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SOURCE OF VARIATION AND HERITABILITY OF DIRECTLY MEASURED TRAITS IN PERFORMANCE TESTING OF SIMMENTAL BULLS

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In order to study the variability and heritability of directly measured traits (growth and body development traits) in performance test of Simmental bulls the data on 371 bulls born and tested over the period of 13 years were used in the analysis. The data were analysed in order to estimate year and month of calving, herd of origin and group in test effect as well as error components. The components of variance were obtained using restricted maximum likelihood (REML) methodology applied to sire model. The year and month of birth had different effect on the variability of the growth traits, while the herd of origin and the test group manifested a consistent, highly significant effect on those growth traits which they could have an effect on. On the other hand, all the body development traits were under a constant and highly significant effect

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manifested by the year of calving, while the month of calving manifested its effect, during test, at different levels of statistical significance. A decreased effect of herd of origin on almost all body dimensions from the start until the end of performance test was universally observed. Heritability estimates for pre-test ADG, in-test and lifetime ADG were 0.27, 0.39 and 0.29, respectively. Heritability estimates for body weights were 0.23, 0.25, and 0.30 for birth weight, test-on weight, and test-off weight, respectively. Heritability estimates for test-off height at withers, circumference of chest, depth of chest and body length were 0.43, 0.30, 0.33 and 0.29.

Key words: bulls, performance test, growth traits, body development, heritability

INTRODUCTION

An accurate assessment of breeding value along with a selection of young bulls as future breeding sires has an utmost importance in the programmes of genetic improvement in cattle (BOGDANOVIĆ *et al,* 2004; BOGDANOVIĆ *et al*, 2005). The first selection of young bulls based on their results is conducted at the end of performance, i.e. direct test. A principal purpose of performance test, is to assesss, as precisely as possible, under the standard conditions of nutrition, housing and care, the genetic, that is, breeding value of young bulls for those traits which are directly measurable on live animals, but at the same time heritable enough to be suitable for direct selection. Those traits, among other features, involve different growth and body development traits. These traits are the most important since productive and reproductive capacity of animal, that is, its future utilization in production and breeding, is directly or indirectly dependent on. Furthermore, the bull`s sire body development affects in a great degree a body development of the offspring, and therefore, the milk production in daughters or the beef production in sons, as well as their reproductive properties and longevity.

Before the evaluation of breeding value for single traits begins, it is necessary to have precise data on variability and heritability of these traits. Among the factors that have a lesser or greater effect on the variability of the traits directly measurable in bull performance test, primarily on the variability of growth traits and body development, the breed effect, herd of origin from which the young bull originates, effect of year, season or the month of bull`s birth and a test group effect are the most significant (BOGDANOVIĆ *et al,* 2002; BOGDANOVIĆ *et al,* 2003; SCHENKEL *et al,* 2004). On the other hand, the heritability of aforementioned traits is, in general, within the range of the medium values of heritability regardless the cattle purpose type or breed (AFOLAYAN *et al,* 2007; ALBERA *et al*, 2001; ARTHUR *et al,* 2001; BOUQUET *et al*, 2010; CROWLEY *et al,* 2010; ERIKSSON *et al,* 2002; ERIKSSON *et al*, 2003; DE MATOS *et al*, 2000) what makes the realization of the programme of genetic improvement very possible. However, the significance which some factors exhibit during the estimation of variability of the traits measured directly in bull performance test, as well as the degree of heritability of those traits, may vary among populations and demands to be established precisely for each true case.

The objective of this paper was to analyse the variability and heritability of directly measured traits of growth traits and body development in performance test of Simmental bulls. These traits are not extremely important only for the breeding value evaluation and ranking of young bulls as potential breeding sires, but they also affect body development and potential productivity of their descendants.

MATERIALS AND METHODS

In order to study the variability and heritability of directly measured traits, ie., growth and body development traits, the official data of the «Livestock-veterinary centre for reproduction and artificial insemination» from Velika Plana, Serbia, were used. The records on 371 bulls born and tested over the period of 13 years were used in the analysis. All the bulls included in this trial had a complete performance test and complete results from all measurements performed during the testing period.

Among the growth traits, the analysis involved a birth weight (BrW), a body weight at the start of test in the age of 4 months, ie. test-on weight (BW_start) and body weight at the end of test in the age of one year, ie. test-off weight (BW_end), as well as the average daily gain before the start of the test, ie. from birth to weaning (ADG_pre-test), during the test (ADG_in-test) and from birth to the end of performance test, ie. lifetime daily gain (ADG_lifetime).

Among the body development traits, the analysis included following linear body dimensions measured at the beginning and at the end of the test: the height of withers (HW_start, HW_end), chest circumference (Cir_start, Cir_end), chest depth (CD_start, CD_end), width of round (WR_start, WR_end) and body length (BL_start, BL_end).

