Estimation of Genetic Parameters of Some Productive and Reproductive Traits in Italian Buffalo. Genetic Evaluation with BLUP-Animal Model

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ABSTRACT : In this study, the Italian milk recorded buffalo population from 1974 to 1996 was analysed with the purpose to estimate genetic and environmental variability and provide genetic parameters for the most important economic traits. High variability between herds was evident due to the poor knowledge of feeding requirements and husbandry technology in this species compared to cattle. Age at first calving was reduced by 57 days during the considered years following efforts made in better feeding and management from 1990; on the contrary, calving interval has increased by 17 days as a consequence of forcing buffaloes to calve in spring, in order to have the peak milk yield when milk is much better paid. Average milk yield increased by 1853 kg during these years, while lactation duration was reduced by 30 days. Season of calving has no effect on all traits. Calving order has a positive effect on milk yield especially because older cows produce more milk in shorter lactations. Heritability for the age at first calving and calving interval was 0.26 and 0.05 respectively. Heritability of productive traits, milk yield and duration of the lactation was 0.19 and 0.13 respectively, with repeatabilities of 0.40 and 0.26. Genetic trend for milk yield was 2.1 kg milk/year for the bulls and 1 kg for all population. The high genetic variability of milk production as well as duration of the lactation, indicates that there are good opportunities for genetic improvement when including these traits in a selection scheme. The low genetic trend registered over 15 years of recording activity can be explained by the fact that neither progeny testing was performed or selection schemes were implemented, due to the difficulties to use artificial insemination in buffalo. *(Asian-Aust. J. Anim. Sci. 2001. Vol. 14, No. 6 : 747-753)*

Key Words : Milk, Age at First Calving, Calving Interval, BLUP-Animal Model

INTRODUCTION

The main purpose of buffalo farming in Italy is the production of milk which is all processed into a high quality and highly appreciated cheese named *mozzarella*. Because of the increasing demand for this dairy product, in the eighties, we assisted to a fast increase of the size of buffalo herds all over the country. From 1985 to 1996, number of buffaloes increased by 48% (from 101,000 heads to 150,000). Buffalo milk production amounts to 150,000 tons/year (ISMEA, 1993). Because buffalo is not submitted to the restrictions established by the European Union to reduce cow milk production, a further increase in buffalo milk production can be foreseen.

Average lactation milk production of a buffalo is 1999 kg, fat and protein percentages are 8.24 and 4.64 respectively (AIA, 1996). In Italy, buffalo milk recording of the productivity started in 1974 by the Italian Breeders Association which was assigned the task of running buffalo herdbooks in 1980. Twenty-five thousands buffaloes/year (20% of total number) are milk recorded every four weeks during the whole lactation in order to assess milk yield, as well as fat and protein content.

According to Pilla and Moioli (1992), the genetic gain for milk from 1975 to 1990 was only 4.6 kg/year, and it is likely that nothing has changed in the following years, which means that no selection has been performed. Furthermore, the results of the progeny testing scheme carried out by the Italian Breeders Association from 1984 to 1996 were disappointing: in fact, due to the difficulties in performing artificial insemination, the farmers made very little use of the semen of the bulls on test.

The methodology for genetic evaluation of buffalo for milk yield was recently approached by Jain and Sadana (2000); however, selection schemes should not be aimed only to increase milk yield and quality but should consider functional traits like age at first calving and calving interval in order to obtain higher productivity all over the lifetime. Optimization of buffalo efficiency requires a prompt re-establishment of reproductive functions after calving together with the reduction of the age at first calving. According to many authors, major causes of culling in buffalo are poor reproductive performances (Ahmad et al., 1992; El-Hariri and Shalash, 1980) mainly for the number of days open (Jainuden, 1990; Shrivastava and Karcheh, 1986), for seasonal estruses (Madan, 1988; Tomar, 1984; Rao and Kogadali, 1983) and for various pathologies as well as congenital anomalies of reproductive tract (Tomar, 1984; Kulkarni, 1992; Awad et al., 1984; Gupta et al., 1991).

Many authors refer that genetic variability of reproductive traits in buffalo is low (Salah-Ud-Din, 1990; Raheja, 1992; Biradar, 1991; Tomar and

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Tripathi, 1992). However, most selection indexes that have been proposed by Indian, Egyptian and Pakistani researchers always take into account reproductive patterns (Gajbhiye and Tripathi, 1991; Juma et al., 1991; Kotbi et al., 1987). In Italy, Scardella et al. (1994) and Catillo et al. (1993) have analysed the variability of calving interval, age at first calving, season of calving and lifetime production by making evident the highly significant effect of environmental factors. An analysis of both genetic and environmental factors affecting milk production in Italian buffalo was found only in the paper from Pilla and Moioli (1992).

