Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 14, Issue 3, 2014
PRINT ISSN 2284-7995, E-ISSN 2285-3952

RESEARCH ON A SIMPLIFIED MIXED MODEL VERSUS CONTEMPORARY COMPARISON USED IN BREEDING VALUE ESTIMATION AND BULLS CLASSIFICATION FOR MILK PRODUCTION CHARACTERS

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Abstract

The paper goal was to set up a simplified BLUP model in order to estimate the bulls' breeding value for milk production characters and establish their hierarchy, Also, it aimed to compare the bulls' hierarchy set up by means of the simplified BLUP model with their hierarchy established by using the traditional contemporary comparison method. In this purpose, a number of 51 Romanian Friesian bulls were used for evaluating their breeding value for milk production characters: milk yield, fat percentage and fat yield during the 305 days of the 1st lactation of a number of 1,989 daughters in various dairy herds. The simplified BLUP model set up in this research work has demonstrated its high precision of breeding value, which varied between 55 and 92, and more than this it proved that in some cases, the position occupied by bulls could be similar with the one registered by using the contemporary comparison. The higher precision assured by the simplified BLUP model is the guarantee that the bulls' hierarchy in catalogues is a correct one. In this way, farmers could chose the best bulls for improving milk yield in their dairy herds.

Key words**:** *bulls' breeding value estimation, contemporary comparison, milk production characters, simplified mixed model*

INTRODUCTION

The use of the highest breeding value bulls in dairy cows populations could assure the growth of milk production as mentioned Draganescu in 1979 [4].
The identification of the best bulls requires to set up the most adequate methods for estimating breeding value for milk production characters [12, 24, 28].
The "contemporary comparison" method, theoretically based by Robertson and Rendel in 1950 [23] and Henderson, Carter and Godfrey in the USA [7], like "herd mate comparison", was very much appreciated for its high efficiency in bulls' breeding value estimation, a reason for which it was largely used in almost all the countries.
Across the time, it was improved in order to increase the precision of the breeding value by eliminating the influence of the mother cows, the differences among dairy herds [21,22], by correcting the regression coefficient and the deviation of daughters performance from their contemporary cows for age [15,16], calving season and month, lactation duration, herd size [17,18], for the number of daughters and their distribution by herds [14], for the dry period [6,25], for calving interval [13] and for the number of offspring per bull [19].
The contemporary comparison method was later replaced by the new methods based on linear mathematical models, assuring a higher precision in breeding value estimation and being easier used due to the fast computers dynamics.
Mathematical models should be set up in accordance with every country conditions regarding: climate, breed, breeding system, herd size, number of selected bulls, and system of data collection, registration, storage and processing [8, 11, 27].
The most important linear mathematical models largely utilized in breeding value

estimation are (a) selection indices [1,2,6], (b) the least square method [3,6] and (c) the best linear unbiased prediction (B.L.U.P.) [26, 29].
The advantage of BLUP compared to selection indices is that the former assures an unbiased linear prediction with the lowest quadratic error.
Later transformed into " mixed model", BLUP method successfully combined the advantages of the selection indices and the least square method, assuring a minimum variance of the breeding value, this model being much better adapted to the present calculation techniques [2,3,6].
In Romania a series of researched obtained important results regarding the implementation of BLUP method in various variants [4,20].
In this context, the paper presents a simplified mathematical model of BLUP to estimate bulls' breeding value for milk production characters in Romania and makes a comparison between the bulls hierarchy base on the simplified BLUP model and contemporary comparison.

MATERIALS AND METHODS

A number of 51 Romanian Friesian bulls were used for evaluating their breeding value for milk production characters based on two methods: (a) a simplified BLUP model and (b)contemporary comparison method. In this purpose, a number of 1,989 daughters of those bulls were tested for their performance at the 1st 305 days lactation for milk production characters: milk yield, fat percentage and fat. The average number of daughters per bull was 39, ranging between 19 and 198. The daughters were tested in their dairy herds. This was a right decision based on the fact that "20-40 daughters tested in dairy herds assure the same selection precision as 20 daughters tested in stations" as mentioned by Robertson and Rendel (1954) cited by Draganescu, 1979 [4].
Starting from the mixed model established by Henderson (1949), in this paper it was set up an own simplified variant in monofactorial classification, according to the mathematical formula:

$Y_{ij} = \mu + s_i + e_{ij}$, (1)

where: Y_{ij} – the performance of the „j" daughter of the „i" bull, μ is a fixed unknown parameter, a_i – the effect of the „i" bull, with the value $s_i = ½\ g_i$, where: g_i – the „i" bull's breeding value, e_{ij} - residual effect (j=1, ..., n_{ij}); a and e are uncorrelated variables with the averages equal to zero and variances $\sum_s^2$ and $\sum_e^2$.

Let's consider $\sum(e_{ij}) = 0, \text{cov}(e_{ij}, e_i, j,) = o$ if i ≠ i', or at least j ≠ j' and $\sum_{ij}^2 = \sum_e^2$. The linear model does not suppose that bulls are relatives among them, $\text{cov}(s_i, s_i) = 0, \sum_{si}^2 = \sum_s^2 = 1/4\sum_A^2$.

Considering that n_i represents the number of daughters of the "i" bull, then the equations of the mixed model are:

$$\begin{bmatrix} n & n_1 & n_2 & \dots \\ n_1 n_1 + \sum_e^2 / \sum_s^2 & & 0 & \dots \\ n_2 & 0 & n_2 + \sum_e^2 / \sum_s^2 & \dots \\ \dots\dots & \dots\dots & \dots\dots & \dots \end{bmatrix} \begin{bmatrix} \mu \\ s_1 \\ s_2 \\ \dots \end{bmatrix} = \begin{bmatrix} y.. \\ y_1 \\ y_2 \\ \dots \end{bmatrix}$$

(2)

The breeding value of the "i" bull, s_i, will be:

$s_i = 2(n_i/n_{i.} + a)\ (y_{i.} - \mu)$ (3)

where: s = $\sum_e^2 / \sum_s^2$. If we consider $n_i/(n_i.+a) = w_i$, then $\bar{\mu} = \sum w_i \bar{y}_{i.} / \sum w_i$.

The precision of the estimated breeding value, R^2, was calculated using the formula:

$$R^2 = w_i - \frac{w_i}{\sum w_i} \quad (4)$$

When n_i has a high value, then $R^2 = w_i(1 - \frac{1}{\sum w_i})$, unde $\sum w_i$ goes to infinity and $1/\sum w_i$ goes to zero.

This simplified mixed model was utilized for estimating the bulls breeding value and its precision for milk production characters: milk yield, fat % and fat quantity for 305 days of lactation at the 1st lactation.
Based on the obtained breeding value, the

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PRINT ISSN 2284-7995, E-ISSN 2285-3952

bulls were classified, each of them coming on a certain position from 1 to n. The summation of the positions occupied for pairs of characters allowed to set up a new hierarchy of the bulls.

Breeding value was also estimated using the contemporary comparison method, based on the formula:

$$\widehat{V}A = 2b\left[(\overline{Y} - \overline{A}y) - 1/2h^2(\overline{X} - \overline{A}_X) + h^2{}_A(\overline{A} - \overline{P})\right] + \overline{P}, \quad (5)$$

where: $\overline{A}$ - herd average, and $\overline{P}$ - breed average, $\overline{Y}$ - mothers average performance, $\overline{A}_X$ - contemporary average performance, and ½ h^2- mother genetic contribution [10, 21,22].

h^2=heritability whose values were 0.25 for milk yield, 0.3 for fat % and 0.25 for fat quantity.

The factor b had the formula:

$$b = \frac{W}{W + \frac{4}{h^2} - 1}, \quad (6)$$

where: W = $\sum_{i=1}^{k} w_i$ and K – number of herds.

$$w_i = \frac{n_1 . n_2}{n_1 + n_2}, \quad (7)$$

where: n_1- number of daughters and n_2 – number of contemporaries.

In order to establish the relationship between the bull classification based on the breeding value estimated by the simplified BLUP model and the classification resulted based on the contemporary comparison it was used the rank correlation method established by Spearman [30] based on the formula:

$$r_s = 1 - \frac{6\sum d^2}{n(n^2 - 1)} \quad (8)$$

The significance of this correlation was tested using Fisher Test for the probabilities P = 0.05 and P = 0.01, using Fisher tables [30].