The analysis of non-genetic sources of variation which affect the variability in the growth traits and body development was performed by the use of general linear model and following equations:

(1) For growth traits: $y_{IKLM} = \mu + G_I + M_K + B_L + F_M + e_{IKLM}$

(2) For body development traits: $y_{IKLM} = \mu + G_I + M_K + B_L + F_M + bw + e_{IKLM}$

Where: y_{IJKLM}: is the observed trait, μ: population mean value for given trait, G_I: fixed effect of the year of bull`s birth (1,..., 13), $M_K$: fixed effect of the bull`s month of birth (1,..., 12), B_L: fixed effect of the bull`s group in the test (1,..., 37), F_M: fixed effect of the herd of origin (1,..., 17), bw: body weight in corresponding month of age as an independent variable, e_{IJKLM}: other non-determined effects or random error with characteristics N (0, σ2).

The estimation of the variance components and calculation of the heritability coefficients were performed by the analysis of sire effect by the application of REML procedure (REML single trait sire model). In this part of analysis the sire component (number of sires, n=27) was treated as random effect, while the fixed factors remained the same as in previously mentioned models (equations 1 and 2). The effect of sire was assessed, primarily, through additive and phenotypic variance. The variance components, ie., sire variance and error variance, were used for the calculation of the heritability coefficients of analyzed traits. Heritability (h^2) was calculated by the application of intraclass correlation of half-brothers per sires which means that the additive genetic variance is the sum of 4 equal variances: variance among and within sires, and variance among and within dams. For the purpose of more accurate understanding of a sire component, the additive variance, environmental variance, and an overall phenotypic variance were calculated. Additive genetic variance was calculated taking into account that one fourth (1/4) of additive genetic variance originates from the variability among sires and that therefore its three fourths (3/4) must be included into variance within sires, ie., error variance. Phenotypic variance is represented by the sum of variances among and within sires. All necessary components were calculated in a reference programme procedures of the statistical packet SAS, 9.1.3. (2007).

RESULTS AND DISCUSSION

Descriptive statistical parameters of analysed traits of growth and body development traits, and the results of the analysis of variance are shown in Tables 1 and 2.

Table 1. Descriptive statistics for analysed growth traits and body decelopment traits in performance tested Simmental bulls

Trait	Parameters				
	$\overline{X}$	SD	CV (%)	Min	Max
Birth weight (kg)	45.11	6.11	13.55	30.00	70.00
Test-on weight (kg)	194.78	24.71	12.69	122.00	261.00
Test-off weight (kg)	515.86	37.17	7.21	405.00	632.00
Pre-Test Average Daily Gain (g)	1231	193	15.71	694	1752
In-Test Average Daily Gain (g)	1318	129	9.75	947	1761
Lifetime Average Daily Gain (g)	1289	102	7.89	984	1598
Height of withers_start of testt	99.88	3.49	3.49	78.00	111.00
Height of withers_end of test	126.00	2.65	2.10	115.00	138.00
Chest circumference_start of test	127.42	6.14	4.82	104.00	151.00
Chest circumference_end of test	184.76	5.95	3.22	163.00	200.00
Chest depth_start of test	42.55	2.25	5.30	35.00	49.00
Chest depth_end of test	60.90	2.15	3.54	55.00	67.00
Width of round_start of test	32.56	3.01	9.23	21.00	39.00
Width of round_end of test	47.63	2.67	5.61	41.00	55.00
Body length_start of test	106.69	5.99	5.61	87.00	122.00
Body length_end of test	147.57	4.65	3.15	130.00	161.00

*Table 2. Analyses of variance for growth and body development traits in performance tested Simmental bulls (mean squares and significance ns. P>0.05; * P<0.05; ** P<0.01; *** P<0.001).*

