STUDY ON THE PERFORMANCE OF MILK PRODUCTION AND GENETIC PARAMETERS IN A HERD OF ROMANIAN BLACK SPOTTED COWS

G. Amariții[1*], A.-S. Neculai-Văleanu[2], V. Vintilă[2], F. Țenu[1], V. Maciuc[1]

[1]Faculty of Food and Animal Sciences, "Ion Ionescu de la Brad" Iasi University of Life Sciences, 8 Mihail Sadoveanu Alley, 700489 Iasi, Romania
[2]Research and Development Station for Cattle Breeding Dancu – Iasi, Romania

Abstract

The present study analyzes the level of production achieved in a herd of Romanian black spotted dairy cows, the values of the genetic parameters and the estimated breeding value for the bulls with the highlighting of the influencing factors on the phenotypic performances. The statistical estimators were calculated with the S.A.V.C. computer program, the genetic parameters were estimated using the REML method and the breeding value was estimated using the BLUP methodology. In the case of normal lactations, the highest production average is 10141.75 kg reached in the third lactation, with 4.05% fat content and 3.38% protein. The heritability of milk production is 0.23 and this character is genetically correlated very strongly with the amount of fat and that of the protein, the coefficient value being 0.99. Although the average productions of the cows are very good, the maximum mean amount for productions being close of the paternal grandmothers which is of 11467 kg of milk, they do not phenotypically express their genetic potential due to the influence of external environmental factors.

Key words: *phenotype, EBV, heritability, correlations*

INTRODUCTION

Dairy herd improvement has been carried out for decades to increase milk production. These achievements have, however, resulted in the decline of many functional traits that are negatively correlated with milk production, as well as reductions in genetic merit for health and fitness. Therefore, although increasing milk yield and milk quality (fat and protein content) are prioritized for profitability, other traits important for selection such as mechanical milking ability, udder health, disease resistance (e.g. against mastitis and internal parasites) and even the nutritional value of milk (such as fatty acid composition) are also considered. New approaches in cattle selection is for animal traits away from milk production and are included milk quality and other non-productive traits. [1].

While the emphasis in selection used to be on milk production (e.g. for the Holstein population in America, breeding values for milk production have reached approx. 3,000 kg.) which led to fertility problems, in the last 20 years the emphasis has shifted to selecting animals for reproductive and health traits [2].

Prior to selection, superior genotypes in the population under selection are identified. The sources of information are phenotypic and genotypic and they are the basis for determining the breeding value of the breeding stock, after which the individuals in the population under selection are ranked. Phenotypic selection is commonly applied to cows and genotypic selection, due to its high

* Corresponding author: amaritiigabriela@yahoo.com
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costs, is mainly applied to bulls used for artificial insemination.

For h^2 values of more than 0.5, the additive genetic variance is responsible for the determination of the respective traits and, as a result, their improvement by selection yields certain results. For traits with low heritability (0.3), genetic progress can only be achieved if, in addition to one's own phenotype it is taken into account in selection the phenotype of descendance and collateral relatives.

Milk production traits comprise quantitative characteristics (milk quantity, fat, and protein) and qualitative elements (percentage of fat and protein). International regulations stipulate that the milk production of dairy cows is expressed as milk quantity, pure fat and pure protein for 305 lactation days of the cow.

The aim of this study is to make a comparative analysis of productivity levels for ancestry and descendance, the genetic parameters of quantitative traits related to milk production and estimate the sires' breeding value (EBV).

MATERIAL AND METHOD

The biological material is constituted from a herd of 235 females belonging to the breed Romanian black spotted (BNR - line of Holstein Freise) that have finished lactation between 01.01.2023 - 30.05.2024 and which represent the descendace.

The herd studied consists of cows exploited for milk production in a farm from the NE of Romania. The animals are rearing in an intensive system, kept in permanent free stall and fed from stock with a single ration, depending on their physiological condition and production level. Cows are milked twice a day.

These breed is an improved one for milk production in which the highest milk production is achieved in the III-IV lactation and the first one should represent 80% of the maximum lactation, as specified in the literature [3,4].

