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Full Length Research Paper

The relationships of phenotype, genotype and some environmental factors with birth weight in Jersey calves

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This study investigated the effects of parity, birth type, gender and birth season on birth weight in Jersey cattle and also investigated the relationships of phenotype and genotype with birth weight. Birth records of the Karakoy farm near Samsun, Turkey for the period from 1998 to 2005 were used as data for this study. Parity ($P < 0.001$), birth type ($P < 0.001$) and gender ($P < 0.001$) had a significant effect on birth weight, whereas season of calving and calving year ($P > 0.05$) were not significant. The birth weight mean of Jersey calves was 20.87 ± 1.79 kg. Total additive genotypic variance was 14.80, phenotypic variance was 38.95 and heritability of birth weight was 0.38. In planning a selection program to achieve ideal birth weight of Jersey calves, birth type, gender and parity need to be included, with the 4th or later parity been most influential.

Key words: Birth weight, estimate of parameter, Jersey, parity, season of birth.

INTRODUCTION

One of the most important requirements for efficient animal breeding is to have high yield capability in the breeding lines. In livestock, production levels are determined by the joint contribution of genetic and environmental factors (Akcapinar and Ozbeyaz, 1999). Growth is largely controlled by genetic factors but can be improved by manipulating environmental factors. Birth weight is an important factor in successful cattle breeding due to its close relationship with survival rate, growth performance, fertility and milk yield. The last trimester of pregnancy is the fastest growth period for the fetus and birth weight is highly dependent on nutrition. Birth weight is also influenced by genotype, gender, type of birth (single or twin) and parity (Akcapinar and Ozbeyaz, 1999; Tilki et al., 2003; Bayram et al., 2008). Male calves are usually heavier than female calves (Bayrakcioglu, 2001; Ahunu et al. 2007; Orenga et al., 2009) and single born calves are also heavier than twins (Akcapinar and Ozbeyaz, 1999; Tilki et al., 2003). Generally, as age of the dam and parity increases, the birth weight of calves also increases. There is conflicting evidence on the effects of season on birth weight. Some studies have reported a significant seasonal effect (Ahunu et al., 1997), but others have reported that the effects of season on birth weight are not significant (Kocak et al., 2007).

The Jersey is a small, early maturing cattle breed with a mean birth weight of approximately 20 kg (Alpan, 1990) and mean milk yield in lactation of about 3000 to 3500 kg (Ozcan and Yalcin, 1985). Production by Jersey cattle is important in the Black Sea Region of Turkey. In Turkey, the breed basically originated from 348 Jersey cattle imported in 1958 from the USA to the Karakoy State Farm. The farm is located near Samsun in the central Black Sea Region of northern Turkey. It is in the eastern part of the Bafra District (41°34' N, 35°55' E) and at 20 m above sea level. Classical closed breeding schemes were applied at the farm for nearly 40 years. Currently, artificial insemination with imported semen is used (Anonymous, 2011). Furthermore, the farm has a vital role in the region due to its being the sole Jersey stud in the Black Sea Region. Currently, there are 804 stud Jerseys at the Farm and about 80 301 pure bred Jerseys and about 195 530 Jersey crossbred cattle raised in the region.

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Jersey calving at the Karakoy farm has suffered from a lower survival rate due to a lower birth weight mean than that in the study of in farm (Akdag and Arslan, 2007). Therefore, this study aimed to determine the effects of some environmental factors (parity, birth type, gender, year and birth season) on birth weight and to estimate the genetic parameters for birth weight of Jersey calves at the Karakoy Farm in Samsun Province, Turkey.

MATERIALS AND METHODS

The birth records of 933 Jersey calves born at the Karakoy State Farm near Samsun, Turkey from 1998 to 2005 were used to produce recursive data for parity, birth type, gender, year, season of calving and pedigree. In order to investigate the environmental effects of parity on birth weight, calves were allocated to subgroups (i = 1, 2 3 or 4; first parity = 1, second parity = 2, third parity = 3 and fourth and above parity = 4); birth type (j = 1 or 2; for single and twin births, respectively); gender (k = 1 or 2 for male or female, respectively); for season of calving (spring, summer, fall and winter, l = 1, 2, 3 or 4, respectively) and for years (i = 1, 2 or 3; 1 = 1998 - 2001; 2 = 2002 - 2003; 3 = 2004 – 2005), according to combinations of those factor levels and their main effects.

In State farm, pregnant cows in dry period pastured in the grass during the day light were fed 3.0 kg additional feeding including corn silage, vetch silage, dried grass hay and concentrate commercial mixed ration with 2800 kcal/kg ME and 18% proteins and same additional feeding program was applied to other pregnant cows in lactation, but was 5.0 kg per cows.

