

Genetic parameters of milk production and reproduction traits of Girolando cattle in Brazil

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ABSTRACT

The objective of this study was to estimate the heritability and genetic, phenotypic, and environmental correlations between 305-day milk yield (305MY), age at first calving (AFC), calving interval (CI) and dry period length (DPL), as well as to compare the productive and reproductive performances of several groups of Girolando cows during their first, second and third parturitions in Brazil. Genetic parameters were estimated using uni- and bi-trait analyses via restricted maximum likelihood (REML). Heritability estimates were similar between uni- and bi-trait analyses and varied from 0.20 to 0.28, 0.00 to 0.08 and 0.07 to 0.14 for 305MY, CI and DPL, respectively, whereas AFC was 0.20. Genetic correlations between 305MY and AFC (−0.49) or DPL (−0.40 to −0.79) show a favourable association. However, an unfavourable genetic association was verified between 305MY and CI (0.59) in the first calving. Environmental and phenotypic correlations between 305MY and CI or DPL showed a favourable association (−0.25 to −0.42 and −0.14 to −0.44). Concerning the cow breed group, a decrease in 305MY was observed as the fraction of the Gyr breed increased, whereas animals from the 1/2 Holstein +1/2 Gyr crossbreeding group yielded better performances for AFC and CI. These results reveal large genetic, phenotypic and environmental variations that could be used in selection programmes.

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Introduction

In milk production systems that are raised on pasture in the Brazilian tropical and subtropical regions, animals from crosses between *Bos taurus* × *Bos indicus* breeds predominate because they are better acclimated to weather conditions in these regions. The greater part of milk yield in Brazil is provided by cows crossed between Holstein and Gyr cattle that are responsible for 80% of the total milk production (ABCG 2012).

During the last few years, there was significant growth in the sale of Girolando semen, which reached 501,199 commercialised doses in 2012 (ASBIA 2013). Furthermore, between 2000 and 2014, there was a 41% increase in the milk yield of Girolando cows (Silva et al. 2016).

Although these scenarios seem favourable for dairy cattle in Brazil, there are several obstacles that need to be overcome, such as problems associated with

interactions between production and reproduction traits and their impact on genetic improvement programmes. Reproduction performance is one of the main factors that influence global efficiency and profitability of milk production systems. Consequently, these traits are of interest to breeders because they improve profitability of their herd. However, several studies indicate that genetic selection to increase milk yield has a response that is correlated with a reduction in fertility due to antagonistic genetic correlations between production and reproduction traits (Ojango & Pollot 2001; Pryce et al. 2002; Makgahlela et al. 2007; Sewalem et al. 2010). Studies in tropical and subtropical regions have revealed unfavourable genetic correlation between milk production and fertility in Holstein cattle and their crossbreeds (Silva et al. 1998; Lôbo et al. 2000; Wenceslau et al. 2000; Balieiro et al. 2003). For the Girolando breed, no studies were found in the literature regarding genetic correlations between production and reproduction traits.

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The aims of this study were: (a) to estimate heritability and genetic, phenotypic, and environmental correlations between 305-day milk yield (305MY) and reproduction traits such as age at first calving (AFC), calving interval (CI) and dry period length (DPL) and (b) to compare production and reproduction performances of several genetic groups of Girolando cattle from Brazil.

Materials and methods

The database that was used in this study contained 86,863 records that were obtained from the Brazilian Girolando Breeders Association in partnership with Embrapa Gado de Leite – National Dairy Cattle Research Center.

Prior to the analysis, the information in the sub files was subjected to a number of limiting restrictions relevant to each trait. The following records were excluded: calving year before 2000 and after 2011; lactation length less than 100 and greater than 730 days; CI less than 300 days or greater than 730 days; 305MY greater than 20,000 kg; DPL less than 20 and greater than 300 days; and records of cows with unknown parents.

The analysed traits for the three first lactations were 305MY, AFC, CI and DPL. We used the records of cows from six genetic groups with Holstein and Gyr crossings (1/4HOL:3/4GYR, 3/8HOL:5/8GYR, 1/2HOL:1/2GYR, 5/8HOL:3/8GYR, 3/4HOL:1/4GYR, 7/8HOL:1/8GYR), which were identified as Holsteins with gene fractions of 1/4, 3/8, 1/2, 5/8, 3/4 and 7/8, respectively (Table 1).

The contemporary groups (CG) were defined by herd-calving year for the traits 305MY, CI and DPL and by herd-birth year for AFC. Only CG with at least three records and daughters from at least two sires per group were used. The calving and birth months were grouped into two seasons: October to March (warm and rainy season) and April to September (dry season).

Table 1. Number of animals per genetic group and traits during the first three lactations of Girolando cows.

Lactation	Trait ^a	Genetic group						Total
		1/4	3/8	1/2	5/8	3/4	7/8	
1st	305MY	275	425	2706	3417	3251	826	10,900
	AFC	275	425	2706	3417	3251	826	10,900
	CI	114	192	1498	1577	1541	405	5327
	DPL	86	171	1377	1441	1432	373	4880
2nd	305MY	208	264	1899	2053	2026	620	7070
	CI	90	123	1033	916	974	308	3444
	DPL	86	112	970	853	909	299	3229
3rd	305MY	177	188	1262	1312	1259	445	4643
	CI	78	91	682	597	577	204	2229
	DPL	74	85	653	556	546	201	2115

^a305MY: 305-day milk yield (kg); AFC: age at the first calving (days); CI: calving interval (days); DPL: dry period length (days).

