

ROBUSTNESS OF SELECTION INDEX AND IT'S  
PREDICTABILITY FOR LIFE TIME  
PRODUCTION IN THARPARKAR CATTLE

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## ROBUSTNESS OF SELECTION INDEX AND IT'S PREDICTABILITY FOR LIFE TIME PRODUCTION IN THARPARKAR CATTLE

A.K. Gupta

are respectively relative economic value, genotypic value, phenotypic value and selection index coefficient value for the  $i^{th}$  trait. Its use as a basis of selection of cows is considered to be the best in maximizing genetic gain in aggregate value of their genotypes. Improvement in overall economic value of cows is expected to simultaneously lead to improvement in their milk production, because normally higher milk producing animals are expected to be more economical.

The use of a selection index constructed on the basis of information for a given herd would be applicable to that herd for some time. Changes in economic values of the traits as also changes in genetic parameters like heritability and genetic correlations would be expected to bring about some changes in selection index coefficients and expected genetic gains for the individual traits. Investigations on effect of variation in genetic parameters and economic values in selection index would throw some light on reliability of wider and prolonged use of selection index once developed.

The criterion for judging suitability of a selection index is the measure of accuracy estimated as correlation between net hereditary value (H) and total phenotypic score (I) or in terms of the expected genetic gain in H by use of selection index as basis of selection. Since, H, the total hereditary value, indicates the total economic value of the genotypes of the traits, which are generally few and manifested early in the life of an animal, e.g., age at first calving, first lactation production and first calving interval, included in H, the expected genetic gain ( $\Delta H$ ) in H would be relevant to such traits as are included in H. The implicit assumption is that gain in H would, also, bring about improvement in economic value for the whole herd life of animals. Therefore, this study was taken to investigate the predictability of selection index based on earlier traits for lifetime milk production and compare it with predictability of lifetime production by its multiple linear regression on such early traits.

## REVIEW OF LITERATURE

The literature is reviewed under three sections:

- i) Selection Index - Methodology
- ii) Applications of Selection Index
- iii) Prediction of lifetime production

### 2.1. SELECTION INDEX - METHODOLOGY

Fisher (1936) developed 'Discriminant function' with a purpose to discriminate the individuals belonging to two different populations. It was Smith (1936), who first made use of this function as a basis for making selection on several characters simultaneously in wheat. Hazel (1943) put forth the genetic basis of constructing selection indexes with an illustration on swine. Harris (1964) developed the equations involving the variance and covariance among the estimates used for index construction.

Sales and Hill (1976) reported that when there was error in parameter estimates, the extra response obtained by including second trait, would be overpredicted. They found the loss in efficiency from poor estimation of parameters as roughly 25% of the squared coefficients of variation of a heritability estimate of the first trait. Niebel et al. (1977) discussed the effects of the revised economic weightings on purebreeding in pigs and found that

the errors, in estimating price and cut component upto 40%, to have little effect on selection index.

Vandepite and Hazel (1977) investigated the effects of errors in the economic weights on the accuracy of selection indexes in pigs. Errors in single economic weighting of  $\pm 50\%$  reduced the relative efficiency of the index by less than 1% and negative errors were found, in general, to be more critical than positive errors. For small sampling errors in the economic weighting vector, when the coefficient of variability (CV) was less than 50%, the loss in relative efficiency was less than 2.6%; but increased to roughly 15% when CV was 100%. Gurnani et al. (1978) assessed the robustness of the selection index coefficients with regard to variation in economic values for first lactation production (FLP), second lactation production (SLP), age at first calving (AFC) and first calving interval (FCI) in Tharparker cattle. The expected genetic advance was affected by 3.3 to 10.7% for an increase of 30% in relative economic values of AFC and FCI, whereas the decrease in economic values of these traits upto 30% affected the expected genetic advance by -8.1% to -3.0%. They suggested that the old selection index could be used when the relative economic values did not undergo a serious change. Using selection index theory, Danel (1979) combined the individual test-days' results in a lactation to estimate the breeding value for dairy bulls. The accuracy of the index ( $r_{HI}$ ) was found not to be affected when the genetic correlations among the test-days were altered or when the

phenotypic variances differed. Individual b-values showed a wide variation and were especially affected by changes in the pattern of heritabilities for the individual test-days. He concluded that the correlation between the index (I) and aggregate genotype (H) was not efficient for measuring the influence of variation in parameters.

## 2.2. APPLICATIONS OF SELECTION INDEX

Tabler and Touchberry (1959) constructed selection indices for milk and fat yield in Holstein Friesian cattle. Selection indices based on milk yield, fat yield/percentage and protein content were extended from time to time by a number of research workers (Teinberg, 1968; Teinberg, 1971; Herrendorfer and Shuler, 1972; Panicke and Zelfel, 1975; Smopova and Effimenko, 1977). Maijala (1978) discussed the use of selection indices to improve the profitability in dairy industry.

There are a number of reports concerning applications of selection indexes based on productive and reproductive traits in dairy cattle. Singh et al. (1969) extended selection indices, based on age at first calving (AFC), birth weight (BW), weight at first calving (WFC), first lactation milk yield (FLY), first service period (FSP) and first dry period (FDP), for genetic improvement in Mariana cattle. They concluded that the selection incorporating only AFC and FLY, with correlation between net hereditary value (H) and selection index (I) as 0.5402, could lead to maximum genetic improvement for AFC, FLY, FSP and a considerable

gain in FDP. Prasad and Prasad (1972) reported the heritabilities for traits viz. overall milk yield (MY), age at first calving (AFC) and first calving interval (FCI) as 0.05, 0.08 and 0.01. Prasad and Prasad (1973a) reported the relative economic values of the three traits as Re. 0.25 per lb, Rs. 32.39 per month and Rs. 42.50 per month. Using these estimates, Prasad and Prasad (1973b) developed a selection index incorporating MY and AFC, with  $r_{HI}$  as 0.540 and reported an overall expected genetic gain per lactation per cow of Rs. 6.69 per generation of selection. Gurnani et al. (1977) analysed the data on first lactation milk yield (FLP), age at first calving (AFC), second lactation milk yield (SLP) and first calving interval (FCI) in Tharparker cattle and developed selection indices with and without restrictions. They found that with the genotypes of all the four traits in the total genotypic score (H), the index  $I = 0.078(FLP) - 2.148(AFC) + 0.661(FCI)$  was optimum. As compared to the weightage on FLP, this index gave about 28 times weightage to AFC and 8 times weightage to FCI. Selection based on this index was expected to give overall genetic advance of Rs. 30.50 per generation of selection.

There are, also, reports of applications of selection index in cattle for the purpose other than milk production. Nowicki and Zuk (1972) constructed selection indices incorporating body measurements to improve the musculature of Polish Black and White Lowland cattle. Vesely and Robison (1972) obtained empirical selection indexes for

beef cattle by multiple regression technique and extended three indices for heifers and three for cows.

Johari and Bhat (1978) computed selection indices for Indian buffaloes. The traits incorporated were: birth weight, 6-month body weight, 12-month body weight, body weight at freshening, age at first calving, first service period, first calving interval, first lactation milk yield and first lactation length. The accuracy value of the indices ranged from 0.41 to 0.47. Total advance in the most efficient index was Rs.57.07 per generation of selection.

