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Milk production of crossbred Holstein × Zebu cows in the northeastern region of Paraná State

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ABSTRACT - The objective of this work was to evaluate milk production of a Holstein × Zebu herd managed on a semi-intensive system at Estação Experimental Joaquim Távora, IAPAR, in the northeastern region of Paraná – Brazil. Two hundred and seventeen records on milk production per lactation period (MY), milk production up to 305 days of lactation (MY305) and length of lactation period (LL) of 82 crossbred cows varying in breed composition were analyzed according to a linear statistical model that included the fixed effects of breed composition, season and year at onset of lactation, order of parturition and place of birth, in addition to the experimental error. Cows born in Joaquim Távora had longer lactation periods and produced more milk than cows born in Ibiporã. The effects of year and season at the beginning of the lactation period influenced all three traits. Both milk production per lactation period and milk production up to 305 days of lactation that began from April to June were superior to those that began from October to December, as well as to those starting from January to March. The order of parturition had a strong effect upon both milk production per lactation period and milk production up to 305 days of lactation. Maximum milk production was attained during the sixth lactation period, although no difference was detected for the contrasts between the sixth and other higher order lactation periods. All traits increased as the proportion of Holstein in the breed composition of the animal increased from 0.5 to 0.875 and decreased thereafter. These results support the argument against complete grading up to Holstein in semi-intensive production systems in sub-tropical regions.

Key Words: crossbreeding, Holstein, zebu, lactation length, semi-intensive system

Produção de leite de vacas mestiças Holandês × Zebu na região nordeste do estado do Paraná

RESUMO - O objetivo deste trabalho foi avaliar a produção leiteira de um rebanho mestiço Holandês × Zebu mantido em sistema de manejo semi-intensivo no nordeste do estado do Paraná. Foram analisadas 217 observações de produção de leite por lactação, de produção de leite até os 305 dias de lactação (PL305) e de duração da lactação de 82 fêmeas bovinas mestiças Holandês × Zebu de diversas composições raciais, com registros de produção no período de 1993 a 2002. As análises estatísticas dos dados foram feitas pelo método dos quadrados mínimos ajustando-se um modelo linear que incluiu os efeitos fixos de grupo genético, estação de início da lactação, ano de início da lactação, ordem do parto, local de nascimento da vaca e erro experimental. Os efeitos de ano e de estação de início da lactação influenciaram as três características. Tanto as produções de leite totais como as PL305 das lactações iniciadas de abril a junho superaram aquelas das lactações iniciadas de outubro a dezembro e de janeiro a março. A ordem do parto teve forte influência sobre ambas as características, tanto na produção de leite por lactação como na PL305. O pico de produção ocorreu na sexta lactação, mas não houve diferença significativa para os contrastes entre a sexta e as demais lactações de ordem superior. A produção de leite total, a PL305 e a duração da lactação aumentaram à medida que a proporção de Holandês na composição racial do animal passou de 0,5 a 0,875 e diminuíram quando a proporção de Holandês chegou a 0,9375. No regime semi-intensivo, não se justifica a substituição completa do gado Zebu pelo gado Holandês.

Palavras-chave: cruzamentos, Holandês, Zebu, duração da lactação, sistema semi-intensivo

Introduction

The northeastern region of Paraná presents low fertility soils, with moderate to severe declivity in most of its extension. The climate type is classified as Cfa according to Köppen classification, described as semi-tropical, where the average daily temperature of the coolest month is below 18ºC (mesothermal) and the average daily temperature of the hottest month is above 22ºC, with warm summers, almost no occurency of frosts and a tendency for the

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concentration of rain during summer months, but without a definite dry season. This type of climate presents a variation in the amount and quality of forage from pastures during the year. Thus, the dairy husbandry of this region shows low productivity, which in turn is worsened by deficiencies in nutrition, health and reproductive management as well as by the low genetic merit of the herds. One way of improving the performance of dairy production systems in regions of warm climate, by means of genetic improvement, is the utilization of crosses between zebu breeds, which exhibit excellent adaptation to tropical environment, with European breeds, which are specialized in milk production, but have serious problems of adaptation to tropical conditions, where high temperatures, poor quality of pastures, parasite infestations and deficient management frequently prevail.

