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# Genetic trends in the development of crossbreeding system in beef breeding

**A.K.F.H. Bhuiyan[2], G. Dietl[1] and G. Klautschek[1]**

[1]Research Institute for the Biology of Farm Animals, D-18196 Dummerstorf, Germany, [2]Department of Animal Breeding and Genetics, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

## Abstract

This study was aimed to look at the effectiveness of a carried out beef crossbreeding program under recurrent selection in Germany. For this, single trait animal model restricted maximum likelihood (REML) and best linear unbiased prediction (BLUP) methodologies were used respectively for variance component and breeding value estimation. Estimated breeding values were regressed on year of birth to obtain estimates of genetic trend for each trait. Estimated annual genetic trends were: in beef cows, -0.38, 0.24, 0.50, 0.32, -0.35, 1.10 and 0.82 kg respectively for body weights at 6,12,15,18 months, first, second and third calving; in beef bulls, ranged from -0.003 to 0.12 cm for nine body measurement traits; 3.69 g and -4.94 NE (net energy) respectively for test period average daily gain and energy efficiency, for birth difficulty -0.002; in fattening hybrids, for body weight at the end of test period (WT-T) 1.18, 0.59,1.52 and 0.96 kg respectively in overall, industrial farms, breeding farms and testing stations; in beef x dairy animals, -0.0002 for birth difficulty and 0.025 kg for birth weight. All estimated trends except back width of beef bulls were significant, generally in the expected direction, low and were of 0.02 to 0.18, 0.07 to 0.33, 0.01 to 0.11 % of the population mean per year respectively for reproduction, production and body measurement traits. These results show that recurrent selection can also be successful for cattle breeding under specialised situations.

**Keywords:** Beef cattle, Crossbreedig, Genetic trend

## Introduction

A clear understanding of the genetic basis of breeding systems is essential before designing a suitable package program combining breeding, management and market needs for specified production situations. For that matter, analysis of genetic effects of various breeding systems in the destined production system is important. Moreover, for making valid conclusion about a particular breeding system, analysis of its effectiveness is equally important. The beef cattle crossbreeding programs which utilises heterosis and the additive genetic merit of different breeds have special value in recurrent selection program, where selection of straightbreds, for use in crossing, is based on the performance of their crossbred progeny. Hence, recurrent selection program can be an important tool for the development of new breeds that better fit production conditions and resources. Several workers have reviewed and reported the results of beef cattle breeding using various approaches and with different objectives (Mrode, 1988; Parnell and Morris, 1994; Gregory et al. 1995a and 1995b; Parnell et al. 1997) but data on the results of beef breeding program making use of recurrent selection approach is almost absent except Flower et al. (1964).

Higher growth rate and lower birth difficulty are very important traits for efficient meat production. Difficult births alone can cause significant economic losses to beef producers through increased risk of survival of both calf and cow and thus affecting entire profitability. But a biological antagonistic relationship exists between birth difficulty and growth traits (Tilsch, 1986; Gregory et al. 1995a) resulting in selection problems (Hanset, 1981). However, simulated selection experiments in beef cattle (Tilsch, 1986) and more recently, results from long-term selection for antagonistic traits in mice (Mohamed et al. 1998) have indicated that breeding programs would be successful if selection is based on an index of such traits. In this context, the genetic trend, which is the change in production per unit of time due to change in mean breeding value of the animals would be an indicator to determine success or failure of this kind of breeding programs. With above view, the objective of this study was to look at the effectiveness of a carried out beef crossbreeding program under recurrent selection in Germany.

## Materials and Methods

In the early 1970s a beef cattle breeding program was initiated in the Eastern part of the former German Democratic Republic (GDR). The objective of the program was to increase the quality and quantity of beef production. The Charolais and the German Beef Simmental were used as beef breed resources. The breeding criteria in the beef breeding part were different indices combining animals growth rate, birth weight and birth situation. Both pure and crossbred beef bulls and cows were selected on the basis of their predicted genetic merit calculated using the said indices. The selected bulls were then put under performance testing program for next step selection followed by progeny testing to make final selection on the basis of their pure-bred (with beef cows) and crossbred (with dairy cows- German Black and White) progeny performance. Performance and progeny testing of both pure and crossbred beef bulls were carried out at different environmental levels. At all stages of the breeding program, artificial insemination (AI) was practised as mating tool and for inbreeding management in the population, a kind of line mating (Falconer, 1989) was followed. The program was started in 1972 and successfully continued until 1990. During this period, the population included pure-bred animals of the said original breeds which were used for the development of a new race of cattle, locally called 'Uckermaerker'. However, at any stage, the crossbred animals formed major part of the population. The design of the breeding program was of recurrent selection type. The whole program was executed under a range of different production environments e.g. testing stations, bull breeding farms and industrial beef farms. In all environments, the nutritional level of the animals was rather poor. Further details on the initiation of the breeding program, origin of experimental animal populations, production environments and results of some preliminary analyses have been reported elsewhere (Löhrke and Klautschek, 1971; Wollert, 1985 and Tilsch, 1986). The recorded pedigree and performance data from this breeding program were used as material for the present study.