### 2.3. PREDICTION OF LIFETIME PRODUCTION

The literature concerning prediction of lifetime production is reviewed under various sub sections as follows:

#### 2.3.1. Relationship of age at first calving with lifetime production of milk and/or fat production

Hansson (1941) reported total fat production (upto 8 years of age) to be decreasing greatly with increase in age at first calving (AFC) in purebred Swedish Red and White cattle. Luthman (1941) found that the animals which calved first at 31-36 months of age, showed higher performance for milk and fat yield than the earlier calvers in Lowland and Mountain Spotted cows. Gethin (1950) reported that the lifetime production, determined on the basis of herd life of a given length (say 7 or 8 years) was higher for earlier calvers than for later ones. Sundaresan et al. (1954) reported negatively significant correlations of AFC with lifetime production in Red Sindhi cattle

and Murrah buffaloes. The correlations of AFC with lifetime production were  $-0.425$ ,  $-0.544$ ,  $-0.662$  for milk production upto 5 years, 7 years and upto 10 years of age respectively in Red Sindhi cows;  $+0.393$ ,  $-0.790$  and  $-0.350$  for milk production upto 5 years, 7 years and 10 years of age respectively in Murrah buffaloes. Venkayya and Anantakrishnan (1957) reported longer productive life for earlier calvers than late calvers in Red Sindhi and Ayrshire x Sindhi cows. Increased lifetime milk yield with decreasing AFC were reported by Wahab (1964) in Dazal cattle and Dutt *et al.* (1965) in Murrah buffaloes. High negatively significant correlations of AFC with lifetime production of milk were reported by Singh *et al.* (1964) in Haryana cattle ranging from  $-0.758$  to  $-0.640$  for farm bred cows and from  $-0.601$  to  $-0.340$  for foundation stock. Singh (1966) found the correlation of AFC with lifetime production upto 10 years of age to be  $-0.3729$  in buffaloes. Negatively significant correlations of AFC with lifetime production ranging from  $-0.708$  to  $-0.150$  were reported by Bhasin and Desai (1967) in Haryana cattle, Gopal and Bhatnagar (1972) for Sahiwal cattle, for Holstein Friesian and Gupta and Bhatnagar (1979) for Tharparkar cows. Increased lifetime milk yield with the decrease in AFC were also reported by Kremarenko and Shesterin (1970) for Russian breeds of cattle; Ahmad *et al.* (1971) for Sahiwal cows in Pakistan and Yanchilin and Kendratera (1977) for Russian breeds of cattle.

No significant effect of AFC on lifetime milk yield was reported by Singh and Sinha (1960) in Tharparkar cattle. The review, thus, indicated that mostly age at first calving had significantly negative association with lifetime milk production.

2.3.2. Relationship of first lactation production with lifetime production of milk:

Sundaresan et al. (1954) reported the correlation of first lactation production (FLP) with lifetime production upto 5 years, 7 years and 10 years of age in Red Sindhi as 0.799, 0.773 and 0.855 respectively. The correlation of FLP with lifetime production of milk upto 6 years, 8 years and 10 years of age in Murrah buffaloes was 0.507, 0.415 and 0.300 respectively. Puri and Sharma (1965) fitted the regression equations on the basis of 40 observations on Tharparkar cows to predict total yield upto 10 years of age on the basis of FLP. The fitted model explained 48% of the variation in Tharparkar, 55% of the variation in Sahiwal breed and 37% in Red Sindhi. Singh et al. (1964) reported the correlations of FLP with lifetime production upto 6 years, 8 years and 10 years of age as 0.861, 0.626 and 0.765 respectively in farm bred and 0.700, 0.670 and 0.543 respectively in foundation stock of Hariana cattle. Singh (1966) reported the correlation of FLP (300-day) with milk production upto 10 years of age as 0.3128 in buffaloes. Bhasin and Desai (1967) reported the correlation of FLP (1ba) with total milk

yield upto 6 years, 8 years and 10 years of age respectively as 0.445, 0.499 and 0.667 in Hariana cattle. Baller (1972) studied Slovakian Pied cows and reported that total milk production upto 6 years of age was highly significantly correlated with milk yield in first lactation with correlation coefficient as 0.561. Gopal and Bhatnagar (1972) calculated the correlation of FLP with total milk yield upto 6 years of age, 8 years and 10 years as 0.470, 0.55 and 0.39 respectively in Sahiwal cattle. Lin and Allaire (1978) found the correlation of FLP with total milk yield upto 4 years of age and 6 years of age as 0.56 and 0.52 respectively. Gupta and Bhatnagar (1979) estimated the correlations of FLP with total milk yield upto 6 years of age, 8 years of age and 10 years of age respectively as 0.633, 0.657 and 0.499 in Tharparkar cows. Increases in lifetime milk yield with increases in FLP were reported by Dutt *et al.* (1965) in Murrah buffaloes, and Hooque and Hodges (1979) in Holstein cows.

Thus most of the reports from tropical as well as temperate countries indicate that lifetime production of milk was positively associated with first lactation milk yield (FLP).

### 2.3.3. Relationship of first calving interval (FCI) with lifetime production of milk:

Wahab (1964) reported that the lifetime milk yield was higher for calving intervals of 350-399 days than for shorter or longer intervals in Dazel cattle. Lin and Allaire (1978) reported the correlation of calving interval (in months) with total milk yield upto 41 months of age, 48 months and

72 months as 0.28, 0.42 and 0.29 respectively. No significant relationship was reported between FCI and 10 years of age in Zebu and crossbred cows by Sundaresan et al. (1954). The published literature on effect of FCI on lifetime milk yield is rather scanty.

2.3.4. Predictability of lifetime production on the basis of age at first calving (AFC) and first lactation milk yield (FLP) taken together:

Sundaresan et al. (1954) developed an equation for predicting production upto 10 years of age for Red Sindhi and 1/4 Jersey-3/4 Sindhi, as a combined group, as follows:

Red Sindhi and 1/4 Jersey-3/4 Sindhi groups:

$$Y = 230 - 30.24X_1 + 2.76X_2; R = 0.84$$

Where,

Y = Predicted 10 year production in 100 lbs of milk.

$X_1$  = Age at first calving in months.

$X_2$  = First lactation 305-day production in 100 lbs of milk.

