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Genetic trend for milk yield in Guzerat herds participating in progeny testing and MOET nucleus schemes

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ABSTRACT. Genetic trends for 305-day milk yield (P305) in Brazilian Guzerat herds under selection were compared. Data from 4898 lactations of 3179 purebred and crossbred cows from various regions of Brazil were used. Milk yield was adjusted for mature age and the contemporary groups were defined as herd and calving year. Genetic parameters were estimated using the MTDFREML program. The model included the random effects of animals and permanent environment, and herd-calving year, calving season and genetic composition as fixed effects. Genetic trends were estimated by linear regression of weighted average estimated breeding values as a function of calving year. The average P305 was 2065 ± 922 kg and the heritability was 0.23 ± 0.03. The annual genetic trend in estimated breeding values of cows for P305 was 7.09 ± 0.71 kg between 1987 and 2004, and 6.47 ± 2.35 kg between 1997 and 2004. For cows born and raised in the multiple ovulation and embryo transfer (MOET) nucleus, this trend was 36.46 ± 24.54 kg/year between 1997 and 2004, 183.14 ± 47.94 kg/year between 1997 and 2000, and 9.13 ± 19.19 kg/year between 2001 and 2004. An average inbreeding coefficient of 0.04 was found for inbred MOET cows in 2004. Increasing the size of the family and introducing new progenies changed reliabilities and predicted transmitting ability estimates of MOET sires. In conclusion, there was a positive genetic trend for milk yield in the MOET nucleus at low inbreeding coefficients due to the increased accuracy and estimated genetic merit, but no changes in the average milk yield were observed.

Key words: MOET, Selection, Progeny test, Zebu, Dairy cattle

INTRODUCTION

Breeding programs for the main economically important traits of Zebu dairy cattle have been recently introduced in Brazil. When the adaptation of Zebu cattle and their milk production potential under tropical conditions are taken into account (Winkler and Penna, 1992), constant monitoring of such programs becomes essential to help define new strategies and adopt technologies and/or methods that lead to improved results for the traits of interest.

Improvement of milk traits is based on the use of genetically superior sires in the herds. These sires are often evaluated in progeny test programs using BLUP and animal model (Arnold et al., 1992). The reliability of BLUP estimated breeding values, defined as the squared correlation between the true breeding value and its estimate, depends on the amount of data used that contributed to the genetic evaluation (Ufford et al., 1978). This method has also been used for the genetic evaluation of Zebu dairy sires in Brazil (Martinez et al., 2005; Teodoro et al., 2005). Regression and correlation coefficients are usually determined to assess the genetic progress of herds participating in breeding programs for milk traits (Boichard et al., 1995).

Some studies undertaken in Brazil have reported a low-genetic progress rate in the Zebu dairy herds under selection, which is attributed to the long generation interval due to both the advanced age at first calving and the long calving interval (Queiroz et al., 1991; Magnabosco et al., 1993; Verneque et al., 2005). Lôbo et al. (1982) and Verneque et al. (1996) estimated yearly trends of 7.0 and 13.88 kg milk, respectively, for the Gyr breed in Brazil. In other studies mainly involving specialized breeds, values of genetic progress in milk yield have been reported ranging from zero to 139 kg/year (Canon and Munoz, 1991; Chaudihary et al., 1994; Boichard et al., 1995; Roman et al., 1999; Hansen, 2000).

Recently, multiple ovulation and embryo transfer (MOET) type nucleus breeding programs proposed by Nicholas and Smith (1983) have been implemented in many countries. The main advantages of these programs include the initial genetic lift due to the genetic superiority of the founder parents and the reduced generation interval since sires are evaluated early. These schemes permit an increase in the genetic progress rate, although there is the possibility of increasing the inbreeding coefficient. Considering the benefits of these schemes, the first Brazilian MOET nucleus, an open-MOET selection nucleus, was set up in 1994 in Guzerat cattle (Penna et al., 1998), at the same time as a progeny test.

The first genetic evaluation of Guzerat individuals in the progeny test and in the MOET nucleus scheme was performed in 2000, with a total of six evaluations having been conducted until now (Teodoro et al., 2005). It is expected that these results had already contributed to the genetic improvement of the Guzerat breed. Thus, the objective of the present study was to evaluate the genetic progress for milk production in the Guzerat dairy herds and particularly in those participating in the MOET nucleus.