The data material comprised four distinct sub-sets or layers of the breeding program, viz. (A) Beef cows, (B) Beef bulls, (C) Beef x Dairy animals and (D) Fattening hybrids. Data were available on reproduction, production and body measurement traits. However, the distribution of traits and number of records in each trait were variable among layers. Data covered a period from 1971 to 1989 in terms of year of birth of animals while for some traits (e.g. body weight of cows at calving1,2 and 3) it went back up to 1965. In A, data were on body weights (kg) at 6,12,15,18 months, first calving, second calving and third calving (W6, W12, W15, W18, WC1, WC2 and WC3). The same in B were: average daily gain (g/day) during test period (ADG-T), energy efficiency (EE-T) during test period (NE, net energy), birth difficulty (BD), body measurements (cm): wither height (WH), hip height (HH), rump length (RL), chest depth (CD), chest width (CW), pelvic size (PS), back width (BW), buttock length (BL) and heart girth (HG). All these traits were measured on bulls at the end of the test period. There were four different levels of the test period viz. (a) 84-365 days, (b) 183-365 days, (c) 155-395 days and (d) 185-395 days. In C, traits were calves birth weight (kg) and their birth difficulty (BD) while in D, data only on the body weight (kg) of fattening hybrid bulls at the end of the test period (WT-T) were available. Birth difficulty (BD) was subjectively evaluated using seven descriptive scores (1 = no difficulty, 2 = difficulty due to abnormal position of calf during birth, 3 = difficulty due to big size of calf, 4 = difficulty which needed veterinary assistance, 5 = difficulty resulting in the birth of dead calf, 6 = difficulty resulting in calf died inside the cow and 7 = difficulty related to premature (6-7 months) birth of calf). But for analyses, only four categories were (scores 2, 3 and 4 = 2 ; scores 5 and 6 = 3) used. Table 1 contains simple means and standard deviations for analysed traits by their population. The beef cows (A) and beef bulls (B) were composed of pure-bred Beef Simmental (FF), Charolais (CH), other beef breeds (sF), ½ FF- ½ CH, ¼ FF- ¾ CH, ≥ ½ FF- ½ sF, ≥ ½ sF - ½ FF, ½ sF-unknown sF, ≥ ½ FF- ½ sF crossbred, ≥ ½ FF- ½ CH , ≥ ½ FF - ½ (sF cross + CH cross), ≥ ½ CH- ½ FF crossbred. Other beef breeds include continental European beef breeds such as Limousin, Chianina, Piemonthese. In D, genotypes in addition to those in A and B were: ≥ ½ sF- ½ CH crossbred, ≥ ½ sF- ½ (FF crossbred + CH crossbred), ≥ ½ FF- ½ unknown cross of sF. The genotype of beef x dairy animals (C) were made up as a result of mating of beef bulls from B defined above with the dairy cows (pure-breds and their crosses) such as German Black and White (SR), cross SR x Jersey (J), cross (SR x J) x Holstein Friesian (HF) and Dairy Simmental (FL).

**Table 1. Means and standard deviations for analysed traits by population**

| Population | Trait | Number of animals | Mean | Standard deviation |
|---|---|---|---|---|
| Beef Cows (A) | Body wt. (kg) at | | | |
| | 6month | 6113 | 212.62 | 20.10 |
| | 12month | 7795 | 325.92 | 41.11 |
| | 15month | 5010 | 381.07 | 44.93 |
| | 18month | 7814 | 418.57 | 46.77 |
| | Calving1 | 7037 | 518.34 | 53.44 |
| | Calving2 | 3661 | 574.61 | 60.49 |
| | Calving3 | 3701 | 620.60 | 64.80 |
| Beef Bulls (B) | ADG-T [1] (g /day) | 4614 | 1280.55 | 168.11 |
| | Energy efficiency (NE[4]) | 5050 | 3427.71 | 534.48 |
| | Birth difficulty[1] | 5975 | 1.09 | 0.43 |
| | Wither height (cm) | 5344 | 124.30 | 4.41 |
| | Hip height (cm) | 3830 | 130.69 | 4.15 |
| | Rump length (cm) | 5283 | 145.43 | 5.52 |
| | Chest depth (cm) | 5176 | 63.76 | 2.68 |
| | Chest width (cm) | 2910 | 48.76 | 3.26 |
| | Pelvic size (cm) | 4731 | 43.81 | 3.18 |
| | Back width (cm) | 4949 | 47.69 | 3.28 |
| | Buttock length (cm) | 2765 | 47.60 | 2.64 |
| | Heart girth (cm) | 4897 | 183.22 | 8.22 |
| Beef x Dairy animals (C) | Birth weight (kg) | 191721 | 39.73 | 5.53 |
| | Birth difficulty [2] | 191721 | 1.13 | 0.69 |
| Fattening Hybrids (D) | WT-T[3] (kg) | 24247 | 466.02 | 45.82 |

[1]average daily gain during test period,[2]measured in scores, [3]body weight of fattening hybrids at the end of test period, [4]net energy equivalent

The original data were checked for animals pedigree and performance. For all independent and dependent variables, thorough completeness, consistency and plausibility checks were performed. Any abnormal data were deleted from the data set. Preliminary fixed model analyses were undertaken with the GLM Procedure (SAS, 1996) to identify significant fixed effects to be included in the later mixed model analyses. Only birth difficulty data were converted into their transformed scale using.

