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Genetic analysis of fertility traits of Holstein dairy cattle in warm and temperate climate

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ABSTRACT. The edited data set for the estimation of heritability, genetic and phenotypic correlations of fertility traits contained up to 23,402 records from 10,894 cows calved between 2001 and 2015. Heritability estimates for success in first service (FS), gestation length (GL), number of inseminations (NI), insemination outcome (IO), calving interval (CI), calving birth weight (CBW) and days open (DO) were low and ranged between 0.016 (DO) and 0.123 (GL). Repeatability of fertility traits was estimated to vary from 0.021 (FS) to 0.411 (IO). The genetic correlations between DO × CI, DO × NI and CI × NI were positive and nearly perfect (0.98, 0.88 and 0.88, respectively), while those between DO × IO and CI × IO were negative (-0.98 and -1, respectively). Further, the phenotypic correlations between DO × CI, DO × NI, CI × NI, CBW × IO and SF × IO were 0.99, 0.83, 0.83, 0.99 and 1, respectively, while those between DO × IO, CI × IO, GL × IO and NI × IO were -0.99, -0.99, -0.99 and -1, respectively. Overall genetic parameters imply a good practical management in heat stress conditions will be essential for improving fertility efficiency.

Keywords: heritability, repeatability, genetic correlation, phenotypic correlation, heat stress.

Análise genética de traços de fertilidade em vacas leiteiras Holstein em climas quentes e temperados

RESUMO. Os dados editados para definir a estimativa de herdabilidade, correlações genéticas e fenotípicas de características de fertilidade continham até 23,402 registros a partir de 10,894 vacas paridas entre 2001 e 2015. As estimativas de herdabilidade para o sucesso no primeiro serviço (SF), duração da gestação (GL), número de inseminações (NI), resultado de inseminação (IO), intervalo entre partos (CI), peso ao nascer (CBW) e dias abertos (DO) foram baixas e variaram entre 0,016 (DO) e 0,123 (GL). A repetitividade das características de fertilidade foi estimada e variou entre 0,021 (SF) e 0,411 (IO). A correlação genética entre DO × CI, DO × NI e CI × NI foi positiva e quase perfeita (0,98, 0,88 e 0,88, respectivamente), enquanto que aquela entre DO × IO e CI × IO foi negativa (-0,98 e -1, respectivamente). A correlação fenotípica entre DO × CI, DO × NI, CI × NI, CBW × IO e SF × IO foi 0,99, 0,83, 0,83, 0,99 e 1, respectivamente, enquanto aquela entre DO × IO, CI × IO, GL × IO e NI × IO foi -0,99, -0,99, -0,99 e -1, respectivamente. Os parâmetros genéticos constatados implicam que será essencial uma gestão bem prática na condição de estresse por calor para melhoria da eficiência da fertilidade.

Palavras-chave: herdabilidade, repetitividade, correlação genética, correlação fenotípica, estresse por calor.