RESULTS AND DISCUSSIONS

Bulls' daughters performance in milk yield for 305 days of the 1st lactation

The bulls' daughters registered an average milk yield for 305 days of lactation of 2,789.2 kg, ranging between the minimum of 1,709.5 kg and the maximum of 4,210.4 kg, reflecting an amplitude of 2,500.9 kg.

Bulls' breeding value for milk production characters, estimated based on the simplified mixed model

The 51 bulls recorded positive breeding values varying between +14.2 kg and 986.1 kg, a reason to be considered that they are able to improve milk yield.

Milk fat percentage registered 3.77 % in average, varying between 3.34 %, the minimum level and 4.24 %, the maximum level. A number of 28 % bulls were considered that they are able to improve fat percentage.

The average fat quantity accounted for 105.34 kg with the minimum level of 58.94 kg and the maximum level of 155.58 kg. The breeding value ranged between +29.19 kg and +0.02 kg. Around 44 % bulls were considered able to improve this character (Table 1).

Breeding value precision

The precision of breeding value varied between 55 in case of the bull number 13 and 92 in case of the bull number 8, depending on the number of daughters taken into consideration.

Of the 52 bulls in study, 4 bulls were not able to improve fat quantity and 30 fat percentage. This could be explained by the fact that between milk quantity and fat percentage it is a negative correlation. A number of 4 bulls are not able to improve the both characters.

Bulls' hierarchy based on their breeding value estimated for each milk production character by means of the simplified mixed model

The bull hierarchy for each character is presented in Table 2.

Bulls' hierarchy based on their breeding value estimated for pairs of milk production characters by means of the simplified mixed model

The pair "Milk yield x Fat %"

It was noticed that if we take into consideration the bulls' breeding value for the pair ***"Milk yield x Fat %"characters***, just a number of 28 bulls of the total 52 recorded positive values, meaning that they could improve the both characters. On the 1st position came the bull number 10, on the 2nd position came the bull number 6 and on the 3rd position came the bull number 17.

Table 1.Bulls' breeding value and its precision for milk production characters

Bull number	Breeding value (+BV)			Precision (R^2)
	Milk yield (kg)	Fat %	Fat quantity (kg)	
1x	986.1	-0.189	29.19	68
2	698.2	0.082	29.03	58
3	654.1	0.085	27.85	87
4	636.7	0.006	24.26	61
5	619.5	0.072	25.47	77
6	601.8	0.102	26.26	58
7x	561.5	-0.035	21.21	80
8	559.2	-0.121	17.06	92
9	545.4	0.058	20.17	63
10	523.2	0.158	23.92	62
11	507.6	0.047	20.04	90
12	500.4	0.065	20.81	86
13	493.0	0.079	19.88	55
14x	489.6	-0.068	16.03	66
15x	475.6	-0.069	15.28	71
16x	465.5	-0.095	14.11	65
17	420.0	0.184	21.47	58
18	370.4	0.039	14.52	83
19x	349.4	-0.102	10.14	79
20x	347.5	-0.036	12.03	62
21	334.1	0.080	12.76	58
22x	324.9	-0/071	10.02	77
23	309.5	0.080	14.44	70
24	301.8	0.267	18.84	72
25x	279.9	-0.058	9.33	63
26	275.0	0.115	14.20	65
27x	274.3	-0.049	8.73	62
28	262.1	0.264	17.82	60
29	249.4	0.000	9.51	74
30	248.2	0.106	12.24	59
31	213.4	0.119	10.87	62
32x	180.5	-0.107	3.17	90
33	178.5	0.090	9.08	62
34x	169.5	-0.029	5.63	55
35	145.3	0.213	11.49	80
36x	137.8	-0.139	1.38	71
37	134.5	0.060	6.08	59
38x	130.1	-0.041	3.94	58
39x	109.0	-0.024	3.01	64
40	102.1	0.057	5.13	59
41xx	94.6	-0.109	-0.27	59
42xx	83.3	-0.123	-0.88	81
43	58.2	0.118	5.25	77
44	50.4	0.093	3.82	63
45	48.8	0.040	3.04	59
46xx	40.9	-0.106	-1.47	59
47	37.6	0.010	2.07	72
48x	29.5	-0.003	0.46	86
49	27.2	0.088	3.08	58
50xx	19.5	-0.052	-0.49	60
51	14.2	0.104	3.03	58