Raw data were obtained from the records of farm and from the Afimilk management program implemented in the farm and those related to the productive performance of the ancestry were obtained from the certificates of origin in the Genealogical Register of the BNR breed.

Regarding the productive performances of the descendance, it was used data about performance in five normal lactations provided by the cattle association carrying out the Official Production Control centralized by the National Livestock Agency (ANZ).

All the primary data collected were statistically processed by Prof. Vasile MACIUC, PhD, from U.S.V. Iassy. For this purpose, the computer program S.A.V.C. was used to determine the arithmetic mean $(\bar{X})$ the arithmetic mean error $(\pm s_{\bar{x}})$, the standard deviation (s), the coefficient of variation (CV%).

Genetic parameters were estimated by the R.E.M.L. (Restricted / residual / reduced Maximum Likelihood) method which is based on an iterative process of maximizing a function. In our case, the final convergence was 99.99% and the number of iterations 73.

Finally, the prediction of the breeding value was carried out using the BLUP methodology being possible by applying the individual animal model by which is meant the situation in which the genetic effect is described at the level of the offspring which is, as a rule, the "author" of the realized performance. According to the animal model, the performance (P_{ij}) of a selection candidate realized in the "i" environment (e.g. in Farm i; F_i) can be represented mathematically as:

$$P_{ij} = F_i + a_{ij} + e_{ij}, \text{ where:}$$

- a_{ij} represents the additive genetic effect of the selection candidate (the animal "j", which achieves performance in the environment/farm "i");

- e_{ij} represents the residual of the model, which includes the influence of other factors not specified in the model.

The model used is of "mixed" type, as it includes at least one fixed and one random factor. [5]. The statistical processing of the data was performed for the ancestry (M, MM and FM) and for the offspring forming the herd studied.

RESULTS AND DISCUSSION

Following statistical processing of the primary data for herd ancestry, the results presented in table 1 were obtained. The statistics values for the main quantitative and qualitative parameters of milk production are presented in graphs comparing descendance' values with those of ancestry.

The bulls used for artificial insemination (AI) have a very valuable ancestry, their dams having on mean productions of 11467.16 kg milk with 3.68% fat and 3.25% protein, this trait showing limits of the variation between 2134-16763 kg and a high variability of 33.964%.

Table 1. Statistics on milk production in the studied herd ancestry

Traits	Statistics	Mother M	Mothers' mothers MM	Father' mother FM
Milk yield (kg)	n	235	226	122
	$X \pm s_x$	9473,02 ±115,15	9626,7±132,682	11467,16±352,614
	S	1765,211	1994,654	389,4751
	CV%	18,634	20,72	33,964
	min-max	3104-14762	1008-16261	2134-16763
Amount of fat (kg)	n	235	226	122
	$X \pm s_x$	386,8±4,904	394,9±4,835	415,85±12,362
	S	75,18	72,681	136,546
	CV%	19,437	18,405	32,835
	min-max	4,4-597	227-653	83-661
Amount of protein (kg)	n	235	226	114
	$X \pm s_x$	329,19±4,135	336,19±4,011	373,46±12,391
	S	63,391	60,306	132,296
	CV%	19,256	17,938	35,424
	min-max	354-485	195-515	68-551
Total amount of fat + protein (kg)	n	235	226	120
	$X \pm s_x$	715,99±8,664	731,09±8,801	770,48±24,402
	S	132,816	132,306	267,307
	CV%	18,55	18,097	34,694
	min-max	239-1071	422-1168	151-1203
Fat content %	n	235	226	122
	$X \pm s_x$	4,1±0,009	4,1±0,007	3,68±0,037
	S	0,132	0,103	0,407
	CV%	3,219	2,526	11,043
	min-max	3,52-4,63	3,62-4,37	3,02-4,5
Protein content %	n	235	226	114
	$X \pm s_x$	3,48±0,015	3,49±0,009	3,25±0,009
	S	0,228	0,129	0,099
	CV%	6,544	3,699	3,053
	min-max	0,64-3,76	3,09-3,77	2,89-3,87

In the case of paternal ancestry (FM) were obtained 415.85 kg fat and 373.46 kg protein per lactation, traits with a high variability within the group, with CV% values of 32.835 and respectively 35.424.