Introduction

Fertility traits are considered very important because of their impact on the economy of dairy cattle breeding. Economic losses due to fertility problems are mainly caused by low dairy yield, prolonged calving intervals, increased insemination costs, few calves per cow per year, increased culling, high replacement costs and shorter reproductive lifespans (González-Recio & Alenda, 2005; Abe, Masuda, & Susuki, 2009). Nonetheless, for many years, genetic improvement programs worldwide did not include reproductive performance, since the selection was mainly focused on milk yield. An exception was Scandinavia, whose selection indices included not only milk yield, but also health and reproductive traits (Miglior, Muir, & Van Doormaal, 2005). Now, the increase in milk yield without considering the reproductive performance is a problem, because it produced an important decline in the reproductive efficiency over time (Pryce, Royal, Garnsworthy, & Mao, 2004; Melendez & Pinedo, 2007). Fertility in lactating dairy cows is also very sensitive to season, especially in hot climates. Global warming and the breeding of selected animals that are more and more sensitive to environmental effects have made this phenomenon, named heat stress, particularly relevant even in temperate areas (Nardone, Ronchi, Lacetera, Ranieri, & Bernabucci, 2010; Ferreira, 2013). Decreasing heat tolerance may be another of the reasons for decline in reproductive efficiency. So, one way to counteract this decline is through genetic selection (Pszczola, Aguilar, & Misztal, 2009). It is difficult to determine which traits must be included in the genetic evaluation of fertility, since they have very low heritability values, i.e., close to 0.1 (Thaller, 1998; Jamrozik, Fatehi, Kistemaker, & Schaeffer, 2005). However, over the last decade, reproductive traits have increasingly been included in the selection indices for reproductive traits in genetic evaluations in different countries, thus highlighting the importance of including fertility in improvement programs of dairy cattle (Miglior et al., 2005). Pozveh, Shadparvar, Shahrbabak, and Taromsari (2009) estimated genetic parameters for calving interval (CI), days open (DO), and gestation length (GL) in traits collected by the Animal Breeding Center of Iran from 1980 to 2004 on a data set including fertility records from 6000 cows. However, these traits and other economically important traits, such as number of insemination (NI), insemination outcome (IO), success in first service (SF) and calving birth weight (CBW) were not considered in heat stress condition. The objectives of this study were to estimate heritability, repeatability, genetic and phenotypic correlations of fertility traits of Holstein dairy cattle in warm and temperate climate.

Material and methods

Reproductive data and editing procedure

The data were collected from Holstein dairy population located in the north of Iran. The edited data set contained up to 23,402 records from 10,894 cows calved during 2001 to 2015. Original data file for reproduction traits consisted of insemination records that were matched to pedigree, lactation, and calving performance information to calculate the traits of interest. The fertility traits selected for this study were success in first service (SF), gestation length (GL), number of inseminations (NI), insemination outcome (IO), calving interval (CI), calving birth weight (CBW) and days open (DO). The SF and IO as binary traits and the NI as categorical trait were considered whereas the GL, CI, CBW and DO were determined as continuous traits. Insemination outcome was defined as 1 = successful if cow became pregnant at insemination time and 0 = failure. Gestation length was measured as an interval from the last insemination to subsequent calving; GL was considered between 240 and 290 d. Days open was defined as the number of days between calving and conception; DO was limited to between 45 and 350 d. Calving interval was defined as the number of days between 2 consecutive calving events. CI records were limited to be between 285 and 640 d. Number of services was defined as the number of inseminations within a lactation; If NI was greater than 10, then NI was assigned to 10. SF was a binary trait defined as 1 = successful if cow became pregnant at first insemination and 0 = failure. Also, CBW was required to be between 20 and 60 kg. Subsequently, cows without pedigree information were excluded.

Climate data

Daily climate records were obtained from the most nearby meteorological station located at the same altitude as the farm studied. The major climatic variables directly affecting livestock are temperature, humidity, air movement and radiation (Konig, Chongkasikit, & Langholz, 2005). Attempts to combine environmental parameters in one single index have had limited success except for the temperature–humidity index (THI) (Kadzere, Murphy, Silanikove, & Maltz, 2002) A daily THI was computed using the following Equation 1 (National Research Council [NRC], 1971):

$$THI = (1.8 \times T + 32) - [(0.55 - 0.0055 \times RH) \times (1.8 \times T - 26)] \quad (1)$$

where:
T is mean daily temperature in degrees centigrade and
RH is the mean daily relative humidity as a percentage.

Insemination records were merged with daily temperature-humidity index. THI on the day of the insemination, 1 d prior and 1 d after insemination were studied as independent variables.

