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Genetic and non-genetic effects on productive and reproductive traits of cows in dual-purpose herds in southeastern Mexico

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ABSTRACT. Data on productive and reproductive performance of cows in dual-purpose herds were analyzed to determine the effect of some environmental and genetic factors on saleable milk yield (SMY), lactation length (LL), daily saleable milk per lactation (DMYL), calving interval (CI), and daily saleable milk per calving interval (MYCI) in dual-purpose herds in Yucatan, Mexico. Repeatabilities (r_e) for these traits were also estimated. Data were obtained from monthly visits to 162 herds from 1996 to 2000. The fixed factors studied were: region (central, eastern and southern), parity number (1 to 6), calving year (1996 to 2000) and calving season (dry, rainy and windy and rainy), genetic group (low- (<0.50%), medium- (50%) and high- (>50%) grade cows with European genes). About 2700 to 7700 cows were evaluated for each trait. All factors had significant effects ($P < 0.05$) on the traits except for region on CI and calving season on DMYL. The overall means for SMY, LL, DMYL, CI, and MYCI were: 1322.3 ± 80.5 kg, 224.8 ± 1.3 days, 5.8 ± 0.1 kg, 555.1 ± 16.5 days, and 3.0 ± 0.1 kg, respectively. The r_e values for SMY, LL, DMYL, CI, and MYCI traits were: 0.19 ± 0.03, 0.08 ± 0.04, 0.16 ± 0.04, 0.00 ± 0.08, and 0.08 ± 0.07, respectively. First parity cows had lower SMY, shorter LL, longer CI, and lower MYCI means than cows with more than one parity. Medium grade cows produced more SMY, DMYL and MYCI and had shorter CI than low- and high-grade cows. Therefore, under Yucatan conditions medium-grade cows should be exploited, and more attention should be given to first parity cows in order to improve the productivity in the herd. The relatively high r_e estimates for SMY and DMYL can be used to calculate most probable producing abilities, in order to identify which cows should be culled.

Key words: Dual-purpose cattle, Reproductive performance, Tropics, Genetic parameters

INTRODUCTION

In Mexico, as in many other Latin American countries, there is a large deficit of milk for human consumption. About 1,300 million liters of milk and its derivates are imported yearly to cover the demand of the almost 100 million Mexicans. In the Mexican tropics the predominant milk production system is the dual-purpose cattle system; this involves milk production with restricted suckling by the calf. Because of its inherent characteristics, such as flexibility, relative market stability and low-production costs, it has the potential to alleviate partially the growing demands for milk products. Dual-purpose cows in Mexico constitute about 60% of the milk cow population; however, they only produce about 20% of the total milk yield (SAGARPA, 2000). Genetically, these dual-purpose cows are the result of undefined crosses of Brown Swiss or Holstein bulls with Zebu cows. This allows the exploitation of heterosis, hopefully to obtain more productive animals adapted to the different production systems. Improvement of the productivity of these systems, through the improvement of economic traits, is fundamental for the milk industry in these tropical regions. Milk yield and reproductive traits are key traits in dual-purpose herds, because they have a direct effect on their productivity and profitability. Knowledge of the environmental factors that affect these traits can help the producer to establish better management programs.

The objectives of the present study were to obtain estimates of productive and reproductive traits for dual-purpose herds in southeastern Mexico, to evaluate the effect of some environmental and genetic factors and to estimate the repeatabilities for these traits.

MATERIAL AND METHODS

Data on the productive and reproductive performance of 162 dual-purpose herds located in Yucatan, Mexico, for the period 1996 to 2000 were used. The area of study is located between 19° 40' and 21° 37' north latitude and 87° 32' and 90° 25' west longitude. The climate of this region is sub-humid tropical, with a summer rainy season. The monthly maximum temperature varies between 35° and 40°C, the mean temperature being 26.6°C. The relative humidity varies from 65 to 100% (mean 78%) and annual rainfall varies from 415 to 1290 mm, depending on the area (INEGI, 2000). Yucatan is classified into three regions according to type of vegetation and agricultural development: the sisal region (center-northern), dedicated mainly to the exploitation of sisal (*Agave fourcroydes*); the agricultural region (southern) with maize and citrus production, and the livestock region (eastern), where 65% of the cattle of the state is concentrated (INEGI, 2000). The sisal, agricultural and livestock regions hold 23, 20 and 57% of Yucatan dairy cattle population, respectively.