The maternal line productions, although much lower compared to bulls one, are good for the breed.

Thus, in the group of mothers the mean of productions is 9473.02 kg of milk with a percentage content of 4.1% fat and 3.48%

protein, with plus variants that had productions of 14762 kg milk/lactation.

In the case of mothers' mothers (MM), the average production is 9626.7 kg milk with fat and protein content of 4.1% and 3.49%. Both analyzed groups (M and MM) are characterized by medium trait homogeneity because the CV% values are 18.634 and 20.72 respectively.

The mean of milk yield for M are with 1.6% (153.68 kg) lower than that of MM. The means for fat and protein productions are close in the maternal line: in M case the fat and protein amounts are 386.8 kg and 329.19 kg and in MM are 394.9 kg and 336.19 kg. These quantitative traits have a medium variability, the CV% coefficient having values between 17,938 - 19,437, the groups being medium homogeneous. For the descendance, the productive performances are presented in comparison with those of ancestry, the mean values being plotted in fig. 1 – 3.

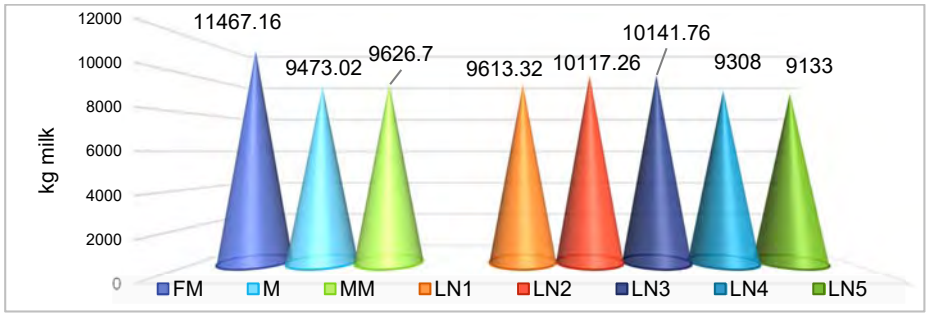

Fig. 1. Dynamics of milk productions in ancestry and descendance

In the herd of descendances, milk production increases up to the third lactation and then decreases in the subsequent lactations. The maximum performance of milk production is 10141.76 kg with 4.05% fat and 3.38% protein. This production performance is higher than that of M and MM, being close in value to that of the paternal grandmothers but 11.56% lower.

The normal lactation duration in the herd is between 295 - 305 days and the milk is of good quality with a relatively constant fat content of 4.01 - 4.07% and protein content of 3.36 - 3.38 %.

In the case of descendance, the mean production calculated for all normal lactations is 9662.67 kg with 4.05% fat and 3.37% protein. These values exceed the national averages calculated for the country's Holstein herd for which, in 2023 were 6890 kg milk with 3.83% fat and 3.45% protein. In Finland, for the Holstein herd, mean for normal lactation production in 2023 was 11049 kg milk with 4.27% fat 3.54% protein. [6]

Compared to the maximum lactation, it can be observed that the mean of the first lactation represents 94.79% of it and that in the second lactation the production is very close, being 10,117.26 kg (-0.24%), which also registers the highest values for the limits of the variation range. Thus, it can be concluded that external environmental factors are determinants for the productive performance of cows from progeny that fail to externalize their inherited genetic potential and that the productive performance in maximum lactation may be higher.