MATERIAL AND METHODS

Animals and management

Data from the Brazilian Zebu Breeders Association and Embrapa Dairy Cattle - National Dairy Cattle Research Center, comprising a total of 4898 lactation records from 3179 cows, 77% Guzerat purebreeds and 23% Guzerat crossbreeds, were used in this study to estimate genetic parameters and merits. Lactations were recorded from 1987 to 2004 in 42 herds distributed in the Southeast, Northeast and Central-West regions of Brazil.

In the progeny test, the 52 sires studied were divided into seven groups representing several genetic lines of the Guzerat breed in Brazil, whereas in the MOET nucleus 40 full-sib families originating from the superovulation and insemination of 25 elite donors and 16 elite sires were evaluated. Donor females ranged from 2.2 to 20.5 years old at the time of superovulatory treatment and 30% of these were 6-8.9 years old. Prior to superovulation, donors were examined for evidence of reproductive disorders, and all had had at least two consecutive estrous cycles (18-24 days long). After the treatment, donors were artificially inseminated 14 h after the onset of estrus with frozen-thawed semen three or four times every 6 h. Non-surgical flushing was carried out approximately 7 days after the last insemination. Following recovery, embryos were cleaned and evaluated under stereoscopic magnification for embryonic stage and quality. All embryos considered viable, i.e., in the morula, early blastocyst, mid blastocyst, late blastocyst or hatched blastocyst stage, and also in excellent, good or fair condition, were loaded into a straw and immediately transferred to recipients using the surgical method.

At first flushing, superovulation treatment failed in around 20% of the donors, and the ones in which it succeeded well averaged 7.53 ± 5.65 (1-25) viable embryos. Approximately 95% of the donors were flushed at least twice; approximately 50% of those flushed twice were flushed a third time. Recipients were crossbred heifers, varying from 1/2 to 3/4 Holstein-Zebu. They were kept under good nutritional and management conditions until treatment with F-2α prostaglandin to attain synchrony with expression of estrus of embryo donors. Pregnancy diagnosis was carried out 53 days after embryo transfer by rectal palpation. A pregnancy rate of almost 65% was reached.

The 305-day lactation records previously adjusted for mature age were used in the genetic evaluation. Ongoing lactation records over 140 days before the evaluation date were extrapolated to the mean of a breed lactation length of 266 days using adjustment factors (Gonçalves et al., 1996). In the progeny test scheme, only sires with daughters in at least two herds were evaluated. The effects of herd and calving year were considered for contemporary grouping and only groups containing at least three records were used in the analysis. The first lactations of the full-sib cows were recorded on the MOET nucleus farms. In addition to the records of all full sibs, records from paternal and maternal half sibs, collateral and ancestral relatives and contemporaries were used in the genetic evaluation of young sires from the MOET nucleus.

Statistical analysis

The genetic parameters and genetic merits (estimated breeding value and expected predicted difference - EPD) for milk production were estimated by means of a mixed animal model using the MTDFREML program (Boldman et al., 1995), including a complete relationship matrix. Milk yield was previously adjusted for mature age, and the contemporary groups were defined as herd and calving year. The model included herd-calving year, calving season and genetic composition of the daughter as fixed effects, and the random effects of permanent environment, animals (daughter, sire and cow) and error.

For estimation of annual genetic trends, only estimated breeding values of cows whose sires had at least four lactation daughters were used. Estimates were weighted by their respective reliabilities and averaged for each calving year. Means were then regressed as a function of calving year using the PROC REG program (SAS®). Two periods were considered: the first from 1987 to 2004, and the second from 1997 to 2004, since in 1997 the daughters born after the beginning of the Guzerat breeding program ended their first lactation.

An additional data set was used for the analysis of genetic trend in the MOET nucleus. In addition to the analysis of the period between 1997 and 2004, a complementary analysis was performed in two periods, from 1997 to 2000 and from 2001 to 2004, due to the decrease in genetic trend observed in the later period.

RESULTS AND DISCUSSION

The average milk yield for 305 days of lactation was 2065 ± 922 kg, with a heritability estimate of 0.23 ± 0.03. Estimated breeding values for milk production ranged from -598 to +912 kg. These estimates indicate the possibility of response to selection for this trait in the Guzerat breed. The mean age at first calving and mean calving interval were 42 ± 7 and 17 ± 3 months, respectively. These values are considered high and need to be reduced to permit a higher rate of genetic progress and a faster financial return for the production system (Verneque et al., 2005).

