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Estimation of the Repeatability of Holstein Milk Yields via Various Statistical Methods

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Abstract This study aims at estimation the repeatability of vital yield characteristics through the Restricted Maximum Likelihood (REML) method by the way of using data with regards to the calving intervals, lactation period, lactation milk yield, dry period and recovered milk yield (2x305 Max.) related to the Holstein herd raised in Ceylanpınar Agriculture Enterprise and comparing the repeatability estimates determined with the help of the REML method, Minimum Quadratic Unbiased Estimation (MQUE), Variance Analysis (VA) and Maximum Likelihood (ML) method. The number of records used for milk yield in the statistical analysis is 1457. The repeatability related to the milk yield characteristics was estimated to be between 0,005 and 0,244. Because of the fact that the repeatability was estimated to be low; it is believed that it might be useful to make the selection based on the mean of two or more records. Estimating the repeatability; the Minimum Quadratic Unbiased Estimation method is most likely to give reliable results for the calving period, dry period and lactation period that meets the r>2Sr condition while REML and ML methods are most likely to give the most reliable results for lactation milk yield and MQUE, VA, REML and ML methods are most likely to give the best results for the adjusted milk yield (2x350 Max.).

Keywords: Milk yield, repeatability, parameter estimations, restricted maximum likelihood, maximum likelihood, minimum quadratic unbiased estimation, variance analysis

Siyah Alaca Süt Verimine Ait Tekrarlama Derecesinin Farklı İstatistik Yöntemlerle Tahmini

Özet: Bu çalışmada, Ceylanpınar Tarım İşletmesi'nde yetiştirilen Siyah Alaca sürüsüne ait, iki buzağılama arasındaki süre, laktasyon süresi, laktasyon süt verimi, kuruda kalma süresi ve düzeltilmiş süt verimi (2x305 E.Ç.)'ne ilişkin verileri kullanarak, Kısıtlı En Çok Olabilirlik (KEÇO) yöntemiyle önemli verim özelliklerinin tekrarlama derecesini tahmin etmek ve KEÇO yöntemiyle, En Küçük Kuadratik Yansız Tahmin Edici (EKKYTE), Varyans Analizi (VA) ve En Çok Olabilirlik (EÇO) yöntemiyle bulunan tekrarlama derecelerini karşılaştırmak amaçlanmıştır. Çalışmada istatistik analizlerde süt verimi için ise 1457 kayıt kullanılmıştır. Siyah Alaca ineklerde önemli süt verim özelliklerine ait tekrarlama dereceleri 0,005 ile 0,244 arasında tahmin edilmiştir. Tekrarlama dereceleri düşük hesaplandığından, yapılacak ayıklamalarda iki veya daha fazla kayıtın ortalamasına göre seçim yapılması daha faydalı olabilir. Tekrarlama derecesinin tahmin edilmesinde, r>2Sr koşulunu sağlayan, iki buzağılama arasındaki süre, kuruda kalma süresi ve laktasyon süresinde EKKYTE yöntemi, laktasyon süt veriminde KEÇO ve EÇO yöntemi, düzeltilmiş süt verimi (2x305 E.Ç)'nde ise EKKYTE, VA, KEÇO ve EÇO yöntemleri güvenilir sonuçlar verebilir.

Anahtar Kelimeler: Süt verimi, tekrarlama derecesi, parametre tahminleri, kısıtlı en çok olabilirlik, en çok olabilirlik, en küçük kuadratik yansız tahmin edici

1. Introduction

The influence of science and technology has resulted in many improvements and changes in many sectors in Turkey. However, it is quite clear that this influence has not caused many changes in the agriculture and livestock sector. Turkey is not among the advanced countries in terms of milk production. The importance of husbandry is rather great to level Turkey up to the advanced countries especially in terms of milk production. Among such enterprises, dairy cattle raising enterprises, milk and milk products industry has an important place and potential. According to the data of the Turkish Statistical Institution, the total of the milk production in 2017 was 20 million and 700 thousand tons. Cows' milk constitutes 90,6% of this amount.