The present work aims to analyse the Italian milk recorded buffalo population from 1974 to 1996, estimate genetic variability and provide genetic parameters for the most important economic traits.

MATERIALS AND METHODS

All records were provided by the Italian Breeders Association and obtained from the official activity of recording of the productivity. All animals born from 1974 to 1994 were included with the following records: age at first calving, calving interval, milk production in the whole lactation, duration of the lactation. Records of animals lacking in pedigree information were not considered, as well as records which were considered non correct, fixing the following limits for the acceptance of the record:

- age at first calving from 550 to 1450 days;
- calving interval from 280 to 1095 days;
- lactation duration: minumum 150 days.

We have therefore analysed 94,028 records of 28,701 buffaloes in 223 herds. Of the 223 herds, 22 consist of groups of small herds that were pooled together on the basis of geographical area and husbandry system so that each herd had at least 40 records in one year. Although it is known that the pooling of records across management groups might confound the estimate of the effect of the sire, by increasing the additive genetic variance of the sires of the pooled herds, the environmental variability between pooled herds was made the lowest possible by grouping only those herds that were located in a close area and used the same husbandry and feeding systems. By using this method, it was possible to increase the informative sample and not to lose many information deriving from small herds.

The herds which where not connected through the sire, the dam or the animal itself, were not included.

Months of calving were grouped in four seasons: 1: Jan., Feb. and March; 2: Apr., May and June; 3: Jul., Aug., Sept.; 4: Oct., Nov., Dec. Parity was also included in the model used for the analysis, grouping together all calvings after the 6th.

Age at first calving was analysed with the following mixed model:

$$Y = Xh + Za + e \qquad (1)$$

where

Y is the known vector of observations,

X is the incidence matrix of fixed effects: herd, year of calving, season of calving;

Z is the incidence matrix of the random effect, the animal;

$\underline{h}$ is the unknown vector of fixed effects: herd, year of calving, season of calving;

$\underline{a}$ is the vector of additive genetic effects,

$\underline{e}$ is the vector of residual effects.

It was assumed that the variance-covariance structure for the trait with this model is as follows:

$$V \begin{bmatrix} a \\ e \end{bmatrix} = \begin{bmatrix} \mathbf{A}\sigma_a^2 & 0 \\ 0 & \mathbf{I}\sigma_e^2 \end{bmatrix}$$

where:

A is the numerator of the relationship matrix,

I is an identity matrix with order number of records,

σ_a^2 is direct genetic variance,

σ_e^2 is variance due to residual (temporary environmental) effects.

Calving interval, milk yield and duration of the lactation were analysed with the following mixed model:

$$Y = Xh + bf + Za + Wp + e \qquad (2)$$

where:

b is the regression coefficient and $\underline{f}$ the vector of the independent trait age at calving;

W is the incidence matrix of the buffaloes with a record;

$\underline{p}$ is the vector of random permanent effects.

It was assumed that the variance-covariance structure for each trait with this model is as follows:

$$V \begin{bmatrix} a \\ p \\ e \end{bmatrix} = \begin{bmatrix} \mathbf{A}\sigma_a^2 & 0 & 0 \\ 0 & \mathbf{I}_p\sigma_e^2 & 0 \\ 0 & 0 & \mathbf{I}\sigma_e^2 \end{bmatrix}$$

where:

A is the numerator of the relationship matrix,

$\mathbf{I}_p$ is an identity matrix with order number of animals with records,

$\mathbf{I}_e$ is an identity matrix with order number of records,

σ_a^2 is direct genetic variance,

σ_p^2 is permanent environmental variance,

σ_e^2 is variance due to residual (temporary environmental) effects.

Solutions and variance components - additive genetic, permanent environmental and residual, were obtained through a REML procedure (Boldman and Van Vleck, 1991).

Additive genetic solutions - breeding values - for each trait were averaged by year of birth for the total population and for the bulls separately to verify the genetic trend. Accuracy of breeding values was calculated according to Meyer (1989).

RESULTS

In table 1 herd effect is reported for the four traits and for three geographical areas: North, Centre and South of Italy. Variability between areas is evident, especially for the age at first calving. The most productive buffaloes are located in central Italy; they have also shorter lactations. We explain the high variability between herds for the poor knowledge of feeding requirements and husbandry technology in this species compared to cattle. In Italy, often, feeding and husbandry systems used for dairy cattle are applied to buffaloes.