After editing the data, the pedigree file that was used to compute the numerator relationship matrix (NRM) had 26,969, 14,323 and 9701 animals for first, second and third lactation, respectively. The total number of animals with records, the number of bulls and cows in the pedigree file and in the data file are presented in Table 2.

To estimate the genetic parameters, uni- and bi-trait analyses were performed for the production and reproduction traits of three calvings. The convergence was not reached when all traits were jointly considered in a multi-trait analysis. For 305MY, CI and DPL, a model containing fixed effects of the herd-calving year, calving season and genetic group of each cow and age at calving as the linear and quadratic covariates was used. For AFC, a model with the fixed effects of herd-birth year, birth season and genetic group of each cow was used. The additive genetic effects of the animals were randomly considered for all traits, with the error considered to be normal and independent.

The uni-trait animal model was fitted to estimate variance components and heritability separately for each trait, while bi-trait animal models were set to estimate genetic correlations between traits.

In the matrix notation, the animal model was as follows:

$$y = X\beta + Zu + e$$

where y is the vector of records for 305MY, AFC, CI and DPL; β is the vector of fixed effects defined above; u is the vector of random animal effects including animals without records, $u \sim N(0, A\sigma_u^2)$; e is the vector of random residual effects, $e \sim N(0, \sigma_e^2)$; and X and Z are incidence matrices assigning observations to fixed and random animal effects, respectively.

The expected values and (co)variances are:

$$E \begin{bmatrix} y \\ u \\ e \end{bmatrix} = \begin{bmatrix} X\beta \\ 0 \\ 0 \end{bmatrix}; V \begin{bmatrix} u \\ e \end{bmatrix} = \begin{bmatrix} G & 0 \\ 0 & R \end{bmatrix} = \begin{bmatrix} A \otimes G_0 & 0 \\ 0 & I \otimes R_0 \end{bmatrix}$$

Table 2. Descriptive statistics for milk yield and reproduction traits of Girolando cows during the first three lactations.

Lactation	Trait ^a	N	Mean	SD	Minimum	Maximum	CV, %
1st	305MY	10,900	3937	1817	212	14,368	46.15
	AFC	10,900	1075	183	700	1650	17.03
	CI	5327	436	92	301	730	21.10
	DPL	4880	110	66	20	300	60.06
2nd	305MY	7070	4237	1995	191	19,183	47.07
	CI	3444	424	88	300	729	20.69
	DPL	3229	117	66	20	300	56.31
3rd	305MY	4643	4471	2105	214	16,981	47.08
	CI	2229	417	83	300	729	19.83
	DPL	2115	114	62	20	300	54.10

^a305MY: 305-day milk yield, kg; AFC: age at the first calving, days; CI: calving interval, days; DPL: dry period length, days.

where G_0 and R_0 denote the matrices of order 2×2 containing the additive genetic and residual variance components, respectively. A represents the NRM among evaluated individuals, I denotes the identity matrix and \otimes denotes the Kronecker operator. Vector β contains the same fixed effects of uni-trait analysis for the corresponding trait, as previously defined.

Bi-trait analyses were performed between each pair of the previously mentioned traits and within each calving order to estimate the genetic, phenotypic and environmental correlations. The models that were used in these analyses were similar to those that were adjusted for uni-trait analyses. The estimates of the co(variance) components were obtained via the restricted maximum likelihood (REML) using the WOMBAT software (Meyer 2007).

Results

The genetic group had a significant effect on milk yield and reproduction traits of Girolando cows ($p < .05$, Table 3). The 7/8 cows had better performances for milk yield in three calvings, although in the third calving, this superiority was not significant in relation to 3/4 cows. 3/4 cows' 305MY was greater ($p < .05$) than 1/4, 3/8, 1/2 and 5/8 cows in the three calvings. However, the performances of 5/8 and 1/2 cows were similar ($p > .05$), but significantly greater ($p < .05$) than 3/8 and 1/4 cows, as they yielded the worst performance for all of the studied traits. Overall, there was a reduction in milk yield as the Gyr breed composition fraction increased.

When evaluating the reproduction traits, there was a reduction in the indexes when the proportion of Holstein or Gyr increased, such that the animals close to 1/2HOL:1/2GYR tended to have better reproduction performances. 1/2 cows presented with the lowest

estimated means for AFC, followed by 3/4 and 5/8 cows with intermediate performances and similar AFC; otherwise, these genetic groups were greater than 7/8, 3/8 and 1/4 cows. The worst performance for AFC was observed in 1/4 cows ($p < .05$).