Although crossbreeding is tacitly associated with the exploitation of heterosis, it cannot be neglected that, in conditions where management and other environmental factors are also being improved, the use of additive breed differences via increases in the proportion of *Bos taurus* genes in the breed composition of animals can result in great benefits to dairy production (Facó et al., 2002).

The objective of this work was to evaluate milk production of a crossbred Holstein × Zebu herd under a semi-intensive management system at Joaquim Távora Experimental Station, which belongs to Instituto Agronômico do Paraná (IAPAR), and it is located in Joaquim Távora in the northeastern region of Paraná-Brazil.

Material and Methods

Data on 217 observations of milk production per lactation period (MY), milk production up to 305 days of duration of lactation period (MY305) and duration of lactation period (LL) from 82 crossbred Holstein × Zebu cows of various breed compositions, recorded at Joaquim Távora Experimental Station - IAPAR, from 1993 to 2002, were analyzed. These cows were generated by mating, via artificial insemination, pure Holstein and ½ Holstein + ½ Zebu crossbred bulls to Holstein × Gyr and Holstein × Guzerath cows, from many breed compositions, to generate animals with no more than 15/16th of Holstein "blood" in the breed composition. The foundation cows were Holstein × Zebu crossbred animals that were transferred to Joaquim Távora from Ibiporã Experimental Station, were they had participated earlier in another project involving crossbreeding for milk production (Perotto et al., 1997). The semen of Holstein bulls was purchased in commercial AI units and that of the crossbred males was collected and processed from animals that belonged to the IAPAR herd.

Joaquim Távora Experimental Station is located at 23º30' of Latitude (South) and at 49º 57' of Longitude (West), at 512 m of altitude (Maack, 1968). According to the sources from Ministério da Agricultura (1990), the predominant soils in Paraná northeastern region are the red-yellow podzolic (60%), litolic (20%), and red latozol groups (20%). Soil fertility is high in 19%, median in 41% and low in 40% of the area. Its topography is highly undulated in 23% of the area, undulated in 68%, and slightly undulated in 9% (Ministério da Agricultura, 1981). The region has an average rain fall of 1,200 mm per year and yearly average temperature of 21.9ºC, with maximum of 30ºC and a minimum of 12.2ºC (IAPAR, 1974).

Milk production per lactation period was computed using the Technical Orientation of the Milk Recording Service Regulations (Decree SNAP number 45, of October 10th, 1986, from the Ministério da Agricultura, published by the Associação Brasileira de Criadores de Bovinos da Raça Holandesa (ABCBRH, 1986). For lactation periods exceeding 305 days, milk production up to 305 days was computed by multiplying the average of the daily records up to 305 days (kg/day) by 305. The duration of each lactation period (days) was computed by the difference between the end date of the lactation period and the start date of the lactation minus the number of days that calves were allowed to suckle the collostrum.

Cows were classified according to the proportion of Holstein genes in their breed composition, independently of the zebu genes fraction be Gyr or Guzerath (Table 1).

The experimental herd was maintained on tropical pastures with a high prevalence of jaragua grass (*Hyparrenia rufa* (Nees) Stapf), in addition to other species such as coast-cross (*Cynodon dactylon* (L.) Pers.), hemarthria (*Hemarthria altissima* (Poiret) Stapf & Hubbard (Gramineae)), star grass (*Cynodon nlemfuensis*, Vanderyst) and bracharia grass (*Brachiaria decumbens* Stapf), and supplemented with elephant grass (*Pennisetum purpureum* Schum.), which was offered by rotational grazing or chopped in troughs. During the winter, when no severe droughts had occurred during the fall, milking cows had access to oat pastures (*Avena sativa* L.) for approximately two hours per day.

