

**ESTIMATES OF BREED DIRECT, MATERNAL AND HETEROSIS EFFECTS
FOR WEANING AND YEARLING WEIGHTS OF BEEF CATTLE IN THE
HUMID TROPICS OF MEXICO**

**[ESTIMACIÓN DE LOS EFECTOS DIRECTOS RACIALES, MATERNOS Y
DE HETEROSIS PARA LOS PESOS AL DESTETE Y AL AÑO DE EDAD DE
GANADO PARA CARNE EN EL TRÓPICO HÚMEDO DE MÉXICO]**

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SUMMARY

The objective of this study was to determine the breed-direct, breed-maternal and heterosis effects for weaning and yearling weights of Brahman cattle and its crosses with Charolais, Simmental and Brown Swiss breeds in a beef cattle system in Tabasco, Mexico. The climate of the region is tropical humid. Data were obtained on 1217 calves born from 1995 to 2007; among the 16 breed-group combinations one was purebred mating (Brahman), 3 two-breed static crosses, 7 three-breed static crosses and 5 backcrosses. Cows were fed in paddocks of Jaragua grass (*Hyparrhenia rufa*) of poor condition and invaded with native grass of *Paspalum* and *Axonopous* genera. Calves remained with their dams until weaning. They were weighed at weaning and about one year of age. Calve weights from the record cards kept at the ranch were used to calculate adjusted weaning (W240) and yearling weights (W365). During the 13 year period of data collection, 711 cows and heifers were inseminated with semen of 23 Charolais (Ch), 50 Simmental (Si), 19 Brown Swiss (BS) and 15 Brahman (Br) unrelated sires. Also 32 Br bulls were used for natural mating. A multiple regression procedure was used to obtain estimates of the breed-direct, breed-maternal and direct heterosis effects for W240 and W365. The overall means and standard errors for W240 and W365 were 178.5 ± 0.89 and 219.9 ± 1.78 kg, respectively. The analysis of variance showed effects ($P < 0.01$) of year of birth, season of birth, sex of the calf, calving number of the cow and year x season interaction on W240, and of year, sex and year x season interaction on W365. Breed-direct and breed-maternal specific effects were significant on W240, but only of breed-direct on W365. Heterosis effects were nonsignificant ($P > 0.05$) for both traits.

Key words: Breed direct effect; breed maternal; heterosis; tropics.

RESUMEN

El objetivo de este estudio fue determinar los efectos raciales directos, raciales maternos y de heterosis para los pesos destete y al año de edad de ganado Brahman y sus cruces con Charolais, Simmental y Suizo Pardo en un sistema de producción de bovinos de carne en Tabasco, México. El clima de la región es tropical húmedo. Los datos se obtuvieron de 1217 becerros nacidos de 1995 a 2007; de las 16 combinaciones de grupos raciales, una fue la raza pura Brahman, 3 fueron cruces estáticas de dos razas, 7 fueron cruces estáticas de tres razas y 5 retrocruzas. Las vacas se alimentaron en potreros de pasto Jaragua (*Hyparrhenia rufa*) con pobre condición e invadidos con pasto nativo de los géneros *Paspalum* y *Axonopous*. Los becerros permanecieron con sus madres hasta el destete. Se pesaron al destete y aproximadamente al año de edad. Se utilizaron los pesos de los registros de producción del rancho para obtener los pesos ajustados al destete (PDA240) y peso al año de edad (PAE). Durante el periodo de 13 años de datos, se inseminaron 711 vacas y novillas, con semen de 23 Charolais (Ch), 50 Simmental (Si), 19 Suizo Pardo (SP) y 15 Brahman (Br) sementales no emparentados. Asimismo, se utilizaron 32 sementales Br para monta natural. Se utilizó un procedimiento de regresión múltiple para obtener estimadas de los efectos raciales directos, maternos y de heterosis para PDA240 y PAE. Las medias generales y errores estándares para PD240 and PAE fueron 178.5 ± 0.89 y 219.9 ± 1.78 kg, respectivamente. Los análisis de varianza mostraron efectos ($P < 0.01$) de año de nacimiento, época de nacimiento, sexo de la cría, número de parto de la vaca y de la interacción año por época sobre PD240, y de año, sexo y de la interacción año por época sobre PAE. Los efectos raciales directos y raciales maternos fueron significativos sobre PD240, pero sólo del racial directo sobre PAE. Los efectos de heterosis para ambas variables no fueron significativos ($P > 0.05$).

