postweaning gains diminish with the postweaning months until it disappears. However, it is in disagreement with studies by Plasse et al., (1981) and Verde et al., (1981) in tropical environments, which have reported significant effect of age of dam on postweaning daily gains. It is interesting to observe that cows that were higher in production in preweaning traits produced lighter calves at 16 months of age, presumably because calves that are receiving more milk during the suckling time are the most affected by the stress of weaning.

Sex of calf was significant (P<.01). This result is in agreement with most studies reviewed. Contrary to all reports, females in this study gained more per day than males. The large animal (bull calves were heavier at weaning than females) after finishing the mother effect suffer more the drastic change in nutrition. On the other hand, management differences contributed to sex effects on weight at 16 months of age. Heifer calves had access to less abrupt grazing lands after weaning so probably they were under lesser stress conditions than bull calves did.

Sire nested within year did not have effect on postweaning gains. This result is in part in agreement with Hernandez (1976). He found differences on postweaning daily gain at 5% of probability level among Charolais bulls but not among Romo or Brahman bulls.

16 Month Weight

Mean 16 month weight for the study was 213.7 kg (Table XXV). No studies were found with the same or similar breeds which recorded postweaning weight at 16 months of age to compare with.

Season of birth did not affect 16 month weight of calves. Yearling weight is a combination of weaning weight and postweaning daily gain. Calves born in the first part of the calving season gained faster after birth and weighed more at weaning but gained slower after weaning. The opposite was true for calves born during the second part of the calving season. Similar weights (214.0 kg) were observed for all calves at 16 months of age. The year x season of calf birth interaction did not affect the 16 month weight of calves. The differences of 16 month weight of calves were, however, erratic from season to season among years. During the years 1978, 1981, and 1982, the first part of calving season was better for the 16 months weight of calves. The opposite was true for 1979, 1980, and 1983.

Age of dam constituted a significant ($P<.01$) source of variation for yearling or 16 month-weight of calves. This result is in accordance with one study in Venezuela (Plasse et al., 1981) but in disagreement with one study in Africa (Gregory et al., 1985). Also, it is in disagreement with the suggestions of Petty and Cartwright (1966), who indicated that the maternal effect on postweaning weight of animals diminishes with the postweaning months until it disappears.

Calves from highly productive cows (4.5 to 9 year old) for weaning traits dropped in postweaning gains compared with poorly productive cows. The advantage gained until weaning was far enough to surpass the production of young cows at 16 months of age; therefore, the same rank as that cited for weaning traits was found for 16 month weight.

Sex was a significant (P<.01) source of variation for the 16-month weight of calves. Males (217.53 kg) were 7.72 kg heavier than females even though they had gained less after weaning. Gregory et al., (1985) in Africa reported 9 kg of difference between males and females and Hernandez (1976) reported the highest (33.8 kg) difference found in the literature reviewed.

The effect of sire was not significant Hernandez (1970) did not find differences among Romo sires on 18 month weight. The same author (1976) found differences among Brahman bulls but not among Charolais nor Romo bulls.

Conformation Score

Mean conformation score for the study was 50.7. No studies done in the tropics have analyzed this factor, therefore, no comparisons can be made with the present results. Only year differences constituted a significant (P<.01) source of variation on conformation score of calves. Conformation score ranged from 48.64 in 1978 to 53.4 in 1979. Even though none of the factors studied significantly affected the yearling conformation or muscling score of calves, it is important to point out that males received lower conformation scores than females, presumably due to the best grazing opportunities (related to topography of the grazing lands) given to females after weaning. Calves born in first part of calving season received higher conformation score and calves out of 3.5-4.5 year old dams the highest score.

TABLE XXIII

LEAST SQUARES MEANS ± STANDARD ERROR FOR PREWEANING TRAITS BY SEX OF CALF, AGE OF DAM AND BY YEAR AND SEASON OF CALF BIRTH

	No. of Calves Born	Calf Traits			
		Birth Weight Kg	Avg. Daily Gain g/d	Weaning Wt. Kg.	Weaning Conf. Score
Overall	637	26.6 ± 0.24	.594 ± 0.006	169.2 ± 1.50	50.1 ± 0.31
Sex					
Males	317	27.3 ± 0.28 a	.634 ± 0.007 a	179.7 ± 1.81 a	51.2 a ± 0.37
Females	320	25.8 ± 0.27 b	.544 ± 0.007 b	158.8 ± 1.74 b	48.9 b ± 0.36
Cow Age Under 3.5	74	25.1 ± 0.42 b	.573 ± 0.012 c	162.8 ± 3.00 b	48.9 b ± 0.60
3.5-4.5	56	26.8 ± 0.46 a	.593 ± 0.013 b	169.3 ± 3.26 b	49.8 b ± 0.65
4.5-9.0	372	27.4 ± 0.25 a	.615 ± 0.006 ab	175.1 ± 1.56 a	51.4 a ± 0.32
Over 9.0	135	27.0 ± 0.33 a	.594 ± 0.009 b	169.7 ± 2.24 b	50.2 b ± 0.45
Year 1978	38	26.0 ± 0.72	.571 ± 0.018	163.1 ± 4.42	48.5 ± 0.92
1979	66	26.0 ± 0.58	.604 ± 0.014	171.2 ± 3.61	51.6 ± 0.75
1980	107	28.2 ± 0.49	.629 ± 0.012	178.9 ± 3.02	51.8 ± 0.62
1981	169	27.5 ± 0.37	.562 ± 0.010	162.5 ± 2.26	49.6 ± 0.47
1982	128	25.1 ± 0.42	.560 ± 0.011	164.5 ± 2.65	47.9 ± 0.54
1983	129	26.6 ± 0.44	.619 ± 0.011	175.2 ± 2.67	51.2 ± 0.55
Season					
1	440	26.5 ± 0.27	.608 ± 0.008 a	171.9 ± 1.75 a	50.3 ± 0.36
2	197	26.6 ± 0.30	.585 ± 0.010 b	166.6 ± 2.02 b	49.9 ± 0.41

abc = Means in the same column within same classification not sharing a common superscript differ ($P<0.05$)
d 1 = First part of the calving season
d 2 = Second part of the calving season

TABLE XXIV

LEAST SQUARES MEANS ± STANDARD ERROR FOR PREWEANING TRAITS FOR YEAR x SEASON OF CALF BIRTH SUBCLASSES

		No. of Calves Born	Calf Traits			
			Birth Weight Kg	ADG. Birth to g/d	Weaning Wt. Kg.	Weaning Conf. Kg
Overall		637	26.6 ± 0.24	.594 ± 0.006	169.2 ± 1.50	50.1 ± 0.31
Year	Season[a]					
1978	1	14	25.7 ± 0.99	.569 ± 0.027	162.2 ± 6.63	51.1 ± 1.34
	2	24	26.3 ± 0.76	.573 ± 0.020	163.9 ± 4.96	45.9 ± 1.00
1979	1	45	25.5 ± 0.57	.579 ± 0.016	164.5 ± 3.99	49.9 ± 0.81
	2	21	26.5 ± 0.82	.628 ± 0.022	177.9 ± 5.52	53.3 ± 1.12
1980	1	80	28.1 ± 0.44	.637 ± 0.012	180.9 ± 2.92	51.5 ± 0.59
	2	27	28.3 ± 0.72	.620 ± 0.020	176.9 ± 4.88	52.0 ± 0.99
1981	1	119	27.8 ± 0.36	.591 ± 0.010	169.8 ± 2.41	50.0 ± 0.49
	2	50	27.2 ± 0.54	.533 ± 0.014	155.3 ± 3.58	49.2 ± 0.73
1982	1	87	25.6 ± 0.43	.613 ± 0.012	172.7 ± 2.90	47.9 ± 0.58
	2	41	24.7 ± 0.58	.547 ± 0.016	156.3 ± 3.96	47.8 ± 0.80
1983	1	95	26.3 ± 0.41	.646 ± 0.011	181.4 ± 2.71	51.3 ± 0.55
	2	34	26.8 ± 0.64	.592 ± 0.017	168.9 ± 4.20	51.2 ± 0.85

a Season of Birth, 1 = First part of the calving season
2 = Second part of the calving season

TABLE XXV

LEAST SQUARES MEANS ± STANDARD ERRORS FOR POSTWEANING TRAITS BY SEX OF CALF, AGE OF COW, YEAR AND SEASON OF CALF BIRTH

	No. of 16 Mos. Calves	Calf Traits: Average Daily Gain g/d	Yearling Wt. Kg	Yearling Conf. Score	SE
Overall	530	.177 ± 0.005	213.7 ± 1.69	50.7 ±	0.33
Sex of Calf					
Males	262	.151 ± 0.006 b	217.5 ± 2.07 a	50.4 ±	0.40
Females	268	.204 ± 0.006 a	209.8 ± 1.99 b	51.9 ±	0.39
Cow Age					
Under 3.5	57	.182 ± 0.010	208.5 ± 3.66 b	50.6 ±	0.73
3.5-4.5	43	.181 ± 0.012	215.6 ± 4.03 b	51.1 ±	0.72
4.5-9.0	320	.177 ± 0.005	219.1 ± 1.74 ab	50.9 ±	0.34
Over 9.0	110	.170 ± 0.008	211.6 ± 2.67 b	49.9 ±	0.50
Year					
1978	32	.160 ± 0.015	204.1 ± 4.91	48.6 ±	0.86
1979	54	.170 ± 0.012	213.2 ± 3.95	53.4 ±	0.70
1980	101	.198 ± 0.010	226.9 ± 3.18	49.8 ±	0.56
1981	122	.127 ± 0.008	199.7 ± 2.68	50.1 ±	0.48
1982	123	.224 ± 0.009	218.6 ± 2.87	51.5 ±	0.52
1983	98	.186 ± 0.009	219.6 ± 3.13		
SEASON					
1	364	.167 ± 0.006	214.0 ± 2.10	51.2 ±	0.39
2	166	.188 ± 0.007	214.0 ± 3.10	50.2 ±	0.44

abc = Means in the same column within same classification not sharing a common superscript differ (P<0.05)

d 1 = First part of the calving season
d 2 = Second part of the calving season

TABLE XXVI

LEAST SQUARES MEANS ± STANDARD ERRORS FOR POSTWEANING TRAITS BY YEAR AND SEASON OF BIRTH INTERACTION SUBCLASSES

			Calf Traits		
		No. of 16 MOS. CALVES	Average Daily Gain g/d	Yearling Weight Kg.	Yearling Conformation Score
Overall		530	.177 ± 0.005	213.7 ± 1.69	50.7 ± 0.33
Year	S				
1978	1	11	.169 ± 0.022	206.0 ± 7.69	48.5 ± 1.33
	2	21	.150 ± 0.016	202.2 ± 5.67	48.8 ± 0.98
1979	1	37	.195 ± 0.012	210.9 ± 4.39	54.5 ± 0.76
	2	17	.145 ± 0.018	215.4 ± 6.30	52.3 ± 1.09
1980	1	76	.183 ± 0.009	225.6 ± 3.20	50.0 ± 0.55
	2	25	.213 ± 0.015	228.3 ± 5.27	49.6 ± 0.91
1981	1	85	.101 ± 0.009	201.5 ± 2.30	51.3 ± 0.52
	2	37	.153 ± 0.013	197.9 ± 4.41	48.9 ± 0.77
1982	1	84	.203 ± 0.009	221.7 ± 3.21	51.5 ± 0.56
	2	39	.245 ± 0.013	215.5 ± 4.34	51.5 ± 0.75
1983	1	71	.148 ± 0.010	216.8 ± 3.40	
	2	27	.224 ± 0.015	222.4 ± 5.07	

Heritabilities and Correlations

Heritabilities and genetic correlations obtained from paternal half-sib analyses of variance and covariance are presented in Table XXVII. The combined estimates of heritability for both sexes were all lower than the average estimates previously reviewed which were: birth weight, .28; preweaning daily gain, .22; weaning weight, .26; weaning conformation score, .51; postweaning daily gain, .41; yearling weight, .39; and yearling conformation score, .59. Nevertheless, with the exceptions of yearling (0.034) and yearling conformation score (0.104) all the other estimates fall within the ranges of the estimates cited previously. The standard errors ranged from .090 to .114.

Heritability for birth weight was the highest (.275) only half unit below the average estimate reviewed previously. The other estimates were far below the average. One possible contributor to the lower estimates in this study was negative bias resulting from selection of parents. Both parents were selected on the basis of 16 month weight with some emphasis on weaning weight. Parents selected on the character whose heritability is being estimated, or on the basis of some other character correlated with it, causes the variance between parents to be reduced and, consequently, the covariance of sibs to be diminished, (Falconer 1982). Another contributor to the lower estimates could be the decrease in genetic variance that occurs in closed populations. The BON herd, since its foundation, has been closed to outside influence of other lines. Only in 1978 was new blood injected from two sires purchased out of the region.

