Bulgarian Journal of Agricultural Science, 17 (No 5) 2011, 680-686
Agricultural Academy

CANONICAL CORRELATION ANALYSIS FOR ESTIMATION OF RELATIONSHIPS BETWEEN SOME TRAITS MEASURED AT WEANING TIME AND SIX-MONTH AGE IN MERINO LAMBS

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Abstract

SAHIN, M., S. CANKAYA and A. CEYHAN, 2011. Canonical correlation analysis for estimation of relationships between some traits measured at weaning time and six-month age in merino lambs. *Bulg. J. Agric. Sci.,* 17: 680-686

In this study, canonical correlation analysis was applied to estimate the relationship between six different morphologic traits (*X* set – at weaning; height at withers (HW), chest depth (CD), chest width (CW), chest girth (CG) and rump width (CD)) measured at weaning and morphological traits of the six-month age (*Y* set – at six-month age; height at withers (HW_6), chest depth (CD_6), chest width (CW_6), chest girth (CG_6) and rump width (RW_6)) measured from 72 lambs of merino, at Marmara Animal Breeding Research Institute. First two of estimated six different canonical correlation coefficients (CCC) between the pairs of canonical variables were found significant (0.717, 0.587, P<0.05). The results obtained from canonical correlation analysis indicated that chest girth and live weight had largest contribution for the explanatory capacity of canonical variables estimated from the morphologic traits of the lambs at the weaning when compared with other body measurements, while height weight and live weight had largest contribution for the explanatory capacity of canonical variables estimated from the morphological traits of the six-month age when compared with other body measurements. The results of this study showed that chest girth and live weight measured at weaning can be used as early selection criteria for genetic improvement in merino lambs.

Key words: canonical correlation coefficient, merino, weaning, six-month age traits

Introduction

Sheep population is approximately 24 million in Turkey (TSAT, 2008). The local breed is majority of the sheep population in Turkey. About 96% of this population is native sheep which has low meat and milk production. The other part of the sheep population is crossbred sheep as mutton Merino which is brought to Karacabey State Farm in 1934, was crossed with Kivircik sheep. At

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Karacabey State Farm careful selection program was also applied, and as a result a new Merino type, Karacabey Merino was developed. It contains about 95 percent German Mutton Merino and 5 percent Kivircik genotype (Yalcin, 1986). The Karacabey merino is raised wool and meat production (Ceyhan et al., 2008; Eyduran et al., 2009; Staikova et al., 2009). It is important to determine the relationship between two or more characters measured at early time and measured hard at or later time, since early selection is one of the modern selection programmes applied for a higher production in animal (Akbas and Takma, 2005; Cankaya and Kayaalp, 2007).

It is important to determine the relationship between the body measurements in different age groups, due to the fact that early selection is one of the methods in animal breeding. Simple correlation analysis is usually preferred by researchers for determining degree and direction of the relationships between body measurements. But one or more of the variables may be interrelated and it is therefore difficult to pinpoint their individual significance.

Canonical correlation analysis is a technique for describing the relationship between two variable set by calculating linear combinations that are maximally correlated (Thompson, 1984). Canonical correlation analysis has the ability to deal with two variable sets simultaneously and to produce both structural and spatial meaning (Bilgin et al., 2003). The applications of canonical correlation analysis such as determination of the relationship between some traits measured pre- and post slaughtering, milk and reproductive traits, production performance and body measurements, milk and wool yield traits, head and scrotum measurements, testicular and body measurements or measurements in different periods (sucking and fattening) and body measurements etc. were discussed in the previous livestock studies (Al-Kandari and Jolliffe, 1997; Fourie et al., 2002; Tatar and Elicin, 2002; Keskin and Dag, 2009; Bilgin et al., 2003**;** Musa et al., 2006**;** Keskin et al., 2005; Akbas and Takma, 2005; Emsen and Davis, 2004). However, to our knowledge, it is not founded the applications of canonical correlation analysis for estimating the relationships of morphologic traits measured at weaning period with morphologic traits of the six-month age in merino lambs. The aims of this paper are: a) to estimate the interrelationship between six different morphologic traits (*X* set – at weaning; height at withers (HW), chest depth (CD), chest width (CW), chest girth (CG) and rump width (CD)) measured at weaning and morphologic traits of the six-month age (*Y* set – at six-month age; height at withers (HW_6), chest depth (CD_6), chest width (CW_6), chest girth (CG_6) and rump width (RW_6)) measured from 72 lambs of merino; b) to determine which variables can be used as early selection criteria for decreasing generation interval and economy in Turkish Merino lambs production.