Palabras clave: Efecto racial directo; racial materno; heterosis; trópico.

INTRODUCTION

The tropics of Mexico occupied 25% of the national territory and contribute with 33% of beef production. In the Mexican tropics, cow-calf systems are based on seasonal extensive grazing, and lower input systems with internal and external parasite control (Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion, 2002). The main cattle population is Zebu (Z), followed by crossbreeds between Z and some *Bos taurus* breeds such as Charolais, Brown Swiss and Simmental. *B. indicus* and *B. taurus* breeds have different biological and economical attributes (Cundiff *et al.*, 1993; Marshall, 1994). The Z has adaptation attributes such as heat and parasite tolerance and ability to survive with limited food resources (Turner, 1980). The BS has the ability to produce milk and beef and has pigment suitable to high solar radiation (Olson *et al.*, 1985). The Charolais breed is important because of its fast rate of growth (Cundiff *et al.*, 1993). In southeastern Mexico an organized database for breed evaluation does not exist, although some commercial farms have information on cattle performance which could contribute with information for breed evaluation and breed comparisons for improving cattle production systems.

Large breed differences in direct and maternal genetic effects exist for most economically important traits in cattle (Cunningham, 1987). These genetic differences can lead to large economic differences among crossing systems, differences that depend on the breed involved and the degree of heterosis utilized by the system. Thus, in order to plan sound breeding programs, it is necessary to know the kind of gene action (additive or nonadditive) and the maternal contribution to the performance of the offspring (Dillard *et al.*, 1980; Robison *et al.*, 1981). The mean performance of breed and breed crosses in terms of direct and maternal average effects of breeds, individual and maternal heterosis components were defined by Dickerson (1973) and the estimation of these parameters by multiple regression approach by Robison *et al.* (1981).

Weaning and yearling weights are important traits to evaluate commercial production and therefore to select for in cattle. However, they are influenced by some environmental and genetic factors, which should be considered for improving cattle management. Factors such as year and season of birth, parity, sex and breed have been reported to affect body weight of cattle at different ages (Reynoso *et al.*, 1987; Magaña and Segura, 1997; Magaña and Segura, 1998). To the authors' knowledge there are few reports on weaning weight (Hinojosa *et al.*, 1979; Reynoso *et al.*, 1987) and weight at 1 year of age in F1 crosses of BS x Z and Ch x Z cattle in Mexico (Vega *et al.*, 2000).

In the tropics there is a lack of information related to comparisons of breeds and crosses (Benyshek, 1998). Some estimates of average direct, maternal and heterosis effects for cattle have been obtained for beef cattle under the subtropical conditions (Plasse, 1989; Magaña and Segura, 2001). However, to the knowledge of the authors no such estimates exist for beef cattle systems under the humid tropical conditions of Mexico.

The objective of the present study was to estimate the breed direct, breed maternal and direct heterosis effects from data obtained for weaning and yearling weights of Charolais, Simmental, Brown Swiss, and Brahman breeds in a beef cattle system in Southeastern Mexico.

MATERIAL AND METHODS

Information for this study was obtained from a beef cattle system located in Tabasco, Mexico. The climate of the region is tropical humid with monthly mean temperature of 26°C and higher than 36°C during the day in spring, summer and part of fall. Annual rainfall is 2240 mm and the average monthly relative humidity is superior to 80% (Duch, 1988)

Source of data and breed groups

Data were obtained on 1217 cattle calved during a period of 13 years (1995 to 2007) on a commercial herd in Tabasco, Mexico. The base population included Zebu (Z) and Zebu crossbred cattle. F₁ cattle were those resulting of the Z cattle inseminated artificially with semen of the Charolais (Ch), Simmental (Si), Brown Swiss (BS), and Brahman (Br) bulls. Backcrosses were those F₁ cows inseminated with *B. taurus* semen or Br semen to produce 16 different breed groups. Among the 16 combinations one was purebred mating (Brahman), 3 two-breed static crosses, 7 three-breed static crosses and 5 backcrosses.

