Egypt. J. Vet. Sci., pp. 1-13

Egyptian Journal of Veterinary Sciences

https://ejvs.journals.ekb.eg/

Estimates of Genetic Parameters for Milk Production Traits and Lactation Persistency in Holstein Cows Using Multi-Trait Models

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Abstract

THIS study was conducted on productive data (n=3399) collected from 1800 Holstein cows that calved between 2009 and 2020. The present study aimed to investigate the fixed effects of parity, calving season, and calving year on milk production traits, and to estimate the relevant genetic parameters. These traits encompass total milk yield (TMY), standardized 305-day milk yield (305d-MY), lactation length (LL), peak yield (PY), lactation persistency (LP), total fat yield (TFY), and total protein yield (TPY). Genetic parameter estimation was conducted using multivariate mixed models utilizing average information restricted maximum likelihood (REML) procedures via the MTDFREML program algorithm. Parity significantly affected LP ($P<0.05$), with cows in higher parities (≥5) exhibiting lower persistency compared to those in lower parities (1st to 4th). The traits studied displayed moderate heritability and high repeatability values, with heritability estimates ranging from 0.26 to 0.37 and repeatability estimates from 0.55 to 0.72. 305d-MY, LP, and TPY exhibited the highest repeatability values. Moderate genetic correlations (0.37 to 0.40) were found between LP and productive traits (TMY, 305d-MY, LL, and TPY), while LP showed slight correlations with TFY and PY (rg= 0.11 and 0.15, respectively). In summary, the study suggests that LP's moderate heritability and higher repeatability values facilitate genetic improvement through selection, advocating for the evaluation of a cow's persistency based on its first lactation. Additionally, the positive phenotypic and genetic correlations between lactation persistency and milk yield imply that selecting for increased milk yield could enhance lactation persistency.

Keywords: Dairy cows, genetic parameters, Holstein, MTDFREML program, milk production, persistency.

Introduction

The foremost objective within dairy farming operations revolves around maximizing profitability, primarily achieved by maintaining consistently high levels of milk production over time. Fundamental variables influencing the total milk yield during the lactation period include lactation length, peak yield, and persistency [1]. Of particular interest is the concept of persistency in lactation, which bears significance owing to its potential to mitigate production costs through its correlation with various parameters such as disease resistance, nutritional expenses, overall milk yield throughout a standardized production cycle, and reproductive efficacy [2]. It makes financial sense to investigate the genetic components of the lactation curve since increasing persistency may result in more efficient and cost-effective milk production. The continuity of milk production is a highly economically relevant aspect of the lactation curve and is pivotal in the selection process [3]. The assessment of lactation

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(Received 27 April 2025, accepted 13 June 2025)
DOI: 10.21608/ejvs.2025.379434.2809

persistency conventionally entails evaluating the rate of decline in production subsequent to reaching peak yield. Numerous environmental factors, including genetic group, herd management, feeding practices, gestation length, parity, and calving season can impact lactation persistency [4]. Compared to cows in subsequent lactations, the first lactation cows had lower peak yield, higher persistency, and flatter lactation curves for milk, protein, and fat yields [5].

When milk yield and lactation persistency are associated, cows displaying higher persistency tend to yield greater profits compared to average cows [6]. Usually, cows with elevated lactation persistency initially produce less milk than anticipated at the onset of lactation. However, they surpass predicted milk yields towards the later stages, thereby extending their productive lifespan in contrast to average cows [7].

Assessment of peak milk time and quantity is crucial as it correlates with both total milk yield and persistency during lactation [5].

Selective breeding for increased persistency can result in a flattened and prolonged lactation curve. This approach diminishes the necessity to dry off high-yielding animals and reduces unproductive intervals within the herd [8]. As a result, persistency not only affects economic aspects but also exerts influence on fertility, health, and feed expenditures [6]. While the implications of genetic variation on the shape of lactation curves are not fully understood [9], there are indications of a positive genetic association between persistency and disease resistance [10]. Therefore, selecting for persistency becomes particularly valuable in situations where direct measurement of disease resistance is challenging. Considering the clear economic benefits that selection for the persistence of milk production provides to the dairy producer, this study aimed to investigate the effect of parity, calving season , and calving year on milk production traits and lactation persistency and to assess their genetic parameters using multivariate mixed models.

Material and Methods

Data and variables

Data files were taken out of the management program (Dairy Comp305, Valley Ag Software, Tulare, CA). A total no of 3399 complete lactation records for 1800 Holstein dairy cows covering a period from 2009 to 2020 were used. Milk production data included total milk yield (TMY), standardized 305–day milk yield (305d-MY), lactation length (LL), peak yield (PY), lactation persistency (LP), total fat yield (TFY), and total protein yield (TPY). According to [11], LP was computed as a ratio of 305d-MY to PY. Before the analysis, records of cows with unknown parents, incomplete records, and calving years before 2009 were excluded, and some limiting restrictions relevant to each trait were performed.