One of the aims of the animal husbandry is to increase the financial income earned from animals. Observations from the husbandry enterprises and various yields acquired are the repetitive characteristics of animals throughout their lives. The repeatability is defined as the correlation between the yield values of an animal in different years and referred to as "r". This parameter indicates the likelihood of individuals that are superior in the first yield years to their coevals to maintain such superiority in the following years. In this way, it is determined whether the selection can be based on the first yield years considering the repeatability. The repeatability is frequently used in enterprises engaged in husbandry.

The repeatability of animals having different amounts of milk yield records can be compared based on the actual yield abilities. Repeatability of various yield characteristics is attributed positive values between 0 and 1 and differ from yield to yield. It differs from race to race or herd to herd for the same yield. It is required to apply a certain standard to animals at different ages to be able to make comparison among cows in terms of milk yield. Mature milk yield is accepted as a standard. Mature period yield has been taken as the basis and the age adjustment coefficients have been developed (Alpan and Arpacık, 1996).

If the repeatability of any yield characteristic is high (40% or above) the individual that has high yield levels in the first yield year in terms of this yield level is most probably expected to have high yield values in the next years, too. If the repeatability of the characteristic is low (1-20%), an individual with high yield level in the previous year is likely to have low yield level in the next year and an individual with low yield level in the previous year is likely to have high yield level in the next year (Evrim and Güneş, 1995).

It could be more accurate to calculate the repeatability estimates of the characters based on the values which are corrected through the elimination of environmental effects such as the age, year, birth season etc. The effect of the year factor as an environmental effect is eliminated automatically when the records of individuals born in the same year are used (Evrim and Güneş, 1995). The breed with the highest yield in the dairy cattle breeding field is Holstein cows. The most important notions in terms of milk yield in Holstein breed are; lactation amount, lactation period, lactation milk yield, dry period and milk yield and adjusted milk yield, respectively.

As cows age starting from the first lactation, their milk yield increases until a certain age depending on the breed, which is approximately 6. High milk yield continues until the ages of 8 to 9. Then the milk yield decreases gradually as cows grow older. The period during which the milk yield reaches the peak is called the "mature age" (Alpan and Arpacık, 1996).