Animal management

Cows were fed in paddocks of Jaragua grass (*Hyparrhenia rufa*) of poor condition and invaded with native grass of the *Paspalum* and *Axonopus* genera. Calves belong to the Br breed and their crosses with Ch, BS and Si breeds. Brahman calves were the product of crossing Z cows with Br bulls or by artificial insemination. Crossbred calves were the product of inseminating Br cows with semen of Ch, BS and Si bulls. Calves remained with their dams all the time until weaning (approximately at 8 months of age). They were weighed at weaning and about one year of age. Cows and calves were vaccinated and dewormed according to a local health program and tick control was according to their presence.

Preparation and data analysis

Weaning weights (WW) from 195 to 285 days and yearling weights (YW) from 325 to 405 days from the record cards kept at the ranch were used to calculate adjusted weaning (W240) and yearling weights (W365). W240 and W365 were calculated as $(WW/AW)*240$ and $(YW/AW)*365$, where AW is the age at weighing time.

Three seasons are recognized in the state of Tabasco: Dry (March to May) characterized by high temperatures, low rainfall and poor forage availability; rainy (June to October) characterized by high rainfall, high temperatures and high forage production; and windy and rainy season (November to February) characterized by short photoperiod, regular rainfall with strong winds and low temperatures during night and early in the morning, creating an environment of scarce forage; and pulmonary and gastrointestinal diseases in the calf. Year information was grouped in six categories: 1995-1996, 1997-1998, 1999-2000, 2001-2002, 2003-2004, 2005-2007.

Statistical analysis

During the 13 year period of data collection, 711 cows and heifers were inseminated with semen of 23 Ch, 50 Si, 19 BS and 15 Br unrelated sires. Also 32 Br bulls were used for natural mating. A multiple regression analysis was carried out to explore the significance of fixed effects and their interactions, as well as, the additive direct, additive maternal and heterosis effects on W240 and W365. The final statistical model used to describe W240 and W365 was:

$$Y_{ijklm} = \mu + P_i + S_j + N_k + G_l + P * S_{ij} + \beta_1 A_{Ch} + \beta_2 A_{Si} + \beta_3 A_{BS} + \beta_4 A_{Br} + \beta_5 H_{Ch*Br} + \beta_6 H_{Si*Br} + \beta_7 H_{BS*Br} + \beta_8 M_{Ch} + \beta_9 M_{Si} + \beta_{10} M_{BS} + \beta_{11} M_{Br} + e_{ijklm}$$

Where:

Y_{ijklm} = W240 or W365 of the mth calf of the lth sex, in the kth calving of the cow, in the jth season of birth, and the ith year of birth.

μ = least square mean for W240 or W365.

P_i = effect of the ith year period of birth ($i=1,2, \dots 7$)

S_j = effect of the jth season of birth ($j=1,2,3$)

N_k = effect of the kth calving number ($k=1,2, \dots 7$)

G_l = effect of the lth sex of the calf ($l= 1,2$)

$P*S_{ij}$ = effect of the ith year per jth season interaction.

$\beta_1, \beta_2, \beta_3, \beta_4$ = breed direct effects for Ch, Si, BS, and Br, respectively.

$A_{Ch}, A_{Si}, A_{BS},$ and A_{Br} = proportion of genes contributed by the Ch, Si, BS, and Br breeds, respectively.

$\beta_5, \beta_6, \beta_7$ = heterosis direct effects due to interaction of any alleles at the same locus, with the alleles being from Ch, Si, BS and Br breeds, respectively.

H_{Ch*Br}, H_{Si*Br} and H_{BS*Br} = proportion of loci occupied by genes from Ch and Br, Si and Br, and BS and Br breeds, respectively.

$\beta_8, \beta_9, \beta_{10}, \beta_{11}$ = breed maternal effects for Ch, Si, BS, and Br, respectively.

$A_{Ch}, A_{Si}, A_{BS},$ and A_{Br} = proportion of genes contributed by the Ch, Si, BS, and Br maternal breeds, respectively.

e_{ijklm} = the random error term.