The effects of calving year was averaged in the three periods representing the three decades of milk recording activity (table 2) to make any trend more evident. The age at first calving was strongly reduced, in order to avoid non productive time, following efforts made in better feeding and management from 1990. On the contrary, calving interval has increased as a consequence of forcing buffaloes to calve in spring, in order to have the peak milk yield in late spring and summer when milk is much better paid.

There was a growing trend in milk yield for the years studied, with a maximum of +157 kg combined with shorter lactations (-15 days).

From table 3 it is evident that the season of calving has a mild effect on all traits. Parity (table 4) did not affect calving intervals, while it has a positive effect on milk yield especially because cows at fourth and fifth parity produce more milk in shorter lactations.

In table 5, variance estimations as well as genetic parameters for all traits are reported. Heritability estimate for the age at first calving (0.26) is higher than the one for calving interval (0.05), very likely because the first trait depends very much on the reaching of puberty and can be affected to a lesser extent by management practices. h^2 for the age at first calving obtained in this work is quite satisfying, indicating a genetic component of 26% of total variability. Genetic parameters of reproductive traits that we found in literature were 0.05 and 0.12 for calving interval from Raheja (1992), while Dahama (1992) indicated that h^2 of a reproductive index including both age at first calving and calving interval was 0.28. When the reproductive index did not include age at first calving but number of calvings in lifetime (Dutt and Yadov, 1997), h^2 was much lower: 0.06. Also h^2 of anestrus 0.06 according to Tomar and Tripathi, (1985) has an effect on calving interval. In Iraqi buffaloes, Juma et al. (1991) found h^2 values for calving interval of 0.13. In our study, repeatability of calving interval was low (0.09) because of the little effect of permanent environmental factors, due to the culling of buffaloes with fertility problems.

Heritability of productive traits, milk yield and duration of the lactation was 0.19 and 0.13 respectively, with repeatabilities of 0.40 and 0.26.

Table 1. Estimates of herd effects by geographical area, for age at first calving, calving interval, milk yield and lactation duration

Area	No. herds	Age at first calving (days)	Calving interval (days)	Milk yield (kg)	Lactation duration (days)
North	14	-40.52	5.79	1084	2.46
Centre	57	-28.88	-10.82	1414	-11.31
South	152	14.56	3.53	-630	4.02

Table 2. Estimates of effects of year of calving, within three periods for age at first calving, calving interval, milk yield and lactation duration

Period	Age at first calving (days)	Calving interval (days)	Milk yield (kg)	Lactation duration (days)
74-79	25.20	-8.81	- 1696	14.67
80-89	7.22	-0.73	- 82	1.90
90-96	-31.92	8.59	157	-15.29

Table 3. Estimates of effects for the season of calving

Season*	Age at first calving (days)	Calving interval (days)	Milk yield (kg)	Lactation duration (days)
1	4.52	8.32	289	1.41
2	-2.42	-2.11	158	-1.75
3	0.27	-8.28	-215	-0.90
4	-2.37	2.07	-232	1.24

(*) 1 = Jan., Feb. and March. 2 = Apr. and May and June. 3 = Jul., Aug., Sept. 4 = Oct., Nov. and Dec.

Table 4. Estimates of effects for parity

Parity	Calving interval (days)	Milk yield (kg)	Lactation duration (days)
1	8.15	-3398	40.90
2	-0.13	-127	2.29
3	-1.63	579	-7.87
4	-2.00	783	-10.07
5	-1.99	886	-11.26
6	-1.58	780	-9.66
>6	-0.82	497	-4.32

Table 5. Structure of the data base, variance components and genetic parameters for age at first calving, calving interval, milk yield and lactation duration

	Age at first calving (days)	Calving interval (days)	Milk yield (kg)	Lactation duration (days)
No. observations	21098	94028	94028	94028
No. Animals (1)	27884	34193	34193	34193
No. buffaloes with record.	21098	28701	28701	28701
Sires (2)	775	820	820	820
Dams (2)	10984	12001	12001	12001
σ_a^2 (3)	4802.97	359.49	320	278.04
σ_p^2 (4)	-	355.11	360	273.71
σ_e^2 (5)	13896.82	7019.46	1000	1588.48
h^2 (6)	0.26	0.05	0.19	0.13
r (7)	-	0.09	0.40	0.26

(1) Including sires and dams with no record. (2) Of recorded progeny. (3) Genetic variance. (4) Permanent environmental variance. (5) Residual variance. (6) Heritability. (7) Repeatability.