Calves had access to the collostrum and remained with their mothers for two days after birth. Thereafter, the calves were separated from the cows and maintained in pastures provided with feeding banks and shelter, but having daily contact with the mothers at milking time when they were allowed to suckle for a short time only to stimulate the

Table 1 - Classification of cows according to the proportion of Holstein genes in their breed composition

Genetic group of cow[1]	Genetic group of dam[1]	Genetic group of sire[1]	Fraction of Holstein	Class of proportion of Holstein
1/2 Holstein + 1/2 Zebu	Zebu	Holstein	0.5000	H1
9/16 Holstein + 7/16 Zebu	5/8 Holstein + 3/8 Zebu	1/2 H+1/2 Zebu	0.5626	H2
5/8 Holstein + 3/8 Zebu	3/4 Holstein + 1/4 Zebu	1/2 H+1/2 Zebu	0.6250	H2
5/8 Holstein + 3/8 Zebu	1/4 Holstein + 3/4 Zebu	Holstein	0.6250	H2
11/16 Holstein + 5/16 Zebu	3/8 Holstein + 5/8 Zebu	Holstein	0.6875	H2
3/4 Holstein + 1/4 Zebu	1/2 Holstein + 1/2 Zebu	Holstein	0.7500	H3
13/16 Holstein + 3/16 Zebu	5/8 Holstein + 3/8 Zebu	Holstein	0.8175	H4
7/8 Holstein + 1/8 Zebu	3/4 Holstein + 1/4 Zebu	Holstein	0.8750	H4
15/16 Holstein + 1/16 Zebu	7/8 Holstein + 1/8 Zebu	Holstein	0.9375	H5

liberation of the milk and after the milking period was over. Up to 60 days of age, calves were offered all the milk from one teat, in the morning and in the afternoon. From 60 days to 90 days of age, the amount of milk that was provided to the calves was reduced, so that they were allowed to suckle the content of one teat only, following the afternoon milking.

Starting in the second week of life, calves commenced receiving a concentrate ration (15 to 16% of crude protein, up to a maximum of 2 kg/animal/day). After 90 days of age, they were kept in pastures of good quality forage and continued to be taken to their mothers at milking, to stimulate the release of milk, but without ingesting any amount of residual milk. The concentrate was given to the calves until they were at the age of 8 months. During this period, heifers were evaluated for body size, and other characteristics such as type and temperament, in order to identify those to be kept as a replacement for culled cows.

From 8 to 12 months of age, heifers were raised on good quality pastures, receiving supplementation during periods of low forage availability on the basis of corn silage and 1 kg of concentrate ration per animal per day. Yearling heifers that remained in the herd joined the dry cows in pastures supplemented in periods of low forage supply with 15 kg of corn silage per animal per day. Culled calves of both sexes left the herd at about 16 to 22 months of age.

Lactating cows were milked twice a day, at 7:00 AM and at 4:00 PM, when they were offered the concentrate ration (20 to 22% CP) on the basis of 1 kg of ration for every 4 kg of milk produced. Estimates of the amount ingested by the calves were also considered, in order to avoid underfeeding the cow. During the day, between the morning and the afternoon milking, these cows were sent to the pastures. Following the afternoon milking, cows received roughage in feeding banks and spent the night in pastures nearby the milking parlor. During the pre-calving period, the cows were maintained separately from the rest of the herd, in small pastures, where they received roughage and the concentrate ration (1 kg/animal/day). All animals in the herd had free access to mineral mixtures, which were offered in appropriate troughs located in the pastures.

The health control of the herd consisted of isolating infected animals, cleaning and disinfection of barns, protection of troughs and drinking facilities and the correct disposal of excretions, residues and corpses of aborted and stillborn animals. Routine health measures included the administration of collostrum to newborn calves, the control of internal and external parasites, controlled exposure of animals to teaks, tests for brucelosis, leptospirosis and tuberculosis, in addition to systematic vaccinations against foot and mouth disease, clostridiosis, pneumoenterites and leptospirosis.