Factors / Traits	Year	Month	Test Group	Herd of Origin	Body weight	Error	Model	R^2
Birth weight	148.002***	28.776$^{NS.}$	-	137.512***	-	28.092	***	0.33
Test-on weight	804.34*	949.53**	940.36***	2956.17***	-	410.71	***	0.47
Test-off weight	6796.59***	1190.66^{NS}	1779.68**	3292.19***	-	986.31	***	0.44
Pre-Test ADG	0.071**	0.064**	-	0.198***	-	0.027	***	0.36
In-Test ADG	0.108***	0.028**	0.023***	0.017$^{NS.}$	-	0.011	***	0.46
Lifetime ADG	0.061***	0.01$^{NS.}$	0.013**	0.021***	-	0.007	***	0.45
HW_start of test	34.59***	14.37*	15.21***	21.19***	1098.20***	6.41	***	0.59
HW_end of test	37.25***	9.17**	11.80***	6.68*	389.00***	3.69	***	0.57
Cir_start of test	90.19***	62.21***	52.37***	94.57***	4017.79***	15.58	***	0.68
Cir_end of test	140.48***	18.61^{NS}	63.48***	42.52***	3343.77***	15.96	***	0.64
DC_start of test	32.26***	3.79*	7.99***	10.52***	366.83***	1.98	***	0.69
DC_end of test	21.12***	4.64 ^{NS}	7.97***	4.38 ^{NS}	268.66***	2.92	***	0.53
WR_start of test	123.09***	10.57***	9.14***	18.42***	337.37***	2.19	***	0.81
WR_end of test	80.00***	6.40**	8.42***	9.40***	296.49***	2.63	***	0.71
BL_start of test	217.02***	44.84***	48.03***	80.63***	2906.97***	13.35	***	0.71
BL_end of test	43.84***	28.95**	30.70***	22.95*	2094.91***	12.00	***	0.56

Both models used for estimation of the non-genetic component of the variance of growth and body development traits manifested a high statistical significance (*P*<0.001), indicating the significant effect of the analysed factors on the growth and body development of young bulls until the age of one year.

The year and month of birth, as fixed factors, had different effect on the variability of the growth traits, while the herd of origin and the test group manifested a consistent, highly significant effect on those growth traits which they could have an effect on. On the other hand, all the traits of body development were under a constant and highly significant effect manifested by the year of calving, while the month of calving manifested its effect, during test, at different levels of statistical significance. A decreased effect of herd of origin on almost all body dimensions from the start until the end of performance test was universally observed. These results are in conformity with the results of the analysis of the effects of single fixed sources of variation on the growth and body development in bulls reported by, BOGDANOVIĆ *et al* (2002); BOGDANOVIĆ *et al* (2003), SCHENKEL *et al* (2004).

During the analysis of the effect of year and month of calving on the growth and body development traits in bulls up to the age of one year, a precise determination of all sources of variation which exhibit their influence inside this effect cannot be always performed properly. No doubt, within the year effect an important place take up climatic factors with their direct effect on the quality of available feed. It should be noted that the effect of year or month involves a whole series of effects which are related to different zootechnical conditions present at certain farm and which can, although not necessarily so, vary widely from year to year.

On the other hand, the farm effect is a very complex factor reflected through the action of different systematic and non-systematic effects of environment, such as maternal effect, animal nutrition, type and quality of stables, health status, climatic effects, farm management, etc. A present variability and the intensity of the action of aforementioned effects on different farms induce this effect to manifest a high statistical significance on almost all traits of growth traits and body development. The components of variance and heritability of the traits of growth and body development traits in young Simmental bulls in performance test are shown in Table 3.

The values of coefficients of heritability for body weight in Simental bulls in the period from their birth up to the age of one year were very close to the results of DE MATOS *et al* (2000) and BOUQUET *et al* (2010), while in comparison with the results of ARTHUR *et al* (2001) and KECLÍK *et al* (2003) they were somewhat lower. The changes in the body weight variances during the performance test indicate that almost all of these shanges are manifested according to very similar biological scheme. During testing there occurs the increase in phenotypical and residual variances and with changes therein they follow a phenotypical expression of body weight in corresponding age.

If the purpose of the performance test is to enable the most complete expression of potential genetic capacities for the animal growth then the heritability for average daily gain in the test is a proper measure of genetic potential for the bull growth. The value of heritability of 0.39 for average daily gain in performance test, ie., in the period of 120-365 days of age, was close to the results of ERIKSSON *et al* (2003), but also somewhat lower than the results reported by KECLÍK *et al* (2003) and CROWLEY *et al* (2010). In general, average daily gains in test have greater heritability values because standardized conditions of feeding, housing and care make more complete expression of additive genetic component possible.

Somewhat higher heritability values for lifetime daily gain in comparison with heritability for average daily gain up to the weaning (0.29 *vs.* 0.27), indicate that up to the age of one year a certain part of maternal effect is eliminated from a whole variance. Heritability values for this trait show that a considerable part of genetic variability is involved therein and that it is likely to expect the positive selection response if the selection was performed on the animal daily gain until the age of one year.

Table 3. Components of variance and heritabilities (h^2 ± standard error) of growth and body development traits in performance tested Simmental bulls (σ^2_S : sire variance, σ^2_e : error variance, σ^2_A : additive variance, σ^2_E : environmental variance, σ^2_P : phenotypic variance).