Sumpf (1986) before any analysis. The number of genetic groups in the datasets for each trait and statistical significance of the fitted fixed effects for all traits are presented in Table 2. The genetic groups were assigned only for animals with missing genetic relationships following Westell et al.(1988). Genetic parameters were estimated by restricted maximum likelihood method (REML), Patterson and Thompson (1971) and breeding values were estimated by best linear unbiased prediction ,BLUP (Henderson, 1975) using single trait animal models. For REML, VCE (Groeneveld,1994) and for BLUP, PEST (Groeneveld et al. 1990) were used. Since animals in all populations had predominantly crossbred genetic make-up, analyses were carried out using data from all animals (pure and crossbred) having record on the trait in question. The genetic group option was used in all animal model analyses. The general animal model used to describe the analysed traits was

$$y = X\beta + Zu + e$$

where, y is the vector of observations, X and Z are known incidence matrices, ß is a vector of fixed effects (farm, year of birth, farm*year of birth, age in days (covariable), sex, mother's calving number, birth weight (covariable), beef fattening situations), u is a vector of random animal effects associated with the additive genetic merit of animal and e is random residual term. The genetic trend in a particular trait over the years encompassed in the data was estimated by regressing the BLUP-derived estimated breeding values (EBVs) on the year of birth of animals (Henderson, 1973). Trends were investigated within the four layers of the breeding program stated above i.e. (A) beef cows,(B) beef bulls,(C) beef x dairy animals and (D) fattening hybrids.

**Table 2. Number of genetic groups and statistical significance of fixed effects**

| Population | Trait | GG[1)] | Farm | YOB | Farm *YOB | Age (d) | Sex | MCN[2)] | Birth wt. | BFS[3)] |
|---|---|---|---|---|---|---|---|---|---|---|
| A | Body wt. (kg) at | | | | | | | | | |
| | 6month | 11 | *** | *** | *** | - | - | - | - | - |
| | 12month | 13 | *** | *** | *** | - | - | - | - | - |
| | 15month | 10 | *** | *** | *** | - | - | - | - | - |
| | 18month | 14 | *** | *** | *** | - | - | - | - | - |
| | Calving1 | 12 | *** | *** | NS | - | - | - | - | - |
| | Calving2 | 8 | *** | *** | *** | - | - | - | - | - |
| | Calving3 | 9 | *** | *** | *** | - | - | - | - | - |
| B | ADG-T [4)] (g/d) | 12 | *** | *** | *** | - | - | - | - | - |
| | En. eff. (NE) | 12 | *** | *** | *** | - | - | - | - | - |
| | Birth difficulty 5) | 11 | *** | *** | NS | - | - | - | - | - |
| | Wither height (cm) | 12 | *** | *** | NS | - | - | - | - | - |
| | Hip height (cm) | 12 | *** | *** | *** | - | - | - | - | - |
| | Rump length (cm) | 12 | *** | *** | NS | - | - | - | - | - |
| | Chest depth (cm) | 12 | *** | *** | NS | - | - | - | - | - |
| | Chest width (cm) | 8 | *** | *** | *** | - | - | - | - | - |
| | Pelvic size (cm) | 11 | *** | *** | NS | - | - | - | - | - |
| | Back width (cm) | 12 | *** | *** | NS | - | - | - | - | - |
| | Buttock leng. (cm) | 8 | NS | *** | NS | - | - | - | - | - |
| | Heart girth (cm) | 12 | *** | *** | NS | - | - | - | - | - |
| C | Birth wt. (kg) | 27 | - | *** | - | - | *** | *** | - | - |
| | Birth difficulty[5)] | 27 | - | *** | - | - | *** | *** | *** | - |
| D | WT-T (kg) | 21 | *** | *** | - | *** | - | - | - | *** |

[1)]number of genetic groups, YOB = year of birth of animal, [2)]calving number of mother, [3)]beef fattening situation, [4)]average daily gain during test period, [5)]measured in scores,

- = Not fitted, *** $P < 0.001$, NS = Non-significant ($P > 0.05$)

## Results and Discussion

### Heritabilities

Estimates of additive genetic variance, heritabilities and genetic trends for the studied traits are given in Table 3. The heritability of growth traits in beef cows were 0.27, 0.33, 0.37, 0.44, 0.26, 0.45 and 0.51 respectively for body weight at 6, 12, 15, 18 months, first calving, second calving and third calving. The $h^2$ of 6, 12, 15 and 18 months body weight of females in our study tend to be slightly lower than Gregory et al. (1995b) respectively for 200, 368, 452 and 522 day weights. However, our results are similar with Koots et al.(1994), as traits of the individual. Body measurement traits of beef bulls had moderate to high heritability (0.28 to 0.58) and are in agreement with Gilbert et al. (1993) and Koots et al. (1994). Heritability of average daily gain (ADG-T) and energy efficiency (EE-T) during test period were respectively 0.50 and 0.40. Koots et al. (1994) and Gregory et al (1995a) respectively reported $h^2$ of 0.31 and 0.43 for postweaning average daily gain (ADG). The heritabilities of birth difficulty were 0.05 and 0.08 respectively as a trait of the individual for beef bulls and beef x dairy animals. Our estimated $h^2$ of 0.05 for beef bulls is much lower than Gregory et al. (1995a) for males (0.27). However, for calving easy expressed as percentage of unassisted, Koots et al. (1994) reported a weighted mean $h^2$ of 0.13 for cows and 0.10 for heifers. On the other hand, a $h^2$ of 0.08 for beef x dairy animals obtained in our study is same as Tilsch (1986) and McGuirk et al. (1998) who respectively used earlier data form this experiment and similar data material. The $h^2$ of birth weight for beef x dairy animals was 0.51. Koots et al (1994) reported a weighted mean $h^2$ of 0.31 whereas estimates from Gregory et al. (1995a), Crump et al. (1997), Tilsch (1986) are respectively 0.44, 0.41 and 0.41. Heritability of body weight of fattening hybrids at the end of 365 or 395-day test period (WT-T) was 0.32 whereas Gregory et al. (1995a) and Koots et al. (1994) reported $h^2$ of 0.35 and 0.33 respectively for 368-day and yearling weight.