Genetic analysis and statistical models

The reproduction traits (SF, GL, NI, CI, CBW and DO) were analyzed with the Equation 2 as follow:

$$P = \mu + parity + YS + DYS + \beta_1 X_{DIM} + \beta_2 (X_{DIM})^2 + \beta_1 X_{AC} + \beta_2 (X_{AC})^2 + animal + pe + e \quad (2)$$

Also, trait of IO was analyzed with the following Equation 3:

$$Q = \mu + parity + YS + DYS + \beta_1 X_{DIM} + \beta_2 (X_{DIM})^2 + \beta_1 X_{AC} + \beta_2 (X_{AC})^2 + \beta_1 X_{THI} + \beta_2 (X_{THI})^2 + animal + pe + e \quad (3)$$

where:
P is the observed trait of SF, GL, NI, CI, CBW and DO; Q is the observed trait of IO;
μ is the mean of trait;
Parity is the fixed effect of parity in 5 classes;
YS is the fixed effect of year-season of calving in 14 and 4 classes, respectively;
DYS is the fixed effect of dystocia score (1 = no problem to 5 = caesarean);
β_1 and β_2 are linear and quadratic regression coefficients of dependent variable (P, Q) on days in milk effect, age of calving or temperature-humidity index effect;
X_{DIM} as continuous variable representing days in milk, in weeks ranged from 15 to 105;
X_{AC} as age of animal at calving in months, ranged from 20 to 135;
X_{THI} as continuous variable representing temperature-humidity index;
Animal is the random additive genetic effect;
pe is the random permanent environmental effect and *e* is the random residual effect. (Co) Variance components were estimated by AI-REML in DMU software package (Madsen & Jensen, 2013) using an animal linear mixed model; univariate threshold models were also carried out for the binary traits. Heritability was estimated as the ratio of the additive genetic variance to total phenotypic variance; and repeatability, as the ratio of the sum of the additive genetic variance plus permanent environmental variance to phenotypic variance, as described by Falconer and Mackay (2001), according Equation 4 and 5:

$$h^2 = \sigma_a^2 / (\sigma_a^2 + \sigma_{pe}^2 + \sigma_e^2); \quad (4)$$

$$R = (\sigma_a^2 + \sigma_{pe}^2) / (\sigma_a^2 + \sigma_{pe}^2 + \sigma_e^2 \quad (5)$$

Genetic and phenotypic correlations between traits were estimated using a series of bivariate animal linear mixed models. The covariance structure for the models was defined as Equation 6 and 7:

$$V \begin{bmatrix} a \\ pe \\ e \end{bmatrix} = \begin{bmatrix} G_0 \otimes A & 0 & 0 \\ 0 & Q_0 \otimes I & 0 \\ 0 & 0 & R_0 \otimes I \end{bmatrix} \quad (6)$$

$$G_0 = \begin{bmatrix} \sigma_{aii}^2 & \sigma_{aij} \\ \sigma_{aji} & \sigma_{ajj}^2 \end{bmatrix}, Q_0 = \begin{bmatrix} \sigma_{peii}^2 & \sigma_{peij} \\ \sigma_{peji} & \sigma_{pejj}^2 \end{bmatrix}, R_0 = \begin{bmatrix} \sigma_{eii}^2 & \sigma_{eij} \\ \sigma_{eji} & \sigma_{ejj}^2 \end{bmatrix},$$
$$G_0 = \begin{bmatrix} \sigma_{aii}^2 & \sigma_{aij} \\ \sigma_{aji} & \sigma_{ajj}^2 \end{bmatrix}, Q_0 = \begin{bmatrix} \sigma_{peii}^2 & \sigma_{peij} \\ \sigma_{peji} & \sigma_{pejj}^2 \end{bmatrix}, R_0 = \begin{bmatrix} \sigma_{eii}^2 & \sigma_{eij} \\ \sigma_{eji} & \sigma_{ejj}^2 \end{bmatrix}, \quad (7)$$