Source: Own calculations

The pair "Milk yield x Fat Yield"

Based on the breeding value registered for these two characters, it was noticed that the first 12 positions were occupied by the first 18 bulls mentioned on the list of the bulls improving each milk production character considered separately.

The pair "Fat % x Fat Yield"

In this case, only 26 bulls registered positive breeding values and their positions are quite different compared with the positions occupied in the previous cases (Table 3).

Table 2.Bulls' classification according to their breeding value for each milk production characters, estimated by means of the simplified mixed model

Bull number	Position occupied for:		
	Milk yield (kg)	Fat %	Fat quantity (kg)
1	1	-	2
2	2	21	1
3	3	20	3
4	4	44	6
5	5	27	5
6	6	15	4
7	7	-	13
8	8	-	16
9	9	30	11
10	10	7	7
11	11	32	12
12	12	28	10
13	13	24	9
14	14	-	17
15	15	-	-
16	16	-	21
17	17	5	8
18	18	35	18
19	19	-	27
20	20	-	24
21	21	-	-
22	22	-	22
23	23	23	19
24	24	2	14
25	25	-	30
26	26	11	20
27	27	-	32
28	28	3	15
29	29	-	29
30	30	13	23
31	31	8	26
32	32	-	39
33	33	18	31
34	34	-	34
35	35	4	25
36	36	-	45
37	37	29	33
38	38	-	37
39	39	-	43
40	40	31	36
41	41	-	-
42	42	-	-
43	43	10	35
44	44	16	38
45	45	34	41
46	46	-	-
47	47	42	44
48	48	-	47
49	49	19	40
50	50	-	-
51	51	14	42

Source: Own calculations

Bulls' hierarchy based on their breeding value estimated for three characters of milk production by means of the simplified mixed model

Table 3. Bulls' classification according to their breeding value for pairs of milk production characters and also for all the three milk production characters, estimated by means of the simplified mixed model

Bull number	Position occupied for:			
	Milk yield x Fat %	Milk yield x Fat yield	Fat % x Fat yield	Milk yield x Fat % x Fat yield
1	-	1	-	-
2	4	1	6	1
3	4	2	7	3
4	13	3	19	9
5	17	3	10	5
6	2	3	5	2
7	-	5	-	-
8	-	8	-	-
9	9	5	15	8
10	1	4	2	1
11	11	7	-	10
12	10	6	14	8
13	8	6	11	7
14	-	10	-	-
15	-	-	-	-
16	-	12	-	-
17	3	9	1	4
18	15	11	20	15
19	-	17	-	-
20	-	16	-	-
21	-	15	-	-
22	-	18	-	-
23	12	14	16	13
24	5	13	3	6
25	-	20	-	-
26	8	17	9	11
27	-	23	-	-
28	6	15	4	7
29	-	22	-	-
30	11	19	13	14
31	10	21	12	14
32	-	28	-	-
33	10	25	18	16
34	-	26	-	-
35	9	24	8	12
36	-	32	-	-
37	18	27	24	19
38	-	29	-	-
39	-	33	-	-
40	20	30	25	20
41	-	-	-	-
42	-	-	-	-
43	15	31	17	17
44	16	33	21	18
45	21	34	26	22
46	-	-	-	-
47	22	36	27	23
48	-	38	-	-
49	19	35	23	21
50	-	-	-	-
51	17	37	22	20

Source: Own calculations

In case of "Milk yield x Fat % x Fat yield", the breeding value allowed 28 bulls to be considered as the best of the all for improving all these three milk production characters at the same time (Table 3).

Comparison regarding bulls' hierarchy based on their breeding value estimated for "Milk yield x Fat yield" by means of the simplified mixed model and by contemporary comparison method

Analyzing the bulls' positions occupied for the couple "Milk yield x Fat yield" characters based on the breeding value calculated by means of the two methods: the simplified BLUP method and the contemporary comparison method, it was noticed that there are substantial differences, because there were used different methods for estimating the breeding value.