Statistical analysis

The data sets for birth weight were from 63 sires and 249 dams. The numbers of animals in the pedigree files for birth weight were 1.245. The dams and sires of all calves with records were known. The effects of parity, birth type, gender, year and birth season were determined by variance analysis using the following factorial designed mathematical model:

$$Y_{ijklmn} = \mu + a_i + b_j + c_k + s_l + y_m + (ay)_{im} + (sy)_{lm} + e_{ijklm},$$

Where, Y_{ijklmn} is birth weight (kg) for n calves; μ is overall mean of the birth weight; a_i is the effect of ith parity (i = 1, 2, 3, 4); b_j is the effect of jth birth type (j = 1, 2); c_k is the effect of kth gender (k= 1 ,2); s_l is the effect of lth season of calving (i= 1, 2, 3, 4); y_m is mth main effect of the year (i = 1, 2, 3; for 1 = 1998 - 2001; 2 = 2002 - 2003; 3 = 2004 -2005); $(ay)_{im}$ and $(sy)_{lm}$ are two-way interaction effects for ith parity and sth seasons with years, respectively and e_{ijklmn} is the residuals for animals individually.

The Scheffe-Ryan-Gabriel-Welsch-Einot multiple range test was used to investigate differences between the average birth weights of groups due to the unbalanced number of observations within the sub-groups. Further investigation of the effects of two-way interactions on birth weight was done with orthogonal polynomials.

The following single trait animal model of Gengler et al. (2006) was applied for birth weight:

$$Y = Xb + Z_1a + Z_2m + Z_3c + e \quad \text{with } \operatorname{cov}(a,m) = 0;$$

$$\operatorname{var}(c) = I_{NC}\sigma_e^2 \text{ and } \operatorname{var}(e) = I_n\sigma_e^2,$$

Where, Y is a vector of birth weight phenotypic observations in the calves; Xb, a and m are the vectors of fixed effects, namely the covariables, direct additive and genetic effects, maternal additive effects and maternal permanent environmental effects, respectively; X_1, Z_1, Z_2 and Z_3 are corresponding incidence matrices related to Y; and e is the vector residual error. A is the numerator relationship matrix, I is the identity matrix, NC is the number of dams, n is the number of animals, including parents without records; and σ_c^2 and σ_e^2 are the maternal permanent environmental and residual error variances, respectively.

The DFREML procedure described by Graser et al. (1987) was fitted to the animal model to estimate genetic and environmental variance. Convergence was assumed when the change in the Euclidian norm of the vector of the first derivate was less than 10^{-6}. Analysis was restarted using the resultant (co) variance component estimates as new priors until changes in the function value and estimates in the scaled parameters were less than 0.01. Phenotypic variance (σ_p^2) was calculated as the sum of direct additive genetic variance (σ_a^2), maternal genetic variance (σ_m^2) and σ_{am}, σ_c^2 and σ_e^2. Total heritability (h^2) was calculated as total additive genetic variance ($\sigma_{total-additive}^2 / \sigma_p^2$). The total genetic variance was the sum of all the genetic effects in the model that is, $\sigma_{total-addition}^2 = (\sigma_a^2 + 0.5\sigma_m^2 + 1.5\sigma_{am})$. The likelihood ratio test was conducted to determine the most suitable model for the birth weight trait in a univariate analysis. The DFREML version 3.0 and SAS (2008) programs were used to include all models and univariate procedures were also applied with DFREML to all models.

RESULTS AND DISCUSSION

The impacts on Jersey calf birth weight of parity, birth type, gender, year and season of calving are provided in Table 1. The average birth weight of the 933 Jersey calves was 20.87±1.79 kg. Parity ($P < 0.001$), birth type ($P < 0.001$) and gender ($P < 0.001$) significantly affected birth weight, whereas season of calving and calving year ($P > 0.05$) were not significant. Compared with this study, average birth weight for the same breed was lower (Cundiff, 1988; Bonczek et al., 1992; Demeke et al., 2004; Washburn et al., 2006) and in other studies, it was higher (Chaudhry et al., 1993; Jain et al., 2000). The lower birth weight in this study than in some studies may be attributable to inadequate nutrition in the final trimester of pregnancy (Tilki et al., 2003). Birth weight for males (20.90±0.06 kg) was typically higher than for females (18.66±0.28 kg), which is in agreement with the results of Legaulth and Touchberry (1962), Ahunu et al. (1997), Bayram et al. (2000), Jain et al. (2000), Kocak et al. (2007), Lateef (2007) and Orenga et al. (2009). Furthermore, males exhibited higher phenotypic variation

Table 1. Environmental factors and phenotypic variance (σ_p^2) affecting birth weight.