where:
A is the numerator relationship matrix;
I was an identity matrix of appropriate order;
$\otimes$ is the Kronecker product;
G_0 = variance and covariance matrix of random additive genetic effects;
σ_{aii}^2 = animal additive genetic variance for trait *i*;
σ_{ajj}^2 = additive genetic variance for trait *j*;
σ_{aij} = σ_{aij} = additive genetic covariance between traits *i* and *j*;
Q_0 = variance and covariance matrix of random permanent environmental effects;
σ_{peii}^2 = permanent environmental variance for trait *i*;
σ_{pejj}^2 = permanent environmental variance for trait *j*;
σ_{peij} = σ_{peji} = permanent environmental covariance between traits *i* and *j*;
R_0 = variance and covariance matrix of residual effects;
σ_{eii}^2 = residual variance for trait *i*;
σ_{ejj}^2 = residual variance for trait *j*; and
σ_{eij} = σ_{eji} = residual covariance between traits *i* and *j*.

Results and discussion

Climatic conditions in the North of Iran

Climatic conditions in the north of Iran (Sari city) could be characterized as mild, and generally warm and temperate. The rain in Sari fallen mostly in the winter, with relatively little rain in the summer. The annual rainfall averaged 690 mm. The lowest precipitation was in June, with an average of 23 mm and the highest occurred in December with an average of 98 mm. The mean of temperature and humidity of present study was 18.26 ± 7.79°C and 75.19 ± 9.29%, respectively. The THI was lowest in January and February (mean of 56), which was associated with the winter season, and highest in June through September (mean of 81), which was associated with the summer season and heat stress condition.

Descriptive statistics

In this study, the mean and standard error for DO was 140.36 days (± 76.16). Also, mean of calving interval was 415.99 days (± 79.62). In accordance to the means of DO and CI traits, average of GL was 278.2 days (± 5.58). Moreover, mean of number of inseminations in this herd was 2.73 (± 1.94). Also, the averages of SF and IO traits of herd were low (0.32 ± 0.003 and 0.31 ± 0.001, respectively). Finally, the mean of calving birth weight was 40.4 kg (± 6.08).

Heritability, repeatability and variance components

Variance components and estimated heritability and repeatability for fertility traits are shown in Table 1. Heritability of GL was higher than others. Estimated heritability for DO and SF was low. However, DO as interval trait showed greater additive genetic variance related to SF as binary trait. Estimated additive genetic variances for CI and DO (11.34 and 7.23, respectively) was much greater than other traits. Additive genetic variance for SF was the least among all assessed traits. Also, permanent environmental variance for CI and DO (11.01 and 7.47, respectively) was the highest and for SF (0.001) was the least among all traits. Likewise, estimated repeatability for DO and SF was lower and for IO was higher than others (Table 1).

Table 1. Genetic variance (σ_a^2), permanent environmental variance (σ_{pe}^2), residual variance (σ_e^2), heritability (h^2) and repeatability (*R*) with standard error (± SE) for fertility traits.

Traits[1]	σ_a^2±SE	σ_{pe}^2±SE	σ_e^2±SE	h^2±SE	*R*±SE
DO	7.23±3.35	7.47±5.16	417.54±6.56	0.016±0.01	0.034±0.013
CI	11.34±3.29	11.01±4.57	363.20±5.52	0.029±0.009	0.057±0.01
GL	3.58±0.41	1.68±0.4	23.71±0.36	0.123±0.104	0.181±0.1
NI	0.06±0.01	0.12±0.02	1.43±0.02	0.041±0.025	0.115±0.03
SF	0.002±0.0009	0.001±0.001	0.13±0.001	0.015±0.008	0.021±0.008
CBW	2.88±0.47	1.71±0.53	27.73±0.52	0.089±0.037	0.142±0.04
IO	0.05±0.02	0.36±0.03	0.60±0.006	0.055±0.017	0.411±0.02

[1]DO = days open, CI = calving interval, GL = gestation length, NI = number of inseminations, SF = success in first service, CBW = calving birth weight, IO = insemination outcome.