The annual genetic trend for the complete data set was 7.09 ± 0.71 kg of milk from 1987 to 2004 (Figure 1). From 1997 to 2004, the coefficient was 6.47 ± 2.35 kg milk/year. These results indicate a respective annual increment of about 0.4 and 0.3% in mean milk production up to 305 days of lactation. Despite these positive coefficients, the phenotypic trend after the beginning of the breeding program (1997) was negative (-45.47 ± 12.76 kg/year).

The genetic trends for milk yield found in the present study are similar to the 7.0 kg/year reported by Lôbo et al. (1982) but lower than the 13.88 kg/year obtained by Verneque et al. (1996), both for the Gyr breed in Brazil. These rates were considerably lower than those reported for Zebu and European herds (Canon and Munoz, 1991; Chaudihary et al., 1994; Boichard et al., 1995; Roman et al., 1999; Hansen, 2000).

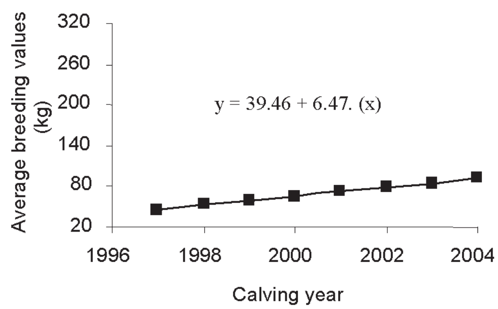

Figure 1. Trend in average breeding values (kg milk) of all cows in the Guzerat dairy herds as a function of calving year (1-8).

The present results show that the breeding program still does not have the expected impact on milk yield in Guzerat dairy herds. This fact can be attributed to the small number of recorded cows, continuous entry of new sires and cows in the milk recording program, a more advanced age at first calving and the long calving interval, as well as the low frequency of use of sires proven and positive for milk yield. Many of these aspects are due to the fact that the Guzerat breeding program was introduced recently. Other aspects are related to dairy operations such as fulfillment of nutritional needs and diet formulation, and milking management (Akers, 2000).

Analysis of the estimated breeding values of cows born and raised in the MOET nucleus showed a regression coefficient of 36.46 ± 24.54 kg milk/year for the period from 1997 to 2004 (Figure 2). This value was positive and much higher than that obtained in the analysis of the complete data set of the same period, i.e., 6.47 ± 2.35 kg. This result, together with the phenotypic trend of 4.14 ± 33.29 kg in the MOET nucleus, indicate that this scheme effectively contributed to the improvement of milk yield in these animals. Therefore, this breeding scheme was the main factor responsible for the genetic trend in the Guzerat dairy herds, since the genetic trend of -5.1 ± 2.7 kg milk/year was estimated from 1997 to 2004 when lactation records of MOET cows were eliminated from the analysis.

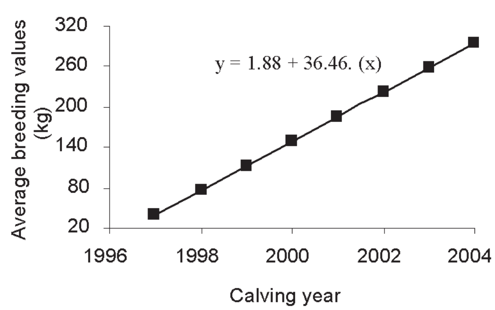

Figure 2. Trend in the average breeding values (kg milk) of Guzerat MOET nucleus cows as a function of calving year (1-8).

Different regression coefficients were obtained when analyzing the average estimated breeding values of MOET nucleus cows during different periods (Figure 3). The trend for milk yield was 183.14 ± 47.94 kg/year for the period from 1997 to 2000, with a corresponding phenotypic trend of 137.30 ± 70.43 kg. These increases were attributed to the increase in the availability of semen from positive proven sires and to the more frequent use of elite dams in the MOET nucleus (Table 1), both resulting in more accurate breeding value estimates. The genetic gain during this period surpassed that in the present study and in studies involving other breeds, thus confirming the importance of MOET nucleus selection as a tool for the improvement of genetic merit and average milk production for 305 days of lactation.

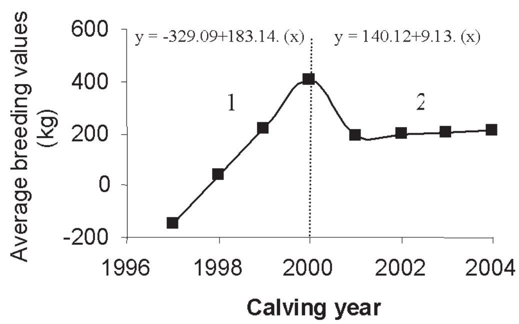

Figure 3. Trends in the average breeding values (kg milk) of Guzerat MOET nucleus cows as a function of the two periods of calving year (1: 1997-2000; 2: 2001-2004).