Since the coefficient of heritability is a ratio and, therefore, it changes when either numerator or denominator changes, a third contributor for the low estimates of heritability in this study could be associated with the unfavorable conditions in the tropics, especially the low level of nutrition which tends to suppress the expression of genetic difference for growth potential.

The genetic, phenotypic and environmental correlations appear in Table XXVII. Most of the standard errors of genetic correlations were above 0.4, making them of little use as point estimates. Exceptions were preweaning gain with weaning weight (SE+0.03) and weaning score with preweaning gain (SE+0.27) and with weaning weight (SE+0.25).

Genetic correlations of birth weight with preweaning traits were positive and low. The average values reviewed previously for these correlations were negative and from moderate to high magnitude. The strong negative correlations with the postweaning traits indicates that genes contributing to high birth weight tend to lower postweaning traits. This result is completely in disagreement with the results reviewed in the literature. Phenotypic and environmental correlations were all positive and from low to moderate magnitude.

Weaning gain had low positive genetic correlation with postweaning gain while environmental and phenotypic correlations were negative. Environmental conditions were opposite for these traits. Calves that have the best environmental (nutritional) conditions during the suckling time have the poorest conditions from weaning to 16 months of age. All the other correlations of preweaning gain with the rest of traits studied were high, indicating that this could be the best point estimator for future performance, especially weaning weight (0.97 $\pm$ 0.032).

Genetic correlations involving weaning weight indicated high relationships with weaning and yearling score; low and negative with postweaning daily gain and low and positive with yearling weight. Phenotypic and environmental correlations with the above traits were moderate to high except for the negative and low values with postweaning traits. Weaning score had negative relationships to postweaning growth traits and positive with yearling conformation. Phenotypic and environmental correlations with yearling weight and yearling score were positive and from moderate to low values and was negative (phenotypic) with postweaning daily gain.

Average daily gain after weaning had a high relationship with yearling weight being in agreement with most studies. Phenotypic and environmental correlation values are positive and of moderate value. Its genetic and phenotpic relationships with yearling score were negative and with high and low values, respectively.

Weaning score was a good predictor of weaning weight, and yearling score predicted yearling weight well. Phenotypic and environmental correlation values were positive and of moderate magnitude.

Conclusions

Sufficient research results in other environments and management systems are not available to accurately and completely evaluate the biological characteristics of BON cattle for their effect on the

TABLE XXVII

ESTIMATES OF HERITABILITY AND GENETIC (G), PHENOTYPIC (P) AND ENVIRONMENTAL (E) CORRELATIONS AMONG GROWTH TRAITS AND CONFORMATION SCORE IN BLANCO OREJINEGRO (BON) CATTLE

		Birth Wt.(BW)	Pre-Weaning ADG(WG)	Weaning Wt.(WT)	Weaning Score(WS)	Post-Weaning ADG(YG)	Year-ling Wt.(YW)	Year-ling Score(YS)
Heritability		.275	.091	.091	.134	.083	.038	.104
Std.Err.		.113	.090	.090	.097	.100	.093	.114
BW	G		.057 ± .49	.289 ± .45	.026 ± .43	-.985 ± .79	-1.256 ± 1.4	-.966 - .877 ± .62
	P		.231	.359	.243	.028	.299	.113
	E		.273	.385	.300	.166	.442	.298
WG	G			.972 ± .83	1.169 ± .27	.205 ± 1.8	.639 ± 1.3	1.310 ± .76
	P			.991	.700	-.187	.725	.432
	E			.993	.644	-.207	.728	.346
WW	G				1.126 ± .25	-.257 ± 2.7	.165 ± 3.3	1.271 ± .97
	P				.705	-.175	.742	.435
	E				.655	-.175	.756	.369
WS	G					-1.549 ± 1.3	-.622 ± .85	.509 ± .59
	P					-.106	.508	.351
	E					.049	.591	.329
YG	G						.913 ± .91	.040 ± .61
	P						.531	.088
	E						.512	.098
YW	G							1.105 ± .40
	P							.641
	E							.592

efficiency of producing beef. However, the data analyzed in this study are sufficient to help characterize the relative strengths and weaknesses of BON cattle with regard to the reproductive and productive traits studied.

BON cattle, for some traits like reproductive performance and preweaning growth traits, have positive relative performances, which are considered adequate and competitive for the environmental and management conditions of the tropics.

In general, BON are well adapted to the abrupt topography and mild temperature of the coffee growing region in the Andes of Colombia. Performance levels of BON cattle were sufficiently adequate for economically important traits to insure a satisfactory contribution to efficient beef production under the conditions studied.

Finally, the preservation of the adapted germplasm of BON is advisable because of their actual and expected future contribution to beef production in their zone of influence. A breed must take advantage of its strengths and improve its weaknesses in order to influence future beef production. For this reason, a recommended selection program to enhance the value of BON cattle for efficient beef production would be to utilize selection procedures that will increase growth rate while, at the same time, minimize any correlated increase in birth weight, which, in this study, was negatively correlated with postweaning daily gain and weight. Since the most critical trait in beef production in tropical environments is reproduction, some selection should also emphasize fast physiological development.

CHAPTER IV

REPRODUCTIVE AND PRODUCTIVE PERFORMANCE OF BLANCO OREJINEGRO (BON) CATTLE AND ITS CROSSES WITH ZEBU, CHAROLAIS AND SANTA GERTRUDIS

Abstract

Reproductive performance and genetic parameters of growth traits in all possible combinations resulting from the mating of BON, Zebu, Charolais and Santa Gertrudis bulls with BON, Zebu and crossbred (F1) BON x Zebu and Zebu x BON cows were analyzed. Data were collected on 507 calves born, 479 calves weaned and 432 completing the postweaning growth phase in a tropical region of Colombia, South America. Calving and weaning rate were significantly higher ($P<.05$) for F1 cows, heterosis values were 11.2 and 12.5%, respectively. Significant individual heterosis effects for the BON and Zebu matings, expressed as a percent of the straightbred mean were: 12.4% for birth weight (BW), 14.1 and 13.6% for both preweaning daily gain (YDG) and 16-month weight (YW) were 25.9 and 16.2%, respectively. The corresponding values for muscling conformation scores at weaning (WS) and at 16 month (YS) were: 9.4 and 7.8%, respectively. Zebu breed was superior compared to the BON breed for most traits, with exception of BW. The pooled maternal heterosis estimate from the appropriate matings of Charolais and Santa Gertrudis bulls were significant and positive for BW, 9.3%; WDG, 9.3% and for WW, 9.2%. They were positive and nonsignificant for

YW, WC and YC: 2.9, 4.4, and .02%, respectively, and negative and significant (P<.05) for YDG (-20%).

Key words: Beef cattle, crossbreeding, heterosis, heritability, genetic correlation.

Introduction

Crossbreeding is an effective tool to improve traits of economic importance in beef cattle. Those traits would include calving, weaning and survival rate, birth weight, preweaning, and postweaning growing traits. Crossing of divergent breeds of cattle should result in the greatest heterotic effect on traits of low heritability traits. Many studies in temperate areas have shown the consequences of crossing divergent breeds of European, British (*Bos taurus*) and indigenous (*Bos indicus*) origin. In the Latin American tropics in the last two decades, the use of crossbreeding has been increasingly accepted in commercial beef enterprises as producers understand the benefits of heterosis and/or breed complementarity. Research involving Criollo breeds (*Bos taurus*) and Zebu (*Bos indicus*) in the tropics of Latin America has indicated that planned crossbreeding systems can increase weaning weight per cow exposed to breeding by 27 percent or more (Plasse, 1981). Since heterosis is maximized as genetic divergence between breed types increases, even greater increases in productivity have resulted when Criollo and Zebu breeds were involved in crosses with European breeds.

The purpose of this study was to evaluate some genetic factors, such as heterosis, heritability and genetic correlations of several productive traits in all possible combinations of the mating of BON, Zebu, Charolais and Santa Gertrudis bulls with BON, Zebu and crossbred (F1) BON x Zebu and Zebu x BON cows, which may provide valuable information for the formulation of efficient breeding programs to increase beef production in the coffee growing region of the Andes of Colombia, South America.

Materials and Methods

Source of Data

Data used in this study were collected at the Instituto Colombiano Agropecuario Experimental Station at El Nus, Colombia, from 1977 through 1983, as part of an experiment in progress to evaluate the genetic potential of the native ("Criollo") breed Blanco Orejinegro (BON) and its crosses with Zebu (Zebu) cattle, and Charolais and Santa Gertrudis.

The station is located between 800 and 1200 meters above sea level in a mountainous region of the Colombian Andes, and is characterized by abrupt topography with poor and eroded soils. Temperature conditions at El Nus are warm to hot with a long wet or rainy season. Rainfall is bimodal and 70% of the annual precipitation occurs mainly from April to June and from August to October. Average rainfall during the years studied was 2155 mm. Meterological data during the years of study was described in Chapter III (Table XVIII).

The topography at El Nus is varied: 64% ondulate, 32% abrupt and 4% flat with acid soils (ph 4.5) which are deficient in nitrogen, calcium, zinc, phosphorum, and copper and has a high content of magnesium, iron, and potasium (Staffe, 1956).

Cattle

BON cattle used in this study were obtained from the herd maintained within the same experimental farm, described in Chapter III.

All Zebu bulls and most of the Zebu cows used in this study originated from cattle imported from the United States and raised in Turipana and La Libertad, experimental stations of ICA in the northern and eastern plains of Colombia, respectively.

The crossbred cows, BON x Zebu or Zebu x BON, were born at the experimental station, some in the preceeding years and some during the course of the study.

The Charolais bulls used in the study were obtained from the "Universidad of Antioquia" and from some other breeders of the region who had produced them from purebred parents obtained from France or the United States. The Santa Gertrudis bulls used in this study were imported from the United States.

Management and Data Collection

The cattle were raised under a good system of management for the region. Cattle were maintained in fenced pastures of Puntero grass (*Hyparrhenia rufa*) in the intermediate altitude of the experimental farm (1000 m) with free access to water and mineral mixture *ad libitum*. They did not receive supplemental feed. Heifers and bulls were selected for mating according to their weights at 16 and 24 months of age with some emphasis on weaning weight. Females were bred at 2 years of age to calve as three year olds. Two year old and older bulls were used for two and in some cases up to three consecutive years.

Mating was made at random. The mating groups consisted of one bull and 25 cows. Each mating group had a heterogenous composition with females of all ages and physiological status (heifers, dry and lactating cows) and of three groups (BON, Zebu and crossbred (F1) BON x Zebu or Zebu x BON). Every year, 3 to 4 BON, 2 to 3 Zebu and 1 to 2 Charolais and Santa Gertrudis sires were used depending on the number of cows available. It was planned to use each bull for at least two years but in a few cases it was necessary to use a bull for only one year or in some cases for more than two, either for reproductive failure or lack of available replacements, respectively. Lack of replacement sires was particularly a problem in the case of the Santa Gertrudis and Charolais bulls.

After partirution, cows which varied in age between 3 and 14 years, were placed on a 90-day breeding season from May through July, (rainy season). Heifers were also mated for a 90-day period but from April to June. The calving season extended from January to April, (dry months).

All animals received curative and preventive treatment against the common diseases in the region and were dehorned at approximately three months of age. In any event animals were culled before 16 months of age and no males were castrated before that age.

Each year all females available for reproduction from the BON, Zebu, BON x Zebu and Zebu x BON groups were distributed among the BON, Zebu, Charolais and Santa Gertrudis bulls, according to the following design.

TABLE XVIII

EXPERIMENTAL DESIGN SHOWING THE TOTAL NUMBER OF CALVES BY SUBCLASS

	Breed of Dam			
Breed of Sire	BON	Zebu	Z x BON or BON x Z	Total
BON	154	58	5	217
Zebu (Z)	47	110	10	167
Charolais	25	16	23	64
Santa Gertrudis	11	17	31	59
TOTALS	237	201	69	507

Each sire from the BON and Zebu breeds produced straightbred calves, two-way crosses and backcrosses each year and in some years Charolais and/or Santa Gertrudis bulls produced two and three-way crosses. Since Charolais and Santa Gertrudis bulls were not present in all years, there exist some degree of confounding between breed of calf and year.

Birth weights were taken during the first 24 hours after birth. At an average age of 8 months, calves were weaned, weighed and assigned a subjective muscling conformation score as described by Stonaker (1971), by a panel of at least three persons. After weaning, males and females were placed in separate fields. At 16 months of age all animals were weighed and assigned a conformation score in the same way as at weaning time. The weights were adjusted to a constant age of 240 and 480 days according to the following formulas:

Adj. 240 day wt.=actual wn. wt. - birth wt.* 240 + birth wt.

age at weaning

Adj. 480 day wt.=actual 16 mo. wt. - actual wn. wt. *240 + Adj. wn.wt.
days between weights

Statistical Analysis

Reproductive Data

Reproductive data were analyzed by developing two-way frequency tables and tested by Chi-square for homegeneity. Tables were developed for year of calf birth (CY), for cow (CG) group and for mating type (MT) and in each case: CY, CG, and MT, by birth type (calf, no calf) and by weaning type (calf weaned, calf no weaned). In both cases, birth and weaning type based on number of cows exposed to breeding.