Trait	N	$\overline{X} \pm S_{\overline{X}}$	σ_p^2	P value
Gender				
Female	464	18.66±0.28[b]	8.67	0.001
Male	469	20.90±0.06[a]	9.82	
Birth type				
Single	921	21.43±0.09[a]	9.64	0.001
Twin	12	20.30±0.08[b]	5.27	
Parity				
First	244	19.79±0.11[c]	8.93	
Second	216	20.81±0.14[b]	10.27	0.001
Third	183	21.26±0.12[a]	7.97	
Other (4>)	290	21.56±0.11[a]	9.01	
Season				
Spring	263	20.95±0.12	9.81	
Summer	248	20.68±0.11	8.59	0.274
Fall	167	20.92±0.15	9.66	
Winter	255	20.92±0.18	10.51	
Year				
>2001	196	20.78±0.17	11.50	0.660
2002-2003	347	20.92±0.11	10.37	
2004-2005	390	20.87±0.08	7.91	
Overall	933	20.87± 1.79		

a,b,c: Means within the same column with differing superscripts are significantly different (p<0.05).

(Table 1) than females, a finding in accordance with Rodriquez et al. 1995.

Comparison of male and female birth weights revealed that there was less variability in the latter. Birth type is an important determinant of birth weight and the birth weight of single born calves was higher than that of twins, as also reported by Akcapinar and Ozbeyaz (1999), Tilki et al. (2003), Bakir et al. (2004) and Olson (2009). When birth weight was examined in relation to parity, birth weights of parity 4 and more were higher than for parities 1, 2 and 3. In other words, parity has an important influence on birth weight and generally, birth weight increases with increasing parity (Legaulth and Touchberry, 1962; Bonczek et al., 1992; Bakir et al., 2004; Washburn et al., 2006; Orenga et al., 2009). A contributing factor to this increase in birth weight may be the increase in volume of the uterus with increasing parity and age of the dam (Akcapinar and Ozbeyaz, 1999; Tilki et al., 2003). When parity according to phenotypic variation in birth weight was examined (Table 1), the variation in birth weight among calves born to second parity dams was the highest.

Although calves born in spring in this study tended to have a higher birth weight (Chaudhry et al., 1993; Bardakcioglu, 2001; Kocak et al., 2007; Lateef 2007), the effect of season on birth weight was not significant (Chaudhry et al., 1993; Ahunu et al., 1997; Jain et al., 2000; Rahman et al., 2007). It may be that for offspring born in spring, fetal growth is most rapid during the last trimester following the winter when dry pasture grass, dry clover and corn silage are optimally available; in addition, extra concentrated feed associated with a more controlled feeding program in the winter season enhanced fetal growth. Moreover, calves born in winter had higher phenotypic variation of birth weight than those born in other seasons and calves born in summer had the lowest phenotypic variation (Table 1). In determining the effects of year on birth weight and phenotypic variation, calves born between 1998 and 2005 had similar birth weights (P > 0.05) and calves born before 2001 had higher variation in birth weight.

The relationship between seasonal birth weight and parity (Table 2) was not significant (P > 0.05). In contrast, birth weight means tended to increase with increasing

Table 2. Relationship of season x parity to birth weight.

Season	Parity	N	$\bar{X} \pm S_{\bar{X}}$	σ_p^2
	1	86	18.35±0.32	9.55
1	2	62	19.61±0.33	9.07
	3	48	20.26±0.34	8.49
	4	67	20.90±0.32	8.72
	1	62	18.23±0.34	8.78
2	2	55	19.70±0.34	9.17
	3	48	19.78±0.37	6.80
	4	83	20.11±0.35	7.63
	1	40	18.39±0.38	9.01
3	2	37	18.98±0.39	9.40
	3	36	19.95±0.39	6.89
	4	54	20.50±0.36	9.17
	1	56	18.28±0.36	8.20
4	2	62	19.56±0.34	12.62
	3	51	19.97±0.36	9.16
	4	86	20.14±0.32	9.89

Table 3. Relationship of year x season to birth weight.

Year	Season	N	$\bar{X} \pm S_{\bar{X}}$	σ_p^2
	1	61	20.55±0.28	10.85
1	2	38	21.02±0.34	10.04
	3	30	20.40±0.44	11.84
	4	67	21.01±0.32	12.68
	1	92	21.40±0.23[a]	10.50
2	2	82	20.32±0.23[b]	10.45
	3	70	20.91±0.25[b]	10.32
	4	103	20.97±0.20[b]	9.80
	1	110	20.80±0.16	8.22
3	2	128	20.82±0.11	6.50
	3	67	21.17±0.19	7.70
	4	85	20.80±0.21	9.49

a,b: Means within the same column with differing superscripts are significantly different (p<0.05).

parity for all seasons and dams in the 4th parity in all seasons had the highest birth weight. Furthermore, in all the seasons except spring, for seasonal phenotypic variation in birth weight with respect to parity, birth weight of the 2nd parity dams was the highest. Interaction effects between birth season and year on birth weight are summarized in Table 3. For calves born between 1998 and 2001 and also in 2004 to 2005, the birth season x year effect for birth weight mean was significant (P < 0.05), whereas for other groupings it was not significant.