Table 1. Average estimated breeding values (EBV) for milk yield of sires and dams according to the calving year of their daughters.

	Year	EBV sires					EBV dam				
		Average	Min	Max	N	%-	Average	Min	Max	N	%-
General herd											
	1997	4 ± 206	-472	734	87	49	40 ± 199	-530	814	214	46
	1998	25 ± 206	-472	734	110	40	72 ± 209	-545	816	245	31
	1999	16 ± 210	-472	734	121	40	48 ± 189	-439	726	229	41
	2000	12 ± 188	-472	734	129	40	64 ± 212	-558	776	191	39
	2001	23 ± 210	-573	734	128	40	77 ± 210	-434	727	198	39
	2002	9 ± 189	-573	734	130	43	50 ± 186	-434	815	231	37
	2003	27 ± 213	-573	734	112	40	101 ± 222	-545	816	189	32
	2004	70 ± 270	-580	734	62	37	129 ± 216	-290	591	89	25
MOET nucleus											
	1997	-115 ± 506	-472	244	2	80	37 ± 228	-138	294	1	83
	1998	223 ± 378	-165	591	3	45	204 ± 190	-138	358	6	33
	1999	107 ± 386	-240	591	4	44	262 ± 166	-45	439	8	9
	2000	122 ± 397	-292	591	6	27	287 ± 208	25	570	7	-
	2001	120 ± 402	-573	591	8	38	278 ± 215	-45	570	7	23
	2002	77 ± 400	-573	591	8	43	238 ± 161	-45	519	10	11
	2003	234 ± 367	-573	686	12	39	297 ± 156	50	533	12	-
	2004	153 ± 396	-580	591	13	24	295 ± 157	39	533	14	-

Min = minimum; Max = maximum; N = number of sires or dams; %- = percentage of daughters of negative sires.

During the subsequent period from 2001 to 2004, the trend for milk yield was 9.13 ± 19.19 kg/year. The decrease in the regression coefficient from 2001 to 2004 was attributed mainly to the reduction in the average parental estimated breeding value of cows that had calved during this period, especially of their sires, and to the increase in the percentage of cows, daughters of negative sires and dams (Table 1). The corresponding phenotypic trend was -5.62 ± 116.08 kg milk/year.

The decrease in the average estimated breeding value of cows observed during the second period may reflect a reduction in the average parental estimated breeding values of animals used as parents in the MOET nucleus (Table 1), but, in addition to these factors, the environmental conditions may also have prevented the expression of the genetic merit of the cows. The reduction in the average parental estimated breeding values was due to the introduction of new sires and dams to constitute new families in the MOET nucleus in an attempt to not only control the inbreeding rate but also to increase genetic variation. This practice probably reduced the genetic progress during this period; however, it is a justified procedure in view of the importance of reproductive efficiency for the genetic and economic progress of the MOET nucleus and the production system (Verneque et al., 2002).

The percentage of cows, daughters of negative sires, remained constant in the milk herds until 2004 despite the increased availability of semen of positive bulls, while in the MOET nucleus this percentage showed a continuous reduction during this period (Table 1), a fact also explaining the superior results in terms of genetic progress in the nucleus. Aspects related to environmental effects on milk production should also be taken into consideration, although these conditions are strictly controlled in the MOET nucleus, while in milk herds these conditions vary widely.

The concomitant analysis of estimated breeding values and milk yields of cows that had calved in the dairy herds and in the MOET nucleus between 1996 and 2003 agreed with the results presented (Figures 4 and 5). As can be observed, the trend in the estimated breeding values found for cows of the dairy herds (Figure 4), although positive, still did not lead to changes in average milk production because of the frequent use of bulls negative for milk yield and probably because of the maintenance or reduction in the nutritional and management conditions of the herds. During this period, 22% of the bulls used in the dairy herds were negative for milk yield, with an average estimated breeding value of -352 kg (range: -581 to -132 kg). On the other hand, a positive correlation between the trends for average milk yield and estimated breeding values was observed for MOET cows (Figure 5). The change in the average milk yield of MOET cows coincided with changes in the average estimated breeding value of their parents, irrespective of the environmental conditions of the nucleus.