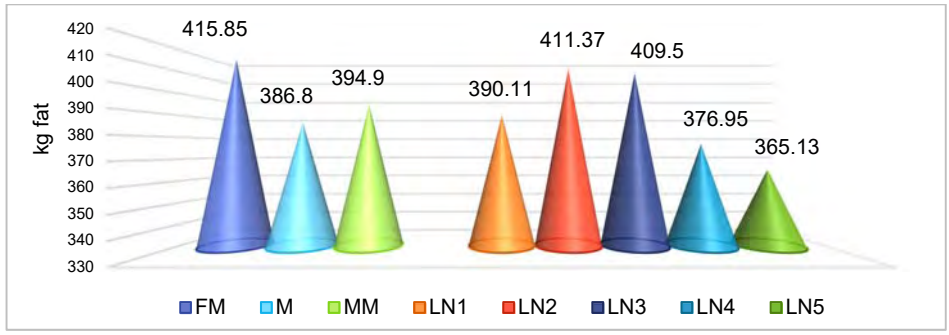

Fig. 2. Dynamics of amount of milk fat in ancestry and descendance

Comparing the performance of ancestry and descendance in terms of fat amount, as can be seen from the graphical representation of the averages in fig.2, we can conclude that in the descendance, the highest milk fat amount of 411.37 kg does not belong to the maximum lactation but to the second one when the milk has a fat content of 4.07%. This average is higher compared to the maternal ancestry, approaching the father' mother FM mean value of 415.85 kg and accounting for 98.9% of it.

In the third lactation, the average of fat amount is 409.5 kg, the milk yield is slightly higher than in second lactation but the percentage fat content is lower at 4.05%.

In the second and third lactation, the descendance analyzed achieved the maximum protein amounts of 340.88 kg and respectively 342.54 kg, above the maternal ancestry averages and close to the FM average of 373.46 kg. (fig. 3). The yields of these two lactations are almost similar and the milk protein content averaged 3.38% in both lactations.

For production traits, the descendance is medium homogeneous to heterogeneous with CV% values in the range 16.757 - 23.781.

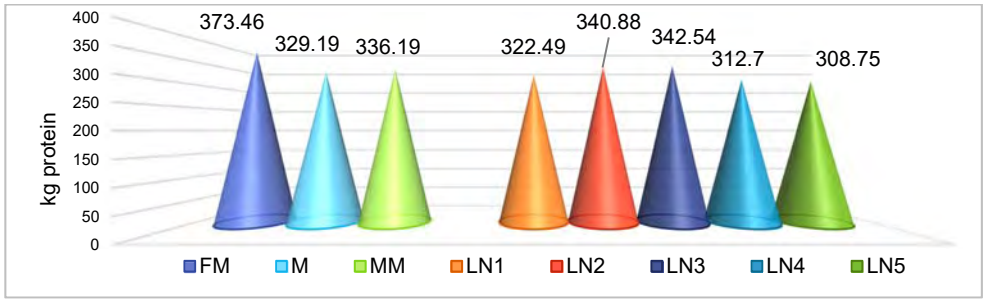

Fig. 3. Dynamic of amount of milk protein in ancestry and descendance

The determination of genetic parameters is important because of the need to know them in herd improvement and they are characteristics of the population for which they are calculated. In the case of the analyzed herd the results obtained are detailed in tables 2 and 3.

Table 2. Coefficient of heritability (h^2) and variance of the main milk production traits in the herd studied

Trait	h^2	The variance due additive genes	The variance "intralot"	The total variance
Milk (kg)	0.23	518574.9	15932135	15413560
Amount of fat (kg)	0.28	777.27	25801.44	25024.17
Amount of protein (kg)	0.25	575.8924	17733.697	17157.805
Fat content (%)	0.69	0.0011	2.3564	2.3575
Protein content (%)	0.62	0.0064	1.6051	1.6114
Duration of NL (zile)	0.26	101.5089	12869.136	12767.627
Persistence of lactation (%)	0.20	29.134	1173.9832	1144.8492

NL – normal lactation

Heritability can be described as the analysis of variation that aims to determine the degree to which a trait varies in a population due to genetic factors, being the proportion of the total variation due to genetic factors [4,7,8,9,10]. The traits with the highest heritability and strong genetic determinism are milk fat percentage and milk protein percentage (table 2) which have for h^2 the value of 0.69 and 0.62 respectively. Milk yield has a lower genetic determination, heritability for this trait being 0,23 close in value to that mentioned by other authors. [11] The other traits such as amount of fat and protein and duration of NL have medium genetic determinism, with h^2 ranging from 0.25 to 0.28. Persistence of lactation is a trait with low value of heritability (0.20)

The correlations between traits are genetic and environmental and the value of the correlation coefficient expresses the covariance of the studied traits. [12]. For the herd studied, the values of the correlation coefficients are as shown in table 3.