Since above model results in a singular matrix, breed direct and breed maternal effects for Ch, Si, and BS were computed as deviations from the Br breed. After the restrictions were imposed on the matrix, the overall least-squares mean was the least-squares mean for the Br breed. Therefore, all results in this study are relative to the performance of the Br breed. In Table 1, general direct, maternal and heterosis effects were obtained from the sum of the specific direct, maternal and heterosis effects divided by the their degrees of freedom ($df=3$).

All data analyses were carried out using the GLM procedure of SAS (SAS, 1995).

RESULTS

The overall means and standard errors for W240 and W365 were 178.5 ± 0.89 and 219.9 ± 1.78 kg, respectively. The analysis of variance showed significant ($P < 0.01$) effects of year of birth, season of birth, sex of the calf, calving number of the cow and year x season interaction on W240 (Table 1), and of year, sex and year x season interaction on W365. Overall breed-direct and breed maternal were significant on W240, but only breed-direct effect on W365 (Table 1). Charolais ($P=0.009$) and BS ($P=0.019$) breed direct effects and breed maternal Ch ($P=0.029$) effects were significant for W240 (Table 2). The breed-direct and breed-maternal effects of Ch, BS and Si breeds were nonsignificant ($P > 0.20$) for W365. Except for the Si x Br negative heterosis value for W240, all heterosis effects were positive but nonsignificant ($P > 0.12$). Cross-specific parameter estimates are shown in Table 2.

Table 1. Means squares for body weight adjusted at 240 (W240) and 365 days (W365) of age of Zebu and crosses with Charolais, Simmental and Brown Swiss cattle in the humid tropics of Mexico.

Sources of variation	df	Mean squares	
		W240	W365
Year of birth (Y)	5	7314.63**	8215.65**
Season of birth (S)	2	25882.33**	3014.75
Calving number	6	2990.08**	1713.01
Sex	1	4403.13**	14898.74**
Y x S interaction	10	6866.73**	4415.22**
General Breed-direct effect	3	11904.01**	4991.29*
General Breed-maternal effect	3	7698.87**	1386.44
General Heterosis	3	624.54	2643.15
Error	1183(486)	961.33	1656.63

() degrees of freedom for W365; *P<0.05; **P<0.01

Table 2. Breed average parameter estimates and standard errors for weights adjusted at 240 and 365 days in a beef cattle system in Tabasco, Mexico.

	W240 (n=1217)	P value	W365 (n=520)	P-value
Mean for Brahman breed	174.6±0.87		202.6±3.76	
Direct effect				
Charolais	18.43±7.07	0.0093	-18.21±15.08	0.2299
Simmental	1.57±5.55	0.7772	-10.33±12.14	0.3692
Brown Swiss	-17.21±7.35	0.0190	16.55±17.64	0.3488
Maternal effect				
Charolais	-27.18±12.58	0.0292	26.96±30.55	0.3780
Simmental	36.26±20.81	0.0816	-5.54±41.92	0.8949
Brown Swiss	-11.24±24.36	0.6497	-16.07±58.26	0.7827
Heterosis				
Charolais	7.93±5.10	0.1207	10.62±11.16	0.3201
Simmental	-19.20±14.29	0.1793	28.85±36.23	0.4173
Brown Swiss	29.23±21.67	0.1778	10.78±49.94	0.8292

*P<0.05; **P<0.01

DISCUSSION

In general, the overall mean W240 (178.5 kg) in this study is similar to the mean (177.7 kg) reported by Reynoso *et al.* (1987) for European x Z crosses and pure Z calves weaned at 232 days of age, in the humid tropics of Mexico. However, it is lower to the mean WW adjusted to 249 days (198.8 and 200.9 kg) for females reported by Magaña and Segura (1998, 2006) and Segura and Gonzalez (1992) for Z breeds in southeastern and northeastern Mexico respectively. Plasse *et al.* (2000) reported also higher WW (188 kg) at 232 days of age for Br, and 1/4 *B. taurus* 3/4 *B. indicus* calves in Venezuela. The mean values from this study are greater than those reported for pure *B. indicus* and for *B. taurus* x *B. indicus* calves in Venezuela (Plasse *et al.*, 2000). However, Magaña and Segura (1997) in Z breeds, other than Br, reported higher mean values for a herd located in Yucatan, Mexico.