For the CI trait, 3/8, 1/2 and 5/8 cows were similar and presented with lower performances in relation to other genetic groups at first calving. Even in the second and third calvings, 3/4 and 7/8 cows had the worst performances for CI. There was no difference ($p < .05$) among 3/8, 1/2 and 5/8 cows (second calving) and 1/4, 3/8 and 5/8 cows (third calving). In relation to DPL, 7/8 and 3/4 cows (greater percentage of Holstein) had shorter dry periods in three calvings, while 1/4 and 3/8 cows (greater percentage of Gyr) presented with longer dry periods ($p < .05$).

The heritability estimates for milk yield and reproduction traits obtained through uni- and bi-trait analyses were similar for the majority of the traits that were studied (Tables 4 and 5). The heritability estimates of 305MY at the first and second calvings were similar (0.27 and 0.28) and was lower at the third calving

Table 4. Estimates of heritability (h^2) and standard errors (SE) for milk yield and reproduction traits of Girolando cows during the first three lactations using uni-trait analyses.

Lactation	Trait ^a	Heritability coefficient of variation		
		h^2	SE	CV _{ar} , %
1st	305MY	0.27	0.03	17.20
	AFC	0.20	0.03	5.70
	CI	0.01	0.02	1.52
	DPL	0.08	0.04	14.73
2nd	305MY	0.28	0.04	18.29
	CI	0.00	0.04	0.16
	DPL	0.07	0.05	13.43
3rd	305MY	0.20	0.05	15.03
	CI	0.08	0.07	5.04
	DPL	0.14	0.08	18.60

^a305MY: 305-day milk yield (kg); AFC: age at first calving (days); CI: calving interval (days); DPL: dry period length (days).

Table 3. Estimates of least square means and standard errors of different genetic groups for milk yield and reproduction traits of Girolando cows during the first three lactations.

Lactation	Trait ^f	Genetic group					
		1/4	3/8	1/2	5/8	3/4	7/8
1st	305MY	3084 ± 96 ^e	3310 ± 74 ^d	3854 ± 36 ^c	3933 ± 31 ^c	4197 ± 31 ^b	4399 ± 56 ^a
	CI	469 ± 10 ^{cd}	439 ± 7 ^{ab}	437 ± 3 ^a	443 ± 3 ^a	453 ± 3 ^{bc}	466 ± 5 ^d
	DPL	164 ± 8 ^a	143 ± 5 ^b	124 ± 2 ^c	124 ± 2 ^c	117 ± 2 ^d	114 ± 4 ^d
	AFC	1165 ± 10 ^a	1132 ± 8 ^b	1051 ± 4 ^e	1081 ± 4 ^d	1075 ± 3 ^d	1106 ± 6 ^c
2nd	305MY	3436 ± 127 ^e	3832 ± 105 ^d	4204 ± 48 ^c	4301 ± 45 ^c	4584 ± 43 ^b	4908 ± 75 ^a
	CI	408 ± 12 ^a	433 ± 9 ^{ab}	426 ± 4 ^a	429 ± 4 ^a	440 ± 4 ^b	445 ± 6 ^b
	DPL	159 ± 9 ^a	132 ± 7 ^{bc}	128 ± 3 ^b	121 ± 3 ^{bc}	118 ± 3 ^{cd}	110 ± 5 ^d
3rd	305MY	3339 ± 164 ^d	3894 ± 135 ^c	4288 ± 62 ^b	4430 ± 58 ^b	4876 ± 56 ^a	4937 ± 93 ^a
	CI	432 ± 14 ^{ab}	420 ± 11 ^{ab}	414 ± 5 ^a	426 ± 5 ^{ab}	429 ± 5 ^b	433 ± 7 ^b
	DPL	144 ± 10 ^a	134 ± 8 ^{ab}	125 ± 4 ^{ab}	120 ± 4 ^{bc}	109 ± 3 ^d	107 ± 6 ^{cd}

^{a-e}Estimates of least square means with different letters in rows are significantly different ($p < .05$).

^f305MY: 305-day milk yield, kg; AFC: age at first calving, days; CI: calving interval, days; DPL: dry period length, days.

Table 5. Estimates of heritability (h^2) and standard errors (SE) for milk yield and reproduction traits of Girolando cows during the first three lactations using bi-trait analyses.

Lactation	Trait ^a	305MY		AFC		CI		DPL	
		h^2	SE	h^2	SE	h^2	SE	h^2	SE
1st	305MY	–		0.27	0.03	0.27	0.03	0.27	0.03
	AFC	0.21	0.03	–		0.20	0.03	0.21	0.03
	CI	0.02	0.02	0.01	0.02	–		0.01	0.02
	DPL	0.08	0.03	0.08	0.04	0.07	0.03	–	
2nd	305MY	–		nc		0.28	0.04	0.28	0.04
	CI	0.01	0.04	nc		–		0.00	0.04
	DPL	0.10	0.05	nc		0.06	0.05	–	
3rd	305MY	–		nc		0.20	0.05	0.20	0.05
	CI	0.09	0.07	nc		–		0.07	0.07
	DPL	0.15	0.08	nc		0.09	0.08	–	

^a305MY: 305-day milk yield, kg; AFC: age at first calving, days; CI: calving interval, days; DPL: dry period length, days; nc=it did not converge.