Animals and herd management

The data of the current study were obtained from the performance records of Holstein cows raised in a private farm located on the Cairo-Alexandria desert road, Egypt. The animals were kept in open yards with shades. During the hot months, a cool spraying system (Korral Kool System®) was used. Based on the level of milk production of each group of lactating cows, the offered concentrate was computed. Throughout the year, cows received two daily feedings of total mixed ration (TMR). The TMR contained concentrates, hay, wheat bran, corn silage, vitamins, minerals, and a buffer in the form of calcium bicarbonate. When a heifer's body weight reached 360 kg, artificial insemination was used for the first time. Herd workers visually observed the onset of estrus twice a day for heat detection purposes. Nearly 50 to 60 days after giving birth, cows were inseminated. On day 42 following the last service, a rectal palpation was used to confirm the pregnancy diagnosis. Beginning at 6:00 a.m., cows were milked three times a day at eight-hour intervals by a milking machine, and the daily milk yield for each cow was recorded using computerized milking units. The cows were dried off approximately sixty days before the expected calving date.

Statistical analysis

The statistical analysis software (SAS, 2011, version 9.3) [12] was used for the estimation of the descriptive statistics for milk production traits. Proc GLM was generated for the estimation of the least squares means (LSM) and standard errors (SE) for the milk production traits (TMY, 305d-MY, LL, PY, TFY, and TPY) in relation to the fixed effects (parity, season of calving, and calving year). The PDIFF option was utilized to compare LSM. The analysis was performed according to the following model:

$Y_{ijk} = \mu + P_i + S_j + Y_k + e_{ijk}$

Where: Y_{ijk} = observed value,

μ = the overall mean,

P_i = parity (1, 2, 3, 4, and ≥ 5),

S_j = season of calving (winter, December to February; spring, March to May; summer, June to August, and autumn, September to November),

Y_k = year of calving (2009 to 2020),

and e_{ijk} = the error term.

The derivative-free restricted maximum likelihood (REML) techniques were applied to extract the variance components of all traits using the MTDFREML software. To estimate the variance components and predict the genetic trend, the model that follows was utilized:

$$Y = X\beta + Za + Wpe + e$$

“Where: Y= observations, β represents the vector of fixed effects (parity, season of calving, and calving year) and the covariate of age at first calving (AFC), a represents the vector of random animal additive genetic effects, and pe represents the vector of random permanent environmental effects, W = matrix relating records to permanent environmental effects, and e = vector of random residual effects. The X and Z incidence matrices link records to both genetic and fixed effects”.

“Phenotypic variance ($\sigma^2 p$) is the total of additive genetic variance ($\sigma^2 a$), permanent environmental variance ($\sigma^2 pe$), and residual variance ($\sigma^2 e$)”.

“The ratio of additive genetic variance to total phenotypic variation ($h^2 a = \sigma^2 a / \sigma 2p$) was used to evaluate heritability, while the ratio of the sum of additive genetic variance and permanent environmental variance to total phenotypic variance was used to measure repeatability”. Repeatability (rep) is equal to $\sigma^2 a + \sigma^2 pe / \sigma^2 p$.

Genetic correlation was calculated as the ratio of the additive genetic covariance of two traits (traits 1 and 2) to the additive genetic standard deviation of the two traits. $rg= \sigma g12 / \sigma g1 \times \sigma g2$ “where: $\sigma g12$ = genetic covariance between trait 1 and trait 2, $\sigma g1$ = genetic additive standard deviation for trait 1, $\sigma g2$ = genetic additive standard deviation for trait 2.”

Phenotypic correlations were estimated as the ratio of the sum of the genetic and environmental covariance (phenotypic covariance) to the phenotypic standard deviations of the two traits. Phenotypic correlations (rp) = $\sigma p12 / \sigma p1\times \sigma p2$ “where: $\sigma p12$ = phenotypic covariance between trait 1 and trait 2, $\sigma p1$ = phenotypic standard deviation for trait 1, $\sigma p2$ = phenotypic standard deviation for trait 2”.

Results and Discussion

Descriptive statistics

Table (1) presents descriptive statistics for the production traits under study. The mean values for TMY, 305d-MY, LL, PY, LP, TFY, and TPY were 8820 kg, 7598 kg, 358 days, 43.3 kg, 180, 271 kg, and 237 kg, respectively. The coefficients of variation (CV) for these production traits varied from 19.8% to 38.7%. The highest CV% was observed for TFY, while the lowest was for PY. TMY and LP exhibited a CV of 36.3%, which was close to TPY's CV of 36.8% but higher than that of 305d-MY (32.7%) and LL (24.3%). The overall means of TMY and 305d-MY (8820 and 7598 kg, respectively) were comparable to values reported in Holstein cows [8, 13, 14]. Contrary to the findings of [15, 16, 17, 18], who reported lower means. However, [19] and [20] obtained higher means.

Furthermore, LL (358 days) exceeded the estimates (315 days) recorded for Holstein cows raised in the tropical conditions of Ethiopia [21] but was lower than those reported by [22] and [19] (391.2 and 413.1 days, respectively).

Regarding PY (43.3 kg), it surpassed the values (33.1 kg) estimated for the same breed by [23]. While being lower than that reported for dairy cattle in Thailand (49 kg) by [24] and [25], who obtained 52.9 kg in Friesian Cows in Egypt. Variations in genotypes and management systems could account for the differences observed across studies.

