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PARTIAL RESULTS REGARDING THE ESTIMATION OF GENETIC PARAMETERS OF PRODUCTION TRAITS IN THE TSURCANA BREEDS

Bogdan IACOB, Horia GROSU

University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: iacobbogdan1995@gmail.com

Abstract

The aim of this study was to estimate the genetic parameters of production traits in the Tsurcana sheep breed, considering its four main varieties: Belă, Breazã, Bucălae and Oacheşă. The research was carried out on a total of 4,837 ewes belonging to the Association of Tsurcana Sheep Breeders "Păstorul" Arad. The analyzed traits included birth weight, weaning weight and milk yield. Statistical analysis was performed using classical descriptive statistics and the BLUP methodology applied to a sire model, in order to estimate heritability and genetic correlations among traits. The results revealed significant phenotypic differences among varieties, with the Oacheşă variety showing superior performance for birth weight and milk yield, while Breazã and Oacheşă recorded the highest weaning weights. Heritability estimates indicated moderate genetic control for all analyzed traits, with higher values for weaning weight in the Belă variety. Genetic correlations between traits were generally low to moderate, suggesting limited correlated responses to selection. These findings support the implementation of differentiated breeding programs adapted to each variety of the Tsurcana breed.

Key words*: genetic parameters, heritability, milk yield, Tsurcana sheep, varieties.*

INTRODUCTION

The sheep and goat sector play a vital role in Romanian agriculture, especially through the effective use of land in areas with natural constraints, where these species account for 80% of land valorization. Although Romania ranks 4th in the EU-28 for total herds, it only ranks 10th in meat production due to low average slaughter weights and a lack of specialized meat breeds. While domestic consumption remains low at 3.5% of total meat intake, Romania has become the EU's top exporter of live sheep, primarily serving Middle Eastern and North African markets. Government initiatives like "Choose the Sheep" and wool subsidies now aim to boost domestic demand and diversify farmer income (Grodea et al., 2018).

The Tsurcana is Romania's oldest and most dominant sheep breed, representing 40% of the national population. Often called the "peasant sheep", this polyvalent breed is prized for its profound fitness and exceptional resistance to harsh weather. Its dominance stems from an ability to thrive in diverse environments, from lowlands to alpine pastures, while enduring long transhumance routes. Highly adaptable, the Tsurcana provides varied production, including high-quality meat, resilient leather, and abundant milk, averaging 80-110 liters per lactation. Additionally, its characteristic rough white wool remains a staple for traditional textiles and Persian carpets (Udrea et al., 2021).

The Tsurcana breed comprises four distinct varieties that occupy different ecological niches and exhibit unique phenotypic traits. The Belă variety is characterized by white wool on the head and limbs, occasionally featuring small black spots near the eyes. In contrast, the Breazã variety is distinguished by a white "V-shaped" facial blaze, a trait positively correlated with superior milk production. The Oacheşă variety is identified by specific black circular patterns around the eyes. Finally, the Bucălae variety features dark extremities and face, with lambs born smoky-colored. These significant physical differences suggest these herds represent distinct subpopulations (Bîrcă et al., 2025).

The Turcana breed formed through reproductive isolation and selection for specific traits. While breeders observe notable phenotypic differences in body size and milk yield, these assessments often stem from subjective selection based on color patterns. For instance, the Breaza variety's

distinctive "V" facial marking is positively correlated with superior milk production. However, these distinctions are largely driven by local environmental conditions and the specific priorities of individual breeders, such as resistance or productivity, rather than standardized genetic benchmarks (Neață et al., 2023).

To improve a breed effectively, one must distinguish between environmental influences and genetic inheritance. Phenotypic traits often result from a combination of external factors and the animal's "inwardness" or genetic profile. While environmental effects can temporarily alter appearance or productivity, only genetic traits are passed to future generations. The use of genetic parameters, specifically heritability and genetic correlations, is essential because traditional morphological markers often have insignificant relevance for long-term improvement (Hrincă, 2017). Heritability quantifies the proportion of variation due to genetics, while genetic correlations reveal how selecting for one trait might inadvertently affect another. Without these parameters, breeding programs are essentially "shooting in the dark", providing only rough estimates rather than precise scientific management. Utilizing biological indicators like biochemical or molecular markers allows for accurate genotypic individualization, ensuring that selection leads to genuine, inheritable progress rather than mere environmental noise (Hrincă, 2017).

Recent research estimated genetic parameters using an animal model to enhance selection efficiency. A low heritability of 0.21 for milk yield and a moderate heritability of 0.34 for wool production. While the overall mean milk yield was 59 ± 0.816 kg, the Tsurcana Brează variety exhibited significantly higher performance compared to the Tsurcana Belă variety. Specifically, all ewes exceeding 100 kg of milk were from the Brează variety. For wool, males produced substantially more than females, averaging 5.37 kg. Breeding values for milk ranged from -5.65 to 5.55, indicating high genetic variation. There is currently limited recent literature comparing the specific genetic parameters across these four distinct varieties, Bucălae, Belă, Brează, and Oacheșă, simultaneously (Rotar et al., 2025).