Table 3. Phenotypic (r_P), genetic (r_G) and environmental (r_E) correlation coefficients for the main milk production traits

Trait 1	Trait 2	r_P	r_G	r_E	Genetic covariance	"Intralot" covariance	Total covariance
Milk yieald (Kg)	Duration of LN	0.37	0.33	0.39	9755.39	66563.60	56808.21
	Fat content	- 0.24	- 0.23	- 0.25	-101.16	784.59	683.43
	Amount of fat	0.99	0.98	0.99	16470.14	119410.73	102940.59
	Protein content	- 0.22	- 0.19	- 0.23	-91.65	411.64	319.98
	Amount of protein	0.88	0.98	0.96	12455.95	74885.46	62429.51
Duration of LN (days)	Fat content	0.43	0.37	0.53	5.45	33.39	27.95
	Amount of fat	0.76	0.67	0.77	361.20	2756.24	2395.04
	Protein content	0.46	0.34	0.48	4.85	20.96	16.10
	Amount of protein	0.69	0.48	0.75	304.45	1786.46	1482.
Fat content (%)	Amount of fat	0.69	0.67	0.7	3.47	33.23	29.76
	Protein content	0.74	0.44	0.84	0.06	0.33	0.27
	Amount of protein	0.7	0.41	0.75	2.96	23.28	20.32
Amount of fat (kg)	Protein content	0.33	0.31	0.43	3.44	16.35	12.9101
	Amount of protein	0.87	0.19	0.96	485.54	3107.23	2621.69
Protein content (%)	Amount of protein	0.75	0.69	0.76	0.4	16.47	16.86

LN – normal lactation

The most important correlations are between milk yield and milk components. In the herd studied, milk yield is phenotypic and genetically very strongly and positively correlated with fat and protein amount (r_G = 0,98) so that improving milk yield will result in higher quantity of fat and protein per lactation. [13].

Strong positive phenotypic correlations based on genetic and environmental correlations also exist between the following traits:
- amount of fat (kg) with that of protein, and each with % milk content;
- amount of protein (kg) with % protein and % fat;
- duration of lactation and quantity of fat and protein;
- % fat with % protein has a value of correlation coefficients of 0,74.

Medium phenotypic correlations are between lactation duration and % fat, % protein and milk yield which in turn is weakly and antagonistically correlated with % fat and % protein.

The productive performance is not largely dependent on lactation duration but, increasing milk production attracts better fat and protein yields even milk fat and protein percentages are decreasing.

The amounts of fat and protein in milk are correlated and influence each other in a positive direction and each in turn depends as phenotypic manifestation on the percentage of these constituents in milk. Increasing the percentage of fat in the milk leads to an increase in the percentage of protein which will result in an increase in the quantities obtained in a lactation.

Table 4. Repeatability coefficient (R) for the main milk production traits

Trait	***R***
Milk yield kg	0.25
Fat %	0.71
Fat amount kg	0.32
Protein %	0.65
Protein amount kg	0.27

In herd studied, the repeatability coefficient values are good for % milk fat and % milk protein, which means that the probability that during successive lactations the performance repeats at the same value is high. For these traits, R values are 0.71 and 0.65 respectively as can be seen from table 4. Poor to average repeatability with R values ranging from 0.25 to 0.32 is manifested in the case of milk yields and the quantities of fat and protein obtained.

Dairy cow breeding is done to increase individual production per lactation. The choice of the male sire whose semen is used for AI is based on its breeding value for the trait of interest, choosing bulls that will achieve the desired performance in the ancestry.

The bulls whose semen has been used for AI of mother cows belong to the Holstein breed, with diversified origins: most are of German origin (12 ♂), 9 of them are of Dutch origin, 6 from the USA, 5 from the native breed BNR, 3 of Danish origin and one each from the Canadian and French Holstein breeds.