Dutt et al. (1965) studied milk yield upto 6 years, 8 years and 10 years of age in Murrah buffaloes and stressed that in addition to the production of first lactation, age at first calving should also be given due weightage in predicting lifetime milk yield. Puri and Sharma (1965) extended multiple regression equations to predict milk yield upto 10 years of age. Multiple regression equation based on AFC and FLP explained more than 75% of the variation in purebred cows and only 40%

in crossbred cows. Singh et al. (1964) studied the effect of AFC ( $X_1$ ) and FLP ( $X_2$ ) on lifetime production in Haryana cattle and estimated three prediction equations for lifetime production (in lbs) fitted as below:

$$\begin{aligned} Y (6 \text{ years}) &= 10386 - 193.06X_1 + 1.595X_2 & R^2 &= 0.829 \\ Y (8 \text{ years}) &= 14600 - 191.04X_1 + 1.740X_2 & R^2 &= 0.577 \\ Y (10 \text{ years}) &= 18925 - 205.09X_1 + 4.039X_2 & R^2 &= 0.763 \end{aligned}$$

Bhasin and Desai (1967) developed multiple regression equations based on AFC ( $X_1$ ) and FLP ( $X_2$ ) for prediction of lifetime production (lbs) in Haryana cattle as follow:

$$\begin{aligned} Y (6 \text{ years}) &= 5211.563 - 98.617X_1 + 1.413X_2 \\ Y (8 \text{ years}) &= 2577.698 - 5.812X_1 + 2.074X_2 \\ Y (10 \text{ years}) &= 6725.106 - 105.791X_1 + 3.863X_2 \end{aligned}$$

The estimation of accuracy ( $R^2$ ) of these fitted regression model was not reported.

Gopal and Bhatnagar (1972) reported that multiple regression equations based on AFC and FLP explained 51%, 51% and 40% of the total variations in lifetime production of milk upto 6 years, 8 years and 10 years of age respectively in Sahiwal cattle. Multiple regression equations based on AFC( $X_1$ ) and FLP( $X_2$ ) for prediction of lifetime milk yield (Y) were fitted as follow:

$$\begin{aligned} Y (6 \text{ years}) &= 9484 - 148.23X_1 + 0.92X_2 \\ Y (8 \text{ years}) &= 10347 - 138.18X_1 + 2.07X_2 \\ Y (10 \text{ years}) &= 14645 - 190.19X_1 + 2.62X_2 \end{aligned}$$

The published literature indicates that quite a good amount of variation in lifetime milk production could be explained by the variation in AFC and FLP.

2.3.5. Predictability of lifetime production on the basis of AFC, FLP and FCI jointly:

Gupta (1977) reported that the prediction equations on the basis of AFC ( $X_1$ ), FLP ( $X_2$ ) and Breeding efficiency ( $X_3$ ) explained 77%, 32% and 47% of the total variations in lifetime milk production upto 6 years, 8 years and 10 years of age respectively in Tharparkar cows. Multiple regression equations for predicting lifetime milk yield (Y) were fitted as follow:

$$Y (6 \text{ years}) = 16793.16 - 257.56X_1 + 0.386X_2 + 3.47X_3$$

$$Y (8 \text{ years}) = 21948.70 - 242.64X_1 + 1.330X_2 + 13.96X_3$$

$$Y (10 \text{ years}) = 21342.61 - 218.36X_1 + 2.440X_2 + 85.43X_3$$

## MATERIAL AND METHODS

Data for the present investigation were taken from the available records of Tharparkar herd maintained at National Dairy Research Institute, Karnal. The herd was established in 1921-31. History of the herd has been dealt in details by Kumaran (1956), Sundaresan *et al.* (1965) and Bhatnagar *et al.* (1976). Raw data were collected on 1223 animals born to 94 sires. However, the number of animals with records on age at first calving, first lactation production and first calving interval were available on 1019 animals born to 88 sires. Data on 557 cows born to 61 sires, which had milk yield upto six years of age, were considered. The number of cows which had normal records upto 10 years of age was 238. These cows had milk-records initiated from 1930 to 1977-78. Information on the parentage, age at first calving (AFC) (months), first 305-day lactation production (FLP) (kg), first calving interval (FCI)(days) and lifetime production (LTP) (measured in three ways - total milk yield upto 6 years of age, milk production upto 8 years of age and total milk production upto 10 years of age), were obtained from the available records. The records with less than 100 days lactation were considered abnormal and ignored. The animals were fed as per feeding standards, approved by the experts. The details of feeding schedules and breeding practices have been detailed by Bhatnagar *et al.* (1976).

### 3.1. CONSTRUCTION OF SELECTION INDEX

Total phenotype score or selection index (I) is expressed as:

$$I = b_1 X_1 + b_2 X_2 + \dots + b_n X_n$$

Where,

I = Total score or index value.

$X_1, X_2, \dots, X_n$  = Phenotypic values of trait 1, trait 2, ..... and so on.

$b_1, b_2, \dots, b_n$  are the weightages to be assigned to different traits in such a way that the correlation ( $r_{HI}$ ) between the index value (I) and total genotypic score (H) is maximized (Hazel, 1943). The total genotypic merit or score (H) is defined as:

$$H = a_1 G_1 + a_2 G_2 + \dots + a_n G_n$$

Where,

$G_1, G_2, \dots$  and  $G_n$  are the genotypic values of the traits 1, 2, .... and n;

$a_1, a_2, \dots$  and  $a_n$  are the relative economic values of the traits 1, 2, .... and n respectively.

Expressing in terms of matrices, the set of normal equations obtained by maximizing  $r_{HI}$  is:

$$\underline{P} \underline{b} = \underline{G} \underline{a}$$

Therefore, the solution for  $b_i$ 's would be:

$$\underline{b} = \underline{P}^{-1} \underline{G} \underline{a}$$

Where,

$\underline{P}$  = Phenotypic variance-covariance matrix of the traits under consideration.

$\underline{G}$  = Genotypic variance-covariance matrix of the traits.

$\underline{a}$  = Column vector of relative economic values.

$\underline{b}$  = Column vector of coefficients in selection Index (I).

Estimates of heritabilities, genetic correlations and phenotypic correlations required for  $\underline{P}$  and  $\underline{G}$  were estimated by Gurnani (personal communication) as shown in the following table 1.

Table 1

Traits	AFC( $X_1$ )	FLP( $X_2$ )	FCI( $X_3$ )
AFC	<u>0.105</u>	-0.694	0.362
FLP	0.036	<u>0.169</u>	0.374
FCI	0.116	0.255	<u>0.254</u>

Where, underlined elements on principal diagonal are heritability estimates of the three traits, elements above principal diagonal are genetic correlations and elements below the principal diagonal are phenotypic correlations. Therefore, the estimates of  $\underline{P}$  and  $\underline{G}$  were as follows:

$$\underline{P} = \begin{pmatrix} 48.366 & 170.910 & 90.090 \\ 170.910 & 465,998.000 & 19439.000 \\ 90.090 & 19439.000 & 12471.000 \end{pmatrix}$$

$$\underline{G} = \begin{pmatrix} 5.078 & -438.88 & 45.91 \\ -438.88 & 78754.0 & 5907.0 \\ 45.91 & 5907.0 & 3168.0 \end{pmatrix}$$

The relative economic values ( $a_1$ 's) were estimated in the following manner:

The studies of Kuber Ram, <sup>and Tomer</sup> Kulwant Singh (1976) on herd of Tharparkar cattle at N.D.R.I. suggested the following figures:

Cost of milk production = Re.1.47 per kg = Rs.1.50 per litre approx.

Cost of rearing a calf to maturity = Rs.3974.20 = Rs.100.00 per month approx.

Cost of maintaining an adult dry cow = Rs.5.0 per day.