The average inbreeding coefficient of MOET nucleus cows, in turn, was zero up to 2003 (Table 2). In 2004, three inbred cows arose, with an average inbreeding coefficient of 0.04. This inbreeding level is considered to be acceptable (Young, 1984) and is slightly lower than the average inbreeding coefficient of 0.05 found for the inbred cows in the dairy herds. This finding can be attributed to the maintenance of an open-MOET nucleus, as well as to the small number of generations, about four, used in the calculation of the inbreeding coefficient of the animals irrespective of their origin, i.e., milk herds or MOET nucleus. The average inbreeding coefficient estimated in the present study was close to that reported by Vieira et al. (2005), 0.03, for herds participating in the beef improvement program of the Guzerat breed.

This is a very important aspect of the MOET nucleus, especially when the harmful effects of inbreeding on reproductive performance are considered (Cassell, 2001). Some strat-

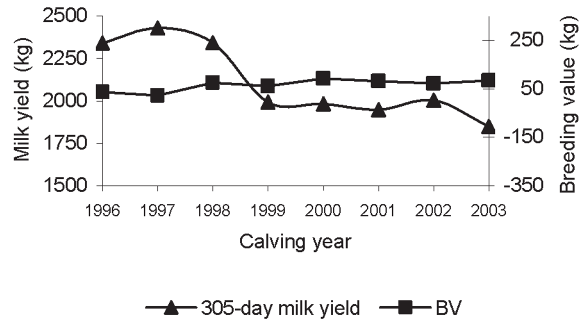

Figure 4. Trends in average 305-day milk yield corrected for mature age and respective breeding values (BV) in dairy herds.

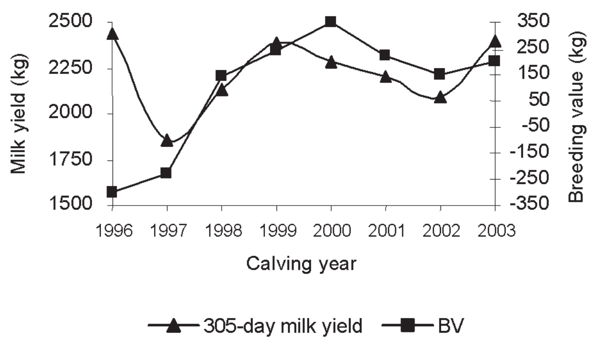

Figure 5. Trends in average 305-day milk yield corrected for mature age and respective breeding values (BV) in the MOET nucleus.

Table 2. Average inbreeding coefficient (F) of inbred cows in the Guzerat herds and in the MOET nucleus scheme under selection for milk yield.

Calving year	Total number of cows	F of cows (N)	Min	Max	Total number of MOET cows	F of MOET cows (N)	Min	Max
1997	310	0.11 (27)	0.02	0.31	5	-	-	-
1998	356	0.09 (24)	0.01	0.31	11	-	-	-
1999	384	0.08 (26)	0.01	0.25	9	-	-	-
2000	349	0.07 (29)	0.01	0.16	9	-	-	-
2001	412	0.06 (35)	0.01	0.16	23	-	-	-
2002	476	0.06 (46)	0.01	0.16	20	-	-	-
2003	440	0.05 (40)	0.01	0.10	25	-	-	-
2004	202	0.05 (29)	0.01	0.13	24	0.04 (3)	0.01	0.05

N = number of inbred cows; Min = minimum; Max = maximum.

egies have been proposed to prevent an increase in the inbreeding coefficient in the nucleus, including directed mating systems (Young, 1984; Toro et al., 1991; Dekkers, 1992) whose gains from selection are larger than the losses by inbreeding. For the future, some alternatives can be suggested to increase the genetic progress by selection with a minimum increase in the inbreeding coefficient. One proposal would be to keep the paternal path, on which the selection pressure is concentrated, closed. Another possibility consists of establishing selection lines.

The trend of the average of EPDs and their respective reliabilities obtained for three positive proven sires originated from the MOET nucleus and classified in the Guzerat sire summaries of 2001 to 2005. The inclusion of progeny information in the evaluation of these sires increased the reliability of the estimates for each evaluation (Figures 6 and 7, and Table 3). However, this effect was not observed for the EPD estimates which oscillated. Differences in environmental and management conditions and in the daughters' deviation from contemporaries between herds where the progenies were raised were among the factors responsible for these oscillations (Canavesi et al., 1995).