Table 6. Genetic (r_G), phenotypic (r_P), and environmental correlations (r_E) and standard errors (SE) among milk yield and reproduction traits of Girolando cows during the first three lactations.

Calving	Trait ^a	Genetic correlations		Phenotypic correlations		Environmental correlations		
		r_G	SE	r_P	SE	r_E	SE	
1st	305MY	AFC	-0.49**	0.09	-0.25**	0.01	-0.11**	0.03
	305MY	CI	0.59	0.42	0.15**	0.02	0.13**	0.03
	305MY	DPL	-0.79**	0.15	-0.37**	0.01	-0.31**	0.03
	AFC	DPL	0.28	0.19	0.06*	0.02	0.01	0.03
	AFC	CI	0.15	0.66	-0.05*	0.02	-0.06*	0.03
	CI	DPL	-0.53**	0.10	0.51**	0.01	0.55**	0.02
	CI	DPL	nc		0.14**	0.02	0.10*	0.04
2nd	305MY	DPL	-0.40*	0.19	-0.42**	0.02	-0.44**	0.04
	CI	DPL	-0.64	nc	0.52**	0.02	0.54**	0.03
	305MY	CI	-0.54	0.37	0.14**	0.03	0.25**	0.06
3rd	305MY	DPL	-0.62*	0.23	-0.40**	0.02	-0.36**	0.05
	CI	DPL	0.26	0.62	0.54**	0.02	0.56**	0.04

^a305MY: 305-day milk yield, kg; AFC: age at first calving, days; CI: calving interval, days; DPL: dry period length, days.

* $p < .05$.

** $p < .01$; nc=it did not converge.

(0.20), while DPL presented with similar estimates at the first and second calvings (0.08 and 0.07) and was higher at the third calving (0.14) (Table 5).

For CI, the estimates were close to zero at the first and second calvings and greater at the third calving (0.08) (Table 5). We highlighted the fact that the estimates of heritability for CI and DPL presented with high standard errors. The AFC was evaluated only at the first calving and presented with a moderate estimate of heritability (0.20), thus indicating additive genetic variations, a fact that justifies its inclusion in the improvement programmes. The AFC is an important economic trait since it affects the beginning of an animal's production and can therefore influence an animal's productivity throughout life.

In addition to heritability, the estimates of additive genetic variation coefficients (CV_a) provided additional information regarding genetic variability (Table 4). These estimates revealed that the greater genetic variation in the population was associated with 305MY (15.03–18.29%) and DPL (13.43–18.60%) during three

calvings, while the lower genetic variations were associated with AFC (5.7%) and CI (0.16–5.04%).

The genetic, phenotypic and environmental correlations between 305MY and AFC were negative, and low to moderate in terms of magnitude, with values of -0.49, -0.25 and -0.11, respectively (Table 6). A similar result was obtained between 305MY and DPL during the three calvings with values that were different than zero. A greater genetic correlation between 305MY and DPL was observed at the first calving (-0.79), therefore, suggesting that genetic selection to increase 305MY would cause a reduction in DPL.

Between AFC and DPL as well as between AFC and CI, we observed positive and low magnitude genetic correlations, 0.28 and 0.15, respectively, at the first calving. The respective phenotypic and environmental correlations were positive and low for AFC and DPL (0.06 and 0.01, respectively) and negative and low between AFC and CI (-0.05 and -0.06, respectively).

The genetic correlation between 305MY and CI was positive and of a moderate magnitude at the first

calving (0.59), and there was a similar magnitude with a negative value at the third calving (−0.54), but at the second calving, the genetic correlation did not converge. The phenotypic and environmental correlations had positive and low magnitude tendencies during calving (0.14–0.15 and 0.10–0.25, respectively). Even between CI and DPL, we verified negative and moderate magnitude genetic correlations, −0.53 and −0.64, respectively, at the first and second calvings, while at the third calving, this value was positive and low (0.26). The phenotypic and environmental correlations for these traits were also positive and moderate and oscillated from 0.51 to 0.54 and from 0.54 to 0.56, respectively, during the three calvings.

Discussion

The genetic group had a significant effect on the variables that were studied. 7/8 and 3/4 cows had greater performances of 305MY in relation to animals from other genetic groups ($p < .05$); however, there was a decrease in this performance as the ratio of the Gyr gene increased. Similar results were reported in the scientific literature for Holstein × Gyr cattle (Facó et al. 2007; McManus et al. 2008b) as well as Holstein × Zebu cattle (Grossi & Freitas 2002; Guimarães et al. 2002) in Brazil and Girolando cattle in Benin (Alkoiret et al. 2011). These authors observed greater milk yields during lactation for animals with greater Holstein genetic composition. Nevertheless, Barbosa et al. (2008), when working with Holstein × Gyr cows in Pernambuco state, Brazil using monthly test-day milk yield records, reported a greater performance of milk yield, fat, and protein production in 1/2 cows, followed by 5/8 cows. The authors attributed this superiority to the maximum heterosis of these animals, which was probably influenced by non-additive genetic effects. Indeed, Madalena et al. (1990) reported that F_1 animals generally presented with greater milk yields and lower AFC in relation to genetic groups with greater proportions of Holstein cattle; however, this superiority declines with the increased production level in response to an environmental improvement.