Additive genetic and phenotypic correlations

As shown in Table 2, estimates of additive genetic correlations varied from -1 for CI and IO to 0.98 for DO and CI. Phenotype correlation estimates ranged -1 for NI and IO to +1 for SF and IO.

In the following discussion, we compare estimates of parameters from this study with means for similar traits in the literature. The heritability for DO, CI, GL, NI, SF, CBW and IO traits reported in the literature are shown in Table 3. The heritability obtained for DO in this research (0.016) was similar to this reported by Ríos-Ultrera, Calderón-Robles, Rosete-Fernández, and Lagunes-Lagunes (2010a). In contrast, some authors reported very higher heritability values (Abe et al., 2009; Pozveh et al., 2009; Sun et al., 2010; Ghiasi et al., 2011; Pantelic, Sretenović, & Ostojić-Andrić, 2011) (Table 3). As for CI, the heritability estimates obtained in this study was 0.029. This is consistent with the results reported by Veerkamp, Koenen, and De Jong (2001) and Wall, Brotherstone, Woolliams, Banos, and Coffey (2003). However, these results were lower than those obtained by Haile-Mariam, Morton, and Goddard (2003), Demeke, Neser, and Schoeman (2004), Restrepo, Pizarro, and Quijano (2008), Pozveh et al. (2009), Ríos-Ultrera et al. (2010a) and Ghiasi et al. (2011). Interval traits (DO and CI) may be affected by management decisions such as the length of the voluntary waiting period or estrus synchronization applied in this farm. The estimate of heritability for GL in this study (0.123) is approximately compatible with previous results in the Holstein breed by Eghbalsaied (2011). In contrast to present estimate, Pozveh et al. (2009) obtained lower values and Olson, Cassell, McAllister, and Washburn (2009) and Johanson, Berger, Tsuruta, and Misztal (2011) reported higher values. The heritability estimate for NI was 0.041, as were those reported by Estrada-León, Magana, and Segura-Correa (2008) in Brown Swiss cows. However, Demeke et al. (2004) reported higher value and Wall et al. (2003), González-Recio and Alenda (2005) and Sun et al. (2010) obtained lower values. The heritability estimate obtained for SF (0.015) was in a good agreement with results from Kadarmideen, Thompson, Coffey, and Kossaibati (2003). Higher estimates (González-Recio & Alenda, 2005; Ghiasi et al., 2011) have also been reported. The obtained heritability value for CBW (0.089) was lower to those reported by Olson et al. (2009) and Johanson et al. (2011). The heritability for IO obtained in this study for Holstein cattle was 0.055, which was similar to these reported by Haile-Mariam et al. (2003), Abe, Masuda, and Susuki (2009) and Tsuruta, Misztal, Huang, and Lawlor (2009). In contrast, Ghiasi et al. (2011) and Zambrano and Echeverri (2014) reported higher and lower heritability values, respectively (Table 3).

Table 2. Additive genetic (above diagonal) and phenotypic (below diagonal) correlations (± SE) for all fertility traits.

Traits[1]	DO	CI	GL	NI	SF	CBW	IO
DO	-	0.98±0.08	-0.20±0.16	0.88±0.18	-0.48±0.31	0.38±0.3	-0.98±0.15
CI	0.99±0.008	-	-0.04±0.03	0.88±0.15	-0.55±0.35	0.32±0.3	-1±0.53
GL	0.13±0.04	0.18±0.04	-	-0.09±0.08	-0.19±0.1	0.007±0.006	-0.38±0.37
NI	0.83±0.01	0.83±0.01	0.15±0.03	-	-0.49±0.39	0.16±0.12	-0.77±0.4
SF	-0.09±0.06	-0.07±0.06	0.08±0.05	-0.17±0.05	-	-0.29±0.28	0.36±0.3
CBW	0.13±0.04	0.15±0.04	0.43±0.03	0.16±0.03	0.06±0.05	-	-0.65±0.33
IO	-0.99±0.17	-0.99±0.13	-0.99±0.6	-1±0.4	1±0.22	0.99±0.3	-

[1]The symbols are the same as Table1.