**Table 3. Estimates of additive genetic variance[1)], heritability, genetic trends and their standard errors (SE) for various traits**

| Population | Trait | Additive genetic variance ($\delta_a^2$) | Heritability ($h^2$) | SE | Genetic trend | SE | Stat. sig.[3)] |
|---|---|---|---|---|---|---|---|
| A | Body wt. (kg) at | | | | | | |
| | 6month | 184.44 | 0.27 | 0.025 | -0.38 | 0.025 | *** |
| | 12month | 364.30 | 0.33 | 0.059 | 0.24 | 0.032 | *** |
| | 15month | 486.35 | 0.37 | 0.026 | 0.50 | 0.051 | *** |
| | 18month | 603.94 | 0.44 | 0.031 | 0.32 | 0.047 | *** |
| | Calving1 | 652.08 | 0.26 | 0.021 | -0.35 | .050 | *** |
| | Calving2 | 1391.18 | 0.45 | 0.023 | 1.10 | 0.13 | *** |
| | Calving3 | 1599.63 | 0.51 | 0.010 | 0.82 | 0.112 | *** |
| B | ADG-T[4)] (g/d) | 12623.16 | 0.50 | 0.008 | 3.69 | 0.276 | *** |
| | Energy effi. (NE) | 114267.54 | 0.40 | 0.042 | -4.94 | 0.610 | *** |
| | Birth difficulty[2)] | 0.013 | 0.05 | 0.014 | -0.002 | .0002 | *** |
| | Wither height (cm) | 6.73 | 0.58 | 0.013 | 0.12 | 0.007 | *** |
| | Hip height (cm) | 7.29 | 0.53 | 0.019 | 0.09 | 0.008 | *** |
| | Rump length (cm) | 7.57 | 0.39 | 0.026 | 0.09 | 0.006 | *** |
| | Chest depth (cm) | 1.57 | 0.28 | 0.014 | 0.03 | 0.003 | *** |
| | Chest width (cm) | 4.53 | 0.51 | 0.011 | -0.05 | 0.007 | *** |
| | Pelvic size (cm) | 2.63 | 0.49 | 0.017 | 0.03 | 0.004 | *** |
| | Back width (cm) | 2.70 | 0.40 | 0.031 | -0.003 | 0.004 | NS |
| | Buttock length (cm) | 2.12 | 0.51 | 0.017 | 0.05 | 0.005 | *** |
| | Heart girth (cm) | 15.38 | 0.31 | 0.027 | 0.10 | 0.009 | *** |
| C | Birth wt. (kg) | 15.07 | 0.51 | 0.001 | 0.025 | 0.002 | *** |
| | Birth difficulty[2)] | 0.02 | 0.08 | 0.005 | -0.0002 | 0.00005 | *** |
| D | WT-T[5)] | 474.06 | 0.32 | 0.012 | 1.18 | 0.022 | *** |

[1)]in squared units, [2)]estimated using transformed data, [3)]statistical significance, [4)]average daily gain during test period, [5)]body wt. of fattening hybrids at the end of test period, ***P < 0.001, NS = Non-significant (P > 0.05)

## Genetic trends

Estimates of genetic trends for the studied traits are given in Table 3. Figures 1 (a & b) and 2 (a & b) show the genetic trends for growth traits in beef cows and body measurement traits in beef bulls respectively. The genetic trends in all growth traits were positive and significant except for 6 months and first calving. The same in all body measurement traits were positive and significant except chest width and back width which were respectively negative significant and non-significant (P > 0.05) negative. The genetic trends for the body weight of fattening hybrids at the end of the test period (WT-T) in industrial farms, breeding farms and testing stations are presented in Figure 3. Overall genetic trend was positive and significant (1.18 kg per year of birth) whereas that in industrial farms, breeding farms and testing stations were respectively 0.59, 1.52 and 0.96 kg per year of birth, all estimates being significant and in the desired direction. The reasons for differences in the degree of genetic trends among beef fattening situations could be that breeding farms were always one generation ahead (called 'genetic lag') of commercial industrial farms and only one half of the genetic progress of industrial hybrids was contributed through beef bulls. It could also be due to environment and /or genotype-environment interaction arising from the use of same beef bulls in different situations.