The selection of birth weight, weaning weight, and milk yield as focal points for the Tsurcana sheep study is justified by their direct impact on the economic viability of Romanian sheep rearing. Birth weight is a critical indicator of genetic progress and selection for "precociousness", with the study recording values over 4.00 kg, significantly higher than the breed's traditional average of 3.00 kg. This initial weight provides a biological advantage for growth performances that are superior from both biologic and economic perspectives. Weaning weight, recorded at an average of 21.42 kg at 90 days, serves as a metric for the lambs' growth potential and the dams' nursing capacity. Finally, milk yield is a primary revenue driver; with an average production of 135.68 kg, it supports both lamb development and the production of dairy goods, though the study notes that low availability of qualified labor can increase exploitation costs (Dărăban et al., 2012).

From a state-of-the-art perspective, it is necessary to underline that, despite the substantial body of literature devoted to the morphological and productive characterization of the Tsurcana breed, the studies dealing with the estimation of genetic parameters of production traits at the level of its constituent varieties remain scarce and fragmentary. The majority of the existing reports either treat the breed as a single, undifferentiated genetic entity, or they focus on a single variety in isolation, without providing a comparative quantitative-genetic framework. Moreover, the few available estimates of heritability and genetic correlations refer mainly to milk yield and wool production, whereas body weight traits at birth and at weaning have been addressed almost exclusively at the phenotypic level, often through descriptive morphometric approaches. This methodological and informational gap is particularly relevant in the Romanian context, in which the Tsurcana represents the most numerous local breed and in which the design of variety-specific improvement programs presupposes an objective genetic-statistical foundation, capable of distinguishing genuine genetic differences among varieties from environmentally induced phenotypic variation. Consequently, an integrated estimation of the genetic parameters for the three productive traits considered, conducted simultaneously and comparatively in all four varieties, constitutes a

necessary preliminary step toward the rational organization of the selection activity in this breed.

In this context, the aim of the research is to estimate the genetic parameters in the Tsurcana breed for each of its varieties. Knowledge of genetic parameters is useful for optimizing breeding programs in any species of economic interest, including sheep, with the goal of maximizing annual genetic progress at the population level. It must be emphasized that the estimation of genetic parameters is not pursued here as an end in itself, but as an indispensable stage in the genetic characterization of the structure of the Tsurcana population and in the elaboration of differentiated improvement programs adapted to each of its varieties. Accordingly, the present study is conceived as a preliminary phase of a wider breeding program, aiming, on the one hand, to provide an objective genetic-statistical description of the four varieties (Belă, Breazǎ, Bucălae, and Oacheșă), and, on the other hand, to deliver the heritability values and genetic correlations required for the formulation of selection criteria, the definition of breeding objectives, and the prediction of expected genetic progress in this autochthonous breed.

MATERIALS AND METHODS

The research was carried out on a population of 4,837 Tsurcana sheep, structured into the four varieties as follows: Belă (1,547 females), Breazǎ (689 females), Bucălae (1,198 females), and Oacheșă (1,403 females), belonging to the Tsurcana Sheep Breeders Association "Pastorul Arad". The information regarding performance levels for the three considered traits (birth weight, weaning weight, and milk yield) was obtained from the aforementioned Association.

For the statistical analysis of the primary data, the following calculation methods were used:

Classical statistical indicators (mean, variance, standard deviation, standard error of the mean, coefficient of variation), the BLUP methodology, applied to an animal model, for estimating genetic parameters. For the classical statistical indicators, the following calculation relationships were used: The arithmetic mean was estimated as the ratio between the sum of the values in the sample (Xi) and their number (n), based on the formula: The variance was obtained as the sum of squared deviations between each value in the sample and the mean of the considered trait, divided by the degrees of freedom: $S^2 = (\sum(X_i - \bar{X})^2)/(n - 1)$ Obtained in this way, the variance is a value expressed in squared units, which is difficult to interpret from a biological point of view; therefore, it is more useful to return to the measurement unit of the considered trait, which involves calculating the standard deviation.

Standard deviation (s). Returning to the unit of measurement of the analyzed trait (kg) is done by extracting the square root of the variance (decoding). The obtained result is called the standard deviation or root mean square deviation: The standard error of the mean was calculated based on the following formula:

$$s\bar{X} = s / \sqrt{n}$$

The coefficient of variation (CV) is a relative measure of variability, expressed as a percentage, and shows how much one unit of standard deviation represents relative to the mean of the analyzed trait. At the sample level, the coefficient of variation is calculated based on the following relationship: The Student's t-test was used to perform comparisons between means. For the estimation of genetic parameters, the BLUP (Best Linear Unbiased Prediction) methodology was used, applied to the sire model, for the 7 traits, according to the following biometric model:

$$Pi = Xibi + Ziai + ei,$$

where:

Pi = the vector of observations for trait i; Xi = incidence matrix for fixed effects, bi = vector of fixed effects for trait i; Zi = incidence matrix for random effects, ai = vector of random effects for trait i; ei = vector of residuals for trait i. To facilitate an easier understanding of the BLUP system of equations, it will be presented for the case of two traits, as follows:

$$\begin{bmatrix} X_1' \cdot r^{11} \cdot X_1 & X_1' \cdot r^{12} \cdot X_2 & X_1' \cdot r^{11} \cdot Z_1 & X_1' \cdot r^{12} \cdot Z_2 \\ X_2' \cdot r^{21} \cdot X_1 & X_2' \cdot r^{22} \cdot X_2 & X_2' \cdot r^{21} \cdot Z_1 & X_2' \cdot r^{22} \cdot Z_2 \\ Z_1' \cdot r^{11} \cdot X_1 & Z_1' \cdot r^{12} \cdot X_2 & Z_1' \cdot r^{11} \cdot Z_1 + A^{-1} \cdot g^{11} & Z_1' \cdot r^{12} \cdot Z_2 + A^{-1} \cdot g^{12} \\ Z_2' \cdot r^{11} \cdot X_1 & Z_2' \cdot r^{22} \cdot X_2 & Z_2' \cdot r^{21} \cdot Z_1 + A^{-1} \cdot g^{21} & Z_2' \cdot r^{22} \cdot Z_2 + A^{-1} \cdot g^{22} \end{bmatrix} \begin{bmatrix} \hat{b}_1 \\ \hat{b}_2 \\ \hat{a}_1 \\ \hat{a}_2 \end{bmatrix}$$

$$= \begin{bmatrix} X_1' \cdot r^{11} \cdot P_1 + X_1' \cdot r^{12} \cdot P_2 \\ X_2' \cdot r^{21} \cdot P_1 + X_2' \cdot r^{22} \cdot P_2 \\ Z_1' \cdot r^{11} \cdot P_1 + Z_1' \cdot r^{12} \cdot P_2 \\ Z_2' \cdot r^{21} \cdot P_1 + Z_2' \cdot r^{22} \cdot P_2 \end{bmatrix}$$

where the matrices G and R contain the genotypic and environmental variances and covariances of the considered traits:

$$G^{-1} = \begin{bmatrix} \boldsymbol{S^2_{I_X}} & \boldsymbol{Cov_{I_{XY}}} \\ \boldsymbol{Cov_{I_{XY}}} & \boldsymbol{S^2_{I_Y}} \end{bmatrix}^{-1} = \begin{bmatrix} g^{11} & g^{12} \\ g^{21} & g^{22} \end{bmatrix}$$

$$R^{-1} = \begin{bmatrix} \boldsymbol{S^2_{i_X}} & \boldsymbol{Cov_{i_{XY}}} \\ \boldsymbol{Cov_{i_{XY}}} & \boldsymbol{S^2_{i_Y}} \end{bmatrix}^{-1} = \begin{bmatrix} r^{11} & r^{12} \\ r^{21} & r^{22} \end{bmatrix}$$

The elements of G and R were estimated using the following formulas: Genetic variance between families (between sire families) for trait X ($\boldsymbol{S^2_{I_X}}$):

$$\boldsymbol{S^2_{I_X}} = \frac{\hat{a}_i{}' \cdot A^{-1} \cdot \hat{a}_i + tr(A^{-1} \cdot C_{ii})}{q}$$

Genetic variance between families (between sire families) for trait Y ($\boldsymbol{S^2_{I_Y}}$):

$$\boldsymbol{S^2_{I_Y}} = \frac{\hat{a}_j{}' \cdot A^{-1} \cdot \hat{a}_j + tr(A^{-1} \cdot C_{jj})}{q}$$

Additive genetic covariance between traits X and Y ($\boldsymbol{Cov_{I_{XY}}}$)

$$\boldsymbol{Cov_{I_{XY}}} = \frac{\hat{a}_i{}' \cdot A^{-1} \cdot \hat{a}_j + tr(A^{-1} \cdot C_{ij})}{q}$$

Environmental (residual) variance for trait X ($\boldsymbol{S^2_{i_X}}$):

$$\boldsymbol{S^2_{i_X}} = \frac{\hat{e}_i{}' \cdot \hat{e}_i + tr(B_{ii})}{n}$$

Environmental (residual) variance for trait Y ($\boldsymbol{S^2_{i_Y}}$):

$$\boldsymbol{S^2_{i_Y}} = \frac{\hat{e}_j{}' \cdot \hat{e}_j + tr(B_{jj})}{n}$$

Environmental (residual) covariance between traits X and Y ($\boldsymbol{Cov_{i_{XY}}}$):

$$\boldsymbol{Cov_{i_{XY}}} = \frac{\hat{e}_i{}' \cdot \hat{e}_j + tr(B_{ij})}{n}$$

$W = [X_1 \oplus X_2 \quad Z_1 \oplus Z_2]$;

$B = W \cdot C \cdot W' = \begin{bmatrix} B_{ii} & B_{ij} \\ B_{ji} & B_{jj} \end{bmatrix}$;

$\oplus$ = Direct Sum

$$e_i = P_i - W \cdot \left[\tilde{b}_1 \quad \tilde{b}_2 \quad \hat{a}_1 \quad \hat{a}_2\right],$$

and e represents the error vector.

