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ESTIMATION OF VARIANCE COMPONENTS AND HERITABILITY OF BIRTH WEIGHT THROUGH DIFFERENT METHODS IN SWEDISH RED AND WHITE CATTLE

V. Aksakal, B. Bayram, M. Yanar* and O. Akbulut*

Gumushane University, Aydin Dogan Vocational School, 29600, Kelkit, Gümüshane, Turkey
*Atatürk University, Department of Animal Science, College of Agriculture, 25240, Erzurum, Turkey.
Corresponding Author e-mail: vaksakal@gumushane.edu.tr

ABSTRACT

Data on 368 birth records of Swedish Red and White cattle herd raised organically at Dogan Organic Dairy Cattle Farm for a period of 2006 and 2009 (4 years) were used to estimate the effects of different environmental factors on birth weight. Additionally, a comparison of four methods for variance component estimation to compute heritability of birth weight was performed using ML (Maximum likelihood), MINQUE (Minimum variance quadratic unbiased estimation), REML (Restricted maximum likelihood) and Henderson's Method III. Average abortion rate, stillbirth rate, twin and single birth rates of Swedish Red and White cattle were as 4.5%, 4.3%, 3.2% and 87.7% respectively. The least squares mean for birth weight was 37.4±0.70 kg. While effects of calving year ($P<0.01$), calving season ($P<0.05$) and sex of calve ($P<0.01$) were significant, and the effect of age of dam was not significant ($P>0.05$). Sire and error variance components and standard error of the heritability obtained by using ML method were lower than those obtained by the other three methods. Heritability estimates for birth weight obtained by ML, REML, MINQUE and Henderson Method III were 0.57±0.22, 0.62±0.24, 0.65±0.25 and 0.59±0.24, respectively. It is concluded that the ML procedure was superior for estimating variance components and heritability of birth weight of Swedish Red and White cattle and non-genetic factors influencing the birth weight should also be considered in selection and an adjustment for the significant environmental factors should be made.

Key words: Swedish Red and White cattle, birth weight, variance components, heritability, organic dairy farming

INTRODUCTION

In recent years, organic livestock farming has increased in European Union countries and Turkey, due to concerns about the negative effects of intensive farming practices on food safety, consumer-health, animal welfare and environment. Some studies on milk yield, reproduction and other health related traits in different cattle breeds raised organically in other countries have been conducted (Reksen *et al*., 1999; Bennedsgaard *et al*., 2003; Roesch *et al*., 2005; Nauta *et al*., 2006), very few have been conducted in Turkey (Bayram *et al*., 2008; Aksakal and Bayram, 2009). No report on birth weight, abortion, stillbirth and twin birth rates in Swedish Red and White cattle reared organically in Turkey is available. Birth weight is the easiest and most reliable criterion of prenatal growth; it is also a significant factor affecting growth and development in the postnatal period; and growth rate, reproduction and milk yield at subsequent ages (Akbulut *et al*., 2001; Eriksson, 2004). Heifers with a high growth rate produce more meat and begin to produce milk and reproduce at an earlier age. A high genetic correlation between birth weight and age at first calving also exits (Kaygısız, 1998).

Various methods have been developed to estimate variance components used extensively for estimation of heritability and of genetic, phenotypic correlations, for construction of selection indices (Güler *et al*., 2010). The most widely known of these methods are Henderson's I, II, III methods and REML (restricted maximum likelihood), MINQUE (minimum variance quadratic unbiased estimation) and ML (maximum likelihood). Many researchers have used these methods to estimate unbiased variance components for many important yield traits in livestock (Smith and Savage, 1992; Akbaş *et al*., 1993; Akbulut, 1996).

The present study was planned to investigate the effects of environmental factors on the birth weight of organically raised Swedish Red and White cattle, to determine some reproduction parameters such as rates of normal birth, stillbirth, abortion and twin births, and to estimate the heritabilities of birth weight through estimation of variance components of birth weight using four different methods such as Henderson's III, REML, MINQUE and ML procedures.

MATERIALS AND METHODS

Data on some performance traits such as birth weight, abortion, stillbirth and twin birth rates of Swedish Red and White cattle maintained at an organic farm from the Kelkit District of Gümüshane Province, Turkey between 2006 and 2009 years were used in this study.