Milking was performed mechanically through the use of a portable milking machine. Milk production records were registered weekly, always on Wednesdays, in order to keep control of production and to help in the feeding management of lactating cows. Regarded to nursing cows, the amount of milk ingested by the calves was estimated by the difference between two weights of the calf taken before and after each sucking. The replacement of adult cows was based primarily on milk production, temperament, easiness of milking, reproductive performance and occurrences of clinical disorders. The end of the lactation period occurred 45 to 60 days prior to the estimated date of the following calving or whenever milk production levels fell below 4 kg/day, a condition that no longer justified the provision of concentrate.

Traits milk production per lactation, milk production up to 305 days of lactation and duration of lactation period were analyzed by ordinary least squares methodology using the GLM procedure in the Statistical Analysis System (SAS Institute, 2000). The linear model that was proposed to explain the variations in the traits was written as:

$$Y_{ijklmn} = \mu + NH_i + EP_j + AP_k + NP_l + LO_m + E_{ijklmn}$$

with the following definition of terms: Y_{ijklmn} = value of the trait under analysis (MY, MY305, LL) of the n^{th} cow, of the m^{th} place of origin, in the l^{th} order of calving, in the k^{th} year of calving, in the j^{th} season of calving and from the i^{th} class of proportion of Holstein "blood" in the breed composition; μ = general mean for the trait under analysis, NH_i = effect of the i^{th} class of proportion of Holstein in the breed composition of the cow (i = 1, ..., 5), where 1 = 0.5000 of Holstein, 2 = 0.5625 to 0.6875 of Holstein, 3 = 0.7500 of Holstein, 4 = 0.78125 to 0.8750 of Holstein and 5 = 0.9375 of Holstein; EP_j = effect of the j^{th} season of calving (j = 1, ..., 4), where 1 = January to March, 2 = April to June, 3 = July to September and 4 = October to December; AP_k = effect of the k^{th} year of calving (k = 1, ..., 10), where 1 = 1993, ..., 10 = 2002; NP_l = effect of the l^{th} order of calving (l = 1, ..., 9), where 1 = first calving, ..., 9 = ninth calving; and, LO_m = effect of the m^{th} place of origin (m = 1, 2), where 1 = Ibiporã and 2 = Joaquim Távora; and E_{ijklmn} = random effect of experimental error peculiar to each observation (Y_{ijklmn}). In order to fulfill the basic assumptions underlying analysis of variance, it was assumed that the errors are independent and distributed according to the normal curve with 0 (zero) mean and σ^2 variance. All effects in the model were assumed to be fixed, except for the error.

Results and Discussion

The proportion of Holstein in the breed composition of the cow and the season of the start date of the lactation period had a strong influence (P<0.001) on total milk production (MY). The same factors were also important sources of variation (P<0.01) for milk production up to 305 days of the lactation period, in addition to exhibiting some effect (P<0.05) on the duration of the lactation period. The year of calving influenced (P<0.001) all three traits in a similar way, whereas the order of calving did not have an effect (P>0.05) on the duration of the lactation period, but was highly significant (P<0.001) for both milk production per lactation period and milk production up to 305 days of the lactation. The place of origin of the cow had a marked effect (P<0.001) on total milk production and also influenced (P<0.01) the duration of the lactation period and, to a smaller extent (P<0.05), the production up to 305 days of lactation.

The values of the coefficient of determination (r^2) varied from 0.32 to 0.40, thus indicating that the proposed model did not give satisfactory explanations for the differences among animals with respect to milk production and to the duration of the lactation period. It is possible that other genetic and environmental factors such as the sire effects and the permanent environmental effects on the cows, which could not be investigated due to the size and the structure of the available data, also contributed to the total variation of the three characters. Other models that were tried in preliminary analyses, replacing the effects of season by those of month or replacing those of the order of calving by the linear and the quadratic effect of the age of the cow at calving did not significantly improve r^2 values.