Material and Methods

Data collection

The material of the study was formed of Turkish Merino (Karacabey Merino) lambs born in Marmara Animal Breeding Research Institute. In terms of the live body measurements of the lambs in the experimental, height at withers, chest depth, chest width, chest girth, and rump width were measured 72 female Turkish Merino lambs. The body measurements were taken by meter at weaning and six mount age of lambs.

All lambs were weighed and ear tagged within 12 hour of the birth. The lambs were kept alone with their mothers in stalls for 3 days after lambing. The lambs were allowed to suckle their mothers twice a day. When the lambs reached 15 days old they were fed *ad libitum* a creep-feed concentrate and good quality alfalfa hay for 3 months. The lambs were weaned at 90 days of age. Than weaning male and female lambs were reared separately by sex groups. After this period, the roughage was given ad libitum, but the concentrate feed was approximately 200 g per lamb per day.

Canonical correlation analysis (CCA)

The canonical correlation analysis (Thompson, 1984), focuses on the correlation between a linear combination of the variables in the weaning variable set (*X*-set, called canonical variable *U*) and a linear combination of the variables in the six-month age variable set (*Y*-set, called canonical variable V) such that the correlation between the two canonical variables is maximized (Gunderson and Muirhead, 1997). Canonical variables (*U* and *V*), which in this study are needed to represent the association between morphologic traits measured at weaning and at the six-month age from 72 lambs of merino**,** are so formed that the first pair has the largest correlation of any linear combination of the original variables. Subsequent pairs also have maximized correlations subject to the constraint that they are uncorrelated with each previous pair (Johnson and Wichern, 2002). Symbolically, given X_{nxp} and Y_{nxq}, then $U_i=Xa_i$ and $V_i=Yb_i$ where a_i and b_i are standardized canonical coefficients that can be used to determine which variables are redundant in interpreting the canonical variables (Cankaya and Kayaalp, 2007). These coefficients indicate the relative importance of the variable set of measurements at the weaning in determining the value of the variable set of the six-month age, with $i=1,\dots,\min(p,q)$. On the other hand, the coefficients can be unstable because of the presence of multicollinearity in the data. For this reason, the canonical loadings are considered to provide a substantive meaning of each variable for the canonical variables (Akbas and Takma, 2005). The result satisfies $Corr(U_i,V_j)=0$, $Corr(U_i,U_j)=0$, $Corr(V_i,V_j)=0$ for i≠j and $Corr(U_i,V_j)=\rho_i$ for $i=j$ (Al-Kandari and Jolliffe, 1997). The canonical correlation coefficient (ρ_i) is the measure of the interrelationship between two variable sets. Let

$$\rho_1^2,\dots,\rho_p^2 \ (0 \le \rho_p^2 \le \dots \le \rho_1^2 \le 1)$$

be min (p,q) ordered eigenvalues (λ_i) of the matrix, $\Sigma_{11}^{-1}\Sigma_{12}\Sigma_{22}^{-1}\Sigma_{21}$ where

$$\Sigma=\begin{bmatrix}\Sigma_{11} & \Sigma_{12}\\ \Sigma_{21} & \Sigma_{22}\end{bmatrix}$$

Their positive roots $\rho_1,\dots,\rho_p$ are the population of canonical correlation coefficients between *U* and *V*.