Phenotypic variances and covariances are obtained by summing the intra-family and inter-family variances and covariances, as follows:

$$P = G + R$$

$$P = \begin{bmatrix} \boldsymbol{S^2_{F_X}} & \boldsymbol{Cov_{F_{XY}}} \\ \boldsymbol{Cov_{F_{XY}}} & \boldsymbol{S^2_{F_Y}} \end{bmatrix} = \begin{bmatrix} \boldsymbol{S^2_{I_X}} & \boldsymbol{Cov_{I_{XY}}} \\ \boldsymbol{Cov_{I_{XY}}} & \boldsymbol{S^2_{I_Y}} \end{bmatrix} + \begin{bmatrix} \boldsymbol{S^2_{i_X}} & \boldsymbol{Cov_{i_{XY}}} \\ \boldsymbol{Cov_{i_{XY}}} & \boldsymbol{S^2_{i_Y}} \end{bmatrix}$$

For trait "X", heritability was obtained using the formula:

$$h^2_X = \frac{4 \cdot \boldsymbol{S^2_{I_X}}}{\boldsymbol{S^2_{F_X}}}$$

Estimation of genotypic correlations and their errors:

The genotypic correlation between traits X and Y ($r_{G_{XY}}$), was determined based on the observational components of intra-family variances and covariances, according to the formula:

$$r_{G_{XY}} = \frac{\boldsymbol{Cov_{I_{XY}}}}{\sqrt{\boldsymbol{S^2_{I_X}} \cdot \boldsymbol{S^2_{I_Y}}}}$$

The error of the genotypic correlation was determined using the formula:

$$S_{r_G} = \frac{1 - r^2_{G_{XY}}}{\sqrt{2}} \cdot \sqrt{\frac{S_{h^2_X} \cdot S_{h^2_Y}}{h^2_X \cdot h^2_Y}}$$

where:

S_{r_G}= the error of the genotypic correlation;

$S_{h^2_X}$= the error of heritability for trait X;

$S_{h^2_Y}$= the error of heritability for trait Y;

h^2_X= heritability of trait X;

h^2_Y= heritability of trait Y.

The error of heritability for trait X was estimated using the formula:

$$S_{h^2_X} = 4 \cdot \sqrt{\frac{[2 \cdot (1-t)^2] \cdot [1 + (k-1) \cdot t]^2}{k \cdot (k-1) \cdot (q-1)}}$$

where:

t=$S_{h^2_X}$/ 4; q = number of sires; k = average sire family size (n/q), n = total number of offspring.

RESULTS AND DISCUSSIONS

Average performances of the Tsurcana breed

In order to assess the current status of the studied population, a statistical analysis of the five considered traits was carried out. The results are presented in Tables 1-4 for each considered variety. For the Belă variety, the analysis of the results presented in Table 1 shows that the mean body weight at birth is 3.29 ± 0.021 kg, with a medium variability of 24.92%, and limits ranging between 2-5 kg.

Table 1. Average performances of production traits in the Tsurcana breed, Belă variety (original data)

Trait	n	Unit	X̄ ± Sx̄	S	CV %	Minimum limit
Birth weight	1547	kg	3.29 ± 0.021	0.819	24.92	2
Weaning weight	1547	kg	29.16 ± 0.192	7.562	25.94	17
Milk yield	1547	kg	56.26 ± 0.399	15.692	27.89	30.15

The mean weaning weight is 29.16 ± 0.192 kg, with a moderate relative variability of 25.94% and limits ranging between 17 and 37.2 kg.
The milk yield has a mean of 56.26 ± 0.399 kg, with a moderate variability of 27.89%, and limits ranging between 30.15 and 100.2 kg.
For the Breazã variety, the analysis of the results presented in Table 2 shows that the mean body weight at birth is 3.06 ± 0.022 kg, with a moderate variability of 18.98%, and limits ranging between 2.1-4.7 kg.

Table 2. Average performances of production traits in the Tsurcana breed, Breazã variety (original data)

Trait	n	Unit	X□ ± Sx□	S	CV %	Minimum limit	Maximum limit
Birth weight	689	kg	3.06 ± 0.022	0.581	18.98	2.1	4.7
Weaning weight	689	kg	29.88 ± 0.184	4.842	16.2	17.3	42
Milk yield	689	kg	56.85 ± 0.44	11.547	20.31	38.54	98.59

The mean weaning weight is 29.88 ± 0.184 kg, with a moderate relative variability of 16.20%, and limits ranging between 17.3 and 42 kg.
The milk yield has a mean of 56.85 ± 0.44 kg, with a moderate variability of 20.31%, and limits ranging between 38.54 and 98.59 kg.
For the Bucălae variety, the analysis of the results presented in Table 3 shows that the mean body weight at birth is 3.14 ± 0.02 kg, with a moderate variability of 22.36%, and limits ranging between 2 and 5 kg.

Table 3. Average performances of production traits in the Tsurcana breed, Bucălae variety (original data)

Trait	n	Unit	X̄ ± Sx̄	S	CV %	Minimum limit	Maximum limit
Birth weight	1198	kg	3.14 ± 0.02	0.701	22.36	2	5
Weaning weight	1198	kg	27.54 ± 0.075	2.607	9.47	17.3	40
Milk yield	1198	kg	60.24 ± 0.498	17.252	28.64	28.51	103.36

The mean weaning weight is 27.54 ± 0.075 kg, with a moderate relative variability of 9.47%, and limits ranging between 17.3 and 40 kg.
The milk yield has a mean of 60.24 ± 0.498 kg, with a moderate variability of 28.64%, and limits ranging between 28.51 and 103.36 kg.
For the Oacheșă variety, the analysis of the results presented in Table 4 shows that the mean body weight at birth is 3.75 ± 0.023 kg, with a moderate variability of 23.40%, and limits ranging between 2 and 5 kg.