Fixed Effects

The LSM and standard errors for the effect of parity, calving season, and calving year on milk production traits are presented in Figs.(1, 2, and 3). The current study revealed a significant influence of parity on production traits (Figure 1). Cows within the first four parities exhibited significantly higher TMY (8793.9, 8642.6, 8647.1, and 8845.8 kg, respectively, $P<0.05$) compared to cows of parity ≥5. Additionally, the results revealed a notable decline in 305d-MY with higher parities (≥5). Furthermore, 305d-MY in first-parity cows was significantly ($P<0.01$) lower than that recorded for third-parity cows (7198.3 kg vs. 7570.1 kg, respectively). Similarly, PY in first-parity cows was significantly ($P<0.01$) lower than that in third-parity cows (42.3 kg vs. 44.0 kg, respectively). These results were in agreement with [26] who recorded the lowest mean 305d-milk yield in the first-parity cows, which tended to rise in the second and third parity and then declined in the subsequent parity. The findings of [27] verified a sharper lactation curve in the mature cows; fully align with the confirmed results of the reduced milk yield during the first parity with a lower peak yield compared to cows in the third lactation.

Similar trends also reported by [28, 29, 30]. Due to their larger bodies and complete mammary gland tissue development, mature cows produce more milk than small cows as parity progresses. After reaching the 5th parity or higher, milk yields started to drop. Because of the repeated pregnancies, there has been a decline in body condition.

LL was significantly influenced by parity (Figure 1, $P<0.001$). First-parity cows exhibited a longer LL (380.2 days) compared to cows in parity 2, 3, 4, or ≥5 (360.5, 354.6, 362.3, and 358.2 days, respectively). In harmony with [31] who obtained a longer LL (323.7 days) in the first-parity cows under the subtropical conditions of Egypt compared to cows of the second and the third parity (296.8 and 220.7 days, respectively, $P<0.01$). However, [14] found no significant effect of parity on LL.

Furthermore, parity exerted a significant effect ($P<0.05$) on LP. The findings demonstrated that cows in the 1st, 2nd, 3rd, and 4th parity displayed higher persistence and yielded greater TFY and TPY compared to cows in parity 5 or higher. Specifically, lactation persistency measured 177.3, 176.7, 177.9, and 176 for the first four parities, respectively, versus 159.2 in parity ≥5. It was observed in the study of [32] who stated that the genetic correlation for persistency between the initial and second parity was 0.86, while it was 0.97 between the second and third parity. Cows in parity 5 or higher were less persistent in their lactations due to the more stress and loss of body condition that resulted from repeated calvings. TFY and TPY in ≥5 parity were significantly lower (248.0 and 216.7 kg, respectively, $P<0.05$) than those in lactations 1 to 4. In the current research, total fat and protein yields in cows of the first, second, and third parity were numerically lower than those of the fourth parity. Nyamushamba, et al. [33] concluded that it would be due to the increased need for nutrients for earlier parity cows limiting milk yield with a decrease in protein and fat yield compared to greater parity cows. Different parities within breeds had different lactation curve shapes for different yield traits [5].

According to the current study, the primiparous cows had higher persistency but a lower peak milk yield. Additionally, compared to the first parity, the peak milk production in the later parities was higher. Cole and Null [7] reported similar findings. The slope of the lactation curve for cows with very high peak production would be steeper than that of cows with low peak production [34].

Regarding the impact of calving season on milk production traits, TMY, LL, PY, TFY, and TPY were significantly affected, while the effect on 305d-MY and LP was found to be insignificant ($p>0.05$) (Figure 2).

The least squares means and standard errors for TMY in spring calvings were statistically higher (8946.2 kg) compared to cows calved in autumn (8102.7 kg). Moreover, LL (343.2 days), TFY (253.2 kg), and TPY (219.3 kg) were significantly lower ($P<0.001$) in autumn calvings compared to those calved in other seasons. In harmony with [14], who reported that the calving season had a significant effect on TMY, and it was significantly lower ($P<0.05$) in autumn. The increase in milk yield in spring was most likely caused by the availability of fresh green fodder and comfortable air temperatures.

According to the effect of the year of calving (Figure 3), all milk production traits studied in this investigation were significantly affected. Differences in productivity were observed between the periods. From 2009 to 2012, productivity diminished while from 2013 to 2020, higher productivity was observed. Moreover, calving years (2009-2012) showed significantly the least PY, LP, TFY, and TPY compared with other periods. Also, [15, 35, 36, 16, 14] reported a significant effect of calving year. Variations in production traits from year to year could be attributed to changes in age of animals, herd size, management, and nutrition from year to year.

Genetic parameters

Heritability estimates

The variance components, heritability, and repeatability estimates for productive traits are detailed in Table (2). The study revealed moderate heritability estimates for milk production traits, ranging from 0.26 to 0.37. Total fat and protein yields exhibited the highest heritability estimates (0.37), while TMY, 305d-MY, and LP had values of 0.26, 0.31, and 0.33, respectively. LL and PY both showed a heritability estimate of 0.32. The heritability estimates obtained for milk production traits indicated that genetics is plausible to improve traits through selection. If the current phenotypic selection is modified to the existing selection on genetic merit in conjunction with effective herd management and addition of new animals from other sources to increase genetic variation within the herd, the herd's future improvement may be significant.

The heritability estimates for TMY and 305d-MY (0.26 and 0.31, respectively) suggest the existence of moderate genetic variation within the smaller herds of Holstein cows in Egypt. Additionally, indicate presence of high levels of correlation between traits that inflate heritability estimates. The heritability of TMY in the current research was similar to those reported in Ethiopian Holstein cows by two traits model (0.25) [21]. While was higher than estimates (0.14 ±0.02) reported for Holstein cows in Italy [37]. In contrast, higher estimates of TMY were reported for the same breed in Egypt (0.44) [22]. The obtained values for 305d-MY (0.31) were comparable with values (0.34) reported for Holstein cattle in Turkey [16]. A close heritability estimate of 0.31 was reported for the same breed in Iran [2]. On the other hand, it was higher than the heritability estimates (0.15±0.05) obtained in the Holstein Friesian herd in Egypt in a study by [15]. Additionally, several authors from other production situations reported lower estimates [15, 21, 24]. However, higher estimates were reported in Egypt by [22]. Such differences in heritability estimates are expected as a result of the size of the genetic data set variation between populations, management and environment conditions, and methods used to estimate the parameter.