There were also developed tables for survival rate for CY, CG, and MT, by liveability type (calf alive at weaning, calf died before weaning) and in this case, based on number of calves born. Statistical evaluation of the data was made by least-squares mixed model procedures (Harvey, 1977, 1982). The effects of year (1) and season (2) of birth, sire within breed, sex of calf, age of dam and the interactions between breed of sire and breed of dam were studied for growth and conformation traits. Significant sources of variation were determined from separate analysis of each trait using full models and the residual mean square was used to test all other effects.

Least-squares means were calculated from a reduced model in which non-significant effects were eliminated. The analysis of birth weight included 507 observations, the analysis of average daily gain from weaning to 16 months of age and weight at 16 months and condition score at 16 months included 432 observations.

To study the effect of season of birth the calving season was divided in two periods as described in Chapter III (Materials and Methods).

Cows were grouped in 4 classes according to their age: less than 3.5 years, most of first calve heifers; 3.5 to 4.5 years, second parity cows; 4.5 to 9.5 year, third to sixth parity cows and the fourth group formed by cows older tan 9.5 years of age. The data of 30 sires were analyzed.

The statistical model was:

$Y_{ijklmno} = U + a_i + b_{ij} + c_k + d_l + f_m + (ad)_{il} + e_{ijklm}$

$Y_{ijklmno}$ is the dependent variable studied;

μ is the overall mean;

a_i is the fixed effect of the i^{th} breed of sire;

b_{ij} is the random effect of j^{th} sire within the i^{th} breed;

c_k is the fixed effect of the k^{th} sex;

d_l is the fixed effect of the l^{th} age of dam;

f_m is the fixed effect of the m^{th} season of birth;

$(ad)_{il}$ is the effect of the interaction of breed of sire with breed of dam;

g_n is the fixed effect of the n^{th} year of birth;

h_o is the fixed effect of the o^{th} season of birth; and,

$e_{ijklmno}$ the experimental error.

Results and Discussion

Cow Reproductive Performance

Reproductive rate (CR) and weaning rate (WR) expressed, respectively, as the number of calves born and weaned per cow exposed; and survival rate (SR) expressed as the number of calves alive at weaning relative to calves born, are given by breed of dam, mating type and year of calf birth in Table XXIX. These comparisons were done by developing two way frequency tables and tested for homogeneity by Chi-square.

Differences among dam breeds for CR were not significant ($P>.10$). Mean calving rate for BON dams was lower than that reported in the first experiment with purebred BON cattle, but higher than that reported for BON cows by Hernandez (1981). Mean calving rate of Zebu and Zebu-BON or BON-Zebu cows was also greater than that reported in the latter study.

The differences between BON and crossbred cows and between crossbred with Zebu cows approached significance ($P<.07$) indicating that differences exist among these cow groups in postpartum conception rates in a limited breeding season.

Heterosis for CR was 19.93% ($P<.05$) which is greater than the upper limit (16%) estimated from several studies between Criollo and Zebu in the Latin American tropics and summarized by Plasse (1983).

Long (1980) reported a mean heterosis value for calving rate among Bos taurus breeds of 7% ranging from 2 to 10%. Franke (1980) reported a weighted average of heterosis for calving rate in studies involving Zebu of 9.9 ranging from 4.4 to 18.8, values very close to the one reported in this study.

Crosses of no practical interest from the commercial point of view, which were used to complete the experimental design had few observations and, therefore, were eliminated from the mating type analysis of reproductive traits. Chi-square value for CR was significant (P<.01). The lowest reproductive performance resulted from the mating of Charolais bulls to Zebu cows BON cows mated to Zebu bulls had significant (P<.01) lower CR. This result is in agreement with the findings of Castro et al. (1971) who reported that reciprocal matings between Romo and Zebus resulted in a lower pregnancy rate in Romo cows mated to Zebu (Zebu) bulls. The authors call this phenomenon "breed discrimination" (social discrimination), exhibited by Zebu bulls. Hernandez (1981) also reported similar results within the same herd. BON x Zebu mating was also lower. The remaining mating groups were above the average of the seven years studied (57.42%).

There were no significant differences for calf survival among all the dam breed groups (P>.10). Values for survival rate are within the range of those reported in the literature reviewed. Nevertheless, it is important to notice that the lowest values were observed for Zebu dams specially when bred to Charolais and Santa Gertrudis bulls. The low survival rate of the later breed group combinations resulted in significant (P<.01) differences for SR among mating groups.

Turner (1980) in his review about "Adaptability Aspects of Zebu Cattle," documented the observations of Reynolds about the normally greater prenatal calving losses in purebred Brahman herds and those of Franke et al. about the incidence of the weak calf syndrome in Brahman cattle. However, in this study, the greatest calving losses occurred among the crosses specified above which is in disagreement with most studies in the review of literature. Higher survival rate from birth to weaning has been found among crossbred calves than among purebreds. Even though calving difficulty was not available for analysis in this study, the greater calf mortality in the Charolais group could have been due to more dystocia problems, since these bulls consistently produced the heaviest calves at birth and Zebu cows the lightest, as will be seen later.

Survival rate of calves measured as a character of the cow was greater for calves out of crossbred (F1) dams than for the average survival rate of either BON or Zebu calves. Heterosis for survival rate was 3.03%, value equal to the upper limit (3%) given for Long (1980) who reported an average value of 2%, ranging from 1 to 3%. Franke (1980), for studies involving Brahman cattle gave a weighted average for survival rate of 4.7% ranging from -4.8% in crosses with Angus to 8.6% in crosses with Hereford.

Year of calf birth did not have a significant effect on survival rate (P>.10) of calves. This result is in agreement with the results of Trail and Gregory (1981) who worked with Boran and Sahival breeds under tropical conditions in Africa. The overall survival rate is very similar to the average reported in other studies with the same breed in the same experimental farm (Hernandez, 1981). The unweighted average given for Hernandez was 94.7% with the lower value for Zebu calves (90.8%).

Weaning rate (WR) is an important economic trait in beef cattle production. This trait is a composite of calving rate and calf survival to weaning. The mean WR was 54.29% and estimates varied from 52.19 to 65.31% in Zebu and crossbred (F1) BON x Zebu cows, respectively. Differences in WR approached significance (P<.07) indicating that even though the differences in CR were not significant, the differences in calf survival accentuated differences at weaning.

Heterosis percentage for WR was 23.63 (P<.05). This value is far above the average of 12.3% compiled by Franke (1980) for crosses among Bos taurus and Bos indicus breeds. The range of the studies summarized by Franke were from 7.1 to 21.2%.

Average WR for reciprocals (46.43%) between BON and Zebu were significantly (P<.05) different from the average of the purebreds (57.18%) indicating that there was large difference among these groups for CR and SR. As a result of the poor reproductive performance of Charolais bulls with Zebu cows and of the differences between reciprocals and straightbreds, overall differences among mating groups were highly significant (P<.01).

Overall Efficiency of Production

Production efficiency can be expressed as the ratio of calf weaning weight to cow weight (Table XXX). Since overall productive efficiency must also take into account the weaning rate (Peacock and

Koger, 1980), the calf weight to cow weight ratio was multiplied by the weaning rate of those matings in Table XXIX in order to provide a measure of production per unit of cow weight exposed to breeding. The product of weaning rate by weaning weight as a measure of kilograms of calf meaned per cow in the breeding herd was also used.

Using the average values of the ratio calf weight to cow weight and calf weight per cow exposed from the purebreds (.25 and 95.1 kg) as a basis for comparison, of the F1 calves from purebred dams only SG x Z were superior for both measures of cow efficiency production by 4 and 7.9%, respectively. The general means of the F1 calves were 12 and 10.5% below that of the straightbreds. This result is in disagreement with all studies consulted in the literature reviewed. The reason for these unusual results were the low reproductive, weaning and survival rates found in some of the crosses, especially those involving Charolais bulls. Values for three breed calves from crossbred (F1) dams were closer, but still lower than those reported in the literature (Frahm and Marshall, 1985, Peacock et al., 1981). The three breed calves were 46.7 and 36% above purebreds for both kilos of calf per cow exposed and for the productive efficiency rate, respectively.

Calf weight to cow weight ratios for the purebred system were slightly higher than the value in the first experiment with BON cattle. The mean for the two crossing systems: two breed calves from purebred dams and three breed calves from crossbred dams were .48 and .49, respectively. Both were considered to be superior to that for the purebred system. These results are in agreement with the observations of Peacock et al. (1981), who found higher levels of heterosis for triple crosses involving Brahman than for single crosses between European British breeds, Charolais and Angus.

The average value of all systems (.47) was above the average value of .41 given by Trail and Gregory (1981) who studied indigenous African breeds in crosses with Angus and Red Poll bulls.

Considering the above measurements only as a character of the cows (Table XXX), it was found that F1 cows had the highest values for all four parameters: cow weight was significantly (P<.01) higher for crossbred cows (429 kg), with 8.7% of advantage over the mean of the two purebred dams; F1 cows also weaned the highest proportion of their own weight (averaged .49), 22.5% above the mean of purebreds; produced more kilos of calf per cow exposed (132.96) which represented 38.5% of increase over the average of the purebred dams. The corresponding values for productive efficiency rate were .32 for crossbred dams and .25 for the purebred dams. Percentage of crossbred dams over purebred was 28%.

First Calve Heifers

Heifers were mated at an average age of 2 years to calf first as a three year-old cows. A separate analysis using SAS procedures (1985) was done to study the effects of breed of dam and year of dam birth on age at calving, weight, production efficiency, calving rate index, production per unit of cow and kilos of calf per heifer in the breeding herd.

To transform the age of cow at first calving to a more understandable measure of efficiency, the following indexing of calving rate was used. It was assumed that with a calving interval of 365 days with 285 day gestation period and an 80-day interval following parturition to conception, cows will have either 1 or 100% of calving rate. The 80-day interval was also chosen to represent an acceptable average time after bulls are introduced into the herd in which virgin heifers would conceive.

In this experiment, heifers were mated at an average age of 2 years so first calving would occur at 3 years given 1 or 100% of calving index rate (CI), according with the following formula for the CI.

$$CI = \frac{\text{Number of calves}}{\text{Age at calving - Age at first mating}}$$

Thus, the calving rate of a heifer calving as a 3 year old cow is 1/(3-2)=1 calf/year.

The calving index was multiplied for the ratio of calf weaning weight to cow weight and for the weaning weight of calf to provide estimates of production per unit of cow and for kilos of calf per heifer in the breeding herd. The index used here is an approximation of the calving rate index used by Stonaker et al. (1985).

Only dam breed effect was significant for all measurements studied. Least squares means from reduced model analysis of variance for all effects appear in Table XXXI. With the only exception of weight at first calving, crossbred (F1) heifers were superior to either BON or Zebu heifers and to the average of the two purebreds. The lower weight at first calving for crossbred (F1) BON-Zebu compared with Zebu heifers is reasonable since they were significantly (P<.01) younger at first parturition.

Heterosis values for all traits ranged from 2.5 for calving weight to 41.4% for calf weaning weight per cow exposed to breeding. These results are in agreement with previous observations showing higher levels of production for crossbred (F1) cows (Peacock et al. 1981, Plasse 1983).

Mature Cow Index

Using the same procedure, as described for the measurements of efficiency of production in heifers, it was found (Table XXXII) that calving index for cow groups were parallel to the values of calving rate given in Table XXIX. Since the calving index measures the calving efficiency of cow at a given age the index is more a character of the cow, therefore, in the analysis of variance effects of mating group (interaction with sire breed) as well as the simple effect of sire breed were not considered. Neither year and season of calf birth nor sex of calf affected the calving index. Calving index decreased with age of cow and this seems logical since cows do not calve every year. The index might be biased in favor of young cows, since only pregnant heifers are considered. Production per unit of cow was significantly (P<.01) higher in crossbred cows. Young cows had higher production per unit due to their higher calving index.

Kilos of calf per cow in the breeding herd was significantly higher in crossbred cows compared to purebreds (Table XXX). Kilos of calf per cow was higher in first calving cows due to the high calving index. Year and season of calf birth and sex of calf significantly (P<.01) affected the production per unit of cow and the kilos of calf per cow in the breeding herd. The pattern of variation was similar in both. Season one and male calves had significantly (P<.01) higher values than season two and female calves, respectively. Variation of kilos of calf per cow in the breeding herd among years was consistent with variation of calf weaning weight.