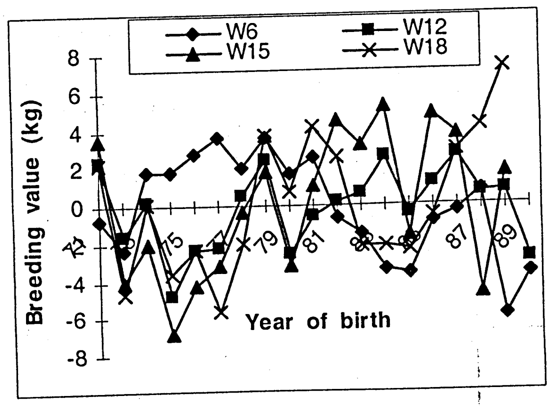


**Fig. 1a. Genetic trends in growth traits for beef cows**

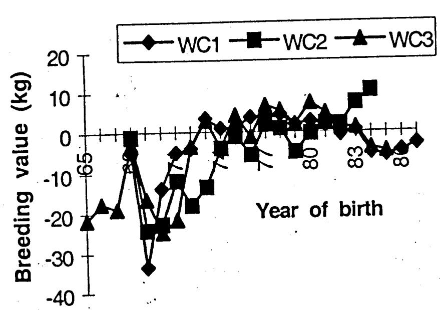


**Fig. 1b. Genetic trends in growth traits for beef cows**

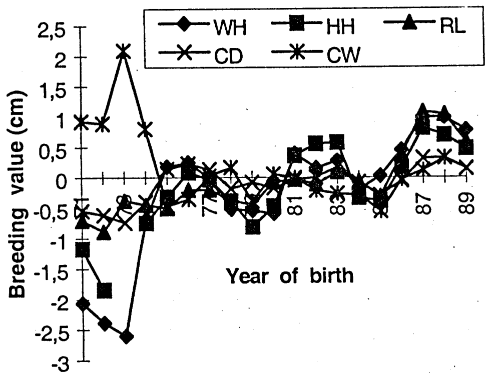


Fig. 2a. Genetic trends in body measurement traits for beef bulls

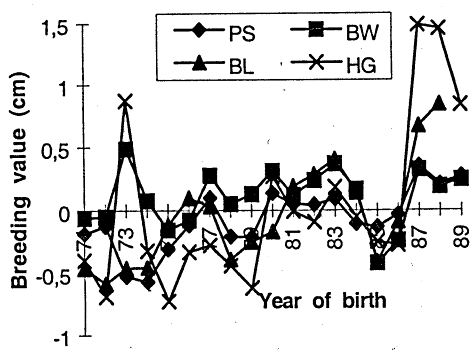


Fig. 2b. Genetic trends in body measurement traits for beef

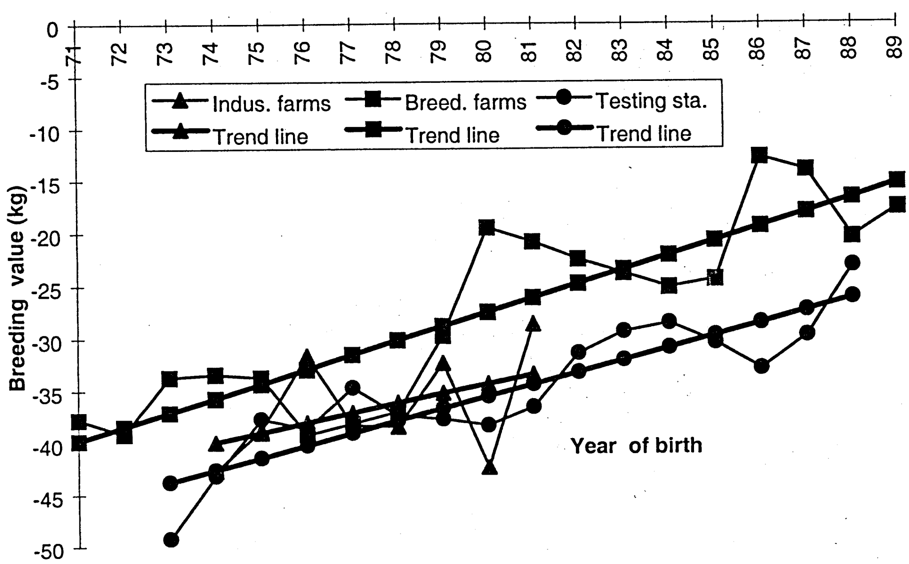


Fig. 3. Genetic trends for the body weight of fattening hybrids at the end of test period

Linear genetic trends for birth difficulty for beef bulls and beef x dairy animals (Figure 4) were significant with -0.002 and -0.0002 units gain per year of birth respectively Genetic trend for birth weight of beef x dairy animals is given in Figure 5 which was positive (0.025 kg) and significant.