LL and PY had heritability estimates of 0.32. The heritability values of LL in this study were higher than estimates (0.03±0.03) by the univariate model in Ethiopian Holstein cows [21]. On the other hand, it was lower than those reported for the same breed in Italy (0.43) and Egypt (0.48) [37, 22, respectively]. Regarding the peak yield estimate, a comparable value was reported (0.25±0.08) in Egypt [25].

However, [24], obtained lower estimates (0.10±0.05) in the first-parity cows.

Concerning lactation persistency estimates (0.33), they were comparable with estimates ranging from 0.16 to 0.48 for different breeds of cows in Kenya [38]. On the other hand, LP was higher than those reported for the first three parities in Iranian Holstein cows (0.01 to 0.12) [39]. LP was 0.08±0.05 in Friesian cows in Egypt [25]. Differences in heritability estimates for persistence between herds are due to variations in management, nutrition, and annual climate changes. Highly productive herds have higher persistency compared to cows with low herd production.

The obtained heritability estimates for total fat yield and total protein yield (0.37) were close to values reported in Danish Holsteins (0.36 and 0.37 for TPY and TFY, respectively) [40]. On the other hand, [2] reported lower estimates (0.27) in Holstein cows.

Repeatability estimates

TPY and 305d-MYwere highly repeatable, with values of 0.70 and 0.72, respectively, while repeatabilities of TMY, LL, PY, and TFY ranged from 0.55 to 0.69 (Table 2). The repeatability estimates for TMY and adjusted 305d-MYwere 0.62 and 0.72, respectively. The repeatability estimate of TMY was comparable with values reported (0.60± 0.01) for Holstein cows in Italy [37] but higher than the obtained values (0.39 - 0.45) in Ethiopian Holstein cows [21].

The repeatability estimates for the adjusted 305d-MY was consistent with those reported by [41] and [42], 0.55 and 0.58, respectively. However, was higher than values reported for the first-parity Iranian Holstein cows (0.40 ±0.001) [39]. Ayalew et al. [21] obtained a repeatability estimate of 0.42±0.02 by univariate model for the same breed. The high repeatability estimates reported in the current study indicate that culling cows for low milk production depending on early age performance records is reliable.

Moreover, the repeatability of lactation length in the present study was higher (0.55). In contrast, lower estimates (0.12 and 0.19) were obtained by [43, 21, respectively].

Regarding persistency, it had a repeatability estimate of 0.70. However, several other studies from various production situations had revealed lower values [39]. The repeatability estimates for TFY and TPY were 0.69 and 0.70, respectively. They exceeded the estimates stated for the same breed in other tropical countries (0.45±0.01 and 0.54 ±0.01, respectively), according to [37]. Tiezzi et al. [44] reported lower repeatability estimates (0.37 and 0.41 for TFY and TPY, respectively). The higher repeatability estimates for all production traits in the present study indicate that the variation in nutrition and management was minor from one record to another, and traits are mainly influenced by genetics and permanent environmental effects. As a result, the repeatability estimates of milk production traits under study help commercial producers cull cows based on the first record.

Phenotypic correlations

Phenotypic correlations among productive traits were positive and moderate, ranging from 0.22 to 0.42 (Table 3). The strongest correlation was observed between TMY and LL, as well as between LL and TFY (rp= 0.42), while the lowest correlation was obtained between PY and LP (0.22). The lowest phenotypic correlation between persistency and peak yield obtained in the present study was in agreement with the findings of [45] who obtained a phenotypic correlation of 0.27 between LP and PY using a biological model.

The total milk yield showed a strong correlation with both 305-day milk yield (rp=0.31) and lactation length (rp=0.42). The high phenotypic correlation between TMY and 305d-MY was in agreement with those reported by [21]. Similarly, [46] found that the Indian village cows had a phenotypic correlation of 0.40 between TMY and LL.

In the current research, the phenotypic correlations between LP and milk production traits (TMY, 305-dMY, LL, and PY) were 0.37, 0.26, 0.25, and 0.22, respectively. Moreover, the phenotypic correlations between LP and total fat and protein yields were 0.25 and 0.32, respectively. These estimates were similar to the findings of [7] who found that the phenotypic correlations of persistency of lactation with milk yield, fat yield, and protein yield were positive and ranged from 0.07 to 0.22 for five breeds of dairy cattle.

Genetic correlations

Genetic correlations among production traits were positive and ranged from 0.11 to 0.66 (Table 3). The highest genetic correlation (0.66) was observed between TMY and LL, while the lowest value (0.11) was obtained between LP and TFY, as well as between PY and TPY. The genetic correlation between 305d-MY and LL was 0.15. On the contrary, a relatively higher and positive (0.73±0.19) genetic correlation was reported for Ethiopian Holstein cows [21]. However, the high genetic correlations between TMY and LL (0.66) obtained in the present study indicate the pleiotropic effect of the genes on the two traits. Additionally, was proposed that an increase in LL would be a correlated response to selection for milk production. Generally speaking, the high correlation between the two traits suggests that lactation milk yield selection can be met with lactation length. These findings were in close agreement with that reported (0.51±0.02) in Ethiopia

[21]. However, [47] obtained a genetic correlation of 0.35 between TMY and LL.

