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Genetic and phenotypic trends of fertility traits for Holstein dairy population in warm and temperate climate

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Abstract The main objective of this study was to investigate genetic and phenotypic trends for fertility traits in Holstein dairy population under warm and temperate climate. Fertility traits were: success in first service, gestation length, number of inseminations, insemination outcome, calving interval, calving birth weight and days open. The edited data set included up to 23,402 records from 9,486 cows. The mean and standard deviation for fertility traits were 0.32±0.003, 278.2±5.58, 2.73±1.94, 0.31±0.001, 415.99±79.62, 40.4±6.08 and 140.36±76.16 for success in first service, gestation length, number of inseminations, insemination outcome, calving interval, calving birth weight and days open, respectively. In general, there were decreasing genetic trends for all traits over the years. On the other hand, there were decreasing phenotypic trend for days open, calving interval, gestation length, number of inseminations and calving birth weight, but estimates of phenotypic trends were positive for success in first service and insemination outcome over the years. It was concluded decreased trend for days open, calving interval, gestation length, number of inseminations and calving birth weight and increased trend for success in first service and insemination outcome traits over time indicated that Holstein dairy producers in warm and temperate climate were successful in managing and improving in nutrition during 1999 to 2013.

Keywords genetic trend, phenotypic trend, fertility, dairy cattle

Introduction

The main purpose of reproductive management of dairy cows is to maximize the number of parturitions during the useful age of cows and thus increasing profitability. Due to unfavorable genetic correlation between productive and reproductive traits (Liu et al 2008) and most emphasis on milk yield in selection of dairy cattle, the reproductive efficiency has decreased since the mid-1980s (Olynk and Wolf 2008). So today, the main factor of economic losses is to be low reproductive efficiency in dairy cattle herds (Holtsmark et al 2008).

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 (HS), particularly relevant even in temperate areas (Ferreira 2013). Decreasing heat tolerance may be one of the reasons for decline in fertility. One way to counteract this decline is through genetic selection (Pszczola et al 2009).

Estimation of genetic trends is necessary to monitor and evaluate selection programs. The estimates of trends in the performance traits of dairy cattle seem to vary from breed to breed and from herd to herd due to differences in locality, management and selection objectives (Amino et al 2007). Many studies have reported decline in Fertility of dairy cattle. For example, in the United States, the conception rate has dropped 6% between 1980 and 2006, which is equivalent of increase for days open to 24 days. This decline in fertility has accompanied by an increase in milk, fat and protein yield to rate of 3500, 130 and 100kg, respectively (Shook 2006). Ilatsia et al (2007) found the genetic trend of calving interval increased by 0.01 day in the Sahiwal cattle in semi-arid Kenya.

In North Carolina, Abdallah and McDaniel (2000) reported days open in the cows born in 1993 conceived about 28 d later than cows born in 1950. Also, they found the highest genetic change in days open was for Holstein cows of born after 1980 (1.1 d/yr). The main objective of this study was to estimate genetic and phenotypic trends for

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fertility traits during years1999 to 2013 in Holstein dairy cattle under warm and temperate climate.

Materials 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 9,486 cows, covering calving years from 1999 to 2013. 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 for successful insemination and 0 for a 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 for successful insemination and 0 for a 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 a most nearby meteorological station located at the same altitude of the examined dairy farm. As was pointed out by Johnson (1994) the major climatic variables directly affecting livestock are temperature, humidity, air movement and radiation. Attempts to combine environmental parameters in one single index have had limited success except for the temperature–humidity index (THI) (Kadzere et al 2002). A daily THI was computed using the following formula (NRC 1971):

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

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 model in follow:

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

Also, trait of IO was analyzed with model in follow:

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

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} is continuous variable representing days in milk, in weeks, with 90 classes ranging from 15 to 105 wk; X_{AC} is continuous variable representing age of animal at calving, as months, with 240 classes, the first class for 20 to 35 m and the last class for 70 to 135 m; X_{THI} is continuous variable representing temperature-humidity index; animal is the random genetic effect; pe is the random permanent environment effect and e is the random residual effect.

Variance components were estimated by restricted maximum likelihood in DMU software package (Madsen and Jensen 2006) using an animal linear mixed model; uni variate 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. Genetic trends were obtained by regressing yearly mean estimates of breeding values on year of birth. Also, phenotypic trends were estimated using the linear regression of average phenotypic values on the birth year.