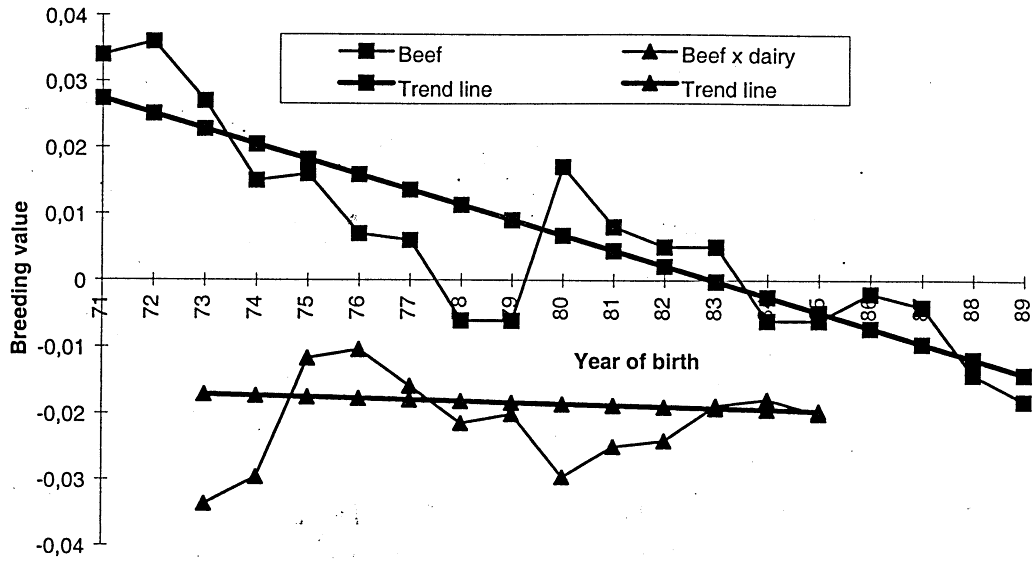


**Fig. 4. Genetic trends in birth difficulty for beef bulls and beef x dairy animals**

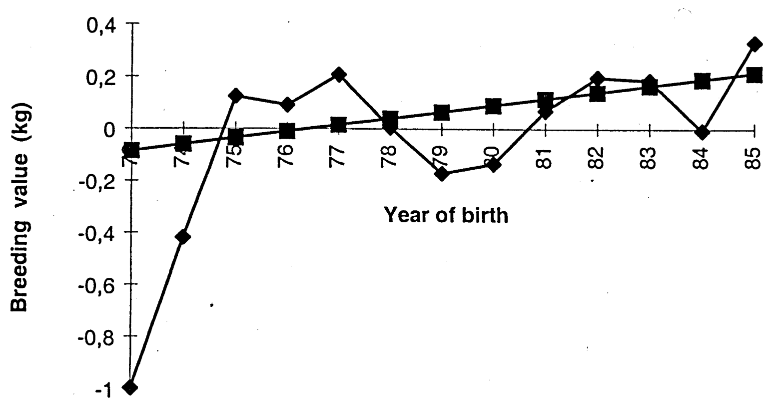


**Fig. 5. Genetic trend in birth weight for beef x dairy animals**

Figure 6 shows the genetic trends ín average daily gain (ADG-T) and energy efficiency (EE-T) of beef bulls during test period which were respectively 3.69 g and -4.94 NE per year of birth. Both estimates were statistically significant and in the expected direction.

The annual genetic trends as per cent of the population means were: in beef cows, 0.18, 0.07, 0.13, 0.08, 0.07, 0.19 and 0.13 respectively for body weight at 6,12,15,18 months, first, second and third calving; for beef bulls, 0.10, 0.07, 0.06, 0.05, 0.10, 0.07, 0.01, 0.11 and 0.05 respectively for wither height, hip height

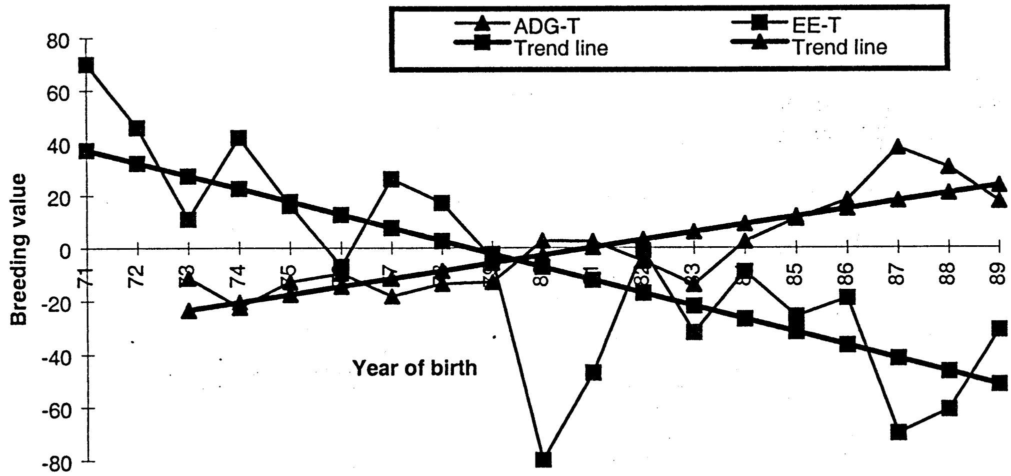


**Fig. 6. Genetic trends in average daily gain (g/day) and energy efficiency (NE) for beef bulls**

rump length, chest depth, chest width, pelvic size, back width, buttock length and heart girth; 0.29 and 0.14 respectively for average daily gain and energy efficiency; for the body weight of fattening hybrids at the end of test period, 0.25, 0.13, 0.33 and 0.21 respectively in overall, industrial farms, breeding farms and testing stations; 0.06 and 0.02 respectively for birth weight and birth difficulty of beef x dairy animals, 0.18 for birth difficulty of beef bulls. These trends were in the range of respectively 0.02 to 0.18, 0.07 to 0.33 and 0.01 to 0.11 per cent of the population mean for reproduction, production and body measurement traits (Table 4).