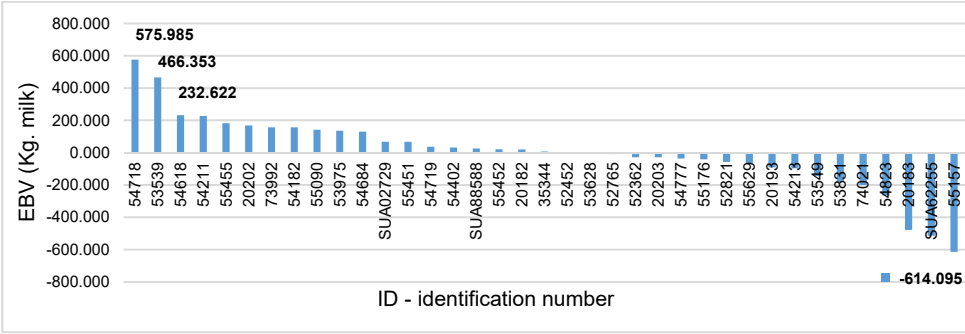

Fig. 4. The breeding value (EBV) of bulls estimated for milk production

Out of the 37 bulls whose semen was used for AI of the maternal female batch, 54.05 % (20 ♂) are milk yield improvers and 17 bulls are milk yield worseners. As can be seen from the data plotted in fig. 4, the identified bull 54718 has the highest improvement value of 575,985 kg milk it is the best choice among all for improving this trait in the herd.

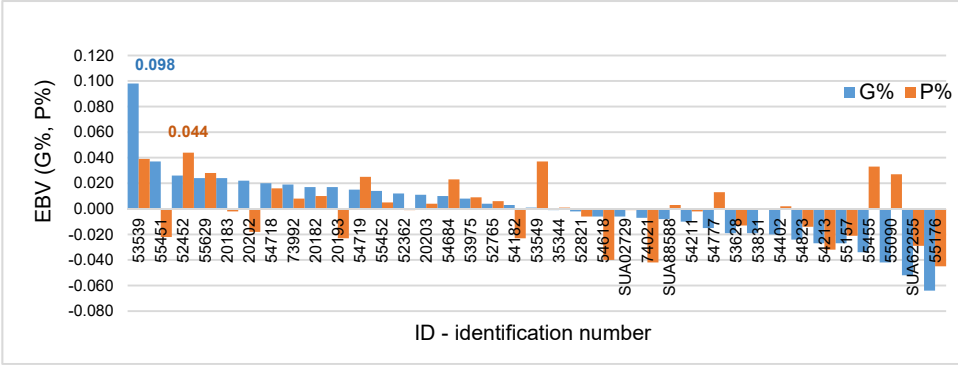

Fig. 5. The breeding value (EBV) of bulls estimated for % G and %P

The milk fat percentage can be improved by using semen from 19 of the 37 bulls, with the highest breeding value for this trait being estimated the sire identified with 53539 of 0.098 % (fig. 5). For 48.65% of the male sires, the improvement value is negative. Protein percentage is a qualitative parameter of milk production and can be improved by 19 of the bulls used for breeding that are character improvers, with values ranging from a minimum of 0.001 (sire identified with 35344) to a maximum value of 0.044 in the case of the bull 52452. (fig. 5.).

CONCLUSIONS

Based on the results obtained and presented in this study, it can be concluded:

- in maternal line ancestry, the mean for performances of quantitative characters are very good but in case of M the values are lower compared to MM, traits being with medium variability for both groups.

- paternal ancestry is very valuable in terms of milk yield because the average of the FM group is 11467.16 kg milk/lactation, with a fat content of 3.68% and 3.25% protein, and the averages for fat and protein are the highest in all ancestry, being 415.85 kg and 373.46 kg respectively.

- in the herd of descendances, the highest mean for milk, fat and protein productions are reached in third lactation which is the maximum from the performances archived point of view.

-the values of mean for maximum milk, fat and protein productions are higher than those in M case and close to that mean values of the FM;

- the first normal lactation represents 94.79% of the maximum lactation (third one) and the average production of the second lactation of 10117.26 kg is close to that of the maximum lactation (third one) of 10141.76 kg.

- though the descendance has very good productions the cows in the herd do not realize their full genetic potential because environmental factors are those that influence their productive performance.