The main characteristics of the dual-purpose herds that we evaluated were described by Osorio-Arce et al. (1999). Briefly, the general management of the herds is based on the milking of crossbred cows by hand, mainly Brown Swiss x Zebu and Holstein x Zebu cows, once a day with the calf nearby, year-round grazing on improved pastures, commonly Guinea grass (*Panicum maximum*) and Star grass (*Cynodon nlemfuensis*), with supplementary feeding during the dry season. Information was obtained from monthly visits to 162 herds of 224. During the visits, milk yield was measured for each cow or taken from farmer's records; also reproductive and productive events, such as calving date, sex of the calf and dry-off date, were registered. The data also included information on herd and cow identification, breed group of the cow, parity number, and total milk yield. Only information from herds with at least two cows in production was used. The main types of cows were Brown Swiss x Zebu (82% of the herds had at least one cow of this type) and Holstein x Zebu (16% of the herds had at least one cow of this type) type. There were some Simmental x Zebu and pure Zebu cows. The breed type was recorded for 52% of the cows. The factors evaluated were region (central, eastern and southern), calving year (from 1996 to 2000), parity number (1 to 6 or more calvings), calving season (dry, rainy and windy and rainy) and breed group (low- (<50%), medium- (50) and high- (>75%) grade *Bos taurus* cows, and cows for which no breed group was determined). The traits analyzed were saleable milk yield in kg (SMY, N = 6758), lactation length in days (LL, N = 7763), daily milk yield in kg (DMYL, N = 6716), calving interval in days (CI, N = 2716), and daily milk yield during a CI (MYCI, N = 2716). DMYL and MYCI were calculated by dividing the SMY of a cow by the respective LL or CI. Data were analyzed using the following mixed model:

$$Y_{ijklmno} = \mu + R_i + H_j(R_i) + CY_k + CS_l + PN_m + GG_n + C_o(GG_n) + E_{ijklmno}$$

where: $Y_{ijklmno}$ = dependent variable (SMY, LL, DMYL, CI, and MYCI); μ = generalized least squares means; R_i = fixed effect of region (central, eastern and southern); $H_j(R_i)$ = random effect of herd within region; CY_k = fixed effect of year of calving (1996 to 2000); CS_l = fixed effect of calving season (dry, rainy and windy and rainy); PN_m = fixed effect of parity number (1-6); GG_n = fixed effect of genetic group (low, medium, high percent *B. taurus*, and undefined); $C_o(GG)_n$ = random effect of cow within GG, and $E_{ijklmno}$ = random error.

Simple interactions were tested in preliminary analysis but they were dropped from the final model because of a lack of significance (P > 0.05). Repeatabilities for the traits were estimated as the proportion of the variance component of cows, compared to the phenotypic variance (between cows + residual component of variance). Components of variance were calculated by the restricted maximum likelihood method (SAS, 2000).

RESULTS

The overall means ± standard errors for SMY, LL, DMYL, CI, and MYCI were 1322.3 ± 80.5 kg, 224.8 ± 1.3 days, 5.8 ± 0.1 kg, 555.1 ± 16.5 days, and 3.0 ± 0.1 kg, respectively. All the factors had significant effects ($P < 0.05$) on the traits except for region on CI and calving season on DMYL (Tables 1 and 2).

Table 1. Generalized least squares means and standard errors by region, year of calving and season of calving for some productive and reproductive traits of cows in dual-purpose herds in Yucatan, Mexico.