Under Canadian beef station-testing situation, de Rose and Wilton (1988) observed annual genetic trends of 0.0025 and 0.0007 kg respectively for Charolais and Simmental for average daily gain during test period whereas we found an estimate of 3.69 g for the same trait. Their estimated trends were in the range of 0.1 to 0.5 % of the population mean whereas Mrode (1988) reported literature averages of 0.63, 0.80 and 2.03 % annual genetic change respectively for weaning weight, yearling weight and postweaning gain. Our estimate for birth weight (0.025 kg per year) is lower than Crump et al. (1998) who observed trends of 0.09 and 0.08 kg per year for birth weight of respectively Charolais and Simmental beef sires under British condition. They also found trends of 1.38 and 1.33 kg per year for 400-day weight respectively for Charolais and Simmental beef sires whereas an equivalent trait in our study, weight of beef bulls at the end of test period (WT-T) resulted trend of 1.18 kg per year. These differences could mainly be due to differences in selection criteria and breeding system followed.

Animal models were used to describe observations on all traits for the estimation of variance components, heritabilities and genetic trends. In the present study, the used model ignored maternal effects for all traits which might have resulted in higher estimates of $h^2$ specially for birth weight and 6 month body weight of beef x dairy animals and beef cows respectively. An upward bias of animal variances and consequently heritability estimates, and downward bias of genetic trend estimates could result from such omissions. However, according to Musani and Mayer (1997), even extreme values for the genetic parameters had little influence on the estimated values for the annual genetic trends. The used animal models incorporated all known relationship information in the analyses, accounted for non-random mating and for changes in genetic means and for reduction in the genetic variance as a result of selection. Moreover, due to incorporation of genetic groups in animal models, the genetic merit of all descendants of any animal that had a missing parent then included a function of the genetic group of the missing ancestor (Westell et al. 1988). In addition, utilisation of both pure-bred and crossbred information for genetic evaluation has become increasingly available nowadays particularly in pig and poultry breeding situations. Therefore, the genetic trends observed in this study are assumed to be a close reflection of actual trends, not the result of omission of maternal or any other extended random genetic terms in the used animal models or combined analyses of both pure and crossbred data.

**Table 4. Estimates of genetic trends in reproduction, production and body measurement traits within different layers of recurrent selection program**

| Category of trait | Trait | Breeding layer | Genetic trend |
|---|---|---|---|
| Reproduction | Birth wt. (kg) | Beef x dairy animals | 0.025 |
| | Birth difficulty [1)] | Beef x dairy animals | -0.0002 |
| | Birth difficulty[1)] | Beef bulls | -0.002 |
| Production | Body wt. (kg) at | | |
| | 6month | Beef cows | -0.38 |
| | 12month | Beef cows | 0.24 |
| | 15month | Beef cows | 0.50 |
| | 18month | Beef cows | 0.32 |
| | Calving1 | Beef cows | -0.35 |
| | Calving2 | Beef cows | 1.10 |
| | Calving3 | Beef cows | 0.82 |
| | ADG-T (g/d) | Beef bulls | 3.69 |
| | Energy efficiency (NE) | Beef bulls | -4.94 |
| | WT-T [2)] (kg) | Fattening hybrids | 1.18 |
| | Overall | Fattening hybrids | 0.59 |
| | Industrial farms | Fattening hybrids | 1.52 |
| | Breeding farms | Fattening hybrids | 0.96 |
| | Testing stations | | |
| Body measurement | Wither height (cm) | Beef bulls | 0.12 |
| | Hip height (cm) | Beef bulls | 0.09 |
| | Rump length (cm) | Beef bulls | 0.09 |
| | Chest depth (cm) | Beef bulls | 0.03 |
| | Chest width (cm) | Beef bulls | -0.05 |
| | Pelvic size (cm) | Beef bulls | 0.03 |
| | Back width (cm) | Beef bulls | -0.003 |
| | Buttock length (cm) | Beef bulls | 0.05 |
| | Heart girth (cm) | Beef bulls | 0.10 |

[1)]transformed data, [2)]body weight of fattening hybrids at the end of the test period

Despite the scale of genetic trends, selection was successful as it changed most of the traits in the desired directions. The estimates of trends reported here (Table 3) are overall population changes in respective traits resulting from recurrent selection practised in both beef bulls and cows. However, the degree of genetic progress in a population is a function of selection intensity, generation interval, accuracy of selection and genetic standard deviation (Falconer, 1989). The first two depends on industry characteristics and the last two on inheritance and are closely dependent on heritability (de Rose and Wilton, 1988). Our estimated trends for any trait were based only on the additive genetic merit of all pure and crossbred animals whereas nonadditive part of the crossbred animals need to be accounted for getting a more clear picture of the total genetic progress achieved in the present beef breeding program.