The relative economic value of a trait is defined as the net return for unit increase in the trait.

Taking sale price of milk as approximately Rs.2.00 per kg, the net return per kg of milk is expected to be approximately Re.0.50 per kg for first lactation production (FLP). The relative economic weight for AFC would be Rs.-100.00.

As lactation production at N.D.R.I. farm is taken for 305 days or less, the increase in FCI is expected to be mainly due to increase in dry period. So, the relative economic weight for FCI was taken as Rs.-5.00.

Thus, the row vector of relative economic values for AFC, FLP and FCI was:

$$\underline{a}' = (a_1, a_2, a_3) = (-100.00, 0.50, -5.00)$$

### 3.1.1. Accuracy of Selection Index:

It is the correlation between total genotype value (H) and total phenotype score (I):

$$r_{HI} = \frac{\text{Cov.}(H, I)}{\sigma_I, \sigma_H}$$

$$= \frac{\underline{a'} \underline{G} \underline{b}}{(\underline{a'} \underline{G} \underline{a})^{1/2} (\underline{b'} \underline{P} \underline{b})^{1/2}}$$

Where,

$$\underline{a'} \underline{G} \underline{b} = \underline{b'} \underline{P} \underline{b}$$

Hence,  $r_{HI}$  would be:

$$r_{HI} = \frac{\underline{b'} \underline{P} \underline{b}}{\underline{a'} \underline{G} \underline{a}}$$

### 3.1.2. Genetic gain for individual traits:

The row vector for genetic gains in AFC, FLP and FCI individually was calculated as follows:

$$(\Delta G_1, \Delta G_2, \Delta G_3) = \frac{i \underline{b'} \underline{G}}{\underline{b'} \underline{P} \underline{b}}$$

Where,

$i$  = Intensity of selection, assumed to be 0.35

corresponding to 20 percent culling,

$\Delta_j$  = Genetic gain in  $j^{\text{th}}$  trait (for  $j = 1, 2$  and  $3$ )

when selection is based on I.

### 3.1.3. Advance in total genotype value (H):

Total gain in net hereditary value (H) was calculated

as:

$$\Delta H = \sum_{j=1}^3 a_j \Delta G_j$$

$a_j$  = Relative economic value for  $j^{\text{th}}$  trait.

$\Delta H$  is identically equal to  $i/\sqrt{h' P h}$

### 3.2. ROBUSTNESS OF SELECTION INDEX

Studies on effect of variation in economic and genetic values on selection index-coefficients, accuracy ( $r_{HI}$ ), genetic gain in individual traits and advance in total genotypic value ( $\Delta H$ ) (when selection index (I) is the basis of selection), were made in the following manner:-

Effect of variation in relative economic values ( $a_i$ 's) was studied for following seven levels of changes: -30%, -20%, -10%, 0% (no change), +10%, +20% and +30% in each of economic traits and in combinations.

Effect of variation in the heritabilities was studied for four levels of changes: 0% (no change), +10%, +20% and +30% in each of economic traits and in combinations. It was assumed that the variation in the heritability values did not affect genetic and phenotypic covariances.

Variations in genetic correlations were considered for the following four levels of changes: 0% (no change), +10%, +20% and +30% in each pair of the economic traits. It was

assumed that the variations in genetic correlations did not alter genetic and phenotypic variances.

### 3.3. PREDICTABILITY OF LIFETIME PRODUCTION

Procedure for prediction of lifetime milk production (LTP) on the basis of three early economic traits and total phenotypic score (I) was followed using regression analysis. The simple linear regression of LTP on three early traits, viz., age at first calving (AFC), first lactation production (FLP) and first calving interval (FCI), was fitted by considering the independent variates one at a time, two at a time and three at a time. The simple linear regression of lifetime production (LTP) on selection index (I) constructed on the basis of considering all possible combinations ( ${}^3C_2 = 3$ ) of two traits at a time and three early economic traits, was fitted. The sets of calculations were done separately for lifetime production upto 6, 8 and 10 years of age. The procedure for fitting simple linear regression and multiple linear regression were as briefly described below:

#### 3.3.1. Simple linear regression analysis:

The linear regression model was:

$$Y = B_0 + BX + E$$

Where,

Y and X are dependent and independent variates respectively.

B is the slope of the regression line fitted;

$B_0$  is the intercept on the Y-axis and E is the residual

error distributed as  $N(0, \sigma^2)$  (Snedecor and Cochran, 1967)

Where,  $b$ , the estimate of  $B$ , is:

$$b_{yx} = \frac{\sum xy}{\sum x^2}$$

taking  $x = (X - \bar{X})$ , and

$$y = (Y - \bar{Y})$$

Then,  $b_0$ , the estimate of  $B_0$ , would be equal to:  $\bar{Y} - b(\bar{X})$

Standard Error (S.E.) of regression coefficient is calculated as:

$$S.E.(b) = \frac{\sqrt{\sum y^2 - b^2 \sum xy}}{(N-2) \sum x^2}$$

Where,

$N$  denotes total number of observations.

Coefficient of determination ( $R^2$ ) was estimated as:

$$R^2 = \frac{(b) \sum xy}{\sum y^2}$$

Correlation coefficient ( $r$ ) was calculated as:

$$r_{xy} = \frac{\sum xy}{\sqrt{\sum x^2 \sum y^2}}$$

### 3.3.2. Multiple linear regression analysis:

Multiple linear regression equation aims at predicting the value of  $Y$  variable (dependent) on the basis of two or more than two independent variable (Parson, 1978).

$$\text{Model : } Y = B_0 + B_1 X_1 + B_2 X_2 + \dots + B_n X_n + E$$

Where,

$B_1, B_2, \dots$  and  $B_n$  are linear partial regression of  $Y$  on  $X_1, X_2, \dots$  and  $X_n$  respectively;  
 $E$  is the residual error distributed as  $N(0, \sigma^2)$ .

$B_0$  = Intercept for the regression line.

$$\text{Taking } x_1 = (X_1 - \bar{X}_1)$$

$$x_2 = (X_2 - \bar{X}_2)$$

.

$$x_n = (X_n - \bar{X}_n)$$

$$y = (Y - \bar{Y})$$

The set of least square normal equations is:

$$\begin{pmatrix} \sum x_1^2 & \sum x_1 x_2 & \sum x_1 x_n \\ \vdots & \vdots & \vdots \\ \sum x_1 x_n & \sum x_2^2 & \sum x_n^2 \end{pmatrix} \begin{pmatrix} b_1 \\ b_2 \\ \vdots \\ b_n \end{pmatrix} = \begin{pmatrix} \sum x_1 y \\ \sum x_2 y \\ \vdots \\ \sum x_n y \end{pmatrix}$$

or

$$\begin{pmatrix} b_1 \\ b_2 \\ \vdots \\ b_n \end{pmatrix} = \begin{pmatrix} \sum x_1^2 & \sum x_1 x_2 & \sum x_1 x_n \\ \vdots & \vdots & \vdots \\ \sum x_1 x_n & \sum x_2^2 & \sum x_n^2 \end{pmatrix}^{-1} \begin{pmatrix} \sum x_1 y \\ \sum x_2 y \\ \vdots \\ \sum x_n y \end{pmatrix}$$

$$= \begin{pmatrix} C_{11} & C_{12} & \dots & C_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ C_{n1} & \dots & \dots & C_{nn} \end{pmatrix} \begin{pmatrix} \sum x_1 y \\ \vdots \\ \vdots \\ \sum x_n y \end{pmatrix}$$

Where,

$b_1, b_2, \dots$  and  $b_n$  are estimates of  $B_1, B_2, \dots$  and  $B_n$ .