Swedish Red and White cattle (from 5 to15 months ages) were imported from Sweden in December 2005. Feeding, housing and animal health regimes of the animals were followed in accordance with organic agriculture regulations issued by the Turkish Ministry of Agriculture and Rural Affairs (TMARA) (Anonymous, 2005). The ration of organically reared dairy cattle comprises 60% roughage and 40% concentrate feed. The rations of organically reared cattle are mainly based on roughage feed. Animals were fed on green fodders (alfalfa and barley) produced according to organic agriculture regulations. Furthermore, common vetch and corn silage are also used for feeding purpose. The climate of the region is continental climate and average temperatures for winter, spring, summer and fall are -1.0, 8.7, 19.1 and 10.9 °C respectively.

The birth weight of the calves born at the farm was recorded within 24 hours after the birth. Related parameters about the reproduction were also recorded. The following linear statistical model was used in statistical analysis of the environmental factors affecting birth weight:

$$Y_{ijklm} = \mu + a_i + b_j + c_k + d_l + e_{ijklm}$$

Where, Y_{ijklm} = birth weight, μ = population mean, a_i = the effect of age of dam (i =5: ≤ 45, 45.1-47.0, 47.1-49.0, 49.1-51.0, ≥ 51.1 months), b_j = the effect of calving year (j =3), c_k = the effect of calving season (k= 4: winter, spring, summer, fall), d_l = the effect of the sex of the calf (l=2: male, female), e_{ijklm} = random error. Calculations were made using the PROC GLM option in the SPSS statistical package program (SPSS, 2004). The Duncan multiple comparison test was used in sub-group comparison of the factors that were found to be statistically significant (Duncan, 1955).

Estimation of variance components for birth weight was made using the mixed model. In estimation of heritability, the term sire effect (s_n) was added to the model described above. Thus, to estimate the heritability of birth weight, σ_s (variance within sire) and σ_e [variance in sire's family (among half-sibs)] were calculated by using Henderson III, REML, MINQUE and ML methods using the PROC VARCOMP option in the SPSS statistical package program (SPSS, 2004). In calculation of heritability degree and standard error, the formulae reported by Güler *et al.* (2010) were used. Estimated variance components were evaluated by using criterion of Swallow and Monahan (σ^2_s / σ^2_e) (Swallow and Monahan, 1984).

RESULTS AND DISCUSSION

Descriptive data for rates of normal birth, twin birth, abortion and stillbirth of Swedish Red and White cattle are presented in Table 1. The rates of normal and twin births between 2006 and 2008 years varied from 83.5% to 90.0% and from 1.1% to 7.2% respectively. The rates of abortion and stillbirth also ranged from 0.8% to 7.1% and from 2.4% to 7.1% respectively. Average stillbirth rate in the Swedish Red and White cattle raised organically was 4.3%. In studies carried out in Sweden, the home country of the breed, Kornmatitsuk *et al.* (2003), Steinbock *et al.* (2006) and Anonymous (2008) reported stillbirth rates of 5.0%, 2.5-3.6% and 5.36%, respectively. The average abortion rate (4.5%) was close to those reported by Aksakal and Bayram (2009) for organically reared Holstein Friesian cattle (4.6%) and by Ugur *et al.* (1994) for Simmentals (3.7%). When the stillbirth and abortion rates were analyzed, it was revealed that, in Turkey, this organically reared breed was not problematic and that rates were consistent with those reported in the literature data.

In the present study, the average rate of twin birth of Swedish Red and White cattle was 3.2%. The Twin birth rate does not exceed 1% in many beef cattle breeds, however it can be quite high in dairy cattle. Silva del Río *et al.* (2007) reported that the twin birth rate varied between 0.3% and 12.0% in different cattle herds; Ghavi Hossein-Zadeh *et al.* (2008) noted that the average twin birth rate for Holstein Friesian cattle was 3.9%. This rate was found out as 4.7% in organically reared Holstein Friesian cattle (Aksakal and Bayram, 2009).