Although heterosis was not evaluated in this study, the better performance of groups 7/8 and 3/4 could be attributed to an improved environment in these herds, which would favour the performance of animals with a greater proportion of Holstein genes. The better performance in the form of reproductive traits was observed for 1/2 cows, who presented with lower indexes of AFC and CI ($p < .05$). These results are similar to those values reported in studies with Holstein × Gyr cows (Facó et al. 2005) and Holstein × Guzarat cows

(Madalena et al. 1990); however, they differ from those that were obtained by McManus et al. (2008b) in that their study highlighted 3/4 cows as earlier animals (844.4 days of AFC) and there was a lower CI (355.7 days). The authors concluded that environmental conditions were limiting factors for Holstein purebred animals when it comes to expressing their genetic potential. In the Republic of Benin, Alkoiret et al. (2011), in a study with Girolando cows, reported a greater performance of AFC in animals with 62.5% of Gyr genes; however, the proportion of Gyr genes had no effect on CI and DPL. Meanwhile, in other studies with Holstein × Zebu cows, significant effects of genetic groups on AFC (Guimarães et al. 2002) and CI (Grossi & Freitas 2002) were not observed.

Alkoiret et al. (2011) evaluated DPL in Girolando cattle and obtained higher values (229 ± 8 days) in comparison to our study. The authors observed a lower DPL in genetic groups 1/2 and 3/4 in comparison to the 3/8 group, but this increase in the proportion of Holstein-Friesian genes did not have any significant effect.

The heritability for 305MY that was obtained in the uni- and bi-trait analyses was similar within calvings and different among calvings. The lower heritability at the third calving may have occurred due to the high phenotypic variations that were observed (33.2 and 7.5% greater than phenotypic variances at the first and second calvings), as well as due to non-identified environmental and random factors (weather, production level, misidentification, size of population that was evaluated, and others). The heritability for 305MY that was obtained in this study was within the ranges (0.19–0.37) that were reported for Holstein × Gyr cows (Facó et al. 2007, 2008, 2009). Also, it is similar to the value of 0.28 that was obtained by Vercesi Filho et al. (2007) in a study with Brazilian dairy crossbred females (*Bos taurus* × *Bos indicus*). However, it is lower than the value of 0.32 that was mentioned by Lôbo et al. (2000) in a review regarding genetic parameters in tropical regions. The differences in relation to the estimates that were reported in the literature can be attributed to several factors such as production levels, population size, analysis model, measurement that was evaluated (adjusted or total milk yield), environmental effects, and others that affect genetic and environmental variances. However, independently of variations that were observed among the estimates, the heritability that was obtained in this study is moderate, which suggests a considerable additive genetic variance that will cause reasonable response to selection for this trait.

The heritability for AFC that was obtained in this study (~ 0.20) was within the range from 0.17 to 0.22

that was reported for Gyr cattle (Balieiro et al. 2003; Santana Júnior et al. 2010). Nevertheless, it was lower than the estimates of 0.33, 0.48 and 0.70 that were reported for Holstein × Gyr, Brazilian dairy crossbred females (*Bos taurus* × *Bos indicus*), and Holstein × Boran cows, respectively (Vercesi Filho et al. 2007; Facó et al. 2008; Haile et al. 2009) and the estimates of 0.23–0.35 that were reported for Holstein cows in Brazil (Val et al. 2004; McManus et al. 2008a). The heritability of the trait AFC indicates that the use of this trait as a selection criterion should cause moderate genetic progress with regards to sexual precocity in Girolando herds.

The heritability that was obtained for CI was low for all calvings (0.00–0.08). The greater value at the third calving (0.08) occurred due to the greater genetic variation and lower phenotypic variation in relation to the other calvings. Small heritability estimates are common in several fertility traits in dairy cattle. Indeed, Berglund (2008) mentioned that in addition to difficulties when it comes to measurement, they present with very low heritability, generally lower than 0.05, mainly due to the large influences of management and the environment. Studies about heritability for CI involving three calvings in crossbred cattle in Brazil are scarce in the literature. The estimates that were obtained in this study were lower than those described by Balieiro et al. (2003), except at the third calving (0.08 vs 0.05) for Gyr cattle, and the value of 0.12 that was obtained by Silva et al. (1998) for the first CI using Holstein cattle in Brazil. However, our estimates are close to those obtained for Holstein cattle in other latitudes (Ojango & Pollot 2001; Montaldo et al. 2010). Differences between the estimates that were obtained in this study and those obtained in other countries may occur due to differences in management and weather that affect genetic and environmental variances, as reported by Berglund (2008).

The low estimates of heritability for CI that were obtained in this study were caused by high phenotypic variance fractions due to environmental variation, thereby suggesting that improvement in this trait could be obtained by improvement in the production environment instead of selection.