Calf Growth Traits

Probabilities of attaining greater F values from analysis of variance for calf pre and postweaning growth and conformation scores appears in Table XXXIII. Year of calf birth significantly (P<.01) affected most traits with the exception of conformation score at weaning, which approach significance (P=0.06). Season of birth was significant (P<.01) for weaning traits but not significant (P>.10) for birth weight and yearling weight and conformation. With the exception of weaning conformation score at weaning the results concerning with the effects of year and season of calf birth on the calf growth traits studied are consistent with the findings in the experiment with pure BON, Chapter III. With the exception of average daily gain after weaning (P>.10), sex of calf and age of dam were significant for all calf traits (P<.01 and P<.05). Sire nested within breed was significant (P<.01) for all preweaning and postweaning traits with the exception of conformation score at weaning and for yearling score (P<.05). Breed of sire significantly (P<.01) affected birth weight

TABLE XXIX

COW REPRODUCTIVE PERFORMANCE BY COW BREED GROUP, MATING GROUP AND BY YEAR OF CALF BIRTH

Breed Type	% Calves Born a	% Live Calves c	% Calves Weaned
Cow Group			
BON (B)	56.03	95.52	53.52
Zebu (Z)	56.28	92.72	52.19
BZ or ZB	67.35	96.97	65.31
Chi-square	4.45	2.49	5.54
Estimate of Heterosis			
1/2(BB+BrBr)	56.16	94.12	52.86
1/2(BrB+BBr)	67.35	96.97	65.35
Heterosis Units	11.19*	2.85	12.49*
Heterosis %	19.93	3.03	23.63
Chi-square	4.01	0.41	4.92
Mating type			
BB = B x B	57.71	95.89	55.34
BBr = B x Z	53.15	91.53	48.65
BrB = Z x B	47.37	93.33	44.21
BrBr = Z x Z	61.20	96.43	59.02
CBr = C x Z	35.56	89.50	31.11
C(BrB or BBr)= C(ZB or BZ)	69.70	95.65	66.65
SGBr = SG x Z	70.37	78.95	55.56
SG(BrB or BBr)= SG(ZB or BZ)	71.43	100.00	71.43
Chi-square	21.79**	14.48*	23.75**
Overall Mean	57.42	94.23	54.29

a B = BON Br = Brahman (Zebu) C = Charolais SG = Santa Gertrudis
b Based on number of cows exposed to breeding
c Based on number of calves born
* (P<.05)
** (P<.01)

TABLE XXX

COW WEIGHT AND MEASURES OF PRODUCTION EFFICIENCY

Item	Cow Weight Kg.	Calf Weaning/ Cow Weight Kg/Kg	Calf Weaned Kg. Per Cow Exposed	Productive Efficiency Rate
Purebreds				
B x	387 ± 6.7	.43 ± .01	89.8	.24
Z x Z	403 ± 5.5	.43 ± .01	100.4	.26
System Mean	395	.43	95.1	.25
Purebred Dams With F1 Calves				
B x Z	401 ± 7.7	.47 ± .01	91.3	.23
Z x B	394 ± 7.7	.49 ± .01	84.3	.22
C x Z	420 ±11.5	.48 ± .02	62.4	.15
SG x Z	403 ±11.6	.46 ± .02	102.6	.26
System Mean	405	.48	85.2	.22
F1 Dams With Three Breed Calves				
C(BZ or ZB)	426 ± 9.8	.48 ± .02	134.2	.32
SG(BZ or ZB)	414 ± 9.2	.50 ± .02	144.7	.36
System Mean	420	.49	139.5	.34
All Dams				
BON	387 ± 5.4	.46 ± .01	94.6	.25
Zebu	402 ± 5.1	.46 ± .01	96.8	.25
ZB or BZ	429 ± 7.6	.49 ± .01	132.9	.32

[a] Calf weaning weifht/low weight multiplied by % calves born (Table XXIX)

TABLE XXXI

LEAST SQUARES MEANS AND STANDARD ERRORS OF MEANS FOR
COW PRODUCTIVE EFFICIENCY AT FIRST CALVING

Item	BON	Zebu	ZB or BZ	Heterosis Units	Heterosis %
No Observations	43	27	29		
Cow Age (years)	3.22 ± .08 a	3.72 ± .1 b	3.03 ± .09 a	-.44 **	12.6
Weight (Kg)	348.3 ± 5.8 a	385.1 ± 7.1 b	376.0 ± b	9.3	2.5
Calf weight/ cow weight	.45 ± .01 a	.49 ± .01 ab	.51 ± .01 b	.04 *	8.54
Calving rate index	.96 ± .05 a	.67 ± .06 a	1.03 ± .06 a	.22 **	26.4
Production effi- ciency rate index d	.44 ± .03	.32 ± .03	.53 ± .03	.15 **	39.5
Kg Calf weaned per cow exposed	150.9 ± 8.9	123.0 ± 11.1	193.6 ± 10.9	56.6 **	41.4

ab Means in the same row not sharing a common superscript differ (P<.05)

c Calving rate index (CI) = $\frac{\text{Number of calves}}{\text{Age at calving - Age at 1st mating}}$

* (P<.05)

** (P<.01)

TABLE XXXII

LEAST SQUARES MEANS ± STANDARD ERRORS OF MEAN FOR INDEX OF COW PRODUCTIVITY TRAITS .

	Calving Rate Index	Production e Efficiency Index	Kg Calf Weaned Per Cow Exposed (Index)
Cow Group			
BON	.84 ± .01 a	.38 ± .007 a	144.4 ± 2.6 a
Zebu	.76 ± .01 b	.35 ± .007 b	136.0 ± 2.6 b
ZB or BZ	.87 ± .01 c	.42 ± .008 c	171.6 ± 2.8 c
Cow Age			
Under 3.5 year	1.04 ± .02 a	.51 ± .01 a	179.4 ± 3.9 a
3.5-4.5	.79 ± .02 b	.38 ± .01 b	150.6 ± 4.5 b
4.5-9.0	.73 ± .01 c	.33 ± .01 c	137.3 ± 1.9 c
Over 9.0 year	.73 ± .01 c	.32 ± .01 c	135.5 ± 2.8 c
Years			
1977	.84 ± .02	.44 ± .01	160.2 ± 3.7
1978	.80 ± .02	.37 ± .01	137.3 ± 3.1
1979	.81 ± .02	.36 ± .01	139.5 ± 3.5
1980	.80 ± .02	.38 ± .01	152.0 ± 3.2
1981	.79 ± .02	.36 ± .01	145.1 ± 3.6
1982	.83 ± .02	.37 ± .01	149.1 ± 4.4
1983	.84 ± .02	.41 ± .01	171.1 ± 6.3
Season f			
1	.82 ± .01	.40 ± .01 a	156.4 ± 2.07 a
2	.82 ± .01	.37 ± .01 b	114.9 ± 2.50 b
Sex			
Males	.82 ± .01	.40 ± .01 a	157.8 ± 2.20
Females	.81 ± .01	.37 ± .01 b	143.4 ± 2.3

abc Means in the same column not sharing a common superscript differ (P<.005)

d Calving rate index (CI) = $\frac{\text{Number of calves (parities)}}{\text{Age at calving - Age at first mating}}$

e Calf weaning weight/cow weight x calving rate index

f 1 = First part of calving season
  2 = Second part of calving season

TABLE XXXIII

PROBABILITIES OF ATTAINING GREATER F-VALUES FROM ANALYSIS OF VARIANCE FOR CALF PREWEANING AND POSTWEANING TRAITS

		Calf Traits						
		Weights			Avg. Daily Gain		Conformation	
Source	Df	Birth	Wn.	Yr.	Prewn.	Postwn.	Wn.	Yr.
Sire/Breed[a]	32	0.01	0.01	0.01	0.01	0.04	0.04	0.02
Breed of Sire (BS)	3	0.01	0.77	0.91	0.80	0.99	0.01	0.14
Breed of Dam (BD)	2	0.01	0.01	0.01	0.01	0.01	0.01	0.01
BS x BD	6	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Year	6	0.01	0.01	0.01	0.01	0.01	0.06	0.01
Season	1	0.27	0.01	0.86	0.01	0.01	0.01	0.34
Sex	1	0.01	0.01	0.01	0.01	0.11	0.01	0.01
Age of Dam	3	0.01	0.01	0.02	0.01	0.35	0.03	0.11
ERROR		453	424	383	424	379	376	375

[a] Sire/Breed = Sire nested within breed

and conformation score at weaning, the remaining traits were not affected (P>.10) by this source of variation.

Breed of dam and the breed of sire by breed of dam interaction were a significant (P<.01) source of variation for all the calf traits analyzed in this experiment.

Birth Weight

Mean birth weight for the study was 28.5 kg. This value is below the average estimates of Criollo x Brahman and/or Brahman x Criollo crosses in the tropic studies (30.0 kg) (Hernandez, 1981; Plasse, 1983) and within the range previously reported (27.5-32.4 kg). Least squares means for birth weight for all the effects studied appears in Table XXXIV. Year of calf birth was an important source of variation (P<.01). This result agrees with the findings of the previous experiment with pure BON.

Season of birth did not have effect on birth weight of calves. This result is in agreement with previous studies in the same experimental farm (Martinez and Hernandez, 1983) and with the results of the previous experiment (Chapter III).

Sex effect was significant (P<.01) on birth weight of calves. All the studies in the literature reviewed reported a significant effect. The difference between sexes was 1.69 kg in favor of males. This value is within the range (0.55-3.3) reported previously and close to the value (1.47) of the previous experiment with pure BON (Chapter III).

Age of dam was a significant (P<.01) source of variation for birth weight of calves. Cows over 4.5 years presented the greatest values for this trait (29.22 kg) with young cows under 3.5 years with the lightest calves. This result agrees with most reports in the literature.

Least squares means for the genetic sources of variation for the preweaning traits appears in Table XXXV. Breed of sire and sire within breed constituted a significant (P<.01) source of variation for birth weight of calves. Charolais (30.08 kg) and Zebu bulls (29.76 kg) produced the heaviest calves and BON (27.45 kg) and Santa Gertrudis (26.57 kg) produced the lightest calves. These results are in accordance with previously cited studies which showed that Charolais-and-Zebu sired calves are consistently heavier at birth than Criollo and Angus bulls (Muller-Hays et al., 1968; Hernandez, 1976, 1981). The maximum difference of 3.57 kg between Charolais-and-Santa Gertrudis sired calves are higher than the average estimate reviewed previously which was 2.8 kg.

Breed of dam effect was a significant (P<.01) source of variation for the birth weight of calves. BON and crossbred (F1) dams between BON and Zebu or Zebu and BON had the heaviest calves, 29.65 and 29.27 kg, respectively, while Zebu dams had the lightest calves (26.48 kg). These results agree, in general, with the studies in the tropics which reported that Criollo cows produced the heaviest calves, Brahman dams the lightest with crossbred (F1) Criollo x Brahman or Brahman x Criollo being intermediate (Munoz and Martin, 1969; Hernandez, 1981; Plasse, 1983).

The maximum difference between BON and Zebu dams was 3.17 kg, value that is above the average estimates previously reported but within the range (0.1-5.8 kg) of those reports. Hernandez (1981) reported a maximum difference between BON and Zebu cows of 4.5 kg.

The effect of breed of sire (BOS) x breed of dam (BOD) interaction on birth weight was significant ($P<.01$). Previously reviewed studies also reported a significant effect BOS x BOD interaction.

BON sires mated to cows other than BON, Santa Gertrudis bulls mated to cows other than crossbred (F1) cows and Zebu bulls with Zebu cows produced calves below the average. All possible combinations with Zebu cows resulted in calves below the average. BON cows in other combinations, exception with Santa Gertrudis bulls, produced calves above the average. The heaviest calves resulted from mating Zebu bulls to BON cows (33.68 kg) and the lightest calves (24.78 kg) resulted from the mating of Santa Gertrudis bulls to Zebu cows.

Charolais bulls in all combinations were close to and above the average while Zebu bull combinations were below the average when mated to dams of their own breed but above when mated to BON or crossbred cows. Combinations of BON and Santa Gertrudis bulls were close to or below the average of birth weight. This factor could be very important in avoiding dystocia problems that usually are associated with Charolais-or-Zebu sired calves, specially when mated to first calve dams.

Average Daily Gain from Birth to Weaning

Mean preweaning gain of this study was 0.667 kg/d (Table XXXIV). Year effects were significant (P<.01) and in agreement with all the previously cited reports which showed that year fluctuations in environmental conditions and thus variation in quality and quantity of available food produce variation in the milk production of cows and, consequently, gain and/or loss of preweaning daily gains of calves.

Season of birth constituted a significant (P<.01) source of variation of calves. As was reported for the first experiment, calves born in the first half of the calving season gained faster 71 g/d more) than calves born in the second half of the same period, immediately before the period of long rains. This result is in agreement with all the studies reviewed previously and conducted in the tropics (Hernandez, 1976; Ocanto et al., 1981; Martinez and Hernandez, 1983).

McElhenney et al., (1985-1986) and Bolton et al., (1986) in North America reported greater preweaning gains for winter-and-spring born calves than for summer-and-fall born calves.

Sex differences were significant (P<.01), which is in agreement with all studies previously cited. Males (700 g/d) gained 65 g more than females. This result is in agreement with all studies reviewed in the literature and also with the results of the previous experiment with pure BON cattle (Chapter III).