Rege and Mosi (1989) analyzed the lactation records of 1156 cows in 30 Kenyan Friesian herds by means of the Best Linear Unbiased estimation. According to the analysis, they estimated the reputation level of lactation milk yield to be 0,487. Sharma and Khan (1989) found the repeatability of dry period to be 0,310 by utilizing the data related to 173 Sahiwal breed cows. Albuquerque et al. (1990) estimated the repeatability of the milk yield to be 0,450 benefitting from 1092 lactation records of 488 cows. Alim (1990) evaluated the lactation time, dry period, calving intervals and milk yield repeatability by using the data varying between 120 and 430 related to Damitta breed, finding the repeatability estimates of the lactation time, dry period and milk yield to be 0,399, 0,335 and 0,455, respectively. Ledic (1992) analyzed 1045 lactation records for 362 Gir breed cows from 1955 to 1988 and determined the repeatability of milk yield to be 0,390. Queiroz et al. (1991) found the repeatability of milk yield to be 0,500 by utilizing 1710 milk records of Holstein cows. Reddy et al. (1991) determined the repeatability estimates of the lactation time, dry period and calving intervals to be 0,90, 0,240 and 0,250, respectively by the way of using 250 lactation records of 53 cows. Wakhungu et al. (1991) acquired 305-day milk yield and the repeatability of calving intervals throughout a period of 20 years by means of the best linear unbiased estimation in Kenya Sahiwal breed. They estimated the repeatability of 305-day milk yield and the calving interval to be 0,460 and 0,390, respectively. Yeotikar and Deshpande. (1991) analyzed the records of 1488 domestic cows raised in 3551 lactations in India between 1974 and 1989 in the study they performed by the use of the Least Squares Method and they estimated the repetition of dry period and calving interval to be 0,110 and 0,040, respectively, employing this method. Deshpande et al. (1992) estimated the repeatability of lactation time and dry period with 1039 records of 309 Jersey breed cows. They found the repeatability of the lactation time and dry period to be 0,110 and 0,170, respectively. Dhumal et al. (1992) estimated the repeatability of the dry period and service period to be 0,200 and 0,240, respectively, in thoroughbred cows while they estimated the same values to be 0,140 and 0,160 in crossbreed cows by means of 218 records related to Red Kandhari and crossbreed cows. Gandhi and Gurnani (1992) estimated the repeatibility intervals of lactation milk yield, 305-day milk yield, lactation time and calving interval to be 0,386, 0,395, 0,252 and 0,138, respectively, by using 8798 lactation records in their study which covers 30 years related to 1731 Sahiwal breed cows. Novy (1992) calculated the repeatability of milk yield for average, minimum and maximum values in the study he performed in cattle from different herds and found these values as 0,260; 0,140 and 0,610, respectively. Pilla and Moioli (1992) analyzed the error variance through the Restricted Maximum Likelihood method while they employed the Maximum Likelihood method to analyses genetic environmental effects in 33333 lactation records related to 9409 Italian buffaloes. They found the repeatability of the total lactation and 270-day milk yield to be 0,470 for both variants. Singh (1992) estimated lactation milk yield in each day and repeatability of calving intervals by benefitting from 24-year data of 5 herds of Sahiwal breed cows. They accordingly found the interval of the repeatability in 5 herds to be 0,420 and 0,770 for lactation milk yield and 0,420 and 0,570 for calving interval. Khalil et al. (1992) found the repeatability of 90-day, 305-day and total lactation milk yield as 0,270; 0,370 and 0,370, respectively. They found the repeatability of lactation time, dry period and calving interval as 0,230; 0,110 and 0,300, respectively, by means of the Polynomial Regression method using 1641 lactation records corrected based on the calving age. Rao and Nagarcenkar (1993) found the repeatability of the milk yield related to different breeds of Friesian x Domestic crossbreeds and Swiss black crossbreeds to be 0,210 and 0,290, respectively. Suzuki and Van Vleck (1994) used the Derived Restricted Maximum Likelihood Method by making use of 20000 records to estimate the repeatability of milk yield in Japanese Holsteins. They estimated the repeatability of milk yield to be 0,520. Atay et al. (1995) analyzed the characteristics of the milk yield of Holstein cattle raised in Ankara Atatürk Forest Farm in their study and found the repeatability of lactation milk yield, 305-day milk yield and lactation time to be 0,336; 0,191 and 0,191, respectively. Vargas and Solana (1995) found the repeatability of 203-day milk yield to be 0,460 in Holstein cows and 0,490 in Jersey breeds by making use of the lactation records between 1979 and 1992 in Holstein and Jersey breeds in Costa Rica. Skorupski et al. (1996) found the repeatability of daily milk yield of cattle, heritability and genetic correlation coefficients using various animal models. They found the repeatability of milk yield to be 0,190 in the study they performed using the REML method. Souze et al. (1996) found the repeatability of lactation milk yield to be 0,400 in thoroughbred cows and 0,380 in crossbreed cows by the way of using 13973 lactation records of thoroughbred and crossbred cows in 10 herds from Gir dairy cattle breed. Gengler et al. (1997) estimated the repeatability of dry periods, the variance components and heritability of 15 linear patterns using 22354 records from 34999 Jersey cows between 1970 and 1980. They found the variance components using the REML method. They found the repeatability of the dry period to be quite low. Jiang (1997) estimated the variance analysis of corrected mixed patterns and REML parameter estimates of the components through Gaussian method and concluded that these estimates were coherent and dispersed normally and asymptomatically and were quite accurate. Lobo (1998) estimated the genetic parameters of the first calving age and the calving intervals of cows raised in sub-arid areas in Brazil using the REML method. They found the repeatability of the calving interval to be 0,150.

2. Materials and Method

1544 lactation yield records of Holsteins raised in Ceylanpınar Agriculture Enterprise were employed as the material of the study. 1156 records were used to calculate the repeatability of the time coefficient between calving periods while 1139 records were used for the dry period; 1470 records used for the lactation time, 1467 records were used for the lactation milk yield and 1457 records were used for the adjusted milk yield (2x305 Max.). Data regarding the calving interval, dry period, lactation period, lactation milk yield, adjusted milk yield (2x305 Max.) was used by benefitting from the data related to Holstein breed.

The error variances and repeatability were calculated for each variable in the pattern by using the Minimum Quadratic Unbiased Estimation (MQUE), Variance Analysis (VA), Maximum Likelihood (ML) and Restricted Maximum Likelihood (REML) regarding the milk yield. Variables regarding seasons and years were considered as the fixed effects to acquire the variance components of the parameters in the application. The variable regarding the cow data was included in the pattern as the random variable. Numbers were assigned by aligning the data from large numbers to small ones according to the ear tag numbers and each cow corresponding to those numbers were assigned with a sequence number. The SPSS package program was utilized for the calculation of the repeatability and error variances regarding the milk yield.