The heritability of trait DPL was similar at the first two calvings (~0.08); however, the value was greater at the third calving (0.14). The greater estimate of DPL was caused by the greater genetic variance that was observed at the third calving ($CV_a=18.6\%$). There are few studies in the literature regarding the estimates of heritability for DPL in Brazil. The results are greater than those that were mentioned in studies involving all lactations (repeatability models), as those reported

by Pereira et al. (2000) obtained estimates of 0.004 and 0.0001 when using uni- and bi-trait analyses, respectively, in Holstein herds in Brazil. Also, they are greater than the value of 0.06 obtained by Silva et al. (2006) when using Mantiqueira cows in Brazil, and the value of 0.05 obtained by Rehman et al. (2008) when using data from the first lactation of Sahiwal cows in Pakistan. The low estimates for DPL that were reported in this study indicate that selection for this trait would not be very effective.

The moderate and negative genetic correlation between 305MY and AFC (–0.49) that was obtained at the first calving implies that part of the additive genes that positively influence milk yield acts on reducing age at the first calving. This result suggests that daughters from high value genetic sires for 305MY present with greater sexual precocity. Therefore, the selection process to increase milk yield would result in a greater precocity of heifers. The genetic correlation between 305MY and AFC that was obtained in this study is greater than that of –0.29, which was described by Balieiro et al. (2003) in studies using Gyr cows, and that of –0.20 reported by Val et al. (2004) for Holstein cows. However, our estimate is lower than those of –0.65 and –0.63, which were mentioned by Silva et al. (1998, 2001) for Holstein and crossbred Mantiqueira cows, respectively. Otherwise, Wenceslau et al. (2000), in a study with dairy Gyr cattle, reported unfavourable genetic correlation between both traits (0.49).

The phenotypic and environmental correlations (–0.25 and –0.11, respectively) differed from those obtained by Balieiro et al. (2003), who reported values of 0.02 and 0.11, respectively, for Gyr cattle; by Silva et al. (1998) who reported 0.09 and 0.22 for Holstein cattle; and by Silva et al. (2001) who reported 0.16 and 0.71 for Mantiqueira cows.

The genetic correlations between the traits 305MY and CI were 0.59 and –0.54 at the first and third calvings, respectively, which suggests genetic antagonism between these traits only at the first calving, although these estimates are low in terms of accuracy. Brazilian researchers that reported similar estimates at the first calving have observed unfavourable associations between both traits (Silva et al. 1998; Lôbo et al. 2000; Balieiro et al. 2003). Nevertheless, other authors did not find unfavourable genetic associations between milk yield and CIs (Ojango & Pollot 2001; Val et al. 2004; Montaldo et al. 2010). Phenotypic and environmental correlations varied between low and moderate, oscillating from 0.14 to 0.15 and 0.10 to 0.25, respectively, during the first three calvings. These results are close to the values described by Montaldo et al. (2010)

in Mexico, which ranged from 0.07 to 0.15 and 0.09 to 0.17, respectively, for Holstein cows during the first three calvings; however, our estimates were lower than the values from 0.23 to 0.26 and 0.19 to 0.27, respectively, which were estimated by Balieiro et al. (2003) for Gyr cows during the first three calvings. The results of this study indicate the possible influence of management practices, since breeders generally give more attention to their high milk production cows by focussing more on nutrition, veterinary care, following up with more doses for re-insemination when conception fails, among various other practices.

The genetic, phenotypic and environmental correlations between 305MY and DPL varied between -0.40 and -0.79 , -0.37 and -0.42 , and -0.31 and -0.44 , respectively, during the first three calvings. Studies regarding correlations between milk yield and DPL are scarce in the literature. In a study with Simmental cattle and crosses between Holsteins and Jerseys in Pakistan, Ahmad et al. (2001) reported estimates of -0.99 and -0.27 for genetic and phenotypic correlations, respectively. However, estimates with opposite signals were obtained by Rehman et al. (2008), who reported values of 0.53, 0.27 and 0.17 for genetic, phenotypic and environmental correlations, respectively, in Sahiwal cows in Pakistan. Overall, the results of this study suggest a favourable association between both traits. Therefore, selection for greater milk yield would result in a shorter DPL, possibly due to the increase in lactation length.

The genetic correlation between CI and DPL at first calving (-0.53) was moderate, while phenotypic (0.51–0.54) and environmental correlations (0.54–0.56) were also moderate. These results differ from those obtained by Ahmad et al. (2001), who reported values of 0.96 and 0.84 for genetic and phenotypic correlations, respectively, for pure and crossbred cows in Pakistan and those obtained by Lôbo et al. (2000), who reported values of 0.97 and 0.74 for genetic and phenotypic correlations using cattle in tropical conditions. The genetic correlation between CI and DPL implies that genes that cause increases in CI due to increases in lactation length consequently reduce DPL. However, the phenotypic correlation that was observed between both traits implies that animals with lower CIs present with shorter dry periods.

The phenotypic correlation between two traits depends on their heritabilities and the genetic and environmental correlations between them. If both traits have low heritabilities, then the phenotypic correlation is determined mainly by environmental correlation; otherwise, if they have high heritabilities, then the genetic correlation is more important (Falconer &

Mackay 1996; Lopes 2005). The management strategies of breeders are the possible environmental causes that can influence these reproduction traits according to their economic interests.