Factor	SMY	LL	DMYL	CI	MYCI
Region					
Central	2205.5 ± 51.5[a]	277.4 ± 6.0[a]	7.63 ± 0.11[a]	428.7 ± 26.0[a]	5.31 ± 0.23[a]
Eastern	1192.0 ± 28.2[c]	225.4 ± 3.4[c]	5.10 ± 0.06[b]	474.5 ± 15.1[a]	2.92 ± 0.14[b]
Southern	1326.6 ± 57.3[b]	242.8 ± 7.1[b]	4.97 ± 0.12[b]	482.4 ± 34.8[a]	2.30 ± 0.29[b]
Year of calving					
1996	2084.5 ± 47.8[a]	317.3 ± 5.1[a]	6.01 ± 0.10[b]	535.1 ± 19.1[b]	4.32 ± 0.16[a]
1997	1741.1 ± 34.9[b]	262.4 ± 4.2[b]	6.29 ± 0.07[a]	557.1 ± 17.0[b]	3.93 ± 0.13[b]
1998	1345.0 ± 34.8[c]	206.7 ± 4.2[c]	6.05 ± 0.07[b]	539.9 ± 17.3[b]	3.22 ± 0.13[d]
1999	1374.6 ± 39.5[c]	250.7 ± 5.0[b,c]	5.20 ± 0.08[c]	381.1 ± 20.9[a]	3.61 ± 0.16[c]
2000	1328.2 ± 39.3[c]	207.4 ± 5.0[c]	6.17 ± 0.08[a,b]	336.1 ± 46.0[a]	4.10 ± 0.34[a,b]
Season of calving					
Dry	1697.5 ± 35.1[a]	267.7 ± 4.7[a]	5.96 ± 0.07[a]	475.0 ± 19.2[b]	4.10 ± 0.15[a]
Rainy	1537.9 ± 35.4[b]	245.4 ± 5.2[b]	5.97 ± 0.07[a]	440.0 ± 19.7[a]	3.87 ± 0.15[a]
Windy and rainy	1448.6 ± 34.3[c]	232.5 ± 4.5[c]	5.90 ± 0.07[a]	470.5 ± 19.1[b]	3.64 ± 0.14[b]

[a,b,c,d]Means with different letters within factor and trait are significantly different ($P < 0.05$). SMY = saleable milk yield; LL = lactation length; DMYL = daily milk yield per lactation; CI = calving interval; MYCI = milk yield per calving interval.

Milk traits and CI means were highest for cows in the central Yucatan region. Cow's SMY was lower in the eastern region, partially because they have the shortest LL. SMY tended to decrease with years of calving and CI means were shortest in 1999 and 2000. The other traits did not show any trend with years. Cows calving in the dry season produced the most SMY, but had the longest CI means. The rainy season, when there was abundant pasture, was intermediate for SMY and had the shortest CI (Table 2). SMY and LL increased with parity number of the cows up to the fourth calving and started to decrease afterwards. CI means for first parity cows were longer than for adult cows, though the difference was not significant.

Medium-grade cows (50% *B. taurus* and 50% *B. indicus*) gave the best SMY values; however, they were not significantly different ($P > 0.05$) from the high-grade cows (>50% *B. taurus*). Medium- and high-grade cows had similar LL values; however, medium-grade cows had the highest DMYL and MYCI means. They also had the shortest CI. Low-grade cows had the poorest milk yield traits. The unknown genotype cows had similar performance to the high-grade cows (Table 2).

Table 2. Generalized least squares means and standard errors by parity number and genetic group for some productive and reproductive traits of cows in dual-purpose herds in Yucatan, Mexico.

Factor	SMY	LL	DMYL	CI	MYCI
Parity number					
1	1436.9 ± 34.3[f]	236.8 ± 4.2[b]	5.58 ± 0.07[c]	491.6 ± 19.1[b]	3.43 ± 0.14[c]
2	1553.8 ± 33.7[d,e]	248.9 ± 4.1[b]	5.84 ± 0.07[b]	469.8 ± 19.0[a,b]	3.65 ± 0.14[b]
3	1609.7 ± 36.9[b,c]	247.6 ± 4.5[b]	6.10 ± 0.08[a,b]	455.2 ± 20.1[a]	3.96 ± 0.15[a]
4	1714.8 ± 41.3[a]	259.3 ± 5.1[a]	6.21 ± 0.09[a]	469.7 ± 21.9[a,b]	4.02 ± 0.17[a]
5	1621.5 ± 46.5[b]	255.9 ± 5.8[a,b]	6.07 ± 0.10[a]	450.1 ± 23.0[a]	3.91 ± 0.18[a]
6	1591.1 ± 53.4[c,d]	244.4 ± 6.7[b]	6.10 ± 0.11[a]	460.7 ± 26.3[a,b]	3.88 ± 0.20[a,b]
Genetic group					
Low	1443.3 ± 65.5[c]	232.2 ± 8.0[b]	5.77 ± 0.14[b]	461.8 ± 30.5[a,b]	3.69 ± 0.24[a,b]
Medium	1664.9 ± 33.6[a]	256.2 ± 4.1[a]	6.17 ± 0.07[a]	431.0 ± 18.5[a]	4.11 ± 0.14[a]
High	1611.1 ± 38.7[a,b]	256.3 ± 4.8[a]	5.85 ± 0.08[b]	480.0 ± 20.5[b]	3.71 ± 0.16[b]
Unknown	1579.6 ± 35.4[b]	249.4 ± 4.3[a]	5.98 ± 0.08[b]	474.6 ± 19.5[b]	3.82 ± 0.15[b]