Although high, the values of the coefficients of variation are smaller than those found by Facó et al. (2002) for the same traits. Among all possible reasons for the large variability in the data analyzed by the cited authors, those associated with the number of herds involved and their nutritional regimes deserve to be emphazided. In contrast, the data analyzed in the present study came from only one herd, managed in only one nutritional regime (semi-intensive).

The general means for the traits were 2,812 kg, 2,657 kg and 275 days, respectively, for total milk production, milk production up to 305 days of the lactation period and duration of the lactation period. The values for the productive traits are slightly lower, but they agree with those of the previously cited authors for the semi-intensive level of management (2,901 kg and 2,830 kg), respectively, for total milk production and for milk production up to 305 days of the lactation period. However, the duration of the lactation period was longer than the general mean for this trait (243 days) as reported by Facó et al. (2002), partly because their study included ¼ Holstein + ¾ Zebu animals, which presented significantly shorter lactation periods compared to those from groups with higher proportion of Holstein genes in the genotype.

The place of origin (or of birth) of the cows was identified as an important source of variation for the duration of the lactation period, as well as for the production of milk. The lactation periods of cows born at Ibiporã Experimental Station were shorter (251 ± 12 days vs 287 ± 15 days) than those of cows born at Joaquim Távora Experimental Station (P<0.01). Correspondingly, both total milk production and milk production up to 305 days of cows born in Joaquim Távora were higher than those from cows that came from Ibiporã. One possible cause for these differences is the genetic merit of the Holstein bulls used in Joaquim Távora, which was better than that of bulls used in Ibiporã.

The order of calving influenced (P<0.001) total milk production, as well as the milk production up to 305 days. As observed by other authors (Junqueira Filho et al., 1992; Farias e Vasconcellos et al., 2003), there was a tendency for milk production to increase with the order of calving to a peak and decline thereafter. In our work, peak production occurred during the sixth lactation period, but, not withstanding the decline in the higher order lactations, there was no significant difference for the contrast between the sixth and the other lactation periods of higher order. This lack of statistical significance can be attributed to the smaller numbers of observations in the last order lactation periods, since the magnitudes of standard errors doubled from the fifth to the ninth lactation period. The effect of calving order was not significant (P>0.05) for the duration of the lactation period, which is in accordance with the report by Lemos et al. (1997), who did not find importance for this factor in the variation of the duration of lactation period in cows used in a study of different strategies of crossbreeding. Likewise, Faria e Vasconcellos et al. (2003), working with crossbred cows of various genetic groups, did not report an effect for the order of calving on the duration of the lactation period. Polastre et al. (1987b) did not find significant effects neither for the linear nor for the quadratic coefficients of regression of the duration of lactation on the age of crossbred Holstein × Zebu cows. Conversely, Milagres et al. (1988a) reported that the age of cow at calving showed linear and quadratic effects on duration of the lactation period in a herd of crossbred cows of Holstein, Schwyz, Jersey and Zebu breeds.

The year had a marked influence (P<0.001) on all three traits analyzed in the present study. Generally, the year of calving includes genetic and environmental factors, such as variations in quantity and in quality of pastures due to changes in temperature, light and rain fall, changes in the genetic merit of the herd, which accumulates over time in response to selection, occasional breakouts of diseases like mastitis, and economic causes like shifts in prices of inputs and produce, which bring about higher or lower investments in the enterprise.