The phenotypic and environmental correlations for AFC and CI were close to zero and within the range of values that was estimated by some authors (Ojango & Pollot 2001; Montaldo et al. 2010).

Conclusions


A better performance for milk yield was obtained for cows with genetic groups 7/8HOL:1/8GYR and 3/4HOL:1/4GYR, which presented with a decline in the production level according to the increase in Gyr breed composition. Animals of the genetic group 1/2HOL:1/2GYR, however, had the best performance for AFC and CI. Unfavourable genetic associations between milk yield and CI indicate that the selection to increase milk yield might increase CI as a response. The wide genetic variations of Girolando cattle for milk yield and reproduction traits, when properly used in genetic improvement programmes, can guarantee moderate genetic gains for these traits of greater interest for Girolando breeders, thereby contributing to the long-term improvement in production and reproduction efficiencies of the herds.


Disclosure statement

No potential conflict of interest was reported by the authors.


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References

- ABCG. 2012. Girolando – a raça mais versátil do mundo tropical. Available from: <http://www.girolando.com.br/site/ogirolando/performance.php>
- Ahmad M, Van Der Werf JHJ, Laved K. 2001. Genetic and phenotypic correlations for some economic traits in dairy cattle. *Pak Vet J.* 21:81–86.
- Alkoiret IT, Yari HM, Gbangboche AB, Lokossou R. 2011. Reproductive performance and milk production of