The selection for body weight at any age usually results in correlated responses in body weight at all other ages (Mrode, 1988). However, a declining trend in the body weight of beef cows at 6 months and at first calving as observed in this study might have attributed through a negative relationship between direct and maternal additive genetic merit of beef cows at those ages. A positive genetic trend in birth weight with concurrent negative trend for birth difficulty in beef x dairy animals and decline in birth difficulty alone in beef bulls in our beef cattle recurrent selection program disagree with Mrode's (1988) commonly held opinion that selection for growth is necessarily accompanied by increased birth weight and dystocia and lends empirical evidence in this context. This might have become possible due to giving proper weight to the component traits (birth weight, growth and birth difficulty) in the used selection indices.

The genetic trends realised for various traits in our study were in the range of 0.01 to 0.33 % of the population mean. Traits used as selection criteria were growth rate, birth weight and birth situation, which showed genetic trends of respectively 0.06, 0.02 and 0.18 and 0.29 % of the population mean. Most estimates were low and fall short of progress calculated by Smith (1984) where artificial insemination is used. However, it has to be kept in mind that all estimated trends observed in our study were essentially indirect type because selection was practised using different indices, bulls were further selected on the basis of their higher growth during test period followed by final selection of bulls on the basis of their progeny performance. Therefore, such low trends are not unexpected. For birth difficulty, genetic trends of 0.18 and 0.02 % of the population mean were observed respectively for beef bulls and beef x dairy animals and this difference in trends for this trait is a reflection of the amount of selection applied in two situations. A further important point to note is that the weighting factors (or indices) were changed during the course of the breeding program which is supposed to have differential effect on the accumulation of desirable alleles in the breeding populations. Moreover, a biological antagonistic relationship exists between higher growth rate and birth difficulty, which warrants a further reason for low genetic trends in the present study. However, according to Mohamed et al. (1998) low response to antagonistic selection (Mohamed et al. 1998) is not surprising because in this situation genetic trend is achieved at considerable costs.

## Crossbreeding systems

The basic objective of beef cattle crossbreeding systems is to optimise simultaneously the use of both nonadditive (heterosis) and additive (breed differences) effects of genes (Gregory and Cundiff, 1980) for specific character(s). In addition, use of complementarity through terminal sire breeds and formation of a new composite or synthetic breed from a multibreed foundation are also aimed at. In case of composite formation the objective is to provide an alternative or a supplement to continuous crossbreeding. Rotational crossbreeding takes advantage of using heterosis in all females and progeny in a self-contained commercial herd, however, fluctuation between generations in additive genetic merit requires use of breeds that are generally compatible. This system depends on a continuous introduction of males of used parental breeds. The reciprocal recurrent selection assumes overdominant loci to be important and alters two genetically different populations to improve their crossbred mean. Selection is based on the mean of crossbred progenies /families and the selected individuals are mated within themselves / families to form a new population. The recurrent selection utilises heterosis and the additive genetic merit of different breeds and here selection of straightbreds, for use in crossing, is based on the performance of their crossbred progeny.

Literature study has revealed exploitation of various crossbreeding systems e.g. rotational, terminal sire, recurrent selection, reciprocal recurrent selection, up-grading etc. to fulfil the needs of specified production system in farm animals. These systems have been found to vary in terms of their mode of application in different species. However, a successful crossbreeding system requires the choice of appropriate breed combinations for the environment with concurrent programs to support the increased production potential of developed crossbred.

Results based on either experimentation or computer simulation to show the relative efficiency of all crossbreeding systems are not available. However, comparison of alternative rotational crossbreeding systems and that between terminal sire and rotational crossing are abundant in different farm species including beef cattle. The reciprocal recurrent selection has largely been exploited by the poultry and swine industry. On the other hand, data pertaining to the results from a recurrent selection programs in any species are nearly absent except Flower et al (1964).

In order to evaluate fully the utility of recurrent selection, it is essential to evaluate the indirect or correlated response occurring in the supporting populations. In the present study, recurrent selection was applied in the pure-bred beef male and female populations and genetic trend was measured as productivity of both pure and crossbred animals in all layers of the breeding population. Moreover, data on a particular trait were not available in animals of all breeding layers due to field based recording system or due to high cost of recording. Selection pressure was much higher on the beef male side which showed greater genetic trends (as per cent of population mean) in production traits of beef bulls compared to traits in other breeding layers. Similar results were reported by Flower et al (1964) from a kind of mass-recurrent selection program in range Hereford cattle in the USA. Their selection pressure also was much higher in the male side with the bulls used and direct selection pressure for combining ability in the recurrent phase was negligible. Their effective heritabilty for birth and weaning weight were respectively 0.86 and 0.77, which were much higher than existing estimates. However, their estimates for genetic progress were positive for birth (0.96 pound or 0.43 kg per year) and weaning weights (4.56 pound or 2.03 kg per year), somewhat larger than expected and genetic progress was greatest in those lines where selection pressure was most intense. In our study, data on the body weight of fattening hybrids at the end of the test period in various fattening situations (Figure 3) has clearly indicated the degree of passage of desirable genes in different sections of recurrent selection program. Moreover, since most of the estimated genetic trends were in the desired direction, it may be reasonable to say that recurrent selection was effective in accumulating desirable genes for higher growth and lower birth difficulty through good genetic compromises built in this beef population.

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