Age of dam significantly (P<.01) affected the preweaning gains of calves. Peak of production (686 g/d) was reached by cows between 4.5 to 9 year old. Cows older than 9 years began declining their production without differing from the highest producing cows. Cows under 3.5 years of age produced the lower preweaing gains (630 kg/d). These results were consistent with those reported in Chapter III.

Sires within breed were a significant (P<.01) source of variation. The equation for individual sires nested within breed was absorbed for the model so their differences cannot be presented. The interest of the present study was not to determine individual sires effects so sires were absorbed in the model.

Sire breed effect did not have significant effect (P>.10) in the preweaning gains of calves (Table XXXV). This result is in disagreement with most studies reviewed. Hernandez, (1981), working with Charolais, BON and Zebu bulls mated to cows of the same breeds used in this study found significant differences due to breed of sire. A possible explanation for this result could be a certain degree of confounding since all breed of sires were not present in all years. The largest difference between sire breeds was 17 g/d between Charolais sires (677 g/d) which ranked first and BON sires (640 g/d) which were last. Nevertheless, this study is in accordance with the general agreement of researchers in that Charolais bulls produced the fastest growing progeny and Criollo bulls the slowest growing progeny.

The analysis of variance (Table XXXIII) showed that the effect of breed of dam was an important source of variation on the average daily gain from birth to weaning (P<.01). All the studies reviewed previously reported significant effect of breed of dam on preweaning gain of calves. Crossbred (F1) cows produced calves with the fastest rate of growth (727 g/d), surpassing Zebu and BON cows by 64 and 114 g/d, respectively. Hernandez (1981) reported the same rank order crossbred, Zebu and finally BON cows with 52 and 98 g/d advantage of crossbred over purebred cows.

In general, in tropical studies Criollo dams ranked last in preweaning daily gain, crossbred cows first and Zebu cows intermediate. In temperate areas of USA among Bos Tauros breeds, Angus cows have better maternal ability than Hereford cows. Studies in Texas (McElhenney 1985, 1986) and Oklahoma (Bolton et al., 1986) have demonstrated that Zebu cows are very good mothers and even have surpassed the maternal ability of Angus cows.

BOS x BOD interaction was a significant ($P<.01$) source of variation for preweaning daily gain. This result agrees with most studies in the literature reviewed. Only one study did not report a significant interaction between breed of sire and dam.

The mating of BON cows with bulls from the same breed produced the slowest growing calves (557 g/d), while the mating of crossbred cows with any of the sire breeds used produced the fastest growing calves. The largest value was found when crossbred cows were retrocrossed with BON bulls. However, this result may be biased since this type of mating was not present in all years and the number of observations were very low. Charolais bulls sired the most rapid growing calves when combined either with crossbred or Zebu cows. BON bulls with purebred cows (BON and Zebu) sired the slowest growing progeny with values far below average when mated to BON and close to the average when mated to Zebu. Charolais bulls combined with Zebu cows produced faster growing progeny than when combined with BON cows. Charolais with BON cows produced slower growing calves than Santa Gertrudis x BON. Charolais and BON are more closely related than

Santa Gertrudis and BON. Both combinations, however, were below average indicating that lower hybrid vigor was developed for BON cattle in combination with other breeds other than Zebu.

Weaning weight

Least square means and standard errors of means for weaning weight for the different non-genetic fixed effects appear in Table XXXIV. Mean weaning weight for the study was 188.6 kg. Year differences constituted a highly significant ($P<.01$) source of variation, which is consistent with the results in Chapter III.

Season of calf birth, in agreement with the results in Chapter III, also constituted a significant ($P<.01$) source of variation. Calves born at the beginning of the dry season were 16.2 kg heavier than calves born at the end of the season. According to this result and with the findings in the first experiment it seems that the most important factor for a good performance of calves are dry conditions just after birth when they depend on the milking ability of the cows combined with higher precipitation before weaning when they have started grazing. Calves born in the second part of the calving season close to the period of heavy rainfall seem to be more affected by the stressful conditions of the beginning of the long rains or by the decline in the quality of forages by the time they are weaned. Laredo and Martinez (1984) found that the crude protein content of the puntero grass (*Hyparrhenia rufa*) declines from August to December (weaning season) compared to the protein content during the first wet season (April-July). Calves weaned late (born in the second part of the calving season) are presumably more affected by this factor.

Male calves in this study were 17.8 kg heavier than females (P<.01). This result agrees with all studies in the literature reviewed. The difference between sexes is close to the average estimates of the previously cited studies which was 18.1 kg.

Age of dam was significant (P<.01) factor of variation in the weaning weight of calves (Table XXXIV). As has been pointed out in almost all studies, weaning weight increases with age of cows. The peak of production was reached in the group of cows between 4.5 to 9.0 year old (mature cows). Lowest production was found in first calf cows; older cows (more than 9 years old) decrease their production compared with the other groups. This result is in agreement with the findings described in Chapter III with purebred BON cattle and with most results in the literature previously cited. The maximum differences found were 15.43 kg between young cows (less than 3.5 years old) and mature cows (4.5-9.0 year old cows).

The findings of this and the previous study are in disagreement with results reported by Hernandez (1970). He found that peak of production was reached later, between 8 to 10 years of age of Romo cows. Martinez and Hernandez (1983) studying BON cattle performance from 1973 to 1976 found that first calving cows had the highest level of production in weaning traits (preweaning gains and weaning weight).

Sire within breed was significant (P<.01). Hernandez (1970 and 1976) found significant differences among sires within breeds. Differences within breeds indicate the possibility of increasing weaning weight through selection.

Breed of sire surprisingly did not have a significant effect on weaning weight of calves. Charolais sires have been associated with the largest weaning weights in tropical and temperate studies, and Criollo bulls with the lowest weaning weights. Maximum difference in this study was found between these two breeds of sires (6.7 kg) which is far below the average (16.5 kg) estimates reviewed previously and close to and above the low range (3.0 kg) of those estimates. This result does not agree with previous results from the same breeds which was 20.2 kg ($P<.01$), (Hernandez, 1981).

Breed of dam effect on weaning weight was a significant ($P<.01$) source of variation. This result is in agreement with most previously reported studies. Weaning weight reflects both rate of growth and birth weight. The pattern of weaning weight least-squares means by cow bred is similar to that of preweaning gains. Crossbred (F1) BON x Zebu and Zebu x BON cows had the heaviest calves at weaning with 18.0 and 26.8 kg over Zebu and BON cows, respectively.

In the tropics, crossbred (F1) cows consistently produced the heaviest calves and Criollo dams the lightest with Zebu being intermediate. The largest difference found in this study is above the average estimate (19.6 kg) previously cited in the literature reviewed.

The effect of interaction of breed of sire x breed of dam on weaning weight was highly significant ($P<.01$). This result is in agreement with many of the experiments previously cited in the literature.

The greatest (208.27 kg) and lowest (162.19 kg) weaning weights were obtained for combination involving BON bulls with crossbred and

BON cows, respectively. This unusual result may be biased for the small number of crossbred (F1) cows used to obtain the first value. This result is then partially in disagreement with the findings in the literature of tropics and even in temperate areas which agree that Charolais sires are first in producing heavy calves at weaning age. Criollo bulls are reported as siring the lightest calves, which is in agreement with this experiment and previously cited reports.

Progeny from Charolais bulls with Zebu and crossbred cows were superior and more uniform in weaning weight than progeny out of Santa Gertrudis bulls in the same type of cows; progeny of either of these two bulls in BON cows is very similar in weaning weight.

Weaning Conformation Score

Weaning conformation score for the study was 54.4 units, (Table XXXIV). This value is 4.77 units above the value observed within the pure BON herd. This seems logical since different breeds or crosses which have been selected (Charolais, Santa Gertrudis) for beef production were used in this experiment.

In almost all aspects considered, weaning score parallel the results of weaning weight. Weaning score as well as weaning weight were significantly affected for season of calf birth, sex of calf, age of dam, sire within breed, breed of dam and the interaction of sire breed x dam breed. Exceptions were year of calf birth, which approached significance in weaning score but was significant for weaning weight, and sire breed, which had significant ($P<.01$) effect on score but not in weaning weight.

These results are in agreement with most studies in that, the same sources of variation that affect weaning weight affect weaning score (Williamson and Humes, 1985; Peacock et al., 1978, 1981).

The highest score, 57.1 was found in 1980 and the lowest, 51.15 in 1977. They, however, do not correspond to the highest and lowest weaning weights and these differences may have resulted because different persons assigned the scores in each year and thus, different judgement exists when making a subjective visual appraisal for conformation of calves.

Calves born in the first half of the calving season were assigned higher scores. Difference ($P<.01$) was 1.6 units. This result is not in agreement with the only report found which considered this factor (Bolton et al., 1986).

Males received higher (55.34) scores than females (53.40). Many studies reviewed previously reported significant effect of sex of calf in the conformation or muscling score of calves. Thrift et al. (1986), did not find an effect of calf sex on conformation score at weaning and Frahm and Marshall (1985) found that sex of calf only approach significance ($P<0.07$).

Age of dam was a significant ($P<.05$) source of variation for the conformation score of calves. This result parallel the weaning weight and thus, calves from the youngest cows received the lowest scores (52.67) and mature cows, between 4.5 to 9.0 year old the highest (55.17). This result is in accordance with the findings of most studies in the review of literature. Peacock et al. (1981) reported the same trend. Frahm and Marshall (1985) did not find effect of age of dam on the conformation score of calves.

Sire within breed of sire was a significant (P<.05) source of variation. The breed of sire effect was also a significant source of variation (P<.01). The rank of sire breed for this trait is not parallel to the rank for weaning weight. Zebu sired calves received the highest scores (56.12) and BON sired calves the lowest (51.7). This result is not in agreement with most studies previously reviewed which showed that Charolais sired calves always are significantly superior in this trait than Zebu sired calves. However, no study which reported those results was conducted in tropical environments so even though differences between Zebu and Charolais were not statistical significant, the result of this study could indicate that higher vigor exist in Zebu calves than in Charolais-sired calves, under adverse or more difficult conditions.

Dam breed effect was also a signifiant (P<.01) source of variation. Calves from crossbred F1 cows received the highest scores (56.5), progeny from BON cows the lowest (51.7) and from Zebu cows being intermediate (54.9). These results are in agreement with all studies reviewed previously. Koger et al. (1975) reported 14% of superiority for this trait in calves out of Brahman-Shorthorn cows.

Sire breed x dam breed interaction was a highly significant source of variation (P<.01) for weaning conformation score. In general, all crossbred groups received higher conformation score than the two groups of pure bred (BON and Zebu) animals (Table XXXV). This result is in agreement with all studies reported previously. Reynolds et al. (1982) reported high scores for all groups of crossbred calves than for Angus calves. Zebu sired calves in crossbred F1 cows received the highest conformation scores (60.45) and BON pure calves the lowest (47.9).

TABLE XXXIV

LEAST SQUARES MEANS ± STANDARD ERROR FOR PREWEANING TRAITS BY AGE OF DAM, SEX OF CALF, YEAR AND SEASON OF CALF BIRTH

		Calf Traits			
	No. of Calves	Birth Weight Kg.	Average Daily Gain g.	Weaning Weight Kg.	Weaning Conformation Score
Overall Mean	507	28.5 ± 0.61	567 ± 0.012	188.6 ± 3.22	54.4 ± 0.69
Age of Dam					
Under 3.5	58	27.4 ± 0.77 b	630 ± 0.017 b	178.5 ± 4.25 b	52.7 ± 0.96 b
3.5-4.5	50	28.3 ± 0.82 ab	680 ± 0.018 a	191.3 ± 4.57 a	54.6 ± 1.02 ab
4.5-9.0	276	29.2 ± 0.62 a	586 ± 0.013 a	193.9 ± 3.31 a	55.2 ± 0.71 a
Over 9.0	124	29.0 ± 0.38 ab	674 ± 0.014 a	190.9 ± 3.69 a	55.0 ± 0.80 a
Sex of Calf					
Males	261	29.3 ± 0.63 a	700 ± 0.013 a	197.3 ± 3.39 a	55.3 ± 0.73 a
Females	247	27.6 ± 0.64 b	635 ± 0.013 b	179.9 ± 3.40 b	53.4 ± 0.73 b
Season[c]					
1	318	28.2 ± 0.63 a	703 ± 0.013 a	197.0 ± 3.33 a	55.2 ± 0.73 a
2	190	28.7 ± 0.66 b	632 ± 0.014 b	180.3 ± 3.56 b	53.6 ± 0.76 b
Year					
1977	69	28.5 ± 1.14	728 ± 0.026	203.2 ± 6.57	51.2 ± 2.05
1978	108	29.5 ± 0.94	626 ± 0.021	179.6 ± 5.32	53.7 ± 1.18
1979	76	27.9 ± 0.88	629 ± 0.019	179.1 ± 4.89	55.3 ± 1.08
1980	105	29.7 ± 0.84	679 ± 0.019	192.6 ± 4.71	57.1 ± 1.04
1981	68	30.2 ± 0.92	633 ± 0.020	182.1 ± 5.13	55.6 ± 1.14
1982	56	26.8 ± 1.01	652 ± 0.022	183.2 ± 5.65	55.2 ± 1.25
1983	26	26.7 ± 1.78	725 ± 0.040	200.7 ±10.07	52.5 ± 2.25

ab Means in the same column within same classification not sharing a common supercript differ (P<0.05).