Estimating the Parameters

There are more than one explanatory variables in the classical linear regression model as given the equation 1.

$$Y = \beta_1 + \beta_2 X_2 + \cdots + \beta_k X_{k+\varepsilon} + \epsilon_i \qquad (1)$$

The parameter number is referred to as k while the independent variable is referred to as k-1. The independent variables are assumed to have the following characteristics.

- The independent variable x_i is a random variable.
- The total of the error terms of the independent variable x_i is 0.
- The variance of the independent variable x_i is fixed.
- The independent variable x_i distributes normally.
- The error term e_i is independent from the independent variable x_i.

There are various methods employed to acquire the parameter estimates under such assumptions among which are; Maximum Likelihood Method (ML), Least Squares Method (LS), Variance Analysis Method (VA), Henderson's 1st Method, Henderson's 2nd Method, Henderson's 3rd Method.

Increasing number of studies carried out in this field leads to an increase in the methods employed to estimate parameters, which are; Restricted Maximum Likelihood (REML), Derived Restricted Maximum Likelihood (DREML), Least Quadratic Unbiased Estimation (LQUE), Least Variance Quadratic Unbiased Estimation (LVQUE). Parameters acquired by the use of these method are expected to be objective, least varianced, effective, best linear and unbiased and have the least mean square *error* and competence characteristics.

The methods of restricted maximum likelihood, variance analysis, least quadratic unbiased estimation was employed in this study. Implications regarding these methods are stated as follows.

Maximum Likelihood Method:

The Maximum Likelihood method is formed by the maximum of the likelihood function. The maximum value of the likelihood value is acquired by equalizing the first derivative taken according to the parameters to zero in which case the partial derivative of the likelihood function is taken according to μ and σ^2 and equalized to zero and functions are solved for unknown parameters (McGilchrist and Cullis, 1991). As in the regression method, $\beta_1, \dots, \beta_k$ random vectors and V vector for i=1,2,…,k for e error term are indicated in the equation 2 in the Maximum Likelihood Method and the Likelihood function (L) of the employed function is indicated in the equation 3.

$$V = \sum_{i=1}^{k} \gamma_i^2 X_i X_i{}' + I_n = \sum_{i=1}^{k+1} \gamma_i^2 V_i \qquad V_i = X_i X_i{}' = I_n \quad i = 1, \dots, k \; için \tag{2}$$

$$L = L(Q) = (2\pi)^{-\frac{n}{2}} |\sigma_e{}^2 V|^{-\frac{1}{2}} \exp\left(\frac{\frac{1}{2}(y - X_0\beta_0)' V^{-1} (y - X_0\beta_0)}{\sigma_e^2}\right) \tag{3}$$

Restricted Maximum Likelihood Method:

The Restricted Maximum Likelihood Method was first published by Thompson in 1962 (Jiang, 1997).

Patterson and Thompson (1971) acquired the variance components estimation in the adjusted block orders using the Restricted Maximum Likelihood Method. The Maximum Likelihood approach allows the estimator to estimate at allowed intervals. The Restricted Maximum Likelihood method has the following characteristics:

- Y should have multiple normal distribution.
- The reciprocal of the matrix should be able to be taken.
- Restrictions in the estimators should be allowable to be in the parameter space.
- There should be a Restricted Maximum Likelihood influenced estimation.
- It should reveal almost the same results as the Least Variance Quadratic Unbiased Estimation.

Variance Analysis Method:

Variance analysis is the comparison of independent variables which are influential on the dependent variable. The independent variable is referred to as the factor while the values taken by the independent variable are referred to as the factor levels. The following matters should be taken into consideration in the variance analysis (Ersöz, 2016):

- Individuals in groups must be similar and homogenous.
- Groups should be independent from each other. It cannot be applied to a dependent group.
- Data must be of perpetual character determined as a result of measurements.
- The number of subjects in groups (n) must be at least 30.
- The number of subjects in groups must be similar or approximate.