Table 3. Heritability reported by several authors for fertility traits.

Authors	Breed	Traits[1]						
		DO	CI	GL	NI	SF	CBW	IO
Ghiasi et al. (2011)	H	0.076	0.074	-	0.046	0.029	-	0.076
Pantelic et al. (2011)	H	0.105	-	-	-	-	-	-
Eghbalsaied (2011)	H	-	-	0.152	-	-	-	-
Johanson et al. (2011)	H	-	-	0.51	-	-	0.26	-
Ríos-Ultrera et al. (2010a)	H	0.010	0.130	-	0.030	-	-	-
Abe et al. (2009)	H	0.074	-	-	-	-	-	0.049
Olson et al. (2009)	HJ	-	-	0.42	-	-	0.49	-
Pozveh et al. (2009)	H	0.06	0.07	0.07	-	-	-	-
Sun et al. (2010)	H	0.067	0.067	-	0.028	-	-	-
Tsuruta et al. (2009)	H	-	-	-	-	-	-	0.052
Restrepo et al. (2008)	H	-	0.090	-	-	-	-	-
Estrada-León et al .(2008)	BS	0.057	0.110	-	0.040	-	-	-
González-Recio and Alenda (2005)	H	0.040	0.040	-	0.020	0.04	-	-
Demeke et al. (2004)	H	0.040	0.080	-	0.070	-	-	-
Haile-Mariam et al. (2003)	H	0.040	0.090	-	0.030	-	-	0.050
Wall et al. (2003)	H	-	0.033	-	0.020	-	-	-
Kadarmideen et al. (2003)	H	-	-	-	-	0.016	-	-
Veerkamp et al. (2001)	H	-	0.032	-	0.034	-	-	-
Zambrano and Echeverri (2014)	HJ	-	-	-	-	-	-	0.03

[1]The symbols are the same as Table 1. HJ – Holstein - Jersey; BS - Brown Swiss.

The low heritability in this study suggested that improvement of fertility traits in cows could be achieved by improving reproductive managements such as successful detection of heat, timely insemination, feeding practice for growing and postpartum animals and controlling heat stress. The repeatability estimate for DO in Holstein (0.034) was lower to those reported by Demeke et al. (2004), Estrada-León et al. (2008) and M'hamdi, Aloulou, Brar, Bouallegue, and Ben Hamouda (2010) which were in range 0.135-0.190. Regarding CI, the repeatability value obtained (0.057) was nearly the same as reported by Ojango and Pollott (2001) (0.06). Nevertheless, Kadarmideen, Thompson, and Simm (2000) obtained lower value (0.049) and some authors (Estrada-León, Magana, & Segura-Correa, 2008; M'hamdi et al., 2010; Ríos-Ultrera, Calderón-Robles, Rosete-Fernández, & Lagunes-Lagunes, 2010a) report higher repeatability values (0.120-0.180). Repeatability for GL was estimated to be 0.181, which was lower than estimated repeatability by Johanson et al. (2011) (0.54). For NI, the repeatability estimate was 0.115, higher than those reported by Kadarmideen et al. (2000), Demeke et al. (2004), Estrada-León et al. (2008) and M'hamdi et al. (2010) which were in a range between 0.022 and 0.08. The estimate of repeatability for SF in this study (0.021) was lower than obtained result in the Holstein breed by Jamdar and Eskandarinasab (2014) (0.077). For IO, the repeatability value found for Holstein dairy cattle (0.411) was higher than those reported by Ríos-Ultrera, Calderón, Rosete, and Lagunes (2010b) and Zambrano and Echeverri (2014) which were 0.03 in Brown Swiss cattle and 0.076 in Holstein-Jersey, respectively. Finally, the estimated repeatability for CBW was 0.142, which was lower than 0.29 obtained by Johanson et al. (2011). The low repeatability estimates obtained for most traits suggest that fertility traits are strongly influenced by temporary environmental factors. It would thus be possible to improve fertility performance through improvement in herd management. This fact suggests that in making decision for culling cows, reproduction performance should take less weight in comparison with production traits, which are considerably more repeatable. The genetic correlation between DO and CI in this study was close to 1 (0.98). This value was similar to those reported by González-Recio and Alenda (2005), Gredler, Fürst, and Sölkner (2007) and Ghiasi et al. (2011), who reported a nearly perfect genetic correlation (0.99, 0.98, and 0.99, respectively). The genetic correlation between DO and NI was high and favorable (0.88). Nearly equivalent results were reported by González-Recio and Alenda (2005) and Pozveh et al. (2009): 0.94 and 0.83, respectively. The joint analysis of CI and NI indicates that the genetic correlation between these 2 traits was 0.88, consistent with those reported by González-Recio and Alenda (2005) and Eghbalsaied (2011) (0.89 and 0.81, respectively). These results suggest that these reproductive traits (DO × CI, DO × NI and CI × NI) are almost genetically equivalent, i.e., they are influenced by the same genes. This is known as pleiotropic effect. The genetic correlation between DO and GL was -0.2. The result obtained in this study was lower than -0.36 reported by Eghbalsaied