For calves born within the year groupings of 1998 to 2001 and 2004 to 2005, birth weight means were similar for all seasons, whereas for year grouping of 2001 to 2003, spring calves had a higher mean birth weight.

Estimation of variance components (parity, season of calving and year) is summarized in Table 4. It revealed total additive genetic variance of 14.80 and phenotypic variance of 38.95 and heritability of birth weight was 0.38. This value, in terms of degree of heritability of birth weight and examined at the intermediate level, is acceptable for Jersey calves. The heritability of birth weight in this study was higher than that of Demeke et al. (2004) which involved crossbred Jersey x Bos inducus and was also higher than for the Sahiwaal breed (Chaudhry et al., 1993). However, heritability of birth weight was 0.54 in pure bred Jersey calves, according

Table 4. Estimates of (co)variance components and their standard errors for direct (σ_a^2) additive genetic variance, maternal (σ_m^2) genetic variance and permanent environmental (σ_c^2) and residual σ_e^2 effects and heritability of birth weight in Jersey calves for various random environmental factors (converged at 10^{-6}).

Trait	σ_a^2	σ_m^2	σ_c^2	σ_e^2	σ_p^2	$\sigma_{total-additive}^2$ (*)	h²(*)
Parity							
First	11.32	1.05	8.18	3.43	37.02	11.85	0.32
Second	11.49	1.11	1.99	4.58	36.50	12.05	0.33
Third	12.08	1.23	1.05	2.78	36.27	12.70	0.35
Other	12.56	1.30	0.72	6.13	33.87	13.21	0.39
Season							
Spring	12.73	1.13	9.17	4.57	33.24	13.30	0.40
Summer	12.48	1.48	11.43	8.41	30.74	13.22	0.43
Fall	12.11	1.03	8.47	3.71	28.69	12.63	0.44
Winter	12.70	0.48	9.76	4.07	39.21	12.94	0.33
Year							
1998-2001	9.73	2.43	7.41	7.47	28.80	10.95	0.38
2002-2003	13.08	1.56	6.03	6.40	33.80	13.86	0.41
2003-2005	14.09	2.07	2.71	6.78	35.17	15.13	0.43
Overall (**)	13.58	2.44	3.75	6.33	38.95	14.80	0.38

*, h²= $\sigma_{total-additive}^2 / \sigma_p^2$ and $\sigma_{total-additive}^2 = (\sigma_a^2 + 0.5\sigma_m^2 + 1.5\sigma_{am})$; ** Full model fitted.

to Abanikannda et al. (2001). In this study, analysis of parity in relation to birth weight gave an esti-mate of phenotypic variance ranging from 33.87 to 37.02 and total additive genetic variance ranging between 11.85 and 13.21. In addition, increasing parity was linked to an increase in genetic variance and that genetic variance (13.21) was highest for parity 4 and above. For the first 3 parities, the increasing parity was correlated with a decrease in environmental variance. When the heritability of birth weight by parity was examined, the first parity birth weight was demonstrated to be most affected by environmental factors.

When the variance components of birth weight related to season were examined (Table 4), total additive genotypic variance ranged from 12.63 to 13.30 and phenotypic variance was between 28.69 and 39.21. In addition, it was observed that the environment affected the birth weight of calves born during the summer more than in the other seasons.

For birth weight, total additive genetic variance of 1998 to 2001, 2002 to 2003 and 2003 to 2005, was estimated to be 10.95, 13.86 and 15.13, respectively. Total environmental variance for the first grouping was estimated to be higher than for the others. This higher estimate suggests that environmental conditions such as feeding and management had an effect on birth weight. Moreover, the lower total genetic variance negatively affected the birth weight of calves born in 1998 to 2001. The results also showed that genetic effects such as direct additive and fixed effects, permanent environmental effects such as management and feeding and maternal effects, have an important role in shaping the birth weight of calves. This study therefore re-emphasizes the influence of environmental factors on birth weight.

Conclusions

In this study, parity, birth type and gender affected the birth weight of Jersey calves. For parity and season, the effects of environmental variance on birth weight were greater than those of genetic variance, while the heritability of birth weight in the herd was defined as moderate. To plan a selection program for ideal birth weight, it is suggested that the 4th and later parities are more advantageous for manipulating environmental factors impact on birth weight.

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