Table 4. Average performances of production traits in the Tsurcana breed, Oacheșă variety (original data)

Trait	N	Unit	X̄ ± Sx̄	S	CV, %	Min. limit	Max. limit
Birth weight	1403	kg	3.75 ± 0.023	0.879	23.4	2	5
Weaning weight	1403	kg	29.84 ± 0.091	3.414	11.44	17.8	40
Milk yield	1403	kg	70.56 ± 0.495	18.526	26.25	34.7	104.4

The mean weaning weight is 29.84 ± 0.091 kg, with a moderate relative variability of 11.44%, and limits ranging between 17.8 and 40 kg.
The milk yield has a mean of 70.56 ± 0.495 kg, with a moderate variability of 26.25%, and limits ranging between 34.7 and 104.4 kg.
Romanian animal production, exhibits significant variations in body traits based on regional climatic conditions. Research conducted over a seven-year period indicates that sheep in North Romania generally achieve greater physical development compared to those in the East. Specifically, the study recorded the smallest mean body weight of 55.75 kg among individuals from Brăila County in East Romania. While most traits like body length and withers height reached their maximum values in Suceava County, weight and other developmental markers remain moderately correlated with local temperature and precipitation levels (Vlaic et al., 2017).

Table 5 summarizes the results regarding the average performances of the four Tsurcana varieties for each of the three analyzed traits.

Table 5. Average performances of production traits in the Tsurcana breed (original data)

Trait	Unit	Bela	Breaza	Bucalae	Oachesa
Birth weight	kg	3.29 ± 0.021	3.06 ± 0.022	3.14 ± 0.020	3.75 ± 0.023
Weaning weight	kg	29.16 ± 0.192	29.88 ± 0.184	27.54 ± 0.075	29.84 ± 0.091
Milk yield	kg	56.26 ± 0.399	56.85 ± 0.44	60.24 ± 0.498	70.56 ± 0.495

The comparative study of the four varieties of the Tsurcana breed (Belă, Brează, Bucălae, and Oacheșă) revealed significant phenotypic differences in the analyzed production traits. The Oacheșă variety recorded higher mean values for both birth weight (3.75 kg) and milk yield (70.56 kg), indicating a high productive potential and remarkable biological efficiency. Regarding weaning weight, the best performances were obtained by the Brează (29.88 kg) and Oacheșă (29.84 kg) varieties, with statistically insignificant differences between them.

The Bucălae variety, although it recorded the lowest weaning weight (27.54 kg), stood out with a relatively high average milk production (60.24 kg), thus exceeding the values recorded by the Bălă and Brează varieties. The Bălă variety showed an intermediate performance, without excelling in any of the studied production traits.

Based on the obtained results, it can be concluded that the Oacheșă variety presents the best prospects for selection aimed at increasing milk production and improving efficiency in the early stages of postnatal development.

In order to assess the statistical differences between the means of the traits for each combination of varieties, the Student's t-test was applied, and the obtained results are presented in Table 6.

The results indicate that there are highly statistically significant differences ($p<0.001$) in birth weight across all comparisons. Particularly notable is the difference between the Belă and Oacheșă varieties, suggesting a pronounced genetic differentiation.

Table 6. Testing the significance of differences (Student's t-test) for birth weight, weaning weight, and milk yield in the Tsurcana breed varieties (original data)

No.	Variety Pair	Birth weight	Weaning weight	Milk yield
1	Belă - Brează	6.51***	2.31*	0.88ns
2	Belă - Bucalae	5.10***	7.09***	6.31***
3	Belă - Oacheșă	14.92***	3.09**	22.70***
4	Brează - Bucălae	2.34***	13.67***	4.60***
5	Brează - Oacheșă	18.76***	0.25ns	17.60***
6	Bucălae - Oacheșă	19.61***	19.05***	14.61***

Regarding weaning weight, significant differences appear in all pairwise comparisons, with extremely high values between Brează and Bucălae (13.67***) and between Belă and Bucălae (7.09***).

Milk yield shows the greatest difference between Belă and Oacheșă (22.70***), while between Belă and Brează the difference is not significant (0.88ns). This suggests that the Bălă and Brează varieties have a similar milk production capacity, whereas Oacheșă stands out with a significantly different production level.

In conclusion, the statistical analysis highlighted significant differences among the Turcana breed varieties, particularly in terms of birth weight and milk yield. The Oacheșă variety shows a distinct milk production compared to the others, while the Brează and Bucălae varieties are clearly differentiated in weaning weight. These results may represent an important basis for developing differentiated selection programs by variety.

Heritability (h^2) represents the proportion of phenotypic variation that is attributed to genetic variation within a population and is an essential parameter for genetic improvement programs. Estimating heritability for productive traits allows the evaluation of the genetic selection potential, and the accuracy of this estimate is reflected by the associated standard error.

Knowledge of trait heritability is of particular importance for both the theory and practice of breeding, at least for two reasons: a) The magnitude of heritability influences all practical breeding decisions, such as: prioritizing genetic improvement or management improvement in order to increase production; choosing the breeding system; selecting the selection method and establishing the selection objective, etc. The

value of heritability is included in all formulas regarding the prediction of breeding value and the effect of selection. In the present study, heritability was obtained as the ratio between additive genetic variance and phenotypic variance, and the results are presented, for each variety, in Tables 7-11.