(2011). For Holstein cows, the genetic correlation between DO and SF was estimated -0.48, which was lower than values obtained by González-Recio and Alenda (2005) and Ghiasi et al. (2011) (-0.94 and -0.83, respectively). The genetic correlation between CI and GL was -0.04 that higher value was reported by Eghbalsaied (2011) (-0.07). The genetic correlation between GL and NI (-0.09) was lower than obtained result by Eghbalsaied (2011) (-0.88). Also, the genetic correlation of GL and CBW was obtained low and near zero (0.007), which was lower than value reported by Johanson et al. (2011) (0.52). For Holstein cattle, the genetic correlation between CI and SF that we obtained was medium and negative (-0.55), similar to the finding obtained by González-Recio and Alenda (2005), who reported a correlation of -0.59 between these 2 traits. Likewise, the genetic correlation between NI and SF was middle and negative (-0.49) that higher value was reported by Kadarmideen et al. (2003) (-0.92). The genetic correlation between NI and IO obtained in this study was nearly high and negative (-0.77), similar to the result reported by Ghiasi et al. (2011) (-0.73). These results suggest that these traits (CI × SF, NI × SF and NI × IO) are not genetically favored, as could be logically expected. The genetic correlation of SF and IO was 0.36, whereas González-Recio and Alenda (2005) and Ghiasi et al. (2011) reported higher values (0.94 and 0.83, respectively). These results suggest that these 2 reproductive traits were essentially the same indicator of fertility and may be originally the same in terms of genetic source. The genetic correlation between CI and IO was -1. The result obtained in this study is similar to those obtained by González-Recio and Alenda (2005), Ghiasi et al. (2011), who both reported a correlation of -0.99 between CI and insemination outcome. Also, the genetic correlation obtained in this study between DO and IO was high and negative (-0.98). This is consistent with the results reported by González-Recio and Alenda (2005) and Ghiasi et al. (2011) (-0.99 in both reports). The estimated genetic correlations among CI × IO and DO × IO indicated that selection for cows with high insemination outcome could lead to shorten DO and CI. Therefore, they could be used as one of the best indicators for cow fertility. This would enable efficient selection for better reproductive performance. The phenotypic correlation between CI and DO in this study was high and positive, with value of 0.99. González-Recio and Alenda (2005), Ghiasi et al. (2011), Eghbalsaied (2011) and Zambrano and Echeverri (2014) reported similar estimates for Holstein dairy cattle (0.91, 0.95, 0.99 and 1 respectively). Likewise, the phenotypic correlation between NI and CI was high (0.83). El Amin, Simerl, and Wilcox (1986), Kadarmideen et al. (2000), Ageeb and Hayes (2000), González-Recio and Alenda (2005) and Ghiasi et al. (2011) reported lower values (0.01, 0.69, 0.05, 0.68 and 0.70, respectively). Similarly, the result obtained in this study regarding the phenotypic correlation between NI and DO was high (0.83). This result was higher than reported by El Amin et al. (1986), Ríos-Ultrera, Calderón-Robles, Rosete-Fernández, and Lagunes-Lagunes (2010c) and Ghiasi et al. (2011) (0.01, 0.56 and 0.73, respectively). The reason of these high correlations may be due to the high use of estrus synchronization programs in warm and temperate climate condition. The phenotypic correlation between IO and NI