These values are lower than those found by Pilla and Moioli (1992), which were calculated on a much lower number of records (2/3 less) and different acceptance limits were established for the records. However, genetic variances were similar: genetic standard deviation for milk yield was here 179 kg milk (it was 194 kg in the previous work). We can conclude that due to the high genetic variability of milk production as well as duration of the lactation, good opportunities for genetic improvement exist. The duration of the lactation has a high effect on the variability of milk production and the variability of these traits depends to a large extent on environmental factors, mainly feeding systems: in fact, by reducing the energy content of the ration during lactation, the buffalo tended to dry-off. The obtained result, i.e. that 13% of the variability of the duration of the lactation has a genetic basis, provides useful information on the inclusion of this trait in global selection indexes for buffalo.

Figures 1 and 2 indicate genetic trends of age at first calving and calving interval, milk yield and duration of the lactation, separately for bulls and for all population. In most cases, a variable trend from one year to the following is evident.

For age at first calving, no variation is evident during the years both in the graph and from the regression coefficient of the observations on the year of birth: -1.2 +/- 0.05 days and -2.7 +/- 0.74 days respectively for all population and the bulls only. We conclude that no selection programme for decreasing the age at first calving was applied during the considered period. Also for calving interval the genetic trend was close to zero, but this trait has much lower

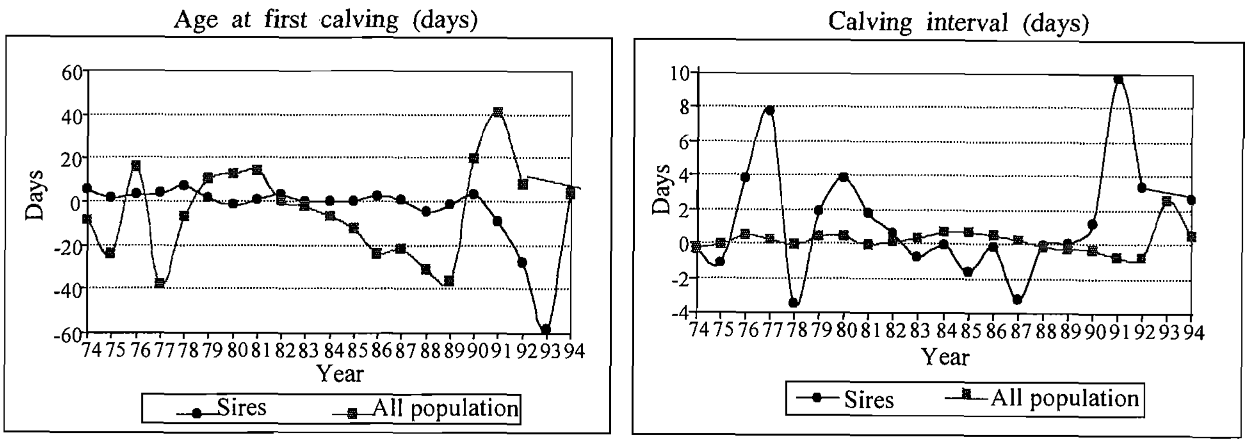

Figure 1. Genetic trend for age at first calving and calving interval for all population and sires