$$\rho_{U_iV_i}=r_i=\sqrt{\lambda_i}=\frac{Cov(U,V)}{\sqrt{Var(U)Var(V)}}=\frac{a'\Sigma_{12}b}{\sqrt{(a'\Sigma_{11}a)(b'\Sigma_{22}b)}};i=1,2,\dots,q$$

Interpretations of canonical correlation analysis (CCA)

The null and alternative hypotheses for assessing the statistical significance of the canonical correlation coefficients are,

$$H_0: \rho_1=\rho_2=\dots=\rho_r=0$$
$$H_1: \rho_i \neq 0 \quad \text{at least one i} = 1,2,\dots,r$$

The *F* test statistic for the statistical significance of ρ_i^2 is

$$F=\frac{1-\lambda_1^{1/t}}{\lambda_1^{1/t}}\frac{sd_2}{sd_1} \sim F_{sd_1,sd_2,\alpha}$$

Here,

$$\lambda_1=\prod_{i=1}^{s}(1-r_i^2);\quad s=\min(p,q);\quad sd_1=pq\quad sd_2=wt-\frac{1}{2}pq+\ ;$$

$$w=n-\frac{1}{2}(p+q+3)\qquad t=\sqrt{\frac{p^2q^2-4}{p^2+q^2-5}}$$

where, *n* is the number of cases, *p* is number of variables in the *X* set, *q* is the number of variables in the *Y* set, and r_i^2: represents the eigenvalues of $\Sigma_{11}^{-1}\Sigma_{12}\Sigma_{22}^{-1}\Sigma_{21}$ or the squared canonical correlations.

Canonical correlation coefficients do not identify the amount of variance accounted for in one variable set by other variable sets. Therefore, it is important to calculate the redundancy measure for each canonical correlation to determine how much of the variance in one set of variables is accounted for by the other set of variables (Sharma, 1996). The redundancy measure can be formulated as below

$$RI_{U_iV_i}=OV(Y|V_i)r_{uv}^2 \qquad OV(Y|V_i)=\frac{\sum_{i=1}^{q}LY_{ij}^2}{q}$$

where $OV(Y|V_i)$ is the averaged variance in *Y* variables that is accounted for by the canonical variant V_i, LY_{ij} which is the loading of the j^{th} Y variable on the i^{th} canonical variant; and q is the number of traits in canonical variants mentioned.

Applications of Canonical Correlation Analysis

While the first six characters were included in the first variable set (X_{nxp}: morphologic traits at weaning), the latter six characters were included in the second variable set (Y_{nxq}: morphological traits of the six-month age). All of the computational work was performed to examine the relationships between the two sets of traits by means of the PROC CONCORR procedure of the SAS 6.0 statistical package (SAS, 1988).

Results and Discussion

Descriptive statistics for the examined characters and correlations displaying the relationships among the morphologic traits are given in Tables 1 and 2, respectively. Highest correlations were predicted between RW_6 and LW_6 (r=0.69, P<0.01) for six-month period; CG and LW (r=0.78, P<0.01) for weaning period; and LW and LW_6 (r=0.68, P<0.01) for the interrelationships between six-month period and weaning period. The lowest correlations were predicted between HW_6 and CG_6 (r=-0.05, P>0.05) for six-month period; HW and RW (r=-0.03, P>0.05) for weaning p; and RW and LW_6 (r=0.18, P>0.05) for the interrelationships between six-month period and weaning period. Although weaning period are important indicators of six-month period, it is extremely difficult to explain simultaneously the relationship between the traits. For this reason, instead of interpreting the correlations, six canonical correlation coefficients were estimated to explain the interrelationships between the studied variable set, since the number of canonical correlations that need to be interpreted is the minimum number of traits within the meaning period or the six-month period (Table 3). First two canonical correlation coefficient were significant (0.717 and 0.587, P<0.05) with respect to the likelihood ratio test (Table 3). In our study, although a different set of variables used, first canonical correlation coefficient is similar to those (0.73, P<0.01) reported by Tatar and Elicin (2002) concluding body weight and measurements in sucking and fattening periods in Ile de France x Akkaraman crossbred male lambs. Based on this result, the paper interprets the relationship between the first pair of canonical variables (U_1 and V_1).