Results

Climatic Conditions in the North of Iran

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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.

Descriptive Statistics

In this study, the mean and standard deviation 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).

Genetic and Phenotypic Trends

Estimates of genetic and phenotypic trends for fertility traits in Holstein dairy cows are presented in Table1. In general, there were decreasing genetic trends for all traits over the years. On the other hand, there were decreasing phenotypic trend for DO, CI, GL, NI and CBW, but estimates of phenotypic trends were positive for SF and IO over the years (Table1).

Mean estimated breeding values and phenotypic trend for CBW and CI by year of birth are shown in Figure1. From 1999 to 2012, genetic trend for CBW and CI irregularly decreased. The mean estimated breeding value of CBW was 0.11 in 1999 and decreased to 0.009 in 2012. Also, the mean estimated breeding value of CI was 0.22 in 1999 and decreased to -0.26 in 2012. For CBW and CI, there were decreasing phenotypic trend from 1999 to 2012. The mean of CBW was 43.9 kg in 1999 and decreased to 36.9 kg in 2012. Also, the mean of CI was 420 days in 1999 and decreased to 364 days in 2012. Decreasing trend for CI had harsh slope from 2009 until 2012 (Figure 1).

Mean estimated breeding values and phenotypic trend for IO and SF by year of birth are shown in Figure 2. Genetic trend of IO had a large variation but there was an increasing trend from 2004 to 2007 and then a decreasing trend until 2009. For SF, there was a constant genetic trend over the years. Increasing of phenotypic trend for IO and SF had harsh slope after 2009. The mean of IO was 0.34 in 2009 and increased to 0.79 in 2012.

The SF, phenotypic level increased from 0.42 in 2009 to 0.74 in 2013 (Figure 2). Also, mean estimated breeding values and phenotypic trend for GL, DO and NI by year of birth are presented in Figure3. Genetic trend of GL had irregular trend, some years positive and some years negative. For DO, there was a decrease in genetic trend from 1999 to 2003 and then genetic trend had a large variation from 2003 onwards. From1999 to 2012, genetic trend of NI irregularly decreased.

The mean estimated breeding value of NI was 0.009 in 1999 and decreased to -0.001 in 2012.Phenotypic means of GL decreased from 1999 (279 days) to 2013 (274 days). In addition, decreasing trend for DO and NI had harsh slope after 2009. The mean of DO was 140.3 days in 2009 and decreased to 124.7 in 2011. For NI, phenotypic level was 2.63 in 2009 and reached to 1.32 in 2013 (Figure 3).

Table 1 Linear regression coefficients of breeding values and phonotypic values (standard deviations) for fertility traits on year of birth for Holstein cows.

Trait [a]	Trend	
	Genetic (SD)	Phenotypic (SD)
DO	-0.007* (0.003)	-1.28* (0.3)
CI	-0.014* (0.005)	-2.54* (0.7)
GL	-0.001ns (0.002)	-0.28** (0.03)
NI	-0.0004ns (0.0002)	-0.01ns (0.02)
SF	-0.00001ns (0.00003)	0.01ns (0.005)
CBW	-0.0027ns (0.003)	-0.49** (0.03)
IO	-0.0004ns (0.001)	0.02* (0.009)

[a] 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.
ns = No significantly different from zero.
*Significant ($p < 0.05$)
**Significant ($p < 0.01$)
SD: Standard Deviation

Discussion

Similar to the current results, Ojango and Pollott (2001) and Hernández et al (2011) reported the genetic trend for the CI was negative in the Holstein-Friesian and Mambí de Cuba cows, respectively. These results were not in agreement with those by authors who obtained a genetic trend to the increment of the CI, such as Hare et al (2006) in the Jersey, Ayrshire, Pardo Suizo, Holstein and Guernsey breeds, in United States (0.49 to 1.07 days.year^{-1}) and Carolino et al (2006) with 0.192 ± 0.004 days.year^{-1} in dairy cows of Portugal.