The Least Quadratic Unbiased Estimation Method:

The pattern must be assigned with an initial value to acquire σ components in the Least Quadratic Unbiased Estimation Method. This value is determined according to the criteria in the equation 4.

$$\gamma^2 = \alpha_i \quad (\alpha_i \geq 0) \; i = 1, \dots, k+1 \tag{4}$$

Elements of S and q are acquired by making use of the equation 5 to acquire a solution of the equation S, σ=q. SSQ (A) in equation 6 refers to the sum of squares of the elements of the matrix A.

$$R = V^{-1} - V^{-1} X_0 \,(X_0{}' V^{-1} X_0) X_0{}' V^{-1} \tag{5}$$

$$s_{ij} = \begin{Bmatrix} \text{SSQ}\left(X_i{}'RX_j\right) & i = 1,\ldots,k & j = 1,\ldots,k \\ \text{SSQ}\left(X_i{}'R\right) & i = 1,\ldots,k & j = 1,\ldots,k \\ \text{SSQ}\left(RX_j\right) & i = k+1 & j = 1,\ldots,k \\ SSQ(R) & i = k+1 & j = k+1 \end{Bmatrix} \text{ n} \quad (6)$$

If the initial value of α_i is 0, R and q elements are acquired as in 7 and 8.

$$s_{k+1,k+1} = n - rank\ (X_0) \quad (7)$$

$$q_{k+1} = yR_y \quad (8)$$

R symmetric matrix of elements S and q are acquired by means of Goodnight (1978) algorithms and formulas in equations 7 and 8. The Least Quadratic Unbiased Estimation of σ is acquired through the matrix solution where $G = (X_0{}'X_0)$; $\widehat{\sigma} = \text{Sq}$ is acquired.

Standard Error of the Repeatability :

The standard error of the repeatability is presented in the equation 9.

$$S_r = \frac{(1-r) * [\,1 + (k-1) * r]}{\sqrt{\frac{1}{2}\ k * (k-1) * (N-1)}} \quad (9)$$

Information regarding the demonstration in the equation 9 is as follows.

$$r = \frac{Present(Intergroup)}{Present(Intergroup) + Present(In - group)}$$

$$k = \frac{1}{N-1} * \left[T - \frac{\sum n^2}{\sum n}\right]$$

T= Number of total records

n= Number of total individuals

N= Coefficient for each individual

For the repeatability to be reliable, it must be (r > 2Sr or 1/2r > Sr) bigger than two times of its own standard error (Evrim and Güneş, 1995).

3. Results and Discussions

Analyses were performed regarding the factors affecting the dependent variables used in the research. The parameters of Present (Intergroup) and Present (In-group) were found for the Variance Analysis, the Least Quadratic Unbiased Estimation, Maximum Likelihood and Restricted Maximum Likelihood estimation methods. Additionally, values of the variance components in the iteration were calculated for the Maximum Likelihood and Restricted Maximum Likelihood estimation. The variance components, repeatability of the independent variables and the standard errors of the repeatability is presented in the Chart 1 by the methods.

The components of calving interval, dry period, lactation time, lactation milk yield and adjusted milk yield can be summarized as follows.

Calving interval: 1156 records were used to calculate the repeatability of the calving interval as a result of the analyses performed. The repeatability estimated according to four different methods were found to be 0,052 with the Least Quadratic Unbiased Estimation; and 0,038 with the Variance Analysis method; and 0,004 with the Maximum Likelihood method and 0,005 with the Restricted Maximum Likelihood method. The repeatability calculated with four different methods was estimated to be low; between 0,004 and 0,0052.

The standard error of the repeatability of the calving interval was calculated through the Restricted Maximum Likelihood, Maximum Likelihood and the Least Quadratic Unbiased Estimation to be 0,019; 0,019; 0,020 and 0,021, respectively. Standards errors are approximate based on the methods. Since the method meeting the r > 2Sr condition is the Least Quadratic Unbiased Estimation method, the repeatability acquired with this method is likely to present more reliable results compared to the other methods.