Trait	σ^2_S	σ^2_e	h^2 ± S.E.	σ^2_A	σ^2_P	σ^2_E
Birth weight	1.674	28.051	0.23 ± 0.02	6.696	29.725	26.796
Test-on weight	29.053	436.547	0.25 ± 0.02	116.212	465.600	414.757
Test-off weight	73.82	906.413	0.30 ± 0.02	295.280	980.233	851.048
Pre-Test ADG	0.002	0.0275	0.27 ± 0.02	0.008	0.030	0.026
In-Test ADG	0.0015	0.014	0.39 ± 0.03	0.006	0.016	0.013
Lifetime ADG	0.0005	0.0065	0.29 ± 0.02	0.002	0.007	0.006
HW_start of test	1.568	8.406	0.63 ± 0.04	6.272	9.974	7.230
HW_end of test	0.677	5.576	0.43 ± 0.03	2.710	6.253	5.068
Cir_start of test	2.989	23.855	0.45 ± 0.03	11.955	26.844	21.614
Cir_end of test	2.019	25.180	0.30 ± 0.02	8.076	27.199	23.666
DC_start of test	0.402	2.886	0.49 ± 0.03	1.610	3.289	2.585
DC_end of test	0.341	3.839	0.33 ± 0.02	1.363	4.180	3.583
BL_start of test	1.825	22.313	0.30 ± 0.02	7.301	24.139	20.944
BL_end of test	1.266	16.247	0.29 ± 0.02	5.065	17.513	15.297

Variance components and heritabilities were calculated for all analysed traits of body development, except for the width of round. In this trait a majority of assessed sire variances were of negative value what disabled every further analysis. All body dimensions measured at the end of test were characterized by the heritability values of about 0.30, except for the height of withers whose heritability was somewhat greater (h^2=0.43). In the trial carried out by AFOLAYAN *et al* (2007), heritabilities for height, length and body circumference measured in different age of cattle were in the interval of 0.42-0.60 for the height of body (wither), from 0.19-0.25 for body length and from 0.09-0.32 for body circumference.

CONCLUSION

Taking into account that according to their biological characteristics the growth and body development traits in bulls have a moderately expressed heritability, a properly defined model for the breeding value estimation of these traits is of a key significance for the success of selection work. Medium values coefficients of heritability from this analysis confirm that these traits are not only under a genetic control but that they are in a significant part under the effect of non-genetic sources of variation as well. The changes in additive variance indicate that more complete expression of bull genetic potential can be expected during the second half of the performance test. In other words, only with the stabilizing of the genetic potential in the second half of the performance test and greater elimination of pre-test effects there is perceived the equalization in the path of expression of phenotypic and additive variance. For that reason it is necessary for the model for bull breeding value estimation in performance test, to include, besides genetic component, all those non-genetic factors of variation characterized either by an expressed significance or by a biological justification as well. A proper evaluation of traits variability, as well as the estimation of their heritability and later breeding value estimation enables a proper choice of future sires by which a certain dissemination of improved genetic base through a greater part of the population of domestic Simmental cattle can be contributed to.

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IZVORI VARIJABILNOSTI I NASLEDNOST DIREKTNO MERENIH OSOBINA U PERFORMANS TESTU BIKOVA SIMENTALSKE RASE

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I z v o d

U cilju proučavanja varijabilnosti i naslednosti direktno merenih osobina (osobine porasta i telesne razvijenosti) u performans testu bikova simentalske rase, podaci o 371 biku koji su rođeni i testirani u peridou od 13 godina su analizirani. Podaci su analizirani kako bi se ocenio uticaj godine i meseca telenja, matične farme i grupe u testu, kao i uticaj ostalih, nedeterminisanih faktora na osobine porasta i telesne razvijenosti, ali i da se procene komponente varijanse pomenutih osobina. Godina i meseca telenja su imali različit efekat na varijabilnost osobina porasta, dok su matična farma i grupa u testu ispoljile konzistentan, visoko značajan uticaj na one osobine na koje su mogle da utiču. Sa druge strane, sve osobine telesne razvijenosti su bile pod stalnim i visoko značajnim uticajem godine telenja, dok je mesec telenja ispoljavao svoj efekat na različitim nivoima statističke značajnosti. Uticaj matične farme se skoro kod svih osobina telesne razvijenosti smanjivao od početka do kraja testa. Koeficijenti heritabiliteta za prosečan dnevni prirast pre testa, u testu i od rođenja do kraja testa iznosili su 0.27, 0.39 i 0.29, odgovarajuće. Za izmerene telesne mase, koeficijenti heritabiliteta su iznosili 0.23, 0.25 i 0.30 za telesnu masu pri telenju, telesnu masu na početku i na kraju testa, odgovarajuće. Koeficijenti heritabiliteta za visinu grebena, obim grudi, dubinu grudi i dužinu tela na kraju performans testa iznosili su 0.43, 0.30, 0.33 i 0.29, odgovarajuće.

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