Calving season also had a highly significant effect on the studied characters. Lactation periods beginning any time between April and September were longer (P<0.011) than those that started between October and December. Both MY and MY305 of lactation periods beginning between April and June were superior to those beginning between October and December (P<0.001), as well as to those beginning between January and March (P<0.05). Similar findings by Polastre et al., 1987a; Milagres et al., 1988b, attributed the effect of the season of the beginning of the lactation period on milk production to the good body condition of the cows at the end of the fall or to the supplementation furnished to the animals during the winter. In studies where the season of calving did not influence milk production (Farias e Vasconcellos et al., 2003), the authors attributed the result to the uniform management of the herd throughout the year. In the present work, cows had access to oat pastures during the winter, which may have contributed to an increase in milk productions of lactation periods beginning from April to June. Moreover, the reduction of milk yield during the warmer months of the year can be associated with the reduced ingestion of food when animals, particularly the most productive ones, are submitted to situations of temperature stress (Klosovski et al., 2002).

The proportion of Holstein genes in the breed composition of the cow strongly influenced (P<0.001) the production of milk and, to a lesser extent (P<0,01), the duration of the lactation period (Tables 2 and 3).

Table 2 - Means for milk production and for duration of lactation period, according to the class of proportion of Holstein genes in the breed composition of the herd

Class of proportion of Holstein[1]	Number of observations	Total milk production (kg)	Milk production up to 305 days (kg)	Duration of lactation (day)
H1: 0.5000	48	2814 ± 163	2674 ± 145	257 ± 14
H2: 0.5625 to 0.6875	29	2740 ± 219	2672 ± 195	249 ± 19
H3: 0.7500	77	3154 ± 143	2993 ± 128	274 ± 12
H4: 0.78125 to 0.,8750	46	3504 ± 172	3279 ± 152	298 ± 15
H5: 0.9375	17	2955 ± 244	2876 ± 217	266 ± 21

[1] Defined by the proportion of Holstein (H) in the breed composition of the animal, where H1 = 0.5000 of H, H2 = 0.5625 to 0.6875 of H, H3 = 0.7500 of H, H4 = 0.78125 to 0.8750 of H and H5 = 0.9375 of H.

Table 3 - Contrasts between means of classes of proportion of Holstein for milk production and for the duration of the lactation period

Contrast[1]	Total milk production (kg)	Milk production up to 305 days (kg)	Duration of lactation (day)
H1 – H2	74 ± 209	2 ± 186	7 ± 18
H1 – H3	-340 ± 164 *	-319 ± 146 *	-17 ± 14
H1 – H4	-690 ± 199 ***	-604 ± 177 ***	-41 ± 17 **
H1 – H5	-141 ± 256	-202 ± 228	-10 ± 22

[1] Defined by the proportion of Holstein (H) in the breed composition of the animal, where H1 = 0.5000 of H, H2 = 0.5625 to 0.6875 of H, H3 = 0.7500 of H, H4 = 0.78125 to 0.8750 of H and H5 = 0.9375 of H.
* = P<0.05, ** = P<0.01, *** = P<0.001.

Considering the conditions under which this work was conducted, defined as a semi-intensive management system, total milk production and milk production up to the 305th day of the lactation period increased as the proportion of Holstein 'blood" in the breed composition of the cow changed from 0.5000 (1/2H + 1/2Z) to 0.8750 (7/8H + 1/8Z) and decreased when the proportion of Holstein "blood" reached 0.9375 (15/16H + 1/16Z). A similar trend was observed in the response of the duration of the lactation period, but, for this trait, there was no difference (P>0.05) between the 1/2H + 1/2Z and the 3/4H + 1/4Z. Therefore, in the semi-intensive management regime, there is no justification for complete grade up of Zebu to Holstein. These results strongly agree with those found by Facó et al. (2002), who, analyzing 3,574 lactation periods in the milk recording program of the Associação Brasileira dos Criadores de Girolando, did not identify any advantage of increasing the fraction of Holstein genes in the extensive management regime, but, in better levels of management (semi-intensive and intensive), they found evidence that this increase is beneficial for the increase in milk yield. However, those authors grouped the 7/8H and the 15/16H classes in the same class, which did not allow for studying the response of the 15/16H class in the semi-intensive regime.