$b_0$ , the estimate of  $B_0$ , is:

$$b_0 = \bar{Y} - (b_1 \bar{X}_1 + b_2 \bar{X}_2 + \dots + b_n \bar{X}_n)$$

Standard Errors (S.E.) of partial regression

coefficients were calculated as follows:-

$$S.E.(b_i) = \sqrt{C_{ii} s^2}$$

Where,  $C_{ii}$  is the element of the inverse matrix belonging to  $i^{th}$  row and  $i^{th}$  column.

$$s^2 = \frac{y^2 - (b_1 \sum x_1 y + b_2 \sum x_2 y + \dots + b_n \sum x_n y)}{n - k - 1}$$

Where,

$n$  = Total number of observations.

$k$  = Number of independent variables.

The coefficient of determination ( $R^2$ ) was calculated on the basis of formula:

$$R^2 = \frac{b_1 \sum x_1 y + b_2 \sum x_2 y + \dots + b_n \sum x_n y}{\sum y^2}$$

## RESULTS AND DISCUSSION

### 4.1. CONSTRUCTION OF SELECTION INDEX

Considering the phenotypic and genotypic variance-covariance matrices and vector of relative economic values given in Material and Methods, the selection index was constructed. These selection index coefficients ( $b$ 's) are given in Table 2, Index No. 4( $I_4$ ). In this index the weightages assigned to age at first calving (AFC) (months) and first calving interval (FCI) (days) were found to be -94 times and -8 times the weightage given to first lactation production (FLP) (kg). The maximum weightage in the selection index is received by the trait which has maximum relative economic value viz. age at first calving (AFC), since differences in heritability estimates of the three traits are comparatively small as compared to differences in relative economic values. Singh *et al.* (1969) reported the weightages for AFC (month), FLP (lbs) and first dry period (FDP) (days) as -60, 1.0 and -0.5, whereas Gurnani *et al.* (1977) reported the relative weightages for AFC (month) and FCI (days) as -28 and -8 times the weight given to FLP (kg) in Tharparkar cows. These differences in the coefficients of selection index for three traits can be accounted for by differences in relative economic values and differences in genotypic and phenotypic parameters.

The accuracy ( $r_{HI}$ ) of selection index, as measured by the correlation between total genotypic score (H) and total phenotypic score (I), was found to be 0.5080 as shown in Table 2. The  $r_{HI}$  estimates were reported to be 0.6230 in Mariana cows by Singh *et al.* (1969), 0.6570 by Prasad and Prasad (1973b) in Tharparkar cows for selection index incorporating AFC, average milk yield, FCI and lactation period and 0.4700 for the most efficient index incorporating AFC, FLP and FCI in Indian buffaloes (Johari and Bhat, 1978).

Expected genetic gain per generation, when selection is based on selection index, as studied here, would be -0.365 months in AFC, 19.80 kg increase in FLP and -7.01 days in FCI. Use of this selection index is very desirable because milk yield would increase and AFC and FCI would decrease. Singh *et al.* (1969) reported the corresponding figures to be -4.44 months for AFC, 325.55 lb in FLP and 27.03 days increase in first dry period in Mariana cows. Gurnani *et al.* (1977) estimated such figures to be -0.12 months for AFC, 31.52 kg in FLP and 5.63 days increase in FCI.

Expected genetic advance ( $\Delta H$ ) in net hereditary merit (H) based on selection index, was estimated to be Rs.81.5 per generation against Rs.30.50 reported by Gurnani *et al.* (1977) in Tharparkar cattle and Rs.57.07 per generation of selection in Indian buffaloes as reported by Johari and Bhat (1978).

The differences in these estimates are due to differences in relative economic values and estimates of genetic and phenotypic parameters of the various breeds/herds located at

different places and times. In order to judge the reliability of the index obtained presently for future use, the variation in selection index coefficients with respect to variation in relative economic values and genetic parameters was investigated.

#### 4.2. ROBUSTNESS OF SELECTION INDEX

Robustness of selection index may be defined as the effect of variation in genetic and phenotypic parameters and relative economic values on index coefficients. This gives a measure of stability of selection index. It was studied with respect to variation in relative economic values and variation in genetic parameters.

##### 4.2.1.a. Effect of variation in relative economic value of age at first calving (AFC) on robustness of selection index:

As the cost of rearing of heifers decreases from Rs.100.00 per month to Rs.70.00 per month (i.e. 30% decrease), the relative economic value ( $a_1$ ) of age at first calving (AFC) will increase from -100.00 to -70.00. Similarly if the cost of rearing of the heifer increases from Rs.100.00 per month to Rs.130.00 per month, the relative economic value ( $a_1$ ) of AFC would decrease from -100.00 to -130.00. Effect of such variation in the cost of rearing upto 30% increase and decrease, at intervals of 10 percent, on index coefficients, accuracy of selection index ( $r_{HI}$ ) and expected genetic gain ( $\Delta H$ ) in net hereditary merit was studied. The results are presented in table 2. It is seen from this table that as the relative economic value of AFC is increased from -100.00 to -70.00, there is general increase in coefficients of selection index

for AFC and FCI, whereas there is decrease in coefficient for FLP. Similar trend in variation of  $b_i$ 's is obtained when the relative economic value ( $a_1$ ) of AFC is decreased (by 30%) from -100 to -130 (Table 2). These trends are more clearly visible when index coefficients are taken relative to the index coefficient for FLP (column 4, table 2). Further the increase in relative economic value ( $a_1$ ) of AFC (corresponding to decrease in the cost of rearing) resulted in practically no significant change in accuracy ( $r_{HI}$ ) of selection index (column 5, table 2).

Increase in relative economic value of AFC resulted in increase in expected genetic gain ( $\Delta G_1$ ) of AFC and FLP ( $\Delta G_2$ ) but expected advance in net hereditary merit would be decreased.

These results, therefore, indicate that with the decrease in cost of rearing, economic values of other traits and genetic and phenotypic parameters remaining same, there would be expected decrease in  $\Delta H$ . It is seen that for 30% increase in  $a_1$ , the decrease in  $\Delta H$  is to the extent of 13.3%. This result at first appears to be strange. However, if the dynamic economic situation is considered, the reduction in cost of rearing is likely to lead to lowering of cost of maintenance during dry period and the cost of milk production. Reduction in cost of rearing would also imply reduction in price index so that the purchase value of a unit of currency would be higher.