The least squares means with their standard errors for factors influencing birth weight in Swedish Red and White calves are also presented in Table 2. While the influences of the calving year ($P<0.01$), calving season ($P<0.05$) and sex of the calves ($P<0.01$) on the birth weight of the calves were significant, the age of dam did not have significant effect on this trait. Male calves were 1.1 kg heavier than female calves. Calves born in spring had lower ($P<0.05$) birth weight than those born in winter and fall.

The overall mean for birth weight of the calves born in the organic dairy farm was 37.4 kg, which was close to the average 39.9 kg birth weight reported for this breed by Philipsson (1977).

The calving year accounted for 23.34% of total variation in birth weight in the present study, compared with 35.85% and 50.18%, respectively, reported for conventionally reared Brown Swiss and Simmental cattle (Kaygısız, 1998) and 25.2% reported by Bakir and Sögüt (1998) for Holstein Friesian calves. Calving year had a significant effect on birth weight of Swedish Red and White cattle reared organically ($P<0.01$). Similarly, Medina-Zaldivar *et al.* (2005), Wasike *et al.* (2006b), Simcic *et al*. (2006), and Ozlütürk *et al.* (2007) reported that year effect was a significant source of variation for birth weight in conventionally reared herds. These findings are consistent with results of the present study.

Calving season had also a significant effect ($P<0.05$) on the birth weight (Table 2) and accounted for 2.98% of total variation in the birth weight. Similarly, Kaygısız (1998) reported that calving season accounted

for 1.43% and 0.62% of total variation in birth weight of Brown Swiss and Simmental calves respectively. Souza and Ramos (1995), Mascioli *et al.* (1996), and Wasike *et al.* (2006a) reported that, in different breeds of conventionally-reared cattle, calving season had a significant effect on birth weight. It was found that calves born in winter had the highest birth weight (38.3kg) and calves born in spring had the lowest birth weight (36.6 kg). The fact that the cattle giving birth in spring had poor feeding conditions during winter when in their last period of pregnancy than those which calved in others seasons might have a negative effect on birth weight of the calves. Bakir and Sögüt (1998) and Vasanthakumar *et al.* (2008) also reported similar findings.

In this study it was found that sex of the calves had a significant effect (P<0.01) on birth weight of Swedish Red and White cattle calves in favor of males (Table 2). In addition, it was found that the birth weights of male calves were approximately 2.9% higher than those of females. Similarly, Mascioli *et al.* (1996) reported that male calves were 3.0% heavier than females; Yanar *et al.* (1995) and Magana *et al.* (2002) reported that male calves were heavier than females (5.0%, 6.5% and 1.9%, respectively). Holland and Odde (1992) reported that this might be related to the higher androgen hormone concentration in male calve fetus; or due to the longer gestation period of male calves. In the present study, sex of the calves accounted for 2.37% of the total variation in birth weight. This result is lower than the values reported by Kaygısız (1998) for Brown Swiss and Simmental (9.92%) and Bakir and Sögüt (1998) for Holstein Friesian 15.34% and 56.7%.

The age of dam did not have a statistically significant effect on birth weight. This contrasts with the results of previous studies (Ugur *et al.,* 1994; Yanar *et al.,* 1997; Kocak *et al.,* 2008), which reported that birth weight increased, depending on the age of the dam (until the age of 5-6 in different breeds); and in later years, birth weight remained unchanged and then decreased. The finding that, in Swedish Red and White cattle calves, the age of the dam was not found to be significant, may be related to the narrow age range of the majority of the dams in the present study (60% were 45-51 months old). It was also revealed that age of dam accounted for a low percentage in the total variation on the birth weight of the calves (1.57%).

Sire and error variance components estimated by Henderson III, ML, REML and MINQUE procedures for birth weight of Swedish Red and White calves, and estimates of heritability of the birth weights with standard errors are presented in Table 3. Sire and environmental variance components obtained from four methods were varied within narrow limits (from 2.190 to 2.636 and from 13.191 to 13.478 respectively). The lower estimates from ML method were obtained. Criteria of Swallow and Monahan (σ^2_s / σ^2_e) were lower than 0.5. In the present study, heritability values with standard errors for birth weight calculated from variance components obtained from various methods were between 0.57±0.22 and 0.65±0.25 (Table 3).