Table 7. Observational components of variance, heritability, and its error for three traits in the Tsurcana breed, Belă variety (original data)

No.	Trait	Phenotypic variance (S_F^2)	Interfamily variance (S_I^2)	Intrafamily variance (S_i^2)	Heritability (h^2)	Heritability error (S_(h^2))
1	Birth weight	0.33	0.012	0.321	0.144	0.069
2	Weaning weight	7.9	0.585	7.312	0.296	0.079
3	Milk yield	33.17	1.669	31.499	0.201	0.073

Table 8. Observational components of variance, heritability, and its error for three traits in the Tsurcana breed, Breză variety (original data)

Trait	Phenotypic variance (S_F^2)	Interfamily variance (S_I^2)	Intrafamily variance (S_i^2)	Heritability (h^2)	Heritability error (S_(h^2))
Birth weight	0.1	0.006	0.091	0.252	0.111
Weaning weight	5.43	0.223	5.208	0.164	0.102
Milk yield	26.59	1.2	25.393	0.18	0.104

Table 9. Observational components of variance, heritability, and its error for three traits in the Tsurcana breed, Bucălae variety (original data)

Trait	Phenotypic variance (S_F^2)	Interfamily variance (S_I^2)	Intrafamily variance (S_i^2)	Heritability (h^2)	Heritability error (S_(h^2))
Birth weight	0.2	0.011	0.192	0.213	0.08
Weaning weight	3.32	0.123	3.2	0.148	0.074
Milk yield	23.85	1.158	22.691	0.194	0.078

Table 10. Observational components of variance, heritability, and its error for three traits in the Tsurcana breed, Oacheșă variety (original data)

Trait	Phenotypic variance (S_F^2)	Interfamily variance (S_I^2)	Intrafamily variance (S_i^2)	Heritability (h^2)	Heritability error (S_(h^2))
Birth weight	0.55	0.015	0.535	0.106	0.071
Weaning weight	4.8	0.223	4.574	0.186	0.077
Milk yield	43.63	2.372	41.255	0.218	0.079

Table 11 presents, in a centralized manner, the results regarding heritability values and their associated errors for the four varieties of the Tsurcana breed.

Table 11. Heritability and its error for three traits in the Turcana breed varieties (original data)

Trait	Belă	Breză	Bucălae	Oacheșă
Birth weight	0.144 ± 0.069	0.252 ± 0.111	0.213 ± 0.080	0.106 ± 0.071
Weaning weight	0.296 ± 0.079	0.164 ± 0.102	0.148 ± 0.074	0.186 ± 0.077
Milk yield	0.201 ± 0.073	0.180 ± 0.104	0.194 ± 0.078	0.218 ± 0.079

From the analysis of the data presented in Table 11, the following conclusions can be drawn: The heritability values for birth weight indicate a moderate genetic influence, ranging between 0.106 (Oacheșă) and 0.252 (Breză). The relatively high error for Breză indicates a lower precision of the estimate. For weaning weight, the Belă variety shows the highest genetic potential ($h^2 = 0.296$), suggesting the possibility of efficient improvement through selection. The other varieties show lower heritability values. Milk yield shows relatively constant heritability values (between 0.180 and 0.218), indicating a stable genetic influence, with moderate errors, making this trait suitable for genetic selection. In conclusion, the heritability estimates for the studied traits in the Turcana breed reveal a moderate genetic influence, which justifies the use of selection for improving these traits. The Belă variety stands out with a higher genetic potential for weaning weight, while the differences in milk yield are more homogeneous among varieties.

From the standpoint of the genetic structure of the Tsurcana population, the variation of heritability among varieties is in itself a result of considerable importance, since it indicates that the additive genetic architecture of the three productive traits is not uniform across the breed. The fact that weaning weight exhibits the highest heritability in the Belă variety ($h^2 = 0.296$) and substantially lower values in the other three varieties (h^2 ranging from 0.148 to 0.186) suggests that the proportion of phenotypic variance explained by additive genetic effects depends, for this trait, on the genetic background of each variety, possibly reflecting different levels of past selection intensity and different effective population sizes. In contrast, the remarkable stability of the heritability values estimated for milk yield (h^2 between 0.180 and 0.218) indicates a comparable additive genetic determinism of lactation across all four varieties, a finding that

recommends milk production as a primary selection objective with predictable response in the entire breed. The lower heritability values obtained for birth weight, accompanied by relatively large standard errors, are consistent with the well-documented influence of maternal and environmental effects on this trait, and they argue against the use of birth weight as a standalone selection criterion. Taken together, these heritability estimates constitute an objective genetic-statistical descriptor of the four varieties, fulfilling one of the functions of the present study as a stage in the characterization of the population structure of the Tsurcana breed and providing the quantitative foundation required for the prediction of the expected genetic gain under alternative selection scenarios.

Genetic correlation between the analyzed traits

Genetic correlation (r_G) expresses the degree of association between two traits at the genetic level and is an important indicator for indirect selection in breeding programs. It allows the estimation of how selection for one trait may genetically influence other correlated traits. The accuracy of these estimates is reflected by the associated standard error. For the calculation of genetic correlation, the observational components of variance and covariance were used. The obtained results are presented in Tables 12-15 for each variety of the Turcana breed.