Furthermore, high genetic correlations were found between 305d-MY and PY, as well as between 305d-MY and TFY (0.58 and 0.57, respectively). Consequently, a high genetic correlation between PY and TFY (0.52) was observed. This implies that the genetic improvement in one trait can trigger a correlated response in the correlated trait. So, the selection of one trait leads to the improvement in the other correlated traits.

Genetic correlation estimates between lactation persistency and productive traits (TMY, 305d-MY, LL, and TPY) were moderate, ranging from 0.37 to 0.40, while LP showed slight correlations with PY and TFY (0.11 and 0.15, respectively). It was noted that LP was genetically correlated with LL (rg = 0.38), which indicates that selection for LP can improve LL. The persistency of lactation was correlated genetically with the first lactation length in Gyr cattle (0.50) [5]. The positive genetic correlation between LP and LL may be due in part to the positive genetic correlations among LP and milk yield, as well as between milk yield and LL [7]. LP was highly genetically correlated with TMY and 305-dMY (0.30. and 0.40, respectively). Jakobsen et al. [40] and Cobuci et al. [48] found that the genetic correlation between LP and 305-day milk yield varied from 0 to 0.47 and from 0.31 to 0.55, respectively. Recording of 305d-MY or TMY is relatively easier than lactation persistency. Consequently, assessment based on 305d-MY or TMY would be simpler to manage than evaluation based on LP due to the availability of human resources and recording infrastructure.

Moreover, the genetic correlation between persistency and TPY was higher (0.37), whereas LP showed a slight correlation with total fat yield (0.11). The large genetic correlation between persistency and milk protein yields was also reported in Iranian Holstein cows [2]. The current study's moderate and positive genetic correlation provides evidence of shared genetic and physiological mechanisms governing these traits.

Conclusion

Our study demonstrated significant effects of calving year and parity on lactation persistency. Cows in the first four parities exhibited higher persistency compared to later lactations. The moderate heritability estimate of LP suggests potential for genetic improvement through selective breeding. Given the high repeatability estimates for LP and milk production traits, culling dairy cows based on their initial records may be practical. Additionally, the moderate positive genetic correlations between milk yield and LP indicate that selecting for higher milk yield can also enhance persistency. These findings highlight the economic importance of lactation persistency, justifying its inclusion in dairy cattle breeding programs for genetic improvement. Thus, accurately estimating genetic parameters is essential for precisely predicting an individual's genetic merit.

Acknowledgments

Not applicable.

Funding statement

This study didn't receive any funding support

Declaration of Conflict of Interest

The authors state that publishing this paper does not involve any conflicts of interest.

Ethical of approval

This research obtained approval from the Research Ethics Committee and the Institutional Animal Care and Use Committee (IACUC) at the Faculty of Veterinary Medicine, Alexandria University, Egypt (Ethics approval number; Au 13 0101 2024 066).

TABLE 1. Descriptive statistics of milk production traits (n=3399)

Traits	Mean	SE	Min	Max	CV (%)
TMY(kg)	8820	54.9	1020	21379	36.3
305d-MY(kg)	7598	42.6	1165	17775	32.7
LL(d)	358	1.49	136	610	24.3
PY(kg)	43.3	0.15	20	70	19.8
LP	180	1.12	24	524	36.3
TFY(kg)	271	1.80	23	712	38.7
TPY(kg)	237	1.49	27	684	36.8

TMY= total lactation milk yield, **305d-MY**= milk yield in 305d, **LL**=lactation length, **PY**= peak yield, **LP**= lactation persistency, **TFY**=total fat yield, and **TPY**=total protein yield.

TABLE 2. Estimates of variance components, heritability, and repeatability for milk production traits

Traits	σ^2a	σ^2pe	σ^2e	σ^2p	h^2a	Rep	C^2	e^2
TMY	0.50721	0.710581	0.74885	1.96664	0.26	0.62	0.36	0.38
305MY	0.60431	0.807529	0.55160	1.96344	0.31	0.72	0.41	0.28
LL	0.70308	0.504068	0.96676	2.17391	0.32	0.55	0.23	0.44
PY	0.79528	0.625605	1.09296	2.51384	0.32	0.57	0.25	0.43
LP	0.90548	1.00575	0.80617	2.71740	0.33	0.70	0.37	0.30
TFY	0.82186	0.700154	0.67591	2.19792	0.37	0.69	0.32	0.31
TPY	1.00508	0.905248	0.80979	2.72011	0.37	0.70	0.33	0.30

σ^2a =direct additive genetic variance, **σ^2pe**= permanent environmental variance, **σ^2e**= residual (temporary environmental variance), **σ^2p**= phenotypic variance, **h^2a**= direct heritability, rep= repeatability, **C^2**= phenotypic variance due to permanent environment, **e2**= phenotypic variance due to residual effects, **TMY**= total milk yield, **305d-MY**= milk yield in 305d, **LL**=lactation length, **PY**= peak yield, **LP**= lactation persistency, **TFY**=total fat yield, and **TPY**=total protein yield.