#### 4.2.1.b. Effect of variation in relative economic value of first lactation production (FLP) on selection index:

Effect of variation in cost of milk production upto 30% increase and decrease, at intervals of 10%, on index

coefficients ( $b_i$ 's), accuracy ( $r_{HI}$ ) of selection index, expected genetic gain in three component traits and expected genetic gain ( $\Delta H$ ) in net hereditary merit was studied. The results are given in table 3. It is seen from this table that as the relative economic value ( $a_2$ ) of first lactation production (FLP) is increased from 0.50 to 0.65, there is general increase in coefficients of selection index for FLP and FCI and a decrease in coefficient for AFC. A similar trend in variation of  $b_i$ 's is obtained when the relative economic value ( $a_2$ ) of FLP is decreased (by 30%) from 0.50 to 0.35 (Table 3). These trends are more clearly visible when index coefficients are taken relative to index coefficient ( $b_2$ ) for FLP (column 4, table 3).

Further the change in relative economic value ( $a_2$ ) of FLP upto 30% resulted in practically no significant change in accuracy ( $r_{HI}$ ) of selection index (column 5, table 3). Further increase in relative economic value of FLP resulted in increased genetic advance for FLP and FCI and a slightly decreased genetic advance for AFC. This can be accounted for by negative genetic association between the two traits viz. FLP and AFC (column 6, table 3). The expected genetic gain in net hereditary merit decreased with increase in relative economic value of FLP (column 7, table 3).

These results, hence, indicate that with the increase in profit per unit (kg) of FLP, other things (i.e. relative economic value of other traits and genetic and phenotypic parameters) remaining same, there would expected

to be increase in  $\Delta H$ . It is seen that for 30% increase in  $a_2$ , the increase in  $\Delta H$  is to the extent of +3.9% (column 8, table 3).

Hence, the increase in profit made per kg of FLP would obviously lead to increased gain in  $H$  or increased profit per generation of selection.

On comparing table 2 and table 3, it is evident that though selection index is reasonably robust to the variation in relative economic values of the component traits upto 30%, yet the effect, in terms of changes in  $\Delta H$ , is more pronounced in case of change in economic value of AFC as compared to that of FLP.

#### 4.2.1.c. Effect of variation in relative economic value of first calving interval on robustness of selection index:

Effect of variation in cost of maintaining an adult dry cow for an extra day ( $a_3$ ) upto 30% increase and decrease, at intervals of 10%, on index coefficients ( $b_i$ 's), accuracy ( $r_{HI}$ ) of selection index, expected genetic gain in three component traits and expected genetic advance ( $\Delta H$ ) in net hereditary merit was studied. The results are presented in table 4.

It is evident from this table that as the relative economic value ( $a_3$ ) of FCI is increased from -5.00 to -3.50, there is general increase in index coefficients for AFC, FLP and FCI. Similar trend in variation of  $b_i$ 's is obtained when the relative economic value ( $a_3$ ) of FCI is decreased (by 30%) from -5.0 to 6.5. These trends are more

clearly visible when index coefficients are taken relative to index coefficient for FLP (column 4, table 4).

Further the increase in the relative economic value of FCI resulted in practically no significant change in accuracy ( $r_{HI}$ ) of selection index (column 5, table 4). The increase in relative economic value,  $a_3$ , lead to a substantial increase in expected genetic gain for FLP and FCI and decrease in expected genetic gain in AFC (column 6, table 4). The expected genetic gain in net hereditary merit decreased with the increase in relative economic value of FCI.

These results, therefore, indicate that with the decrease in cost of maintaining a dry cow for an extra day, other things (i.e. relative economic values of other traits and genetic and phenotypic parameters) remaining same, there would expected to be decrease in  $\Delta H$ . It is seen that for 30% increase in  $a_3$ , the decrease in  $\Delta H$  is to the extent of 11.9% (column 8, table 4).

The effect of variation in relative economic value on  $r_{HI}$  and  $\Delta H$  is more pronounced here than in case of FLP and less marked than that in case of AFC.

4.2.1.d. Effect of variation in relative economic values of the component traits (in combination) on robustness of selection index:

Effect of variation in relative economic values of AFC, FLP and FCI (taking at least two at a time) upto 30% increase or decrease, at intervals of 10%, on index coefficients, accuracy of selection index, expected genetic gain in three component traits and expected genetic advance in

net hereditary merit was studied. The results are presented in table 5.

The results indicate that if there is simultaneous change in the relative economic values of the three traits, that is, if the cost of rearing, cost of maintenance and the net return from sale of milk, change by 30 percent (Index  $I_{10}$  and  $I_{11}$ , table 5), there is no change in selection index coefficients, accuracy of selection index ( $r_{HI}$ ) and the expected genetic gains in the component traits but the change in  $\Delta H$  (expected genetic gain in H) changes to the same extent (i.e. approximately 30%).

However, if the relative economic value of a trait is increased, the greater weight has to be given in the selection index to that trait and there is some increase in  $\Delta H$ . As an example, if the cost of rearing is increased i.e. relative economic value ( $a_1$ ) of AFC is decreased, slightly lesser weight is to be given to AFC in selection index but there would be greater decrease (increase in the negative direction) in expected genetic gain of AFC and consequently greater increase in  $\Delta H$ . Among the three traits considered in this study, a given percent change in relative economic value of age at first calving (AFC) had more impact on change in  $\Delta H$ , followed by FCI and there was least effect of a given proportionate change in relative economic value of FLP on  $\Delta H$ . This seems to be due to initial higher economic value for  $a_1$ , followed by that of  $a_3$  and being least for  $a_2$ .

Vandepite and Hazel (1977) reported that the errors in single economic weighting of  $\pm 50\%$  reduced the relative efficiency of the index by less than 1%. Gurnani et al. (1978) reported the expected genetic advance to be affected to the extent of 3.3 to 10.7% for an increase of 30% in relative economic value of AFC and FCI, whereas the decrease in relative economic values upto 30% of these traits affected the expected genetic advance by -8.1% to -3.0%.

#### 4.2.2. Effect of variation in heritability estimate of individual traits on robustness of selection index

When the traits considered in a selection index are genetically and phenotypically independent, increase in heritability of a trait would be expected to result in increase in the weight for that trait in the selection index and the genetic gain in that trait would be expected to increase. However, when the traits are not independent, it will be of interest to know as to how the change in heritability of a trait would affect the relative weight of that trait as compared to other traits in index, accuracy of selection index, genetic gain in the individual traits and the total gain in net hereditary merit (H). Variation in heritability estimates of three traits upto 30% was affected and the values of index coefficients, accuracy of index, genetic gain expected in individual traits and total gain in net hereditary merit are given in table 6.

It is seen from this table that with the increase in heritability of AFC, the absolute value of the relative

weight ( $b_1^*$ ) of AFC increased and the relative weight ( $b_3^*$ ) of FCI was unaffected. The accuracy of the index increased to a small extent. There was increase in absolute value of genetic gain for AFC and increase in genetic gain for FLP but decrease in absolute value of genetic gain for FCI. Total genetic gain ( $\Delta H$ ) increased upto 5.24% for 30% increase in heritability estimate of AFC.