Ansari-Lari et al (2009) reported that calving interval in Iranian Holsteins in Fars province decreased from 435 days in 2000 to 389 days in 2005. Also, in present study, the mean of calving interval in Iranian Holstein in Mazandaran province decreased from 420 days in 1999 to 364 days in 2012.Pahlevan and Moghimi Esfandabadi (2010) found the

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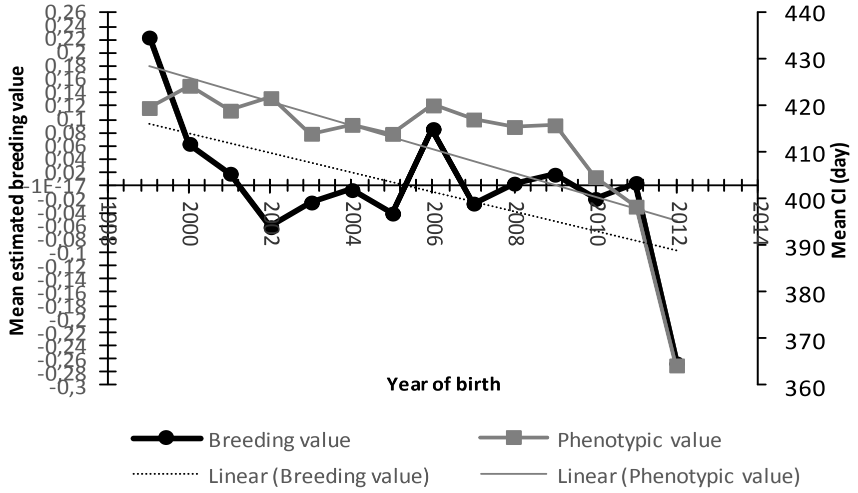
genetic trend of CI was positive and equal to 0.8 days.year^{-1} in Iranian Holstein cows while in this research, the genetic trend was calculated negative and equal to -0.014 days.year^{-1}.

A



B

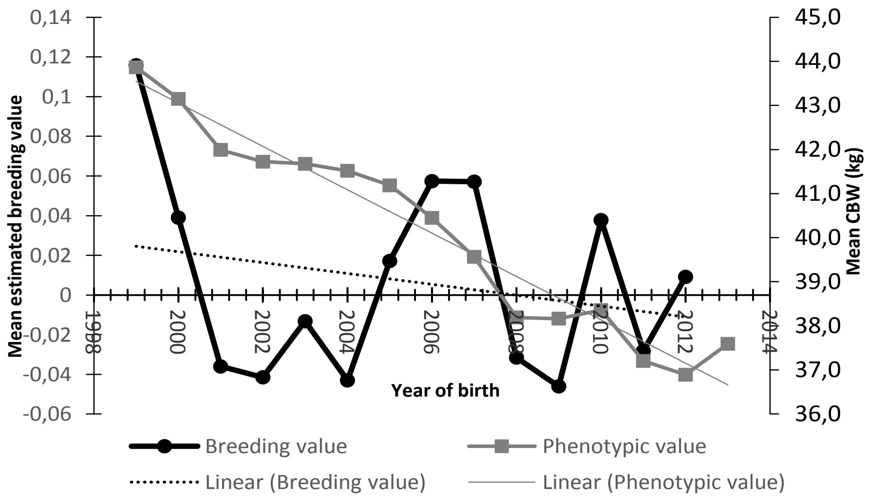


Figure 1 Mean estimated breeding values and phenotypic trend for CI (A) and CBW (B) by year of birth in Holstein dairy cows.

The main reason of this variation was dissimilarity in environmental conditions such as feeding and management of the farms. Also, Nafez et al (2012) reported the genetic and phenotypic trends of calving interval were 0.02 and 0.37 days.year^{-1}, respectively in Iranian Holstein cows. However, in present study, the genetic and phenotypic trends of CI were -0.014 and -2.54 days.year^{-1}, respectively.

Ghiasi et al (2013) identified the phenotypic trend of fertility traits was unfavorable in Iranian Holstein cows. They reported the regression coefficients of mean traits on the year of birth were 0.048 and -0.013 for NI and SF, respectively. However, in this study, the phenotypic trend was negative and favorable for NI trait so that the value of reduction in the number of inseminations was -0.01 in every year. Also, the reduction of NI reflects increase of SF. Therefore, the regression coefficient of SF on the year of birth was positive and favorable so that the increase of SF was 0.01 in every year. These values indicate that improving of NI and SF traits have been done in Holstein dairy cattle in warm and temperate climate during 1999 to 2012.