The significant (P<0.01) effects of year, season and their interaction on W240 and year and year x season interaction on W365, emphasize the effect of the between and within year changes in management and availability of forage for the animals. Sex of the calf had a significant effect on W240 and W365, the males being heavier (179.1±1.86 and 226.8±3.95 kg) than the females (171.5±1.86 and 215.2±3.75 kg). However, Osorio and Segura (2008) in the same region of Tabasco, but in dual-purpose cattle, did not find differences for W224 between males and females. Therefore, management differences and food availability could result on significant or nonsignificant sex effects. Osorio and Segura (2008) stated that when food is plenty male calves grow faster than females.

Calving number of the cow had a significant effect on W240. First calving cows and cows with more than 7 parities had lower W240. Similar results have been reported by Osorio and Segura (2001) in the same

region and system. Calves born from younger cows normally have lower weights at weaning and gain less weight than those born from older cows. These results agree with other reports in the literature that show that age of dam or calving number has a significant effect on preweaning growth of Z cattle (Magaña and Segura, 1998) and of crossbred *B. taurus* x *B. indicus* cattle (Reynoso *et al.*, 1987; Galdo *et al.*, 2002).

Calving number had no effect on W365 (Table 1). The lack of significant effect of calving number on postweaning growth traits means that the advantage of a better maternal environment provided by older cows is lost after weaning. Segura and Gonzalez (1992) in a study with Br cattle did not find significant effects of calving number on postweaning growth, measured as body weight at 12 months of age. Also, Magaña and Segura (2006) found significant effect of calving number on W240 but no on weight at 18 months of age.

Charolais breed-direct effect for W240 was positive but their breed maternal deviations was negative as found in Florida, USA by Peacock *et al.* (1981) for W205. This also agrees with previous results of a negative correlation between direct and maternal effects (Robinson, 1996). Therefore the better performance of Ch crosses could be explained on the base of the direct genetic effects on growth, although its maternal ability seems not to be so good under the conditions of this study. At the contrary, Si direct effects were not different from zero, but Si showed important breed maternal effect, which suggests a good maternal ability for this breed. Surprisingly, the BS crosses showed negative breed-direct and breed-maternal effects, which indicates a lower W240 compared with the Br calves. BS is recognized as a breed adapted to the tropics and with good maternal ability (Olson, 1985). Therefore, some management practices or environmental effects might be influencing its performance in this study. Magaña and Segura (2006) found a better performance of the crosses of Ch x Br and BS x Br in a sub-humid tropical environment of Yucatan, Mexico. They also, did not find differences between F1 Ch x Z and BS x Z cattle at weaning and weight at 18 months of age in a subhumid environment. Many authors reported a better performance of *B. taurus* x Z crosses than Z pure breeds (Peacock *et al.*, 1981; Plasse *et al.*, 2000; Magaña and Segura, 2006).

General heterosis estimated for W240 and W365 were 5.94 ± 4.86 and 9.03 ± 7.4 which are lower than values reported by Franke (1980) between Br x British cattle breeds. Heterosis for each specific cross was not significant for W240 and W365, probably due to an interaction of genotype by management. Successful crossbreeding requires the choice of appropriate breed combinations for the environment and production

system management programs to support the increased production potential of crossbred cattle (Koger, 1980). When forage is available and of good quality, crossbred animals usually perform better compared with Z cattle. The improvement of the performance of such crosses depends not only on the level of heterosis but also on concentrate feeding and the level of management than is ordinarily available in the herd.

CONCLUSIONS

Non-genetics factors were important sources of variation for W240 and W365 and should be taken in consideration to improve cattle management and growth traits. Differences among breeds in breed-direct and breed maternal effects were found for W240 and only of breed-direct effects for W365. Under the present conditions of this study, the non-significant heterosis effects, suggest that crossbred animals will not expected to perform better than the Brahman breed; however, food availability and management might be limiting the genetic potential of the crossbred cattle.

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