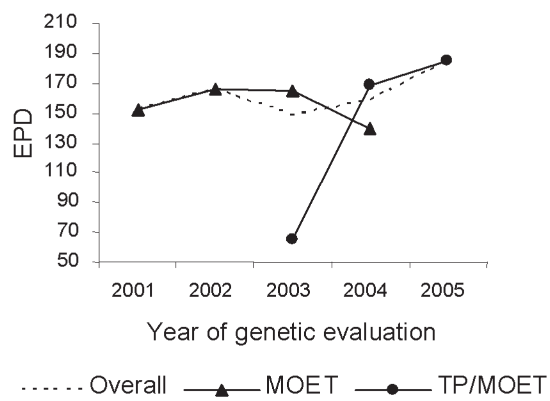

Figure 6. Trends in average expected predicted differences (EPDs) of MOET nucleus sires according to the type of information used.

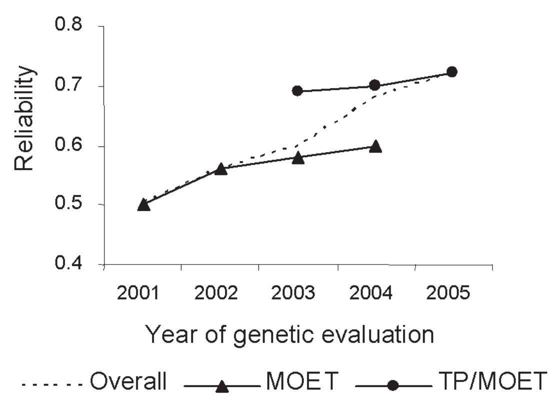

Figure 7. Trends in average reliabilities of MOET nucleus sires according to the type of information used.

The effect of progeny information on EPD estimates and reliabilities for MOET nucleus sires is evident from the concomitant analysis of Figures 6 and 7, and Table 3. Particularly from 2003 to 2004, an increase in the average EPDs for these sires could be seen as the progeny

Table 3. Number of full sibs (FS) and half sibs (HS) and of progenies (NP) in the herds (NH) in each year of genetic evaluation.

Sire	Year of sire summary				
	2001	2002	2003	2004	2005
	FS/HS (NP/NH)				
1	1/21 (-/-)	1/27 (-/-)	1/40 (-/-)	1/61 (3/1)	1/62 (6/1)
2	4/27 (-/-)	4/36 (-/-)	4/50 (5/2)	4/61 (16/6)	4/64 (27/7)
3	3/43 (-/-)	4/51 (2/1)	4/67 (9/1)	4/76 (13/1)	4/80 (21/1)

information was introduced (TP/MOET), while the average EPDs for sires evaluated based only on family information (MOET) remained practically constant until 2003 despite an increase in the amount and type of these data (Figure 6 and Table 3). With respect to reliability (Figure 7), a higher level was reached in the evaluations of MOET nucleus sires that used progeny information.

Simultaneous gathering of a large number of full- and half-sib data in sire evaluation, as observed from 2001 to 2002, can result in more reliable EPD estimates for the MOET nucleus animals (Figure 7). However, because of the variation in the superovulatory response (Peixoto et al., 2004), the MOET results are unpredictable and limit the success of selection in MOET nucleus schemes (Nicholas and Smith, 1983). Thus, the progeny information from other herds, mainly due to the small size of MOET families, permits higher levels of reliability of the EPD estimates of MOET sires and, in this case, can be used in genetic evaluations.

These results emphasize the importance of adding progeny information to genetic evaluation based on family information. This finding indicates that, despite the change in EPD values and their respective reliabilities, the evaluations based on family information were efficient in discriminating positive and negative bulls since the bulls classified as positive remained positive in all evaluations (Teodoro et al., 2005).

CONCLUSIONS

The MOET nucleus selection scheme can produce sires of high genetic merit for improvement of milk yield, although the average milk yield in the Guzerat dairy herds does not reflect as yet a benefit from the introduction of proven sires. The impact of the use of bulls submitted to progeny testing on the average milk production was still not positive and indicates the need for increasing the number of herds and daughters per herd. It is expected that the use of proven and positive bulls will increase over the next years in order to increase the profitability of the milk production system.

The inbreeding coefficients found for the MOET nucleus cows still seem to be low, thus not impairing survival, reproduction and production traits. However, the constant monitoring of this scheme is necessary, as well as the adoption of procedures to prevent an increase in the inbreeding coefficient to harmful levels, mainly in terms of survival and reproduction traits that, on a medium- and long-term basis, would make the MOET nucleus selection program impracticable.

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