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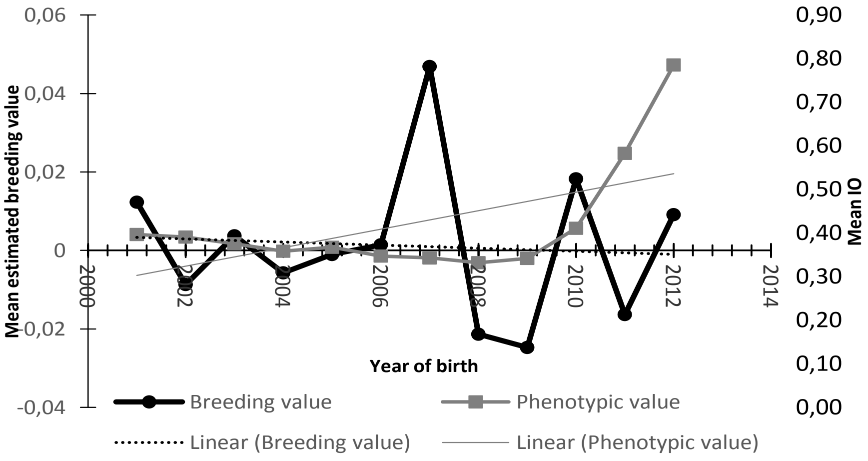
A



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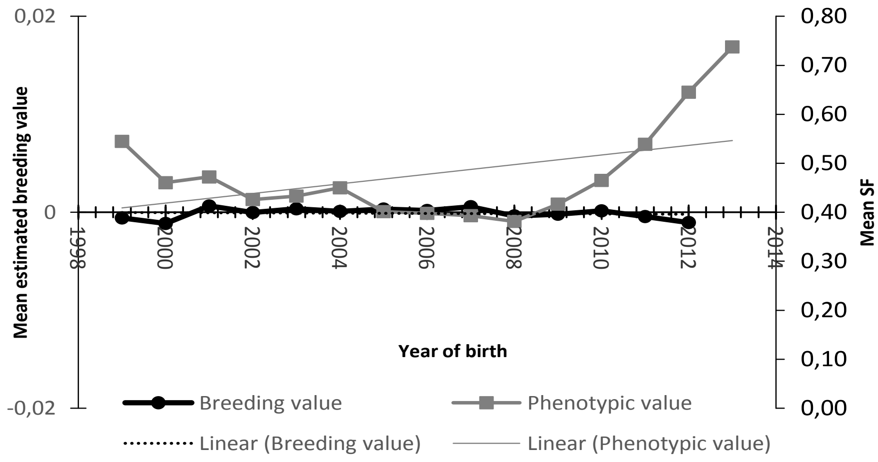

Figure 2 Mean estimated breeding values and phenotypic trend for IO (A) and SF (B) by year of birth in Holstein dairy cows.

In study of genetic trend of fertility traits in 532 and 29 farms of *Holstein* and Jersey cows, respectively, Washburn et al (2002) reported the mean of DO has increased 44 and 30 days.year^{-1} in *Holstein* and Jersey cows, respectively, during 1976 to 1999. Also, the number of insemination per conception of 1 service in 1976 increased to 3 services in 1994. Moreover, Lucy (2001) indicated the NI increased from 1.76 to 3 services during 20 years. Whereas in present research, we found the mean of DO has decreased to 20 days.year^{-1} during 1999 to 2011. Also, NI of 1.84 services in 1999 increased to 2.63services in 2009 and then decreased to 1.32 services in 2013.

Similar to present study, Deljoo Isaloo and Pasha Eskandari Nasab (2011) reported the genetic trend of DO and genetic and phenotypic trends of CI were negative. Unlike this research, they explained the phenotypic trend of DO and genetic and phenotypic trends of NI were positive. As well as, we found the genetic trend of CBW was negative and for IO, SF and NI was negative and close to zero.