Standardized canonical coefficients (canonical weights) were given for the first pair of canonical variables in Tables 4. These coefficients indicate the effects of weaning period on the six-month period. Therefore, the canonical variants (U_1 and V_1) representing the optimal linear combinations of dependent and independent variables can be

Table 1

Descriptive values for examined characters (n=72)

For weaning period	X variable set mean ± S.D*	For six-month period	Y variable set mean ± S.D*
Height at withers, cm (HW)	54.4 ± 2.93	Height at withers, cm (HW_6)	63.3 ± 60.2
Chest depth, cm (CD)	21.3 ± 1.09	Chest depth, cm (CD_6)	24.9 ± 1.46
Chest width, cm (CW)	16 ± 1.28	Chest width, cm (CW_6)	19.3 ± 2.07
Chest girth, cm (CG)	76.1 ± 5.78	Chest girth, cm (CG_6)	90.2 ± 6.56
Rump width, cm (RW)	14.2 ± 1.44	Rump width, cm (RW_6)	19.8 ± 1.53
Live weight, kg (LW)	29.1 ± 4.45	Live weight, kg (LW_6)	42.1 ± 5.41

*SD: Standard deviation

Table 2

The correlation matrix between morphologic traits

	HW	CD	CW	CG	RW	LW	HW_6	CD_6	CW_6	CG_6	RW_6
CD	0.50**										
CW	0.06^{-}	0.38**									
CG	0.25*	0.58**	0.66**								
RW	**-0.03**$^{-}$	0.20*	0.44**	0.46**							
LW	0.47**	0.75**	0.52**	**0.78****	0.27*						
HW_6	0.52**	0.40**	0.14^{-}	0.28*	0.05^{-}	0.47**					
CD_6	0.22^{-}	0.44**	0.19^{-}	0.48**	0.20^{-}	0.48**	0.32**				
CW_6	-0.06^{-}	0.22^{-}	0.46**	0.52**	0.28*	0.38**	0.06^{-}	0.45**			
CG_6	-0.10^{-}	0.18^{-}	0.32**	0.49**	0.37**	0.29*	**-0.05**$^{-}$	0.53**	0.71**		
RW_6	0.11^{-}	0.29*	0.38**	0.45**	0.16^{-}	0.48**	0.38**	0.37**	0.73**	0.41**	
LW_6	0.25*	0.45**	0.36**	0.54**	**0.18**$^{-}$	**0.68****	0.44**	0.66**	0.68**	0.56**	**0.69****

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

\- Correlation is not statistically significant at the 0.05 level (2-tailed). The superscript indicates that no correlation was found between the traits (for example between HW and RW). Other words, bold figures presented the highest and lowest correlation between the traits.

Table 3

Summary results for the CCA

Pair of canonical variables	Canonical correlation	Squared canonical correlation	Eigenvalue	DF	Likelihood ratio	Probability Pr>F
U_1V_1	0.717	0.514	1.057	36	0.225	<0.001
U_2V_2	0.587	0.344	0.525	25	0.462	0.023
U_3V_3	0.447	0.199	0.25	16	0.704	0.124
U_4V_4	0.294	0.086	0.095	9	0.88	0.51
U_5V_5	0.191	0.037	0.038	4	0.963	0.66
U_6V_6	0.007	<0.001	<0.001	1	0.999	0.958

defined by using the standardized canonical coefficients as,

$U_1 = (0.16\ HW) - (0.11\ CD) - (0.07\ CW) - (0.21\ CG) - (0.06\ RW) + (1.18\ LW)$

$V_1 = (0.28\ HW\_6) + (0.04\ CD\_6) - (0.21\ CW\_6) - (0.19\ CG\_6) + (0.01\ RW\_6) + 0.98\ LW\_6)$

Accordingly, if the values of the height at withers (HW) and the live weight (LW) increase at the weaning, chest width (CW_6) and chest girth (CG_6) at the six-month age will decrease, and the height at withers (HW_6) and live weight (LW_6) at the six-month age will increase.