TABLE 3. Estimates of phenotypic correlations (above diagonal) and genetic correlations (below diagonal) for milk production traits

Trait	TMY	305d-MY	LL	PY	LP	TFY	TPY
TMY	-	0.31	0.42	0.29	0.37	0.37	0.37
305-dMY	0.36	-	0.28	0.31	0.26	0.38	0.37
LL	0.66	0.15	-	0.29	0.25	0.42	0.33
PY	0.37	0.58	0.28	-	0.22	0.38	0.31
LP	0.39	0.40	0.38	0.15	-	0.25	0.32
TFY	0.15	0.57	0.26	0.52	0.11	-	0.29
TPY	0.28	0.25	0.48	0.11	0.37	0.44	-

TMY= total lactation milk yield, **305d-MY**= milk yield in 305d, **LL**=lactation length, **PY**= peak yield, **LP**= lactation persistency, **TFY**=total fat yield, and **TPY**=total protein yield.

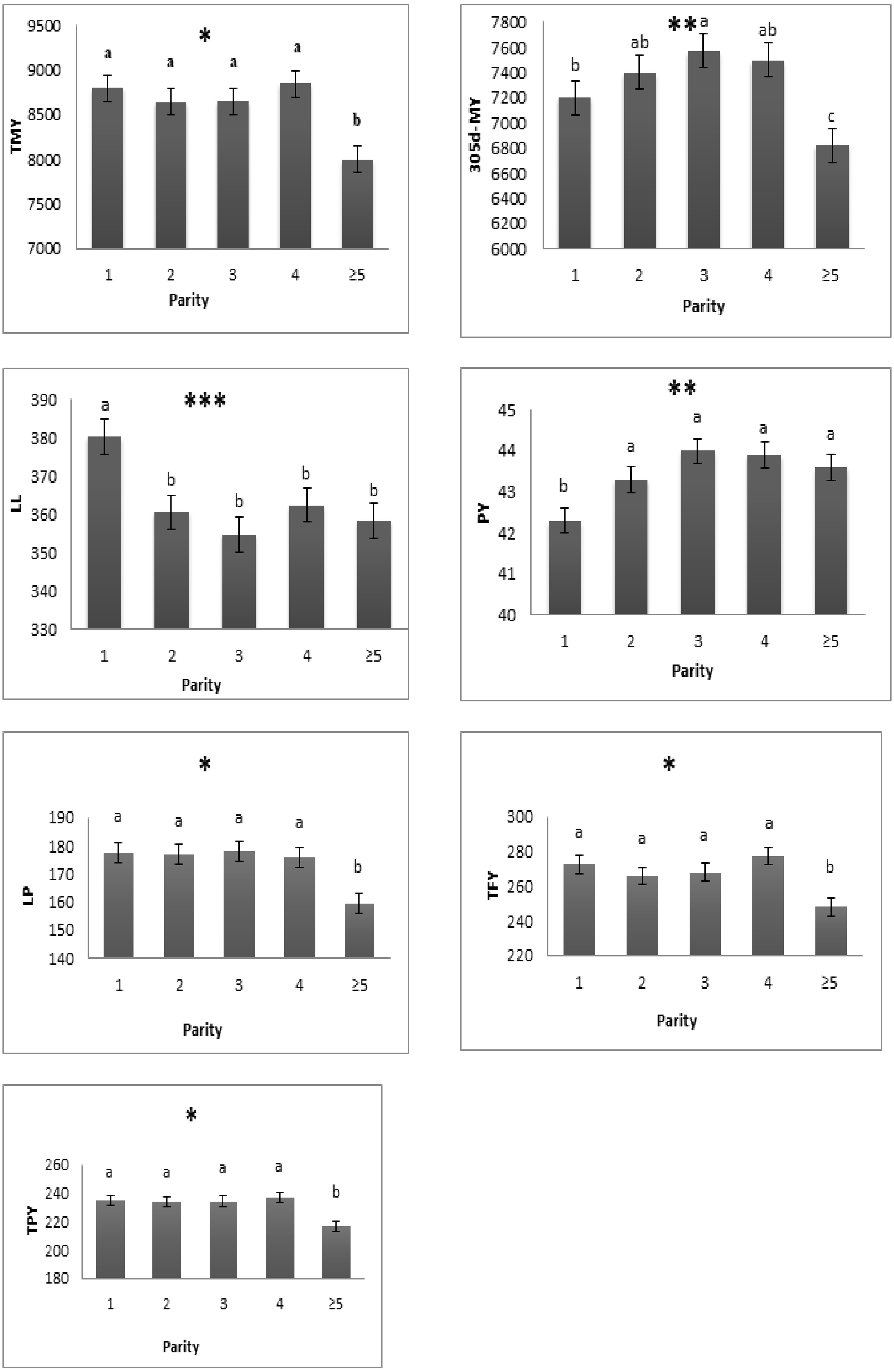

Fig. 1. Least squares means (with SE) of milk production traits across parities of Holstein cows. Means with different letters are significantly different * P<0.05, ** P<0.01, *** P<0.001.