Madalena et al. (1990) analyzed data from 660 first and second lactation periods in order to characterize six crossbred Holstein × Guzerath groups (1/4H to 31/32H), distributed in 65 farms classified according to the management level (high and low), and observed that milk production of the 1/2H group was less than those from the 3/4H and 7/8H groups in the high level of management. Nevertheless, in the same level of management, the performance of the 31/32H group remained higher than that of the 1/2H group. This was not true for the 15/16H group in this work, probably because what was defined here as the semi-intensive management system does not correspond exactly to the high level of management as defined by those authors. On the other hand, in the low level of management, performance declined linearly as the proportion of Holstein departed from the 1/2H group, thus indicating that the increase in the proportion of Holstein in the breed composition of the herd is justifiable only if accompanied by improvement in the level of management.

The duration of the lactation period also increased as the proportion of Holstein increased up to 7/8H and decreased when it reached 15/16H, thus suggesting that high proportions of Holstein in the herd compromise performance for this trait in semi-intensive production regimes. Facó et al. (2002) reported increased duration in the lactation period from 1/2H to 3/4H groups and from this to 7/8H group when the productions were registered in the semi-intensive regime. This was in contrast to the findings on production on the intensive regime. Lemos et al. (1997) studied the duration of the lactation period in data from 295 observations of 125 cows originated from four different crossbreeding strategies (F1, F2-synthetic, rotational crossing and continuous crossing) of the milk production system settled at CNPGL/EMBRAPA, Coronel Pacheco-MG from 1989 to 1993. There were no significant differences between the 1/2H and the 15/16H groups. Madalena et al. (1990) reported that the 1/2H group presented shorter lactation periods than those from the 3/4H and the 7/8H groups in the high level of management.

The number and the distribution of the data for each class of Holstein proportion did not allow fitting by models capable of identifying genetic effects responsible for the differences detected here (Table 3). Many authors (Madalena et al., 1990; Perotto et al., 1999; Facó et al., 2002, 2008) used the multiple regression model (Robison et al., 1981) to obtain estimates of heterosis effects separated from the breed's transmitted effects. This approach is based on the assumption that the expression of heterosis is a linear function of the coefficient of individual heterozygosis (an expression which defines the expected proportion of loci with one gene from one breed and the other gene from another breed). For the data used in the present study, coefficient for the breed's additive (or transmitted) effect ranges from 0.5000 to 0.9375 (Table 1). For the same genetic groups, the coefficient of individual heterozygosis ranges from 0.125, in the 15/16H + 1/16Z group, to 1.00 in the 1/2H + 1/2Z group. The lack of groups with low proportions of Holstein like the 1/4H + 3/4Z or even the pure zebu group does not permit a complete separation of the additive effects from the heterotic ones. Furthermore, the additive-dominance model (Cunningham and Syrstad, 1987) would ignore important genetic effects such as maternal heterosis and epistasis, which for the groups represented in this work would not be independent from the additive and individual heterotic effects.

The hypothesis underlying this work postulates that the concomitant improvement of the management level and the genetic merit of the herd. i.e., the exploitation of semi-intensive production systems, is a good option for dairy production farms in the region of the study. Even though there are conflicting results in the literature, (Madalena et al., 1990; Facó et al., 2002), the consensus is that the phenomenon of heterosis loses importance as the environmental conditions are improved. Therefore, the results in this study found for milk production and for the duration of lactation period confirm that, under the conditions in which this work was conducted, the breed additive effects are more important than those of heterosis. Nevertheless, the total efficiency of a dairy farm depends heavily on reproductive characters, like calving interval, for which heterosis can be more important than it is for the traits analyzed here.

Conclusions

In semi-intensive production systems of the northeastern region of Paraná State, the best performance in terms of milk production per lactation period are obtained from cows with 3/4 to 7/8 of Holstein genes in the breed composition.

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