Variables with larger canonical loadings

Table 4

Standardized canonical coefficients for canonical variables

	X – Variable set							*Y* – Variable set					
	HW	CD	CW	CG	RW	LW		HW_6	CD_6	CW_6	CG_6	RW_6	LW_6
U_1	0.16	-0.11	-0.07	-0.21	-0.06	1.18	V_1	0.28	0.04	-0.21	-0.19	0.01	0.98
U_2	-0.41	0.07	0.04	1.13	-0.17	-0.55	V_2	-0.03	0.22	0.63	0.62	0.08	-0.59

Table 5

Canonical loadings of the original variables with their canonical variables

	X – Variable set							*Y* – Variable set					
	HW	CD	CW	CG	RW	LW		HW_6	CD_6	CW_6	CG_6	RW_6	LW_6
U_1	0.61	0.69	0.35	0.61	0.11	0.96	V_1	0.73	0.59	0.37	0.23	0.58	0.9
U_2	-0.35	0.16	0.59	0.76	0.59	0.26	V_2	-0.18	0.46	0.83	0.89	0.46	0.37

Table 6

Cross loading of the original variables with opposite canonical variables

	X – Variable set							*Y – Variable set*					
	HW	CD	CW	CG	RW	LW		HW_6	CD_6	CW_6	CG_6	RW_6	LW_6
V_1	0.44	0.5	0.25	0.44	0.08	0.69	U_1	0.52	0.42	0.26	0.16	0.42	0.64
V_2	-0.21	0.1	0.35	0.45	0.35	0.15	U_2	-0.11	0.27	0.49	0.52	0.27	0.22

Table 7

The explained total variation ratio by canonical variables for the variable sets

X – Variable set				*Y* – Variable set			
Variance extracted		Redundancy		Variance extracted		Redundancy	
U_1	0.52	V_1	0.267	V_1	0.372	U_1	0.191
U_2	0.344	V_2	0.118	V_2	0.45	U_2	0.155

contributed more to the multivariate relationships between morphologic traits measured at weaning time and six-month age (Table 5). The loadings for the six-month period suggested that the height at withers (HW_6) and live weight (LW_6) were more influential than other characters in forming V_1. The loadings for Chest depth (CD) and live weight (LW) was more influential than other characters in forming U_1. According to the cross loadings, LW_6 and LW contributed the most to canonical variates V_1 and U_1, respectively (Table 6).

In the present study, it was found that 37.2 and 45.0% of total variation in the six-month period set was explained by all canonical variables V_i, while the redundancy measure of 0.19.1 for the first canonical variable suggests that about 19.1% of the ratio was explained by canonical variable U_1. Also, it was found that 52.0% of total variation in the weaning period set was explained by the first canonical variable U_1, while the redundancy measure of 0.267 for first canonical variable suggests that about 26.7% of the ratio was explained by canonical variable V_1 (Table 7).

Conclusion

To this end, this study has revealed the relationships between morphologic traits measured at weaning and morphological traits of the six-month age. Chest depth and live weight were the most influential factors in this relation. Results obtained from this work will help breeding practices and research on performance by guiding breeders in selecting the best animal at weaning period. In conclusion, the efficiency of selection may be increased by decreasing generation interval in Turkish Merino lambs production.

Acknowledgements

The authors gratefully acknowledge the support of the staff and facilities of the Marmara Animal Breeding Research Institute.

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Received November, 2, 2010; accepted for printing May, 23, 2011.