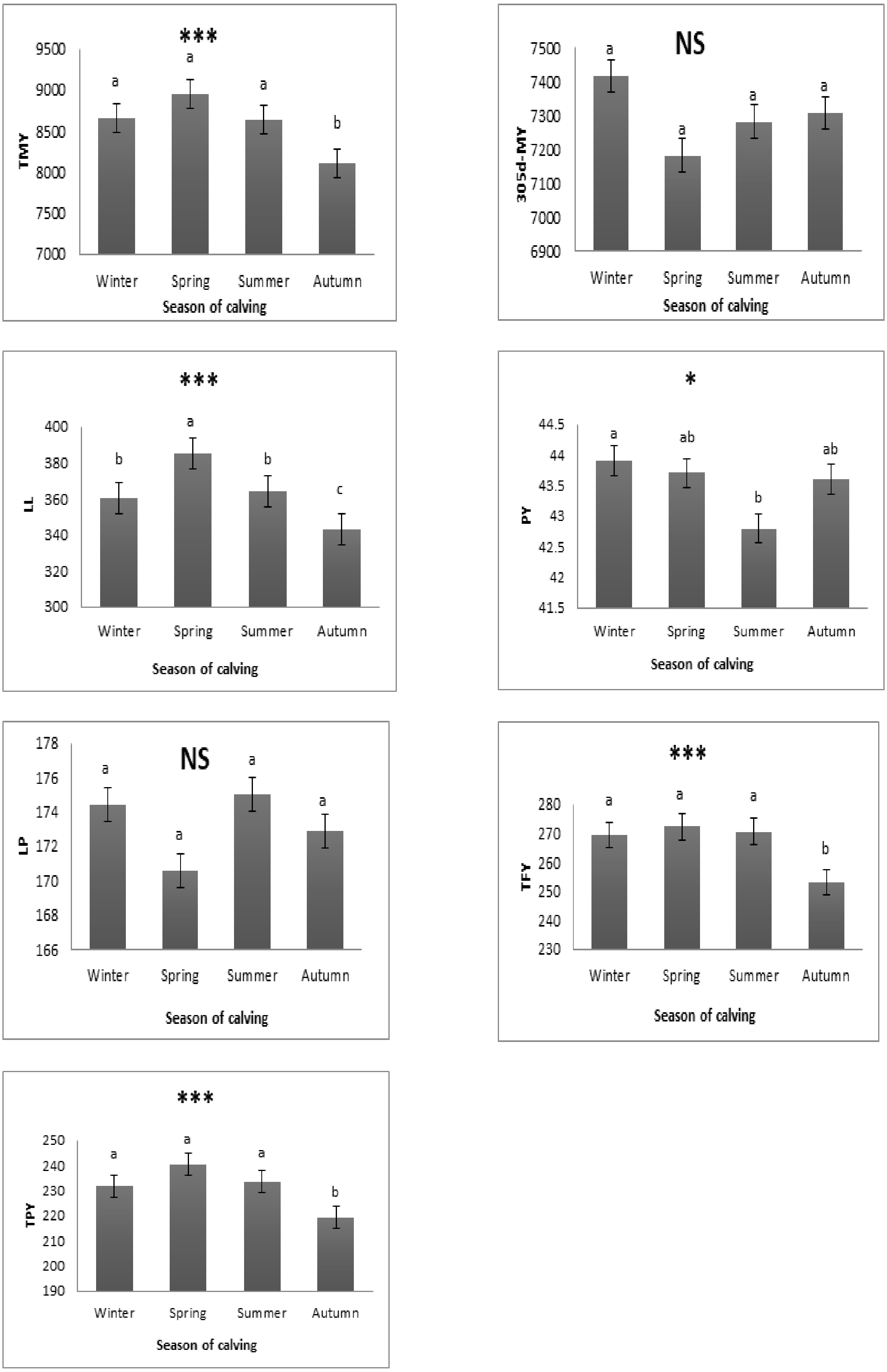

Fig. 2. Least squares means (with SE) of milk production traits in relation to the season of calving in Holstein cows. Means with different letters are significantly different * P<0.05, ** P<0.01, *** P<0.001.