c 1 = First part of calving season
 2 = Second part of calving season

TABLE XXXV

LEAST SQUARES MEANS ± STANDARD ERRORS OF MEANS FOR PREWEANING TRAITS BY BREEDS OF SIRE AND DAM, AND BY BREED OF SIRE x BREED OF DAM INTERACTION

	No. Calves Born	Birth Weight Kg	Average Daily Gain Kg.	Weaning Weight Kg.	Weaning Conformation Score
BREED OF SIRE					
BON (B)	218	27.45 ± 1.10 b	0.640 ± 0.022	185.77 ± 5.72	51.77 ± 1.17 b
Zebu (Z)	167	29.76 ± 0.90 a	0.658 ± 0.018	187.76 ± 4.77	56.12 ± 1.03 a
Charolais (C)	64	30.08 ± 1.23 a	0.677 ± 0.025	192.47 ± 6.53	55.84 ± 1.34 a
Sta. Gertrudis (SG)	59	26.57 ± 1.57 b	0.675 ± 0.031	188.56 ± 8.28	53.75 ± 1.64 b
BREED OF DAM					
BON	237	29.65 ± 0.69 a	0.613 ± 0.015 c	176.79 ± 3.78 b	51.65 ± 0.83 b
BREED OF SIRE x BREED OF DAM					
B x B	154	28.45 ± 0.78	0.557 ± 0.017	162.19 ± 4.31	47.90 ± 0.96
B x Z	59	26.98 ± 0.88	0.667 ± 0.019	186.85 ± 4.87	54.57 ± 1.07
B x BZ or ZB	5	27.13 ± 2.58	0.754 ± 0.055	208.27 ± 13.96	52.83 ± 2.95
Z x B	47	33.68 ± 0.92	0.655 ± 0.020	190.79 ± 5.06	55.37 ± 1.15
Z x Z	110	25.71 ± 0.65	0.602 ± 0.014	170.19 ± 3.58	52.64 ± 0.82
Z x ZB or ZB	10	29.91 ± 1.82	0.718 ± 0.039	202.33 ± 9.92	60.35 ± 2.34
C x B	25	30.33 ± 1.27	0.604 ± 0.029	175.71 ± 7.44	52.77 ± 1.63
C x Z	16	28.46 ± 1.53	0.718 ± 0.033	200.47 ± 8.39	57.95 ± 1.73
C x BZ or ZB	23	31.46 ± 1.32	0.709 ± 0.028	201.24 ± 7.16	56.80 ± 1.48
SG x B	11	26.33 ± 2.05	0.634 ± 0.042	178.49 ± 10.99	50.58 ± 2.24
SG x Z	17	24.78 ± 1.72	0.666 ± 0.036	184.69 ± 9.20	54.74 ± 1.88
SG x BZ or ZB	31	28.61 ± 1.36	0.725 ± 0.028	202.51 ± 7.26	55.92 ± 1.49

* Means in the same column not sharing a common superscript differ (P<.05)

Charolais sires combinations received higher scores than Santa Gertrudis sire combinations and this result seems to be logical since Charolais has been selected for longer time for beef production than Santa Gertrudis. Zebu cows combined better than BON dams with Charolais and Santa Gertrudis bulls.

Average Daily Gain from Weaning to 16 Months

Least-squares means and standard errors of means for the different non-genetic effects studied appear in Table XXXVI. Mean average daily gain after weaning for the study was 208 g/d.

As was pointed out before (Chapter III), the variable environmental conditions throughout years and their influence on available food and disease problems was cause of the significant ($P<.01$) differences on postweaning gain of calves. Other factors may have been producing year variation. Among those possible factors we can mention confounding effects between years due to the presence or absence of certain crosses; number of animals per hectare, disease problems, etc.

Season of birth was a significant ($P<.01$) source of variation for postweaning daily gains. This result agrees with most studies conducted in tropical areas and reviewed previously. Opposite to the effect on preweaning traits, calves born during the second part of the calving season gained faster than calves born during the first part of the calving season. Similar results were reported in the first experiment with pure BON cattle. The above findings mean that favorable conditions for weaning of calves do not correspond to the same conditions at 16 months of age.

Males gained more per day but this difference was not statistically significant (P>.10). This result is not in agreement with most studies in the literature. Different management practices between males and females (females were placed in less abrupt grazing lands) may have contributed to the low difference between sexes which have been reported to be higher either in feedlot or pasture experiments. Hernandez (1970) reported differences in favor of males of 291 g/d in pasture experiments. Preston and Willis (1975) reported an average for postweaning daily gain from several studies of 145 g/d in favor of males (bulls and steers) over heifers.

Age of dam was not a significant (P>.10) source of variation for postweaning daily gain. This result is not in agreement with studies in the tropics by Plasse et al., (1981) and Verde et al., (1981) and in agreement with other studies also in the tropics by Hernandez (1976) and Hoogestijn et al. (1981) and with the results of the previous experiment with BON cattle. Despite the non-significant effect found for age of dam, it is important to see the tendency for calves that gained faster before weaning being the slowest growing after weaning. The same tendency was observed in the experiment with BON cattle. A possible explanation for this phenomenon is that calves consuming more milk are less forced to graze and, consequently, they are more affected by the stress of weaning or that there exists a compensatory growth for calves out of low producing cows.

According to Petty and Cartwright (1966), the maternal effect on postweaning daily gain of the progeny diminishes with the postweaning months until it disappears.

Least-squares means for the genetic causes of variation of postweaning appear in Table XXXVII. Sire within breed was significant (P<.05) for postweaning gain. The solution for the individual sire breed effect was absorbed by the model so this effect will not be discussed. Effect of sire breed on postweaning daily gains was not significant (P>.10). Hernandez (1981) found highly significant differences for postweaning daily gain among progeny of Zebu, BON and Charolais sires, which ranked in that order. The rank of the same sire breeds in this study only partially coincide since Zebu bulls were still above Charolais and BON but Charolais, in this case, was above BON. Santa Gertrudis ranked first in the present study. Their progeny gained 212 g/d. Maximum differences betwen first and last ranked sires were only of 8 g/d, which are far below the average estimated of several studies (Hernandez, 1976, 1981; Gregory et al., 1985; Dhuyvetter et al., 1985).

Differences in average daily gain after weaning among breed of dam groups were highly significant (P<.01). This result is in agreement with most of the previously cited reports. Calves out of purebred dams gained 226 g/d, 54 g/d above the average of crossbred (F1) BON x Zebu or Zebu x BON cows. In general, low postweaning gains were obtained as was stated above when crossbred cows were mated to any of the four types of sire breeds used in this study. This seems logical because the large animal, (a calf receiving lots of milk) suffers more the drastic change in nutrition present after finishing the mother effect.

Hernandez (1976), found that gain after weaning on pasture for calves out of purebred Zebu and/or Romo cows was far above the average daily gains of calves out of crossbred (F1) dams in combination with Charolais, Romo or Zebu bulls. Hernandez (1981) working with cattle from the same experimental farm, found the same pattern and the same rank of cow groups.

Differences associated with the sire breed x dam breed interaction on postweaning daily gains were highly significant (P<.01). This effect is in agreement with the previously cited reports in the literature.

The lowest postweaning gains (146 g/d) were obtained with the backcross between Zebu bulls and crossbred (F1) cows. The best and more uniform combinations in this study, all above or very close to the overall mean, were all the first crosses out of BON or Zebu cows with all the four types of sire breeds used.

16 Month Weight

Least squares means of the 16-month weight for the non-genetic factors appear in Table XXXVI. The overall least squares mean for the study was 235.9 kg.

Year of calf birth significantly (P<.01) affected the 16-month weight of calves. Results in this study agree with most of the previously reviewed. Maximum differences between poorest and best years (1977-1981) were 21.3 kg. Only one study in the literature reviewed (Gregory et al., 1985) did not report year effect on postweaning weight of cattle.

The effect of season of birth on the 16-month weight of calves was not significant (P<.10). This result does not agree with most studies in the literature. However, this result is in accordance with the previously cited results in Chapter III for the pure herd BON. The most reasonable explanation for this result is the negative environmental correlation between weaning traits and postweaning yearling gain. Good environmental conditions during the suckling time correspond to opposite environmental conditions after weaning resulting in a compensation effect of season of birth and season of final 16-month weight, which equalize or reduce differences found at weaning time. Calves born at the beginning of calving season, scarcely outweighed calves born in the second half of the calving season by 0.57 kg.

Sex of calf was a highly significant (P<.01) source of variation. Males were 17.4 kg heavier than females. Results of this study agree with all studies previously reviewed. The difference between sexes in this study are very close to the average estimate differences (15.4 kg) given by Preston and Willis (1975), and are above the differences (9.0 kg) reported for African cattle by Gregory et al. (1985) and below the average reported for male and female crosses of Romo, Brahman and Charolais cattle (33.8 kg) given by Hernandez (1976).

Age of dam effect was highly significant (P<.01). This result is not in agreement with most results in the previously reviewed literature. Only one report in tropical environments (Plasse, 1981) reported significant effect on postweaning daily gain. Postweaning daily gains were in opposite direction as preweaning gains; however, final 16-month weight followed the same pattern as did weaning weight among cow age groups. The differences among cow age groups were almost of the same magnitude resulting in significant differences among them.

In Table XXXVII appears the least-squares means for the different genetic effects of 16-month weight. Sire within breed was a significant (P<.01) factor of variation for yearling weight, meaning that selection within breed would result in improvement of this trait. Hernandez (1976) found differences among Zebu sires but not among Charolais or Romo sires. In 1970, the same author did not find differences among Romo sires.

Breed of sire effect was not significant (P>.10). This result is not in agreement with most studies in the literature reviewed.

Hernandez (1981) compared, from 1971 to 1976, the performance of Charolais, Zebu and Criollo bulls, including BON, and reported significant differences among sire breeds. At El Nus, he found that Zebu bulls ranked first with 278.3 kg with 0.9 and 17.0 kg more than Charolais and BON progenies.

Maximum differences found in this study were 6.46 kg between Charolais (239.02 kg) and BON (232.56 kg).

Since the genetic potential of Charolais sires is quite superior to that of Criollo bulls, the non-significant difference found in this study between BON and Charolais bulls could be the reflection of the better adaptation to the tropics of the Criollo breeds as compared to Charolais; or a certain degree of confounding between the presence or absence of some breed combinations during certain years. Sire breed rank in this study was Charolais, Santa Gertrudis, Zebu and BON.

Dam breed effect was significant (P<.01). This result agrees with most studies reviewed previously. Progeny from crossbred (F1) cows ranked first (242.4 kg) with Zebu cows being second (238.8 kg) and BON cows last (226.7 kg). Even though postweaning gains were opposite to this rank, the rank at 16-months of age was the same found at weaning time since the postweaning gains could not offset the differences at weaning time. This result is in agreement with a previous study (Hernandez, 1981) with the same group of cows in the same experimental farm when mated to Charolais, Zebu and BON bulls.

Sire breed by dam breed interaction was highly significant (P<.01) source of variation. This result is in agreement with most of the studies reviewed previously which reported significant effects of this interaction either on 18 month weight or slaughter weight.

With the exception of Zebu x BON calves (251.1 kg), all progeny combinations where BON cows were involved were below the average indicating that level of heterosis diminishes when crosses are done between less divergent breeds (Charolais, BON and Santa Gertrudis). All combinations involving Zebu and/or crossbred (F1) cows were above average. Charolais and Santa Gertrudis sire combinations with cow group other than BON dams were above average with the largest 16-month weight when Charolais bulls were mated to Zebu cows. The following heaviest group at 16 month of age was the product of crossing Zebu bulls with BON cows. These results are confirming the general knowledge that largest level of heterosis are found crossing divergent breeds or species, Bos taurus, (BON, Charolais) and Bos Indicus

(Zebu). Santa Gertrudis crosses with crossbred (F1) and Zebu dams were intermediate and above and close to the average.

Yearling Conformation Score

Yearling conformation score for the study was 55.1 units (Table XXXVI). This value is 4.4 units above the value observed within the pure BON herd. This result seems to be logical since different breeds or crosses selected for beef production were used in this experiment.

As well as weaning score parallel weaning weight yearling score parallel yearling weight in that almost all sources of variation which affected yearling weight affected yearling score (Table XXXIII).

Year of calf birth was a significant ($P<.01$) source of variation. This result is in agreement with the results reported for the purebred BON in Chapter III. Since not all mating groups were present in all years, and since different persons assign the subjective visual appraisal of the conformation of animals, bias in this measures may exist.

Season of birth in agreement with the results discussed in Chapter III did not affect the yearling score of calves. No other study was found which reported such effect for comparison.