obtained in this study was perfect and negative (-1), and it was higher than results obtained by González-Recio and Alenda (2005) and Ghiasi et al. (2011) (-0.75 and -0.73, respectively). The obtained higher and negative correlation may also be explained by the factor discussed above. The phenotypic correlation between IO and CI was -0.99, similar the values reported by González-Recio and Alenda (2005) and Ghiasi et al. (2011) (-0.91 and -0.95, respectively). Likewise, the phenotypic correlation between IO and DO, the value obtained in this study was -0.99, which is consistent with the results reported by González-Recio and Alenda (2005) and Ghiasi et al. (2011) (-1 and -0.98, respectively), which indicate that the degree of phenotypic association between these 2 traits is high and negative. In relation to the phenotypic correlation between IO and SF, the value obtained in the present study was perfect and favorable associated, presenting 1 in the population studied. This result was higher than findings of González-Recio and Alenda (2005) and Ghiasi et al. (2011) who reported 0.61 and 0.55, respectively. In relation to the phenotypic correlation between GL and CI, the value obtained in this study was 0.18, which was higher than reported value by Pozveh et al. (2009) (0.002). As for phenotypic correlation between NI and GL, the value obtained was 0.15. This result was positive and higher than obtained value by Eghbalsaied (2011) (-0.13). The phenotypic correlation between GL and DO was 0.13, unlike the lower value reported by Pozveh et al. (2009) (0.003). The phenotypic correlation between SF and NI was -0.17, which is lower than result obtained by Kadarmideen et al. (2003), González-Recio and Alenda (2005) and Ghiasi et al. (2011) (-0.69, -0.76 and -0.7, respectively). Also, phenotypic correlation between SF and CI was low and negative associated with value of -0.07. Kadarmideen et al. (2003), González-Recio and Alenda (2005) and Ghiasi et al. (2011) reported phenotypic correlation values which were moderate and negative (-0.54, -0.54 and -0.53, respectively). Similarly, phenotypic correlation between SF and DO was low and negative (-0.09) which was lower than results of González-Recio and Alenda (2005), and Ghiasi et al. (2011) (-0.61 and -0.55, respectively). Low phenotypic correlations between SF × NI, SF × CI and SF × DO may be due to the fact that present study was carried out in region with warm and temperate climate, unlike most of the studies which were carried out in zones with a subtropical climate.

Conclusion

According to the results, this study confirms that reproductive traits present low heritability, < 10% in most cases, in Holstein dairy cattle, suggesting that fertility is affected mostly by the environment. Therefore, good management of the fertility traits in heat stress condition must be considered in order to improve reproductive efficiency. The high and negative genetic correlations for DO × IO and CI × IO, and high and positive genetic correlations for DO × CI, DO × NI, and CI × NI in this study suggest that these reproductive traits are genetically equivalent, i.e., they are influenced by the same genes. This obviously favors the selection of these traits, as we can predict what will happen to several of the reproductive traits after performing selection on one of them. In this manner, we can integrate information on different traits to propose more efficient selection strategies.

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