With the increase in the heritability estimate of FLP, the absolute value of relative weight ( $b_1^*$ ) for AFC decreased but the relative weight ( $b_3^*$ ) of FCI remained unaffected (column 4, table 6). The accuracy ( $r_{HI}$ ) of the index increased to a small extent. Genetic gain for AFC was affected slightly, whereas there was increase in genetic gain for FLP and FCI. Total genetic gain ( $\Delta H$ ) increased upto 4.27% for 30% increase in heritability estimate of FLP.

Further it is seen from this table (indexes  $I_8$  to  $I_{10}$ ) that with the increase in heritability estimate of FCI, there was decrease in absolute value of relative weight for AFC and the absolute value of relative weight of FCI ( $b_3^*$ ) also increased. The accuracy ( $r_{HI}$ ) of the index increased to a small extent. There was decrease in absolute value of genetic gain for AFC and in genetic gain for FLP and an increase in absolute value of genetic gain for FCI. Total advance in aggregate genotype ( $H$ ) increased upto 14.49% for 30% increase in heritability estimate of FCI.

When the heritability estimates of both, AFC and FLP were increased by 30%, there was increase in absolute

value of relative weight for AFC and a slight decrease in the absolute value of relative weight for FCI (Index<sub>11</sub>, table 6). The accuracy of the index was affected to a small extent. There was increase in absolute value of genetic gain for AFC, increase in genetic gain for FLP and a slight decrease in absolute value of genetic gain for FCI. Gain in aggregate genotype (H) increased by 9.34%.

When the heritability estimates of both AFC and FCI increased by 30%, simultaneously, there was increase in absolute value of relative weight for AFC as well as FCI (I<sub>12</sub>, table 6). The accuracy of the index was again affected to a small extent. There was increase in absolute value of genetic gain for AFC and FCI but decrease in genetic gain for FLP. Expected genetic gain in total genotypic score (H) increased by 18.96%.

Again when there was affected an increase of 30% in the heritability estimates of FLP and FCI, simultaneously, the absolute value of relative weight for AFC was decreased while the absolute value of relative weight for FCI was increased slightly. The accuracy ( $r_{HI}$ ) of the index was slightly increased. There was decrease in absolute value of genetic gain for AFC and FCI and an increase in genetic gain for FLP. Total gain in net hereditary merit increased by 18.56%.

When the heritability estimates of all the three component traits were increased by 30% simultaneously, there was decrease in absolute value of relative weight for AFC and an

increase in that for FCI. Accuracy of the index was, also, slightly increased. Correspondingly there was increase in genetic gain for FLP with an increase in absolute value of genetic gain for AFC as well as FCI. Gain in total genotypic score increased by 22.87%.

The general conclusions from the above results are that with the increase in heritability of any trait in the index, the absolute value of weight in the index for that trait is increased, the absolute value of expected genetic gain for that trait increases and the expected genetic gain in total genotypic score (H) is increased. The gain in H was highest when the heritability of FCI was increased followed by that for FLP and AFC. Further it was seen that expected genetic gain for FLP increased when heritability of either AFC or FLP or both was increased but it decreased when heritability of FCI was increased.

#### 4.2.3. Effect of variation in genetic correlation values on robustness of selection index:

As has been given under Material and Methods, genetic correlation between AFC and FLP was negative and high, whereas that between FLP and FCI as well as between AFC and FCI was positive but low in magnitude. Increase in genetic correlation  $r_{G12}$  between AFC and FLP resulted in decrease in absolute value of relative weight for AFC as well as that of FCI (Table 7). The accuracy ( $r_{HI}$ ) was slightly increased. The absolute values of genetic gain for AFC and FLP increased, whereas absolute value of genetic gain for FCI decreased.

Increase in genetic correlation of AFC and FCI resulted in increase in absolute value of relative weights for AFC and FCI and a slight decrease in genetic gain for FLP. The genetic gain in H increased.

When the genetic correlation,  $r_{G23}$ , between FLP and FCI was increased, there was increase in absolute value of relative weights for AFC and FCI, slight decrease in value of accuracy, a slight decrease in absolute values of genetic gain for AFC and FCI and expected genetic gain for FLP. The expected gain in H was, also, decreased.

From this it could be concluded that milk production as also, the total gain in H increased to the greatest extent when there was increase in genetic correlation between AFC and FLP, whereas increase in genetic correlation between FLP and FCI would decrease the genetic gain in FLP and expected gain in total genotypic score (H).

#### 4.3. PREDICTION OF LIFETIME PRODUCTION OF MILK ON THE BASIS OF AGE AT FIRST CALVING (AFC), FIRST LACTATION MILK PRODUCTION (FLP), AND FIRST CALVING INTERVAL (FCI)

The purpose of any selection and breeding programme involving dairy cattle is to maximize the genetic improvement in milk producing ability without increasing the cost of milk production. Keeping these objectives in view, it appears appropriate to judge the improvement, that would occur in any selection programme, in total milk production upto a certain fixed age of the animal say upto 6 years, 8 or 10 years of age. Waiting for such a long time to get cow's own record

would obviously not be a feasible proposition both from genetic and economic point of view. Thus selection for improvement of such traits has to be affected on the basis of early traits. The early traits taken were age at first calving (AFC) (months), first lactation production (FLP) (kg) and first calving interval (FCI) (days). The "Lifetime milk production (kg)" (LTP) has been defined as milk production of cows upto 6 years, 8 years and 10 years. The predictability of LTP has been judged by estimating the regression of LTP separately on three independent traits and by fitting multiple linear regression of LTP on all possible combinations of the three independent traits taken two at a time and all three.

If we wish to maximize improvement in LTP, as defined here, then we need to evaluate as to what extent LTP will be predictable on the basis of selection index. This has been done by estimating the regression of LTP on selection index value of each cow and comparing its accuracy with multiple regression approach as mentioned above.

4.3.1. Average age at first calving (AFC), first lactation milk production (FLP), first calving interval (FCI) and lifetime milk production (LTP):

In table 8 are given the estimates of average age at first calving (AFC), first lactation milk production (FLP), first calving interval (FCI) and lifetime milk production (LTP) separately for the three groups of cows classified on the basis of available records upto 6 years, 8 years and 10 years of age respectively. It is observed from this table that there is practically no difference in average and coefficient of

variation of AFC and FCI in three groups of cows but there is slight increase in average first lactation production (FLP) from group-I (cows with milk records upto 6 years of age) to group-III (cows having records upto 10 years of age). The coefficient of variation of FLP slightly increased from group-I *decreased* to group-III.

These results indicate that after cows had attained six years of age, there has been no selection for AFC and FCI and mild selection for FLP. Thus the calculations of predictability of LTP would not be expected to be seriously affected by selection.

#### 4.3.2. Prediction of lifetime milk production upto six years of age (Group-I):

The regression of lifetime production (6 years) on age at first calving (AFC) was  $-211.93 \pm 14.081$  kg/month (table 9). Correlation of lifetime milk production with AFC was  $-0.6998$  in contrast with  $-0.782$  in Mariana cattle reported by Singh *et al.* (1964),  $-0.697$  reported by Dutt *et al.* (1965) in Murrah buffaloes,  $-0.617$  by Bhasin and Desai (1967) in Mariana cattle,  $-0.62$  by Gopal and Bhatnagar (1972) in Sahiwal cows,  $-0.15$  in Holstein Friesian cattle by Lin and Allaire (1978) and  $-0.708$  in Tharparkar cows by Gupta and Bhatnagar (1979). Variation in AFC would explain 48.97% of the variation in lifetime milk production.