Table 1. Rates of normal birth, twin birth, abortion and stillbirth

Years	Number of Pregnant Cows N	Normal Birth N	%	Abortion N	%	Stillbirth N	%	Twin Birth N	%
2006	85	71	83.5	6	7.1	6	7.1	1	1.2
2007	179	161	90.0	10	5.6	6	3.4	2	1.1
2008	125	112	89.6	1	0.8	3	2.4	9	7.2
Mean			87.7		4.5		4.3		3.2

Table 2. Least square means and standard errors for birth weight

	N	Birth Weight (kg)
		$X \pm S_x$
Overall Mean	368	37.4 ± 0.7
Calving Year		**
2006	73	34.7 ± 0.7^{c}
2007	165	37.4 ± 0.6^{b}
2008	130	40.1 ± 0.5^{a}
Calving Season		*
Winter	122	38.3 ± 0.6^{a}
Spring	103	36.6 ± 0.6^{b}
Summer	81	37.0 ± 0.6^{ab}
Fall	62	37.6 ± 0.7^{a}
Sex of Calves		**
Male	188	37.9 ± 0.5
Female	180	36.8 ± 0.5
Age of Dam (months)		NS
≤ 45	61	37.7 ± 0.7
45.1-47.0	62	38.2 ± 0.7
47.1-49.0	77	37.3 ± 0.6
49.1-51.0	85	37.4 ± 0.6
≥ 51.1	83	36.4 ± 0.6

$X \pm S_x$: Least square means ± Standard error, * : P<0.05, ** : P<0.01, NS: Non-significant, $^{a, b, c}$: Means with different superscript are statistically different.

Table 3. Sire (σ2s) and error (σ2e) variance components and heritability with standard error (h2±Sx) estimates for birth weight

	Henderson. Method III	MINQUE	ML	REML
σ^2_s	2.330	2.636	2.190	2.470
σ^2_e	13.453	13.456	13.191	13.478
σ^2_s / σ^2_e	0.173	0.195	0.166	0.183
$h^2 \pm S_x$	0.59 ±0.24	0.65 ±0.25	0.57 ±0.22	0.62±0.24

The ML procedure produced lower estimates of sire and error variance components than the other three methods. Smith and Savage (1992) and Akbaş *et al.* (1993) associated the result with the nature of the ML method, and they concluded that other methods yielded similar results with the ML procedure when the balanced data were used. Additionally, σ^2_s / σ^2_e values were lower than 0.5 for all methods. Swallow and Monahan (1984) reported that ML estimator of sire variance components had downward bias which might be large when σ^2_s / σ^2_e was greater than 0.5. In the present study, the value is smaller than 0.5, and the ML estimator of σ^2_s has small bias and is preferred estimator (Table 3). Results of the present study are in accordance with findings of Akbulut (1996) and Güler *et al.* (2010).

The heritability with the smallest standard error was also provided by ML procedure in the present study (Table 3). Error in estimates of genetic parameters (heritability and correlations) results in under or overestimates of the genetic response. This bias will be accumulated at each generation, if it was corrected. This could lead to an intolerable degree of the trait considered after several generations. Such errors in the estimates also hamper choosing the optimal selection (Güler *et al.,* 2010). Heritability values calculated by using different methods for variance component estimation were lower than those reported by Khan and Akhtar (1995) in Jerseys (0.75); however, they were higher than the values reported by Simcic *et al.* (2006) for Charolais and Limousins (0.62); Souza and Ramos (1995) (0.54) for Nellore cattle; Wasike *et al.* (2006) for Boran breed cattle (0.36); and Akbulut *et al.* (2001) for Brown Swiss and Holstein Friesian 0.36 and 0.24. The high heritability determined for birth weight indicates that this trait is significantly controlled by additive gene effects. It also indicates that, for this trait, a selection of the breed reared in this farm can result in significant improvement for the birth weight.

Conclusions: The results presented here suggested that the four different methods for variance component estimation gave relatively similar findings, since data used in the study were relatively balanced. However, since the ML procedure is more flexible and estimates smaller sire and error variance components as well as lower standard error for heritability estimates, the ML method could be recommended for estimation of variance components to compute heritability of birth weight in Swedish Red and White cattle reared organically. Environmental factors affecting birth weight should also need to be considered in selection for birth weight and adjustments for the significant non-genetic factors have to be made.

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