But, the bulls number 5,8,16, 23, 28, 35, 38 and 40 occupied almost the same positions, which could be determined by the following factors:

(a) the genetic differences between bulls which were compensated by calculations;

(b) many times, the both methods assure almost the same bulls' hierarchy as Henderson (1949) affirmed (Table 4).

Rank correlation

It was noticed that there were significant correlations between the positions occupied by bulls for milk yield and fat yield, proving that a high breeding value bull for one of these characters could alsoimprove the other one.Therefore, it is enough to evaluate the breeding value for milk yield to improve fat yield (Table 5).

The rank correlation among the hierarchy of the bulls assessed by means of the simplified BLUP model and the contemporary comparison method was r = 0.563, being substantially siognificant for the probabilities P=0.05 and P = 0.01.

This proved that BLUP method modifies in a certain way the positions occupied by bulls established by means of the contemporay comparison method, but not too much. Its superiority is given by its higher precision, unbiased, not influenced, compared to the other method.

Table 4. Bulls' classification according to their breeding value for the pair "Milk yield x Fat yield" determined by means of the simplified mixed model and contemporary comparison method as well

Bull number	Position occupied according to the method used for breeding value estimation	
	Simplified BLUP model	Contemporary comparison
1	1	26
2	1	21
3	2	22
4	3	24
5x	4	6
6	4	10
7	4	31
8x	5	6
9	5	28
10	6	27
11	6	29
12	7	34
13	8	16
14	9	2
15	10	14
16x	11	9
17	12	37
18	13	28
19	14	9
20	15	33
21	15	7
22	16	13
23x	17	18
24	17	3
25	18	25
26	19	25
27	20	8
28x	21	19
29	22	30
30	23	1
31	24	4
32	25	11
33	26	36
34	27	35
35x	28	27
36	29	17
37	30	20
38x	31	32
39	33	15
40x	34	32
41	35	31
42	37	16
43	32	26
44	33	30
45	36	12
46	38	15
47	39	14
48	40	22
49	41	17
50	41	13
51	42	24

Source: Own calculations

Table 5. Rank correlations between the bulls' hierarchy for varuous characters of milk production

Character	Milk yield	Fat %
Fat %	$0,377^{xx}$	-
Fat yield	$0,974^{xx}$	$0,467^{xx}$

Source: Own calculations

CONCLUSIONS

There are a lot of systematic factors affecting the precision of breeding value estimation. For this reason, the methods used for estimating bulls' breeding value have been improved from contemporary comparison to mixed model.

More than that, the fast evolution of the electronic equipment for data processing allowed as linear mathematical models to be largely used in breeding value assessment in almost all the countries at the world level.

In Romania, contemporary comparison was successfully applied for an important period of time, but the need of higher precision in breeding value estimation imposed to be replaced by BLUP and mixed model.

The simplified BLUP model established and utilized in this research work has demonstrated a high precision of breeding value a reason to consider this model as one of the best for a correct bulls' classification. In this way, farmers could chose the best bulls mentioned in the bulls catalogue for improving milk production characters in the dairy cow population.

Also, the fact that milk yield is closely correlated with milk quantity, it is enough to take into consideration the hierarchy of the bulls established on their breeding value for milk yield.

The comparison regarding the bulls' hierarchy established by the two methods: the simplified BLUP model and contemporary comparison proved that in some cases, it is possible as the bulls' position to be similar.

The use of the BLUP model and mixed model in the current animal breeding is a complex, useful and efficient tool for breeding value estimation with the highest accuracy with a deep impact on the correct hierarchy of the reproductive animals.

In this way, dairy farmers could chose the best bulls from the bulls catalogues according to their breeding value for milk production characters and use their frozen semen in artificial insemination in order to increase milk yield in the cow population.

ACKNOWLEDGMENTS

The author thanks the dairy farmers where the bulls' daughters were tested during the 305 days of the 1st lactation and for their support to provide the data needed for checking the availability of this simplified mixed model.

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