Table 12. Observational components of genotypic covariance, genotypic correlation, and its error for the three traits in the Tsurcana breed, Belă variety (original data)

Trait combination	Interfamily covariance (Cov_I)	Genotypic correlation (r_G)	Error of genotypic correlation (S_(r_G))
Birth weight - Weaning weight (12)	-0.005	-0.057	0.252
Birth weight - Milk yield (13)	0.017	0.12	0.291
Weaning weight - Milk yield (23)	0.025	0.026	0.219

Table 13. Observational components of genotypic covariance, genotypic correlation, and its error for the seven traits in the Tsurcana breed, Breză variety (original data)

Trait combination	Interfamily covariance (Cov_I)	Genotypic correlation (r_G)	Error of genotypic correlation (S_(r_G))
Birth weight - Weaning weight (12)	0.003	0.074	0.368
Birth weight - Milk yield (13)	0.011	0.131	0.35
Weaning weight - Milk yield (23)	0.254	0.491	0.32

Table 14. Observational components of genotypic covariance, genotypic correlation, and its error for the seven traits in the Tsurcana breed, Bucălae variety (original data)

Trait combination	Interfamily covariance (Cov_I)	Genotypic correlation (r_G)	Error of genotypic correlation (S_(r_G))
Birth weight - Weaning weight (12)	0.006	0.156	0.299
Birth weight - Milk yield (13)	0.026	0.234	0.26
Weaning weight - Milk yield (23)	0.053	0.141	0.312

Table 15. Observational components of genotypic covariance, genotypic correlation, and its error for the seven traits in the Tsurcana breed, Oacheșă variety (original data)

Trait combination	Interfamily covariance (Cov_I)	Genotypic correlation (r_G)	Error of genotypic correlation (S_(r_G))
Birth weight - Weaning weight (12)	0.004	0.079	0.369
Birth weight - Milk yield (13)	0.018	0.099	0.345
Weaning weight - Milk yield (23)	0.068	0.093	0.271

Table 16 presents, in a centralized manner, the results regarding the values of genotypic correlation and their associated errors for the four varieties of the Tsurcana breed.

Table 16. Genotypic correlation and its error for three traits in the Turcana breed varieties (original data)

Trait combination	Belă	Breză	Bucălae	Oacheșă
Birth weight - Weaning weight (12)	-0.057 ± 0.252	0.074 ± 0.368	0.156 ± 0.299	0.079 ± 0.369
Birth weight - Milk yield (13)	0.12 ± 0.291	0.131 ± 0.350	0.234 ± 0.260	0.099 ± 0.345
Weaning weight - Milk yield (23)	0.026 ± 0.219	0.491 ± 0.320	0.141 ± 0.312	0.093 ± 0.271

From the analysis of the results presented in Table 16, the following conclusions can be drawn: For the combination birth weight – weaning weight, the genetic correlations are close to zero, with slightly positive values, except for the Belă variety, where it is slightly negative (-0.057). The genetic correlation between birth weight and milk yield is positive but moderate, ranging between 0.099 and 0.234, indicating the possibility of modest simultaneous genetic progress between these traits. The correlation between weaning weight and milk yield is generally low, with a higher value for the Breză variety (0.491), which may

suggest a stronger genetic relationship between these two traits in this variety.

From the perspective of the design of breeding programs for the Tsurcana breed, the pattern of genotypic correlations reported in Table 16 has direct operational consequences. The fact that, in three of the four varieties, the genetic association between weaning weight and milk yield is weak (r_G between 0.026 and 0.141) indicates that selection applied for growth traits is not expected to generate a substantial correlated response in the dairy aptitude, and that the two breeding objectives must therefore be pursued by means of independent selection criteria or through an appropriately weighted aggregate index. The notable exception observed in the Brează variety (r_G = 0.491 between weaning weight and milk yield) is consistent with the dairy specialization historically attributed to this variety and suggests that, in this particular subpopulation, a single selection criterion may simultaneously improve both traits. The low to moderate genetic correlations between birth weight and the other two traits indicate, in turn, that an emphasis on increased birth weight, if not properly controlled, will not automatically translate into proportional improvements of weaning weight or milk yield, and that the dystocia risk associated with excessively high birth weights must be evaluated separately. Considered jointly with the heritability estimates, these genetic correlations enable the formulation of variety-specific selection indices and provide the parameters necessary for the prediction of direct and correlated genetic responses, thereby fulfilling the second function of the present study as a foundation for the development of differentiated improvement programs within the Turcana breed.

Research conducted over a seven-year period indicates that sheep in North Romania generally achieve greater physical development compared to those in the East. Specifically, the study recorded the smallest mean body weight of 55.75 kg among individuals from Brăila County in East Romania. While most traits like body length and withers height reached their maximum values in Suceava County, weight and other developmental markers remain moderately correlated with local temperature and precipitation levels (Vlaic et al., 2017).