Sex of calf significantly ($P<.01$) influenced the 16 month score of calves. Males (55.8) surpassed females by 1.3 units. No study was found which reported sex differences for this trait at yearling age.

Age of dam did not have effect on the 16-month weight of calves. No study in the literature reviewed was found to compare with these findings. However, it is important to observe that the yearling score paralleled the yearling weights when considered by cow age groups. Progeny from young cows received the lowest scores (54.6) and cows between 4.5 to 9.0 years, the highest (56.1).

Least-squares means for yearling conformation score for the genetic factors studied appear in Table XXXVII. The effect of breed of sire was not significant. This result is not in agreement with the findings of Dhuyvetter et al. (1985) who found that Charolais sired progeny surpassed Limousin-sired progeny for this trait. Nevertheless, the findings in this study are partially in agreement with the above study since Charolais sired progeny in this study ranked first (56.8), and BON were last (53.3). Breed of dam significantly (P<.01) influenced the yearling conformation score of calves. Progeny from Brahman cows ranked first, BON cows' progeny were last with crossbred (F1) progeny being intermediate.

Sire breed x dam breed interaction was also a significant (P<.01) source of variation for yearling conformation score.

With the exceptions of Charolais-BON and Santa Gertrudis-BON calves, all crossbred calves received higher scores than pure-bred Zebu and/or BON calves.

Charolais crosses received higher scores than Santa Gertrudis crosses. Zebu crosses either by paternal or maternal line received higher scores than BON crosses.

TABLE XXXVI

LEAST SQUARES MEANS ± STANDARD ERRORS FOR POSTWEANING TRAITS BY AGE OF DAM, SEX OF CALF, YEAR AND SEASON OF CALF BIRTH

	No. of Calves	Average Daily Gain g/d	Yearling Weight Kg	Yearling Conformation Score
Overall Mean	432	208 ± 0.009	235.9 ± 3.98	55.1 ± 0.61
Age of Dam				
Under 3.5	49	212 ± 0.013	226.9 ± 5.05 b	54.6 ± 0.85
3.5-4.5	42	208 ± 0.014	237.9 ± 5.39 ab	54.6 ± 0.92
4.5-9.0	234	199 ± 0.010	239.5 ± 4.12 a	56.1 ± 0.65
Over 9.0	107	211 ± 0.011	239.4 ± 4.49 a	55.2 ± 0.73
Sex				
Males	224	212 ± 0.010	245.2 ± 4.11 a	55.8 ± 0.64 a
Females	208	203 ± 0.010	226.6 ± 4.19 b	54.5 ± 0.66 b
Season[c]				
1	267	177 ± 0.010 b	236.2 ± 4.10	54.9 ± 0.64
2	161	238 ± 0.010 a	235.6 ± 4.32	55.4 ± 0.69
Year				
1977	59	180 ± 0.019	245.3 ± 7.11	59.8 ± 1.29
1978	92	234 ± 0.015	234.7 ± 5.67	55.5 ± 0.99
1979	68	209 ± 0.014	229.4 ± 5.33	55.4 ± 0.92
1980	98	209 ± 0.014	242.2 ± 5.31	52.9 ± 0.90
1981	62	173 ± 0.016	223.9 ± 5.95	53.1 ± 1.03
1982	53	242 ± 0.018	239.9 ± 6.84	53.9 ± 1.21

ab Means in the same colum within same classification not sharing a common superscript differ ($P<0.05$).

c 1 = First part of calving season
2 = Second part of calving season

TABLE XXXVII

LEAST-SQUARES MEANS ± ERRORS FOR POSTWEANING TRAITS BY BREED OF SIRE, BREED OF DAM, AND BY BREED OF SIRE X BREED OF DAM SUBCLASSES

	No. of Calves	Average Daily Gain g/d	Yearling Weight Kg	Yearling Conformation Score
Breed of Sire				
BON (B)	183	204 ± 0.020	232.6 ± 8.19	53.3 ± 1.29 b
Zebu (Z)	143	208 ± 0.014	235.5 ± 6.14	55.5 ± 0.94 a
Charolais (C)	53	207 ± 0.018	239.0 ± 7.69	56.8 ± 1.17 a
Sta. Gertrudis (SG)	53	212 ± 0.022	236.7 ± 9.77	54.9 ± 1.44 ab
Breed of Dam				
BON (B)	210	220 ± 0.011 a	226.7 ± 4.42 b	53.4 ± 0.71 b
Zebu (Z)	166	231 ± 0.011 a	238.8 ± 4.38 a	56.3 ± 0.70 a
B x Z or Z x B	56	172 ± 0.016 b	242.4 ± 5.97 a	55.7 ± 1.04 ab
Breed of Sire x Breed of Dam				
B x B	135	187 ± 0.012	205.7 ± 4.76	49.7 ± 0.82
B x Z	45	242 ± 0.015	243.2 ± 5.63	55.2 ± 0.97
B x BZ or ZB	3	183 ± 0.049	248.8 ± 19.09	54.9 ± 3.26
Z x B	45	264 ± 0.014	251.1 ± 5.61	57.3 ± 0.96
Z x Z	90	215 ± 0.011	219.3 ± 4.18	54.7 ± 0.70
Z x BZ or ZB	8	146 ± 0.031	236.0 ± 12.47	54.4 ± 2.08
C x B	19	206 ± 0.022	220.7 ± 8.76	53.7 ± 1.45
C x Z	14	244 ± 0.024	257.1 ± 9.65	58.1 ± 1.56
C x BZ or ZB	20	170 ± 0.021	239.3 ± 8.39	58.7 ± 1.43
SG x B	11	224 ± 0.030	229.2 ± 12.39	52.9 ± 1.95
SG x Z	17	223 ± 0.025	235.5 ± 10.40	57.1 ± 1.64
SG x BZ or ZB	25	189 ± 0.022	245.4 ± 9.14	54.7 ± 1.44

ab Means in the same column within same classification not sharing a common superscript differ ($P<.05$)

Linear Comparisons

Heterosis

Individual and maternal heterosis for calves from BON, Zebu and crossbred (F1) cows appears in Tables XXXVIII through XLI. Individual heterosis values for all 7 traits studied were highly significant (P<.01) and all of them were higher than the average estimates reviewed previously, which were: birth weight, 6.7%; preweaning gain, 11.0%; weaning weight 8.5%; weaning conformation score, 8.0%; postweaning gain 16.1% and yearling weight 11.0%.

Heterosis values in percentages in this study ranged from 7.78% for yearling conformation score to 25.87% for postweaning gain. The heterosis values found are very similar to the heterosis for birth weight (4.7%), preweaning gain (14.7%), weaning weight (13.1%), postweaning gain (22.7%), and 18 month weight (16.7%) reported by Hernandez (1976) for crosses between Romo and Zebu, in Colombia. The results of this study confirm the conclusion of Stonaker (1975) who stated that crosses between Zebu and Criollo or Zebu and Charolais breeds have usually shown a higher level of heterosis in tropical Latin American than is observed in crosses between European breeds in temperate climates. Long (1980) reported higher levels of heterosis when Zebu cattle are involved in crosses with European or British breeds; however, none of the values reported by Long are greater than the values in this study.

Heterosis values for the five growth traits in this study are within the range or above the average estimates reviewed by Plasse (1983) for tropical Latin American studies.

Breed Maternal Effects

Reciprocal cross differences (BONZ-ZBON) reflect differences in breed maternal ability between BON and Zebu (Z) breeds. Significant (P<.01) reciprocal cross differences for birth weight in favor of calves with BON dams are consistent with the results of Hernandez (1976) and Munos and Martin (1969). Criollo dams mated to Zebu bulls have higher birth weights than Zebu cows mated to Criollo bulls. Only preweaning daily gain differences which did not differ (P>.10) were in favor of calves out of Zebu cows. BON-Z calves gained faster (.012 kg/d) than Z-BON calves. Hernandez (1976) reported 0.025 kg/d in favor of calves with Zebu cows but those differences were not significant.

Weaning weight, weaning condition score and postweaning breed maternal effects were not significant but all of them in favor of calves from BON cows. Even though postweaning growth differences were not significant, they were in the same direction as those studied by Hernandez (1976) and Munoz and Martin (1969) who reported advantage of calves with Criollo dams over calves with Zebu dams. The weaning weight results are of similar magnitude as those reported by Hernandez (1976) but in different direction. He gave advantage of calves from Zebu cows and in this study in agreement with Munos and Martin (1969) the advantage was in favor of calves from BON cows. Conformation scores were also in favor of calves from BON cows. No studies that considered those traits were found to compare with.

Breed of Sire Differences

Breed of sire differences reflect one-half of the difference in direct effects between BON and Zebu breeds. The Zebu breed was superior for all traits but statistical differences were only found in weaning score. The Zebu breed was 2.8 units above the BON breed.

Differences Between Straightbreds

Differences between straightbreds include differences between the BON and Zebu breeds in breed maternal and breed direct effects combined. The greater birth weight ($P<.01$) for BON is in agreement with all studies in the tropics which have reported highest birth weight for calves from Criollo cows. In all growth traits ($P>.10$) and conformation traits ($P<.01$), Zebu was superior to BON and this result is in agreement with most studies in the tropics which reported superiority of Zebu over Criollo breeds in growth traits. Conformation score reports were not found in tropical studies.

Hybrid Vigor Over Better Straightbreds

In order for heterosis to be useful, it must exceed the better parental breed. With the only exception of yearling conformation score, all other traits reciprocals had significant advantage at one or five percent probability than either straightbred. Only for birth weight the comparison was made based on the BON breed, since it is the only characteristic that BON surpasses Zebu. The percentage of hybrid vigor for growing traits over the better parental breed (Zebu) were all greater than the estimate values given by Hernandez (1976) in Colombia for crosses between Romo and Zebu, which were: birth weight, 5.7; preweaning gain, 3.4; weaning weight, 3.7; postweaning gain, 9.9; and for 18 months weight, 6.6 percent.

Plasse (1983) summarized heterosis values over Zebu for growing traits in crosses between Criollo and Zebu (Zebu). The average values estimated were: birth weight, 12; preweaning gain, 6; weaning weight, 7; postweaning daily gain, 22; and 12 percent for postweaning weight. As can be seen with the only exception of postweaning gain (17.67 vs. 22%), all percentages of superiority of F1 BON x Zebu over Zebu were greater than the average estimates given by Plasse.

Superiority percentage of F1 BON x Zebu over Zebu in this study, are generally over or of the same magnitude as those previously reported for the same breeds by Hernandez (1981), which were: preweaning gain, 5.2; weaning weight, 6.4; postweaning gain, 20.4; and yearling weight 9.4 percent.

Individual heterosis values and the superiority or hybrid vigor of F1 BON x Zebu over Zebu were of high magnitude for postweaning traits. This is very important since the more critical period in beef cattle production on pasture in the tropics is after weaning.

Reciprocal vs. Backcrosses

Reciprocals surpass the backcrosses in birth weight and weaning traits, which is a reflection of the maternal ability of the crossbred F1 BON x Zebu cows. After weaning, reciprocals surpass backcrosses indicating that the loss of hybrid vigor in the backcross is manifested when the maternal effect is complete.

None of the differences were significant which may be very important in planning crossbreeding programs in the tropics where specialized beef breeds do not prosper and thus, cannot be used successfully.

Two-way Crosses vs. Three-way Crosses

The average of the two types of three way crosses (SG(B x Z)) and (Ch(B x Z)), surpass the average of the two-way crosses (B x Z, Z x B, Ch x B, Ch x Z, SG x B, and SG x Z), for all traits except for postweaning gains, which was significant at 1 percent probability level. This result is in agreement with the findings of Hernandez (1976), who worked with Romo-Brahman and Charolais crosses.

Significant differences ($P<.01$) in favor of three-way crosses existed for preweaning gain and weaning weight. Differences in birth weight and weaning condition score were not significant ($P>.10$). Despite the significant ($P<.01$) advantage of two-way crosses over three-way crosses in postweaning gain, these were superior at 16-month weight due to the advantage accumulated until weaning due to the better maternal ability of the crossbred cows.

Charolais vs. Santa Gertrudis Sires with Zebu Cows

This comparison is important since the most popular and common breed in Colombia is the Zebu (Zebu) breed, and since its production when mated to bulls of the same breed can be improved by exploiting its production potential through heterosis and breed complementarity. Charolais and Santa Gertrudis are also very popular in Colombia as paternal breeds.

Charolais sires were superior to Santa Gertrudis sires in all the growth and conformation traits studied when both of them were mated to Zebu cows. However, none of the differences were significant probably because most of them were associated with large standard errors.

These results seem logical since greater level of heterosis in F1 crosses are expected between the mating of divergent breeds. Santa Gertrudis, is a synthetic made up of 3/8 of Zebu and 5/8 of Shorthorn.