Table 1. Variance components of dependent variables, repeatability s and standard errors of the repeatability s by method

Çizelge 1. *Bağımlı değişkenlerin varyansları, s tekrarlanabilirliği ve metot tarafından s tekrarlanabilirliğinin standart hatası*

Methods	Variance Components	Parameter Estimations				
		Calving interval	Dry Period	Lactation Time	Lactation Milk Yield	Adjusted Milk Yield (2x3305 Max.)
Restricted Maximum Likelihood	Present (Intergroup)	10,421	7,263	31,024	236085,361	311689,998
	Present (In-Group)	2062.259	602,606	1550,451	1209905,296	1423491,059
	Repeatability	**0,005**	**0,012**	**0,020**	**0,163**	**0,180**
	Standard Error	**0,019**	**0,021**	**0,025**	**0,055**	**0,029**
Maximum Likelihood	Present (Intergroup)	7,350	6,445	29,549	234249,893	309988,682
	Present (In-Group)	2039,379	595,761	1543,919	1196548,933	1408510,986
	Repeatability	**0,004**	**0,011**	**0,019**	**0,164**	**0,180**
	Standard Error	**0,019**	**0,021**	**0,025**	**0,055**	**0,029**
Variance Analysis	Present (Intergroup)	77,774	22,529	49,091	235710,520	334928,495
	Present (In-Group)	1995,144	587,388	1532,377	1215329,738	1361731,168
	Repeatability	**0,038**	**0,037**	**0,031**	**0,162**	**0,197**
	Standard Error	**0,020**	**0,022**	**0,020**	**0,069**	**0,029**
The Least Quadratic Unbiased Estimation	Present (Intergroup)	110,030	30,874	61,578	223642,957	443767,081
	Present (In-Group)	1999,993	589,156	1534,535	12154339,791	1370918,135
	Repeatability	**0,052**	**0,050**	**0,039**	**0,155**	**0,244**
	Standard Error	**0,021**	**0,023**	**0,018**	**0,057**	**0,031**

Dry Period: Repeatability was acquired by means of four different methods using 1139 records to calculate the repeatability of dry period. The repeatability estimates were determined to be 0,050 with the Least Quadratic Unbiased Estimation method; 0,037 with the Variance Analysis; 0,011 with the Maximum Likelihood method and 0,012 with the Restricted Maximum Likelihood method. The repeatability s calculated with four different methods were determined to be low.

The standard error of the repeatability of dry period was calculated between 0,021 and 0,023 according to the four methods. The standard error estimated through the Restricted Maximum Likelihood method and the Maximum Likelihood method was determined to be 0,021. However, since the method meeting the r > 2S r condition is the Least Quadratic Unbiased Estimation method, the repeatability is likely to present more reliable results than the other methods.

Lactation Time: Four different methods were employed to estimate the repeatability of lactation time by using 1470 records. The repeatability was determined to be 0,039 with the Least Quadratic Unbiased Estimation method; 0,031 with the Variance Analysis; 0,0,019 with the Maximum Likelihood and; 0,020 with the

Restricted Maximum Likelihood. The repeatability was estimated in values lower than 0,040 as a result of the calculations made by means of the four different methods.

The standard error of the repeatability of the lactation time was calculated to be 0,025; 0,025, 0,020 and 0,018, respectively, through the methods of Restricted Maximum Likelihood, Maximum Likelihood, Variance Analysis and the Least Quadratic Unbiased Estimation. The standard estimated by the use of the Restricted Maximum Likelihood and Maximum Likelihood methods was calculated to be higher compared to the Variance Analysis and the Least Quadratic Unbiased Estimation methods. Since the method meeting the r > 2Sr condition is the Least Quadratic Unbiased Estimation method, the repeatability acquired through this method is likely to present more reliable results compared to the other methods.

Lactation Milk Yield: 1467 records were utilized to estimate the repeatability of the lactation milk yield and the repeatability estimates were determined according to the four methods. The repeatability was determined to be 0,155 with the Least Quadratic Unbiased Estimation method; 0,162 with the Variance Analysis method; 0,164 with the Maximum Likelihood method and 0,163 with the Restricted Maximum Likelihood method. The values acquired as a result of the calculations performed according to all four methods were estimated to be lower than 0,170 which is low.

Standard errors of the repeatability were calculated to be 0,055; 0,055; 0,069 and 0,057, respectively, by use of the Restricted Maximum Likelihood, Maximum Likelihood, Variance Analysis and the Least Quadratic Unbiased Estimation methods. The standard errors of the repeatability calculated with the Restricted Maximum Likelihood and Maximum Likelihood methods were found to be the same. The standard errors acquired through these two methods were determined to be lower according to the Variance Analysis and the Least Quadratic Unbiased Estimation methods. Since the Restricted Maximum Likelihood and Maximum Likelihood methods meet the r>2Sr condition, they are likely to present more reliable results compared to the other methods.