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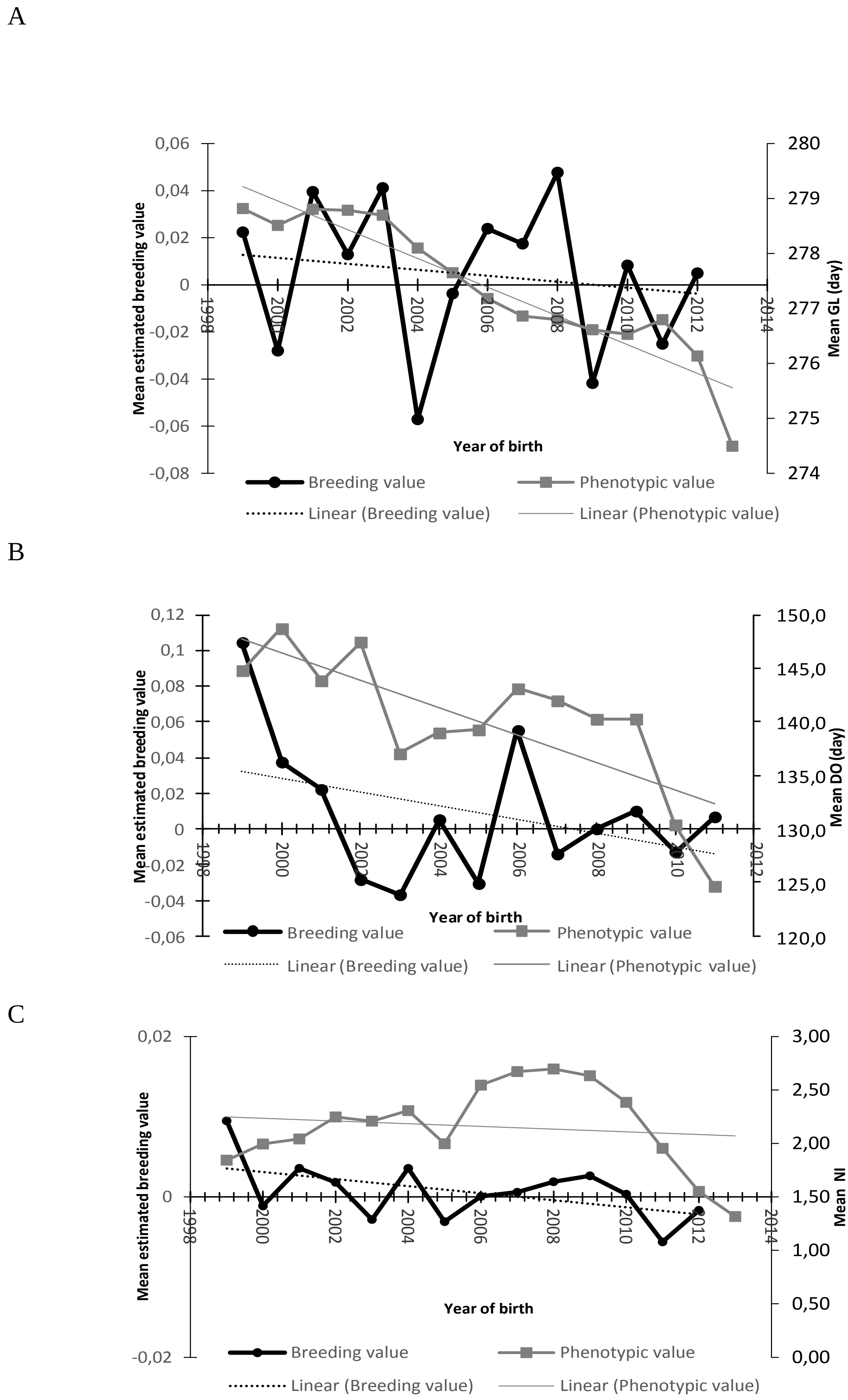

Figure 3 Mean estimated breeding values and phenotypic trend for GL (A), DO (B) and NI (C) by year of birth in Holstein dairy cows.

Therefore, we can use these traits in selection index for improvement of performance. Also, the genetic trend of gestation length was calculated negative with value of -0.001 that showed there was genetic improvement for this trait in

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farm during the last years. Genetic and phonotypic trend for DO, CI and phonotypic trend for GL, CBW and IO were significant ($p < 0.05$). However, they were not significant for other traits.

Conclusion

The results lead to the conclusion that decreased trend for DO, CI, GL, NI, CBW and Increased trend for SF and IO traits over time indicated that *Holstein* dairy producers in warm and temperate climate in Iran were successfully managed and improved in nutrition during 1999 to 2013.

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