[a,b,c,d,e,f]Means with different letters within factor and trait are significantly different ($P < 0.05$). SMY = saleable milk yield; LL = lactation length; DMYL = daily milk yield during a lactation; CI = calving interval; MYCI = daily milk yield during a calving interval; Low = <50% *Bos taurus* x Zebu; Medium = 50% *B. taurus* x 50% *B. indicus*; High = >50% *B. taurus* x *B. indicus*; Unknown = cows without a breed group registered.

The highest repeatabilities were obtained for SMY and DMYL and the lowest was for CI (Table 3).

Table 3. Variance components and repeatability (r_e) estimates for some economic traits of cows in dual-purpose cattle systems under tropical conditions in Yucatan, Mexico.

Trait	N	σ_v^2	σ_e^2	r_e
SMY	4760	84535.0	439060.0	0.19 ± 0.03
LL	4751	701.6	7706.3	0.08 ± 0.04
CI	1445	0.0	28457.1	0.00 ± 0.08
DMYL	4751	0.37	1.9777	0.16 ± 0.04
MYCI	1310	0.2112	2.3315	0.08 ± 0.07

N = number of observations; SMY= saleable milk yield; LL = lactation length; DMYL = daily milk yield per lactation; CI = calving interval; MYCI = daily milk yield during the calving interval. σ_v^2 and σ_e^2 components of variance due to cow and residual, respectively.

DISCUSSION

In general, the means of the milk traits studied were within the range of values reported for dual-purpose herds in Latin America (Torres, 1991; Teodoro and Lemos, 1992; Vaccaro, 1992; Vaccaro et al., 1992, 1995; Amézquita and Lema, 1997). However, the average CI found in this study (555.1 days) was higher than the average values (range 429-490 days) previously reported for dairy and dual-purpose cows in the tropics (Cunningham and Syrstad, 1987; Vaccaro, 1992), which means that the herds evaluated in our study had a poor reproductive performance.

Environmental factors

Region

Vaccaro et al. (1992) reported significant differences between localities in Venezuela for economically important traits in dual-purpose herds. They associated these differences with management and availability of pasture. However, differences were also attributed to breed group composition of the herds and differences in herd management. In the central region of Yucatan, most herds had high- and medium-grade *B. taurus* cows; whereas in the eastern and southern regions the cows were predominantly medium- to low-grade cows. Also production systems are more intensive in herds of the Central region of the Yucatan (Osorio-Arce et al., 1999; Magaña et al., 2001a). The better management and milking cows in the Central region were apparently the motives for this region having the highest values for SMY, LL, shortest CI intervals and highest daily milk yields per cow/lactation or per CI (Table 1). This means that it would be possible to increase the production in the eastern and southern regions (at least at the level of the central region) with better management, feeding and by using high-grade *B. taurus*, but no pure cows, unless drastic changes in management are made. In this respect, it has been shown that saleable milk increases as nutritional management increases, but variable costs of milk production also increase, and consequently it is not profitable (Magaña et al., 2001b). However, more research is needed on the economic consequences of different plans of improvement in order to determine the best alternative for the dual-purpose cattle systems of Yucatan.

Year of calving

Year of calving had a significant effect ($P < 0.05$) on all traits. The effects of this are a result of the interaction of a set of environmental, technical and administrative management practices that make its interpretation difficult; however, it is an important source of variation that must be considered in the statistical analysis in order to better interpret of results. Year-of-calving effects on milk traits and CI have been reported for several studies made in Mexico (Román et al., 1978; Hernández-Reyes et al., 2000; Osorio-Arce and Segura-Correa, 2001). The better CI means in years 1999 and 2000 are due to a bias estimation of this trait, because it requires two consecutive calvings for a interval calculation; therefore, the data for these last years did not include the non-calving cows; it only included the ones that calved the earliest.