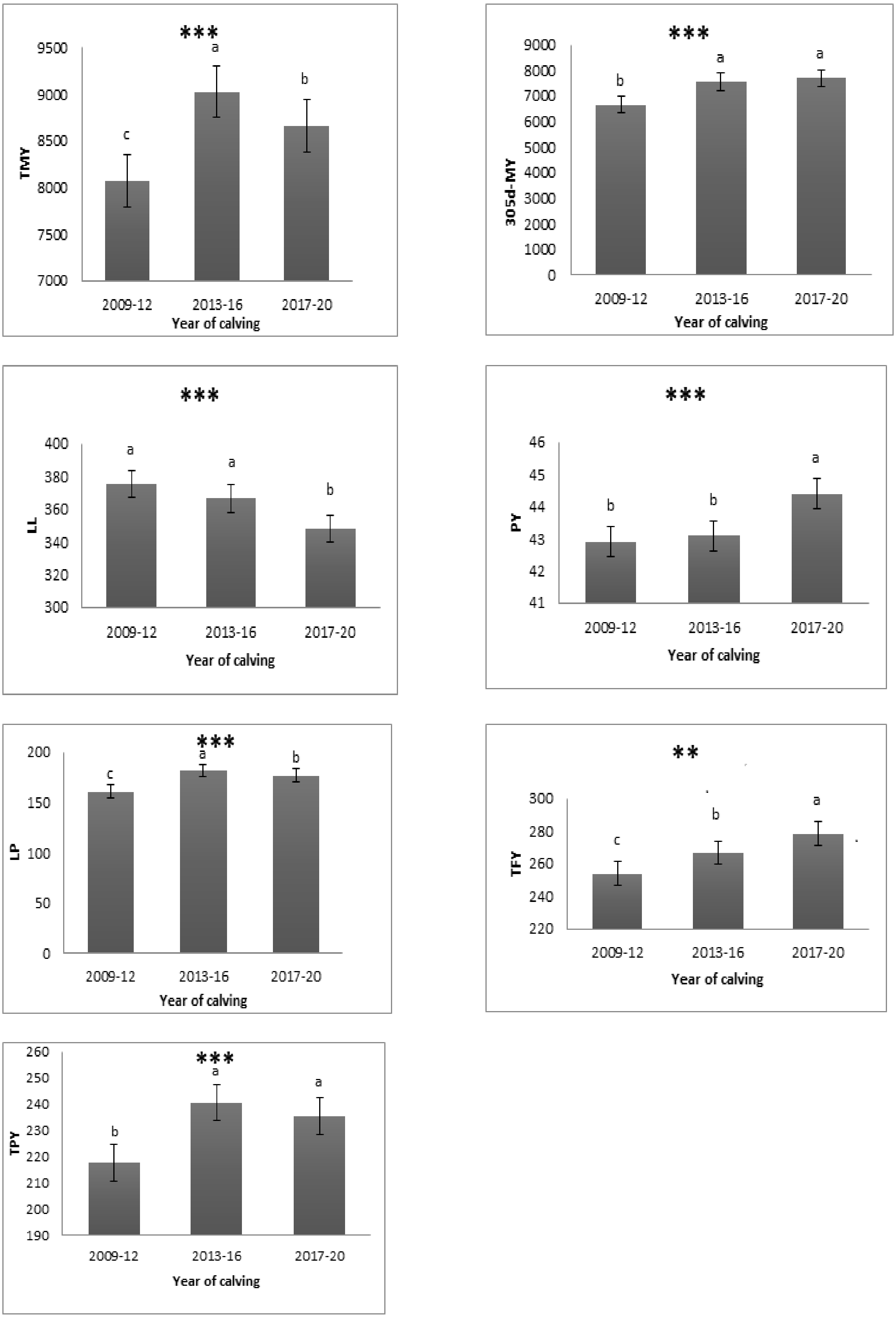

Fig. 3. Least squares means (with SE) of milk production traits in relation to the year of calving in Holstein cows. Means with different letters are significantly different * P<0.05, ** P<0.01, *** P<0.001.

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تقديرالمعايير الوراثية لصفات إنتاج الحليب والمثابرة في أبقار الهولشتاين باستخدام النماذج متعددة السمات.

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الملخص

تم إجراء هذه الدراسة بناءً على بيانات إنتاجية (عددها = 3399) جُمعت من مزرعة خاصة لأبقار الهولشتاين بين عامي 2009 و2020. هدفت الدراسة إلى تحليل تأثير بعض العوامل الثابتة مثل عدد الولادات ، موسم الولادة، وسنة الولادة على صفات إنتاج الحليب، بالإضافة إلى تقدير المعلمات الوراثية المرتبطة بهذه الصفات. شملت الصفات المدروسة: الإنتاج الكلي للحليب(TMY) ، إنتاج الحليب القياسي لمدة 305 أيام (305d-MY)، طول فترة الحليب (LL) ، أعلى إنتاج يومي(PY) ، المثابرة (LP) ، الإنتاج الكلي للدهن(TFY) ، والإنتاج الكلي للبروتين (TPY). تم تقدير المعلمات الوراثية باستخدام النماذج متعددة السمات من خلال طريقة الحد الأقصى للاحتملية المقيدة باستخدام معلومات المتوسط (REML) ، بواسطة برنامج MTDFREML. أظهرت النتائج أن عدد الولادات أثر بشكل معنوي على المثابرة ($P<0.05$)، حيث سجلت الأبقار ذات عدد الولادات العالي (≥5) انخفاضًا في المثابرة مقارنة بالأبقار في الولادات من الأولى إلى الرابعة. أظهرت الصفات المدروسة بانها ذات مكافئ وراثى متوسط (تراوح بين 0.26 إلى 0.37) ومعامل تكراري عالي (تراوح بين 0.55 إلى 0.72)، حيث سجلت صفتا المثابرة في الحليب والإنتاج الكلي للبروتين وانتاج الحليب لمدة 305 ايام أعلى قيم للمعامل التكراري. كما لوحظت ارتباطات وراثية متوسطة (تتراوح من 0.37 إلى 0.40) بين المثابرة وبعض الصفات الإنتاجية (TMY ، 305d-MY، LL, وTPY)، بينما كانت الارتباطات الوراثية مع كل من TFY و PY ضعيفة .($rg= 0.11$ and 0.15) . بشكل عام، تشير نتائج الدراسة إلى أن المكافئ الوراثى المتوسط والمعامل التكراري العالي لصفة المثابرة في الحليب تدعم إمكانية تحسينها وراثيًا عن طريق الانتخاب، مع التوصية بتقييم استمرارية الحليب بناءً على بيانات أول سجل حليب للبقرة. كما أن الارتباطات الإيجابية بين استمرارية الحليب وإنتاج الحليب تدل على أن الانتخاب لتحسين إنتاج الحليب قد يؤدي أيضًا إلى تحسين استمرارية الحليب.

الكلمات المفتاحية :أبقار الحليب، المعلمات الوراثية، هولشتاين، برنامجMTDFREML ، إنتاج الحليب، المثابرة.