- Girolando cows in the Ranch of Kpinnou, South-West of Benin Republic. *J Anim Vet Adv.* 10:2588–2592.
- ASBIA. 2013. Relatório Anual de importação, exportação e comercialização de sêmen 2012. Available from: <http://www.asbia.org.br/novo/upload/mercado/index2012.pdf>
- Balieiro ES, Pereira JCC, Verneque RS, Balieiro JCC, Valente J. 2003. Estimativas de herdabilidade e correlações fenotípicas, genéticas e de ambiente entre algumas características reprodutivas e produção de leite na raça Gir. *Arq Bras Med Vet Zoo.* 55:85–91.
- Barbosa SBP, Ramalho RP, Monardes HG, Dias FM, Santos DC, Batista AMV. 2008. Milk and fat production of crossbred Holstein-Gir cows (*Bos taurus taurus*–*Bos taurus indicus*) in the Agreste region of the Brazilian state of Pernambuco. *Genet Mol Biol.* 31:468–474.
- Berglund B. 2008. Genetic improvement of dairy cow reproductive performance. *Reprod Domest Anim.* 43:89–95.
- Facó O, Lôbo RNB, Martins Filho R, Lima FAM. 2005. Idade ao Primeiro Parto e Intervalo de Partos de Cinco Grupos Genéticos Holandês × Gir no Brasil. *Rev Bras Zootec.* 34:1920–1926.
- Facó O, Lôbo RNB, Martins Filho R, Martins GA, Oliveira SMP, Azevêdo DMMR. 2008. Efeitos genéticos aditivos e não-aditivos para características produtivas e reprodutivas em vacas mestiças Holandês × Gir. *Rev Bras Zootec.* 37:48–53.
- Facó O, Martins Filho R, Lôbo RNB, Azevedo DMMR, Oliveira SMP. 2009. Efeito da redução da variação da duração de lactação na avaliação genética de bovinos leiteiros mestiços. *Rev Ciênc Agron.* 40:287–292.
- Facó O, Martins Filho R, Lôbo RNB, Oliveira SMP, Martins GA. 2007. Heterogeneidade de (co)variância para a produção de leite nos grupos genéticos formadores da raça Girolando. *Rev Ciênc Agron.* 38:304–309.
- Falconer DS, Mackay TFC. 1996. Introduction to quantitative genetics. 4th ed. Essex: Longman Group Ltd.
- Grossi SF, Freitas MAR. 2002. Eficiência Reprodutiva e Produtiva em Rebanhos Leiteiros Comerciais Monitorados por Sistema Informatizado. *Rev Bras Zootec.* 31:1362–1366.
- Guimarães JD, Alves NG, Costa EP, Silva MR, Costa FMJ, Zamperlini B. 2002. Eficiência reprodutiva e produtiva em vacas das raças Gir, Holandês e cruzadas Holandês × Zebu. *Rev Bras Zootec.* 31:641–647.
- Haile A, Joshi BK, Ayalew W, Tegegne A, Singh A. 2009. Genetic evaluation of Ethiopian Boran cattle and their crosses with Holstein Friesian in central Ethiopia: reproductive traits. *J Agric Sci.* 147:81–89.
- Lôbo RNB, Madalena FE, Vieira AR. 2000. Average estimates of genetic parameters for beef and dairy cattle in tropical regions. *Anim Breed Abstr.* 68:433–462.
- Lopes PS. 2005. Teoria do Melhoramento Animal. 1st ed. Belo Horizonte: FEPMVZ.
- Madalena FE, Teodoro RL, Lemos AM, Monteiro JBN, Barbosa RT. 1990. Evaluation of strategies for crossbreeding of dairy cattle in Brazil. *J Dairy Sci.* 73:1887–1901.
- Makgahlela ML, Banga CB, Norris D, Dzama K, Ng'ambi JW. 2007. Genetic correlations between female fertility and production traits in South African Holstein cattle. *S Afr J Anim Sci.* 37:180–188.
- McManus C, Louvandini H, Falcão RA, Garcia JAS, Saueressig MG. 2008a. Parâmetros reprodutivos para gado Holandês em confinamento total no Centro-Oeste do Brasil. *Ciênc Anim Bras.* 9:272–283.
- McManus C, Teixeira RA, Dias LT, Louvandini H, Oliveira BEM. 2008b. Características produtivas e reprodutivas de vacas Holandesas e mestiças Holandês × Gir no Planalto Central. *Rev Bras Zootec.* 37:819–823.
- Meyer K. 2007. WOMBAT: a tool for mixed model analyses in quantitative genetics by restricted maximum likelihood (REML). *J Zhejiang Univ Sci B.* 8:815–821.
- Montaldo HH, Castillo-Juárez H, Valencia-Posadas M, Cienfuegos-Rivas EG, Ruiz-López FJ. 2010. Genetic and environmental parameters for milk production, udder health, and fertility traits in Mexican Holstein cows. *J Dairy Sci.* 93:2168–2175.
- Ojango JM, Pollot GE. 2001. Genetics of milk yield and fertility traits in Holstein-Friesian cattle on large-scale Kenyan farms. *J Anim Sci.* 79:1742–1750.
- Pereira IG, Gonçalves TM, Oliveira AIG, Teixeira NM. 2000. Fatores de Variação e Parâmetros Genéticos dos Períodos de Serviço e Seco em Bovinos da Raça Holandês no Estado de Minas Gerais. *Rev Bras Zootec.* 29:1005–1013.
- Pryce JE, Coffey MP, Brotherstone SH, Woolliams JA. 2002. Genetic relationships between calving interval and body condition score conditional on milk yield. *J Dairy Sci.* 85:1590–1595.
- Rehman ZU, Khan MS, Bhatti SA, Iqbal J, Iqbal A. 2008. Factors affecting first lactation performance of Sahiwal cattle in Pakistan. *Arch Tierz Dummerstorf.* 51:305–317.
- Santana Júnior ML, Lopes PS, Verneque RS, Pereira RJ, Lagrotta MR, Peixoto MGCD. 2010. Parâmetros genéticos de características reprodutivas de touros e vacas Gir Leiteiro. *Rev Bras Zootec.* 39:1717–1722.
- Sewalem A, Kistemaker GJ, Miglior F. 2010. Relationship between female fertility and production traits in Canadian Holsteins. *J Dairy Sci.* 93:4427–4434.
- Silva MVGB, Bergmann JAG, Martinez ML, Pereira CS, Ferraz JBS, Silva HCM. 1998. Associação genética, fenotípica e de ambiente entre medidas de eficiência reprodutiva e produção de leite na raça holandesa. *Rev Bras Zootec.* 27:1115–1122.
- Silva MVGB, Cobuci JA, Ferreira WJ, Guaragna GP, Oliveira PRP. 2001. Respostas Correlacionadas em Características Reprodutivas no Programa de Melhoramento do Ecótipo Mantiqueira para Produção de leite. *Rev Bras Zootec.* 30:1228–1235.
- Silva MVGB, Ferreira WJ, Cobuci JA, Oliveira PRP, Machado MA, Ferreira CP. 2006. Efeitos genéticos e de ambiente em um rebanho do ecótipo Mantiqueira. II. Características produtivas. *Ciênc Agrotec.* 30:529–537.
- Silva MVGB, Martins MF, Cembranelli MAR, Paiva LC, Panetto JCC, Alves BRC, Campos MM, Carvalho BC. 2016. Girolando breed genetic improvement program – Sire summary – Progeny test results – June/2016. Juiz De Fora: Embrapa Gado De Leite, 2016. 50 (Embrapa Gado de Leite, Documentos, 190). Available from: <https://www.embrapa.br/busca-de-publicacoes/-/publicacao/1050998/girolando-breed-genetic-improvement-program—sire-summary—progeny-test-results—june-2016>
- Val JE, Freitas MAR, Oliveira HN, Cardoso VL, Machado PF, Paneto JCC. 2004. Indicadores de desempenho em

- rebanho da raça Holandesa: curvas de crescimento e altura, características reprodutivas, produtivas e parâmetros genéticos. *Arq Bras Med Vet Zoo*. 56:86–93.
- Vercesi Filho AE, Madalena FE, Albuquerque LG, Freitas AF, Borges LE, Ferreira JJ, Teodoro RL, Faria FJC. 2007. Parâmetros genéticos entre características de leite, de peso e a idade ao primeiro parto em gado mestiço leiteiro (*Bos taurus*×*Bos indicus*). *Arq Bras Med Vet Zoo*. 59:983–990.
- Wenceslau AA, Lopes PS, Teodoro RL, Verneque RS, Euclides RF, Ferreira WJ, Silva MA. 2000. Estimação de Parâmetros Genéticos de Medidas de Conformação, Produção de Leite e Idade ao Primeiro Parto em Vacas da Raça Gir Leiteiro. *Rev Bras Zootec*. 29:153–158.