Purebred Tsurcana lambs maintain a stable, constant growth rate during their first 90 days of life. At birth, they average 4.167 kg, with males weighing 4.295 kg and females 4.058 kg. Unlike crossbreds, purebred gender does not significantly influence weight. By 90 days, the population reaches an average of 17.275 kg. Crossing Tsurcana ewes with Blanc du Massif Central rams drastically improves results; crossbred lambs weigh 29.273 kg at three months, gaining 11.998 kg or nearly 70% more than purebreds (Borzan et al., 2023).

In the Sibiu region, purebred Tsurcana lambs reared under highland conditions registered significantly lower weaning weights compared to Suffolk crossbreeds. At the weaning age of 90 days, male Tsurcana lambs reached an average body weight of 18.58 kg, while female lambs averaged 16.69 kg. These weights were recorded after a suckling period where lambs were fed predominantly on maternal milk without supplementary feeding. In contrast, Suffolk x Tsurcana crossbreds were substantially heavier, outperforming the purebred males by 37.35% and the females by 43.02% (Popa, D. et al. 2013). Based on the research findings, the weaning weight of Tsurcana lambs, measured at 60 days, varies significantly depending on the type of birth and sex. For lambs from single births, males achieved a weaning weight of 16.458 ± 0.467 kg. Females from single births reached a lower weight of 15.380 ± 0.561 kg, representing a difference of approximately 7% compared to their male counterparts. Moreover, in the case of twin births, the weaning weights were predictably lower. Tsurcana males from twins reached 15.618 ± 0.355 kg, while twin females achieved the lowest average weight in the study at 14.493 ± 0.389 kg. Overall, the Tsurcana breed showed lower quantitative meat production performance at weaning compared to the Țigaie breed across all categories (Călin et al., 2024).

The Tsurcana sheep population in North-East Romania exhibits high milking capacity, with an average yield of 94.234 liters recorded during the first 85 days of lactation. Research confirms a strong positive correlation between suckled milk quantity and lamb growth speed, particularly during the first 15 days (r_p: 0.84) and up to 28 days postpartum. This relationship weakens as weaning approaches at 85 days,

dropping to r_p: 0.24. While ewe age influences lamb birth weight, milking capacity remains the primary driver of development. Selection for this trait is vital for improving meat production efficiency (Pascal et al., 2011). According to the breed standard, the total milk production per lactation ranges from 100 to 120 kg, while the specific milked milk yield is approximately 60 to 70 kg. Research on the Bala ecotype highlights its strong performance, with an average milked milk production of 82 kg recorded between 2016 and 2019. Although this reflects a numerical difference of nearly 12 kg above the standard's upper limit, statistical analysis confirms the Belă ecotype remains within the breed's standard performance (Puie et al., 2020).

CONCLUSIONS

The statistical analysis of the three productive traits demonstrated that the four varieties of the Tsurcana breed are characterized by distinct phenotypic profiles. The Oacheșă variety recorded the highest mean values both for birth weight (3.75 kg) and for milk yield (70.56 kg), while the Breazăand Oacheșă varieties shared the highest mean weaning weights (29.88 kg and 29.84 kg, respectively). The Student's t-test confirmed that the majority of the pairwise differences among varieties are highly statistically significant, a finding that supports the treatment of the four varieties as separate genetic-statistical subpopulations within the breed and that motivates the variety-specific estimation of genetic parameters performed in the present paper.

The heritability values estimated for the three traits indicate a moderate degree of additive genetic determination, with results ranging from 0.106 to 0.252 for birth weight, from 0.148 to 0.296 for weaning weight, and from 0.180 to 0.218 for milk yield. The highest heritability for weaning weight was recorded in the Bălă variety ($h^2 = 0.296$), which singles it out as the variety with the greatest potential for improvement of growth performance through mass selection, whereas milk yield exhibited a remarkable stability of the heritability values across all four varieties, recommending this trait as a primary selection objective with predictable genetic response throughout the breed. The lower and less precise heritability estimates obtained for birth weight argue against its use as a stand-alone selection criterion and reinforce the necessity of accounting for maternal and environmental effects in further analyses.

The estimated genotypic correlations between the analyzed pairs of traits proved to be generally low to moderate, with most values close to zero, which indicates that selection applied for one trait will not generate a substantial correlated response in the other traits and that, consequently, the corresponding breeding objectives must be pursued through independent selection criteria or through an appropriately weighted aggregate index. A notable exception was observed in the Breazăvariety, where the genetic correlation between weaning weight and milk yield reached a moderate positive value ($r_G = 0.491$), suggesting that, in this particular subpopulation, a simultaneous genetic improvement of growth and milk production is feasible and consistent with the historical dairy specialization of the variety.

Taken together, the results presented in this paper should be interpreted not as a self-contained outcome, but as a stage in the genetic characterization of the population structure of the Tsurcana breed and as the quantitative-genetic foundation required for the development of variety-specific breeding programs. The simultaneous availability of phenotypic descriptors, heritability estimates, and genotypic correlations enables the formulation of differentiated selection objectives, the definition of operationally appropriate selection criteria, and the prediction of expected genetic progress in each of the four varieties (Belă, Breazăă, Bucălae, and Oacheșă). Subsequent stages of the research will be directed toward the estimation of individual breeding values, the validation of the selection responses obtained, and the integration of the present findings into a coherent national improvement scheme for the Tsurcana breed, in agreement with the priorities of the Romanian sheep sector.

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