Adjusted Milk Yield (2x305 Max.): 1457 records were utilized to estimate the adjusted milk yield (2x305 Max.) repeatability and four different methods were employed. The repeatability was determined to be 0,244 with the Least Quadratic Unbiased Estimation method; 0,197 with the Variance Analysis; 0,180 with the Maximum Likelihood method and 0,180 with the Restricted Maximum Likelihood method. The repeatability was below 0,200 with the Maximum Likelihood and Restricted Maximum Likelihood methods employed; close to 0,200 with the Restricted Maximum Likelihood method and above 0,200 with the Least Quadratic Unbiased Estimation.

Standard errors of the repeatability were calculated to be 0,029; 0,029; 0,029 and 0,031, respectively, by use of the Restricted Maximum Likelihood, Maximum Likelihood, Variance Analysis and the Least Quadratic Unbiased Estimation methods. The standard errors of the repeatability calculated according to all four methods were found to be the same and these methods are likely to present reliable results since they meet the r>2Sr condition.

Swallow and Monahan (1984) reported that the parameter estimations acquired by use of the Least Quadratic Unbiased Estimation and Variance Analysis methods presented approximate results as the parameters acquired through the Maximum Likelihood and Restricted Maximum Likelihood methods. Estimations similar to the results reported by Swallow and Monahan (1984) were obtained in this study, too.

Koutsoyiannis (1989) stated that the Restricted Maximum Likelihood method had lower variances than the Maximum Likelihood method.

4. Conclusion and Recommendations

The repeatability for calving interval, dry period, lactation time, lactation milk yield, adjusted milk yield (2x305 Max.) were calculated by use of the Least Quadratic Unbiased Estimation, Variance Analysis, Maximum Likelihood and Restricted Maximum Likelihood methods by making use of the data of the Holstein herd raised in Ceylanpınar Agriculture Enterprise.

The repeatability acquired through the Least Quadratic Unbiased Estimation method for calving interval, dry period, lactation time, lactation milk yield and adjusted milk yield (2x305 Max.) was estimated higher compared to the repeatability calculated with the other methods. The reason is that the in-group variance calculated with the Least Quadratic Unbiased Estimation method was higher than the in-group variance determined by use of the other methods. Since the solutions are obtained based on the initial value in the iteration with the Least Quadratic Unbiased Estimation method, different results may be acquired from the same data.

In many cases, the estimates of the Restricted Maximum Likelihood and Maximum Likelihood methods can be preferred over the Variance Analysis. The most important reason for that is that the assumption that the REML and ML distribution is normal. Coherent estimates can be acquired through the Maximum Likelihood method while coherent estimates can be acquired through the Variance Analysis only when the characteristics of its distribution is known. Additionally, the Variance Analysis method can present negative variances.

Analyzing the variance components found as a result of this study, it was determined that the variance components calculated via the Maximum Likelihood method were lower than the variance components calculated via the Restricted Maximum Likelihood method and the variance components acquired through the Least Quadratic Unbiased Estimation and Variance Analysis had a greater value compared to the Maximum Likelihood and Restricted Maximum Likelihood methods. Standard errors of the repeatability by methods were determined to be between 0,019 and 0,021 for the calving interval; 0,021 and 0,023 for dry period; 0,018 and 0,025 for lactation time; 0,055 and 0,069 for the lactation milk yield and 0,029 and 0,031 for adjusted milk yield (2x305 Max.). Standard errors of the repeatability were calculated to be small and close to each other in all four methods.

The selection based on the first yield period of the yield characteristics with low repeatability cannot be expected to be quite reliable or successful. In such characters, better results can be expected based on the selection to be made according to the mean of the first two or three records rather than the selection to be made according to a single record (Arıtürk and Yalçın, 1966).

Since the repeatability of calving interval, dry period, lactation time, lactation milk yield, adjusted milk yield (2x305 Max.) were estimated to between 0,04 and 0,244, it may be useful to make the selection according to the mean of two or more records.

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