The following conclusions can be drawn from the analysis of genetic parameter values and correlations between traits:

-the heritability coefficient value for milk yield is low, $h^2 = 0.23$.

- fat and protein percentage have strong genetic determinism, being highly inheritable (0,69; 0,62).

- characters such as duration of normal lactation, amount of fat and protein in milk, persistence of lactation have weak genetic determinism $h^2 = 0.20 - 0.28$.

- the percentage of fat and protein in milk are two highly repeatable characters in the herd, (R = 0.64 - 0.71) while the rest of traits has low repeatability.

- most of the traits are highly genetic and environmental correlated, especially the production ones;

- productive performance is medium correlated with duration of lactation, whereas increased milk production leads to better fat and protein yields.

- after prioritization according to the estimated improvement value, bulls identified with 54718 are recommended for improving milk production, 53539 for % fat and 52452 for % protein;

- the optimal variant, as an improver of these traits is the sire identified with the number 53539 which for milk production has EVB = 466,353 kg and for % protein is an improver of 0,039%.

For the dairy herd studied it is recommended:

- management measures to improve environmental factors dependent on the technology of rearing and maintenance of cows, to increase productive performance, to phenotypic externalization of the genetic potential of the animals.

- increasing heritability of production traits by increasing genetic variance and decreasing the environmental one.

- continuous improvement of milk yield and fat content, given the importance of these traits for the economic efficiency of dairy cow breeding.

- the selection nucleus will include offspring with production above the herd average.

REFERENCES

1. Gutiérrez-Reinoso, MA; Aponte, PM; García-Herreros, M Genomic and Phenotypic Udder Evaluation for Dairy Cattle Selection: A Review. *Animals*. **2023**, *13*(10), 1588. https://doi.org/10.3390/ani13101588
2. Lima, FS; Silvestre, FT; Peñagaricano, F; Thatcher, WW Early genomic prediction of daughter pregnancy rate is associated with improved reproductive performance in Holstein dairy cows. *Journal of Dairy Science* **2020**, *103* (4), 3312-3324. https://doi.org/10.3168/jds.2019-17488.
3. Acatincăi, S Cattle breeding technology. *Agroprint Publishing House* **2010**, Timișoara.
4. Maciuc, V Cattle breeding management. *Alfa Publishing House* **2006**, Iași.
5. Grosu, H; Lungu, S; Oltenacu, PA; Drăgănescu, C; Raluca Mateescu Predicting the breeding value of cattle. *Ceres Publishing House* **2019**, București.
6. https://my.icar.org/stats/list.
7. Ivancia, M Animal breeding. *Alfa Publishing House* **2020**, Iași.
8. Georgescu, Gh. et al Cattle farming treaty. *Ceres Publishing House*, **1988,** *vol. 1*, București.
9. Negruțiu, E; Petre, A Domestic animal breeding. *Didactic and Pedagogical Publishing House*, **1975**, București.
10. Pearson, HC Is heritability explanatorily useful ? *Stud. Hist. Phil. Biol. & Biomed. Sci*. **2007**, *38* (1), 270–288. https://1910apt0v-y-https-doi-org.z.e-nformation.ro/10.1016/j.shpsc.2006.12.012
11. Dragotoiu, T; Nicoleta Isfan; Loredana Stroilescu; Dragotoiu, D; Monica Marin; Izabela Oprea Study on the heritability of milk production in a line of Holstein Freise. *AgroLife Scientific Journal*, **2015**, *4*(1). https://agrolifejournal.usamv.ro/index.php/agrolife/article/view/387
12. Schneider, H; Segelke, D; Tetens, J; Thaller, G; Bennewitz, J A genomic assessment of the correlation between milk production traits and claw and udder health traits in Holstein dairy cattle. *Journal of Dairy Science* **2023**, *106* (2), 1190-1205. DOI: 10.3168/jds.2022-22312
13. Cue, RI; Monardes, HG; Hayes, JF Correlations Between Production Traits in First Lactation Holstein Cows. *Journal of Dairy Science* **1987**, *70* (10), 2132-2137. DOI: 10.3168/jds.S0022-0302(87)80264-3