Season of calving

Season effects on economically important traits are of interest because of their association, especially in the tropics, to direct effects of forage availability and quality, temperature and humidity on the animals. In our study, milk yield trait means were superior for cows calving in the dry season; however, cows calving in this period may had longest CI (Table 1). Feed supplementation may help to solve this problem. The benefits of a better feeding and management on production and reproduction of cattle have been documented (Román-Ponce, 1992; Vaccaro et al., 1997; Combellas, 1998).

In our study, cows calving in the dry season produced 11 and 17% more SMY than cows calving in the rainy and rainy and windy seasons, respectively (Table 1). This agree with Vaccaro (1992) who found more milk per cow in Venezuela when calving occurred in the dry season compared to the other seasons. However, Hernández-Reyes et al. (2000) and Román et al. (1978) did not find significant differences between seasons in Yucatan and Veracruz, Mexico, respectively. Villegas and Román (1986) observed that cows calving in the rainy season in Veracruz had the best milk performance. Seasonal differences in milk traits are expected to be influenced by feeding management practices in the regions or herds, as well by the type of tropical climate (subhumid or humid).

Cows calving in the rainy season had a better reproductive performance than those calving in the dry or windy and rainy seasons (Table 1). Vaccaro (1992) and Villegas and Román (1986) found a better performance of cows of dual-purpose herds that calved during the season with the greatest availability of forage in studies made in Venezuela and Mexico, respectively.

Parity number

First parity and oldest cows had the lowest SMY generalized least squares means; however, first parity cows also had the worst CI, and as a result they had the poorest milk yield/cow (Table 2). The quadratic curve response to parity for SMY is similar to findings in other studies made in the tropics (Villegas and Román, 1986; MacKinnon et al., 1996; Hernández-Reyes et al., 2000). Differences in milk yield in dual-purpose cattle herds can be from 23 to 40% more for mature cows than for the first parity cows (Vaccaro et al., 1995). The differences in milk-yield traits in our study were partly due to a shorter LL for the first parity cows but also to the fact that young cows are still growing and developing the mammary system.

The longest CI obtained for the first parity cows is similar to what was found in previous studies in the tropics (Villegas and Román, 1986; Vaccaro, 1992). The longer CI could be due to a delay in the re-start of postpartum estrus in lactating young cows and to the greater effect of the stress of lactation in younger than in older cows (Galina and Arthur, 1989). Also, maintenance and requirement for growth are more important in these young cows to assure an effective reproductive performance. As a consequence of having the lowest milk yields and the longest CI, first parity cows had the lowest milk yield per day (Table 2). Vaccaro et al. (1995) suggested correcting for this factor when evaluating cows for selection.

Genetic group

In general, medium-grade cows performed better than the other genetic groups. Low-grade *B. taurus* cows produced less milk per lactation or per day than medium- or high-grade cows and cows with unregistered breed group (Table 2). They also had the shortest LL, but they had similar CI values. An advantage of medium-grade cows in dual-purpose systems has been reported in other countries (Cunningham and Syrstad, 1987; Madalena, 1998; Vaccaro et al., 1995, 1997; Vaccaro, 1998; Magaña et al., 2001a). SMY superiority of the medium-grade cows compared to the high-grade cows was not dependent on LL. The performance of the unregistered breed group cows was closest to the high-grade cows, so probably this group was composed of a high proportion of high-grade cows; however, this cannot be proved. The results of this study reinforce the concept of an advantage for medium-grade cows in dual-purpose production systems. However, how to keep a population of 1/2 *B. taurus* x 1/2 *B. indicus* cows without losing productivity is a problem. Some breeding alternatives have been suggested (Madalena, 1993; Teodoro et al., 1996; Vaccaro, 1998).

Repeatability

The low repeatabilities that we obtained indicate that genetic and permanent environmental effects are not important in determining milk traits and CIs. The repeatability estimates for SMY, LL and CI that we found were lower than those reported for Creole and dual-purpose cattle in other studies made in Mexico (De Alba et al., 1978; De Alba and Kennedy, 1985, 1994; Hernández-Reyes et al., 2000). The high r_e values for SMY and DMYL indicate that they can be used to calculate most probable producing abilities, in order to identify which cows should be culled.

CONCLUSIONS

Under the Yucatan conditions, medium grade cows should be exploited and more attention should be given to first parity cows in order to improve the productivity in the herds. The relatively high repeatabilities for SMY and DMYL indicate that it would be possible to calculate the most probable productivity for a cow in order to determine which cows should be culled.

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