Charolais vs. Santa Gertrudis Sires with Crossbred (F1) Bon-Zebu Cows

Mating crossbred dams to sires of a third breed allows maximum utilization of heterotic effects and provides the opportunity to make greater use of breed complementarity. Charolais sires surpassed Santa Gertrudis sires in birth weight and in both conformation traits; however, only conformation score at 16 months of age was significant ($P<.05$). These results are in agreement with previously reviewed studies, which showed that Charolais sires, compared to other Bos taurus breeds, produce heavier calves at birth and their progeny received higher conformation score.

In preweaning and postweaning groth traits Santa Gertrudis-sired progeny were superior to Charolais-sired progeny; however, none of the differences were significant. These results indicate that the best proportion of Bos indicus for the tropics is in the neighborhood of 1/2 or slightly above. The triple cross of Charolais with crossbred (F1), BON x Zebu cows reduced that proportion to 1/4. Many studies conducted in tropical areas have indicated that more than 3/4 of Bos taurus proportion reduced adaptability to the harsh environmental conditions of the tropics.

Maternal heterosis

For all the three types of estimates of maternal heterosis (Charolais and Santa Gertrudis sires and combined), the preweaning traits gave positive values. These results are in agreement with most results in the literature (Cundiff, 1970; Franke, 1980; Koger, 1980; and Long, 1980).

None of the estimates when Charolais were used as sires were significant ($P>.10$). Preweaning and weaning weight estimates were significant when Santa Gertrudis sires were used ($P<.05$). From the pooled or combined estimates, birth weight, preweaning gain ($P<.05$) and weaning weight were significant ($P<.01$).

Postweaning daily gain for all three types of estimates was negative. The Charolais crosses and the combined Charolais-Santa Gertrudis crosses estimate were significant ($P<.05$) the Santa Gertrudis cross estimate was not significant. These results are in agreement with Olson et al. (1978) who reported negative maternal heterosis for postweaning daily gain. Even though maternal heterosis had a negative effect on postweaning daily gain, calves from crossbred BON-Zebu dams were still heavier at 16 month of age than the average 16-months weight of calves from purebred dams.

Olson et al. (1978 b), reported negative maternal heterosis for postweaning daily gain (-1.5%) but even with this negative effect, that calves from crossbred dams were heavier at slaughter age than calves from purebred dams.

Weaning score was positive and non-significant for any of the three types of estimates of maternal heterosis. The conformation score at 16 months of age was not significant and positive, negative and positive for Charolais, Santa Gertrudis and combined estimate, respectively.

The greater differences found with Santa Gertrudis crosses may indicate that, under the drastic conditions of the tropics, the Santa Gertrudis breed has better combining ability with Criollo and Zebu breeds than Charolais, probably due to the Zebu blood that the Santa Gertrudis breed possesses. However, it is important to notice that Charolais-Zebu crosses had slightly higher performance than Santa Gertrudis-Zebu crosses and this factor could be narrowing the differences between triple crosses and two-way crosses and, therefore, confounding the results.

No study in the tropics which estimate maternal heterosis were found; however, evidence of the superiority of crossbred F1 Romo-Zebu cows mated to Charolais bulls was presented by Hernandez (1976). Plasse (1981) summarizing results from Latin American tropics reported a 22% of superiority of the triple-cross, Charolais mated to Criollo-Zebu cows over Zebu (Zebu) and 29% over Criollo.

Conclusions

The higher reproductive rate of crossbred (F1) BON x Zebu and Zebu x BON cows, the greater viability and, therefore, weaning rate of their progeny, jointly with the high levels of individual heterosis of the F1 crossbred calves resulting from the BON and Zebu breeds confirm the high value of crossbreeding as a mating system to improve beef production. The large heterotic effects found in this experiment, which ranged from 7.8 for 16-month muscling conformation score to 25.9% for postweaning daily gain, are thought to be due to the extreme diversity in the development of these breeds. Zebu calves, however, appear to be better adapted to the environmental conditions imposed in this study; therefore, when the two breeds were crossed, the Zebu ability to grow was enhanced due to the increase in adaptability from the BON influence. On the other hand, BON adaptability is of greater advantage because it permits the expression of the greater Zebu growth ability.

Of great practical and useful interest was the superiority of F1 calves over the straightbred Zebu cattle; the hybrid vigor ranged from 2.9 for muscling score at 16 months of age to 17.5 for average daily gain after weaning.

Crossbred F1 females showed exceptional maternal ability. The preweaning traits showed positive and significant heterotic effects. Maternal heterosis for preweaning traits ranged from 4.4% ($P>.10$) for weaning score to 9.3% ($P<.05$) for both birth weight and average daily gain before weaning. Even though postweaning daily gain was affected adversely by maternal heterosis, calves from crossbred dams were still heavier (2.9%) at 16 months of age and received higher conformation scores (0.02%).

Even though no significant differences were found between Charolais and Santa Gertrudis sire progenies when they were mated to F1 cows, the slight advantage of Santa Gertrudis-sired calves over Charolais-sired calves indicates that the hard conditions that are present for range cattle after weaning in tropical zones are enhanced by higher proportion of Zebu genes.

Finally, the continuation of crossbreeding research programs must be followed. Other exotic breeds may be included with prudence in order to test alternative breeding programs including the Zebu and Criollo breeds for increased beef production in the tropics of Latin America.

TABLE XXXVIII

ESTIMATES OF BREED GROUP DIFFERENCES, INDIVIDUAL HETEROSIS BREED MATERNAL AND BREED DIRECT EFFECTS FOR PREWEANING TRAITS

Item	Birth Weight Kg .	SE	ADG. Birth to Weaning Kg/d	Weaning Weight Kg.	SE	Conformation Score	SE
Breed Group Means							
1/2(BB+ZZ)	26.98		0.580	166.18		50.27	
1/2(BZ+ZB)	30.33		0.661	188.82		54.97	
Heterosis Units	3.35	± 0.78**	0.082 ± 0.02**	22.64	± 4.25**	4.70	± 0.87**
Heterosis %	12.42		14.05	13.62		9.35	
Reciprocal Differences							
(BZ-ZB)	-6.70	± 1.40**	0.012 ± 0.03	-3.94	± 7.91	-0.80	± 1.96
Advantage Over Better Straightbred							
1/2[(BZ+ZB)-(BB or ZZ)]	2.08	± 0.98*	0.059 ± 0.02**	18.65	± 5.14**	-2.33	± 1.10*
Heterosis %	7.36		9.8	10.96		4.4	
Breed of Sire Differences							
[(BB+ZB)-(ZZ+ZB)]	-2.08	± 1.07	-0.016 ± 0.02	-5.96	± 5.72	-2.77	± 1.23*
Differences Between Straightbreds							
(BB-ZZ)	2.54	± 1.16*	-0.045 ± 0.02	7.97	± 6.25	-4.74	± 1.33**
Reciprocal vs. Back Crosses (BZ+ZB)-[B(ZB)+Z(BZ)]	1.81	± 2.16	-0.075 ± 0.045	-16.48	±11.49	-1.62	± 2.41
Two-way vs. Three-way Crosses							
(BZ+ZB+CB+CZ+SGB+SGZ)-SG(BZ ZB)+C(BZ ZB)	-1.61	± 1.04	-0.059 ± 0.022**	-15.71	± 5.62**	-2.03	± 1.14

C = Charoalis   SG = Santa Gertrudis   Z = Zebu (Brahman)   B = BON

* (P<.05)

** (P<.01)

TABLE XXXIX

ESTIMATES OF BREED GROUP DIFFERENCES, MATERNAL HETEROSIS AND BREED DIRECT EFFECTS FOR PREWEANING TRAITS

Item	Birth Weight Kg.	ADG. Birth to Weaning Kg/d	Weaning Weight Kg.	Conformation Score
Maternal Heterosis with Charolais Crosses				
C x (BZ or ZB) -	31.46	0.709	201.24	56.80
1/2(CB+CZ)	29.40	0.661	188.09	55.36
Heterosis Units	2.07 ± 1.58	0.048 ± 0.03	13.15 ± 8.71	1.44 ± 1.76
Heterosis %	7.04	7.26	7.02	2.60
Maternal Heterosis with Santa Gertrudis Crosses				
SG x (BZ or ZB)-	28.61	0.725	202.51	55.92
1/2(SGB + SGZ)	25.56	0.650	181.59	52.66
Heterosis Units	3.05 ± 1.54	0.075 ± 0.04*	20.93 ± 9.25*	3.26 ± 1.86
Heterosis %	11.95	11.54	11.53	6.19
Pooled Estimate of Maternal Heterosis				
1/2(CBZ + SGBZ)	30.04	0.717	201.91	56.36
1/4(CB+CZ+SGB+SGZ)	27.48	0.656	184.84	54.0
Heterosis Units	2.56 ± 1.17*	0.061 ± 0.03*	17.04 ± 6.34**	2.35 ± 1.28
Heterosis %	9.32	9.30	9.23	4.35
Charolais vs. Santa Gertrudis Sires with crossbred (F1) cows				
[C(BZ)-SG(BZ)	2.85 ± 1.81	-0.016 ± 0.04	- 1.27 ± 9.76	0.88 ± 1.96
Charolais vs. Santa Gertrudis Sires with Zebu Cows				
(CZ)-(SGZ)	3.68 ± 2.12	0.052 ± 0.045	15.79 ±11.47	3.20 ± 2.30

C = Charoalis SG = Santa Gertrudis Z = Zebu (Brahman) B = BON

* (P<.05)

** (P<.01)

TABLE XL

ESTIMATES OF BREED GROUP DIFFERENCES, INDIVIDUAL HETEROSIS BREED MATERNAL AND BREED DIRECT EFFECTS FOR POSTWEANING TRAITS

Item	ADG Wn. 16 Mo. Kg.	16 Mo. Weight Kg.	16 Mo. Conformation Score
Breed Group Means			
1/2(BB+ZZ)	0.201	212.47	52.21
1/2(BZ+ZB)	0.253	247.12	56.27
Heterosis Units	0.052 ± 0.012**	34.65 ± 4.98**	4.06 ± 0.81**
Heterosis %	25.87	16.24%	7.78
Reciprocal Differences			
(BZ-ZB)	-0.022 ± 0.022	-7.88 ± 9.28	-2.15 ± 1.51
Advantage Over Better Straightbred			
1/2[(BZ+ZB)-(BB or ZZ)]	0.038 ± 0.015*	27.85 ± 6.11**	1.58 ± 0.99
Heterosis %	17.67	12.70	2.89
Breed of Sire Differences			
[(BB+BZ)-(ZZ+ZB)]	-0.025 ± 0.016	10.74 ± 6.711	3.55 ± 1.08
Differences Between Straightbreds			
(BB-ZZ)	0.028 ± 0.018	-13.61 ± 7.30	-4.97 ± 1.18**
Reciprocal vs. Back Crosses			
(BZ+ZB)-[B(ZB)+Z(BZ)]	0.088 ± 0.037	4.70 ±15.28	1.62 ± 2.46
Two-way vs. Three-way Crosses			
(BZ+ZB+CB+CZ+SGB+SGZ)-SG(BZ ZB)+C(BZ ZB)	0.054 ± 0.017**	2.87 ± 6.87	-0.95 ± 1.13

C = Charolais SG = Santa Gertrudis Z = Zebu (Brahman) B = BON

* (P<.05)

** (P<.01)

TABLE XLI

ESTIMATES OF BREED GROUP DIFFERENCES, MATERNAL HETEROSIS AND BREED DIRECT EFFECTS FOR POSTWEANING TRAITS

Item	ADG Wn. 16 Mo. Kg .	SE	16 Mo. Weight KG.	SE	16 Mo. Conformation Score	SE
Maternal Heterosis with Charolais Crosses						
C x (BZ or ZB) -	0.170		239.26		58.68	
1/2(CB+CZ)	0.225		238.90		55.89	
Heterosis Units	-0.055	± 0.026*	0.37	±10.50	2.79	± 1.78
Heterosis %	-24.44		0.15		4.99	
Maternal Heterosis with Santa Gertrudis Crosses						
SG x (BZ or ZB)-	0.189		245.39		54.67	
1/2(SGB + SGZ)	0.224		232.33		55.01	
Heterosis Units	-0.035	± 0.027	13.06	±11.16	-0.34	± 1.79
Heterosis %	-15.63		5.62		-0.62	
Pooled Estimate of Maternal Heterosis						
1/2(CBZ + SGBZ)	0.180		242.33		56.68	
1/4(CB+CZ+SGB+SGZ)	0.225		235.62		55.45	
Heterosis Units	0.045	± 1.19*	6.71	± 7.69	1.23	± 1.26
Heterosis %	-20.00		2.85		0.02	
Charolais vs. Santa Gertrudis Sires with crossbred (F1) cows.						
[C(BZ)-SG(BZ)]	-0.018	± 0.029	- 6.13	± 12.14	4.00	± 2.00 *
Charolais vs. Santa Gertrudis Sires with Zebu Cows						
(CZ)-(SGZ)	0.021	± 0.033	21.64	±13.54	0.94	± 2.17

C = Charolais   SG = Santa Gertrudis   Z = Zebu (Brahman)   B = BON

* (P<.05)
** (P<.01)

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