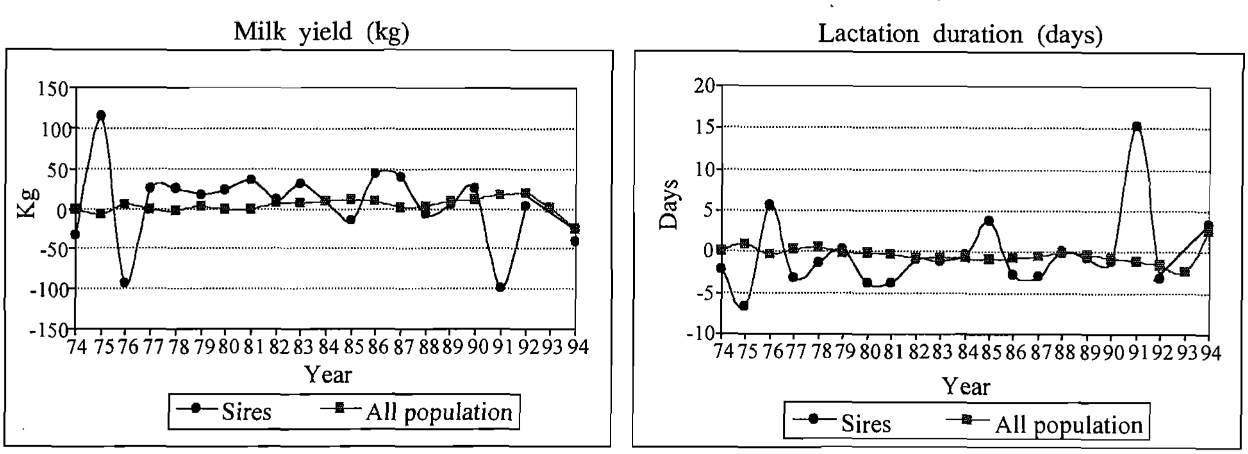

Figure 2. Genetic trend for milk yield and lactation duration for all population and sires

genetic determinism.

Genetic trend for milk yield was 2.1 kg milk/year for the bulls and 1 kg for all population. High variability of breeding values during the years is evident for the bulls while, for all population, values were steadier. Same results were obtained for the duration of the lactation.

In table 6, average values of breeding values for all traits as well as averages of individual accuracy values associated with breeding values are reported. Bull breeding values are very variable according to the year of birth, which indicates that farmers choose them only on the basis of a personal evaluation. Bull breeding values for age at first calving reported in table 6 indicate that for this trait bulls have a higher genetic potential compared to females to reduce non-productive life in their progeny, with a variability of 55 days and an accuracy of estimation of 50%.

There are non significant differences between the average breeding values for calving interval in bulls and females, and the accuracy is lower (36%).

In the trait milk production, average breeding value of sires is lower than average breeding value of females, which confirms the fact that in Italy selection is performed on the basis of females. The variability of breeding values of production traits is higher in bulls (accuracy= 54% for milk yield and 49% for lactation duration). Because accuracy values depend on the number of observations, the incomplete registration of the genealogies caused the values to be so low.

DISCUSSION

From the reported study which included all the Italian milk recorded buffalo population, it is evident that no genetic improvement was obtained despite of the performed milk recording activity, for the following two reasons:

1. It is difficult to register the genealogies, therefore many records are incomplete;
2. Artificial insemination (AI) was applied to a very low extent, therefore the planned progeny test could not be performed.

The two mentioned reasons contributed to slow-down buffalo genetic improvement in Italy. In fact, buffalo estrus is not detectable, therefore inseminations often are offered at the wrong time, causing a low pregnancy rate. Barile et al. (1999) refer a fertility rate of 45% after two inseminations, and this value is highly variable between herds and inseminators (from 7 to 70%). Moreover, because buffalo suffer from seasonal anestrus, farmers are afraid of missing detection of heat because they could miss the pregnancy and the milk yield of all year; for this reason they assign two or even three bulls at the same time to one group of breedable buffaloes. This practice, while increasing fertility rate, does not allow paternity assessment and bulls cannot be genetically evaluated. A paper from Pilla et al. (1996) refers that, in Italy, sire registration was missing in 50,000 out of 60,000 milk recorded animals. In this situation, we might suggest the use of techniques like finger printing for paternity assessment, until the conditions for which AI will be more successful are established.

However, the high variability, both environmental and additive genetic of the analysed traits will allow to set up the selection schemes for fast genetic improvement. From the examined results it is possible to conclude that when using the breeding value for age at first calving we will reduce the non-productive period in any management system. The same will apply when using the breeding values for milk yield and lactation duration. On the contrary, when using the breeding value for calving interval, no great improvement of this trait is to be expected, due to the poor genetic determinism of this trait.

Table 6. Average breeding values (BV) for age at first calving, calving interval, milk yield and lactation duration, standard deviations (SD) and accuracy of estimation

	Females	Sires	Total
Age at first calving			
no. observations	27109	775	27884
BV (days)	-2.55	-8.65	-2.72
SD (days)	37.74	55.33	38.35
Accuracy	0.49	0.50	0.49
Calving interval			
no. observations	33373	820	34193
BV (days)	-0.02	-0.27	-0.02
SD (days)	7.49	9.28	7.54
Accuracy	0.36	0.35	0.36
Milk yield			
BV (kg)	10	-10	10
SD (kg)	100	120	110
Accuracy	0.54	0.52	0.54
Lactation duration			
BV (days)	-0.56	-0.33	-0.55
SD (days)	8.88	10.88	8.93
Accuracy	0.49	0.48	0.49

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