The regression of lifetime production on FLP was  $2.111 \pm 0.168$  kg/kg (Table 9). The correlation of lifetime production with FLP was  $0.6342$  which is more than the values

reported by Dutt et al. (1965) in Murrah buffaloes, Bhasin and Desai (1967) in Mariana cattle, Gopal and Bhatnagar (1972) in Sahiwal cows, Lin and Allaire (1978) in Holstein Friesian cows and Gupta and Bhatnagar (1979) in Tharparkar cows. The value is less than that reported by Singh et al. (1964) in Mariana cattle. In this study, FLP, alone, would explain 40.22% of the variation in lifetime production.

Regression of lifetime production on first calving interval (FCI) was  $-3.793 \pm 1.283$  kg/day and the correlation coefficient between lifetime production and FCI was  $-0.1889$ . This value is in contrast with 0.181 reported by Gupta and Bhatnagar (1979) in Tharparkar breed and 0.29 reported in Holstein Friesian by Lin and Allaire (1978). It is seen that variation in FCI, alone would explain only about 3.57% of the variation in lifetime production.

Multiple regression equation based on AFC and FLP was, as has been shown in 4th row of table 9. Multiple regression equation would explain 72.86% of the variation in lifetime milk production. This is in contrast with  $R^2$  values reported by Singh et al. (1964) as 0.8290 in Mariana cows, Dutt et al. (1965) as 0.7190 in Murrah buffaloes and Gopal and Bhatnagar (1972) as 0.5100 in Sahiwal cows.

Multiple regression equation based on AFC and FCI was, as has been given in 5th row of table 9. This prediction equation would explain 50.02% of the variation in lifetime production of milk. Multiple regression equation based on FLP and FCI was as has been shown in 6th row of

table 9. This prediction equation would explain 45.31% of the variation in lifetime milk production. Multiple regression equation based on AFC, FLP and FCI, as shown in last row of table 9, would explain 74.99% of the variation in lifetime milk production, in contrast with  $R^2$  value reported by Gupta and Bhatnagar (1979) as 0.77 in Tharparkar cows.

#### 4.3.3. Prediction of lifetime production of milk upto 8 years of age (Group-II):

Regression of lifetime milk production (upto 8 years) on age at first calving (AFC) was  $-244.35 \pm 21.39$  kg/month as shown in table 10. The correlation of lifetime milk production upto 8 years with age at first calving was  $-0.5966$  which is high negative and statistically significant ( $P/0.01$ ). This value is in contrast with values reported by Singh *et al.* (1964) as  $-0.637$  in Haryana cattle, Dutt *et al.* (1965) as  $-0.447$  in Murrah buffaloes, Bhasin and Desai (1967) as  $-0.510$  in Haryana cows, Gopal and Bhatnagar as  $-0.540$  in Sahiwal breed and Gupta and Bhatnagar (1979) as  $-0.675$  in Tharparkar breed. Variation in AFC would explain 35.60% of the variation in milk production upto 8 years.

The regression of 8-year production on FLP was  $2.905 \pm 0.224$  kg/kg and the correlation coefficient was 0.6454 (Table 10). This value is more than the values reported by Dutt *et al.* (1965) as 0.375 in Murrah buffaloes, Bhasin and Desai (1967) as 0.499 in Haryana breed and Gopal and Bhatnagar (1972) as 0.55 in Sahiwal breed. However, this value is less than those reported by Singh *et al.* (1964) as 0.763 in Haryana breed and Gupta and Bhatnagar (1979) as 0.657 in Tharparkar

breed. Variation in FLP, alone, would explain 41.65% of the variation in 8 years production of milk.

The regression of 8-year milk production on first calving interval (FCI) was  $-5.16 \pm 1.73$  kg/day and the correlation coefficient was 0.1900 as shown in second row, table 10. This value is less than that reported by Gupta and Bhatnagar (1979) as 0.2450 in Tharparkar breed. Larger value obtained by them might be accounted for by the difference in number of observations taken by them. Variation in FCI alone, would not explain more than 3.61% of the variation in lifetime milk production upto 8 years.

Multiple regression equation based on AFC and FLP, to predict lifetime production was as shown in 4th row, table 10. Multiple regression equation would explain 63.06% of the variation in 8 years milk production. This  $R^2$  value is larger than  $R^2$  values reported by Singh et al. (1964) as 57.70% in Haryana cows and Gopal and Bhatnagar (1972) as 51.00% in Sahiwal breed. However,  $R^2$  value of prediction equation based on AFC and FLP is less than that reported by Dutt et al. (1965) as 71.90% in Murrah buffaloes.

Multiple regression equation based on AFC and FCI to predict lifetime production (upto 8 years) was as shown in 5th row, table 10. This multiple regression equation would explain 35.95% of the variation in lifetime milk production. Multiple regression based on FLP and FCI, as shown in 6th row, table 10, would explain 46.22% of the variation in lifetime milk production.

Multiple regression equation based on AFC, FLP and FCI as shown in last row, table 10, would explain the variation in 8-year milk production by 65.73%. Addition of FCI to multiple regression equation based on only AFC and FLP, does not bring about significant increase in predictability for lifetime production upto 8 years. However, present  $R^2$  value is fairly higher than that reported by Gupta and Bhatnagar (1979) as 32.00% in Tharparkar breed.

4.3.4. Prediction of lifetime milk production upto 10 years of age (Group-III):

Regression of lifetime milk production (upto 10 years) on AFC was  $-244.11 \pm 26.685$  kg/month and the correlation coefficient was  $-0.5140$  (Table 11). The estimate of correlation value was higher than those reported by Dutt *et al.* (1965) as  $-0.206$  in Murrah buffaloes, Singh (1966) as  $-0.3729$  in buffaloes, Bhasin and Desai (1967) as  $-0.477$  in Haryana breed and Gupta and Bhatnagar (1972) as  $-0.51$  in Sahiwal breed of cattle. However the correlation value of this study is smaller than that reported by Sundaresan *et al.* (1954) as  $-0.662$  in Red Sindhi, Singh *et al.* (1964) as  $-0.534$  in Haryana cows, Puri and Sharma (1965) as  $-0.756$  in Tharparkar breed and Gupta and Bhatnagar (1979) as  $-0.634$  in Tharparkar breed of cattle. Age at first calving alone would explain 26.42% of the variation in lifetime milk production upto 10 years.

Regression of lifetime milk production on FLP was  $3.104 \pm 0.279$  kg/kg and the correlation coefficient was  $0.5887$  (Table 11). The correlation value was higher than that

reported by Dutt et al. (1965) as 0.500 in Murrah buffaloes, Singh (1966) as 0.3128 in buffaloes, Gopal and Bhatnagar (1972) as 0.39 in Sahiwal breed and Gupta and Bhatnagar (1979) as 0.499 in Tharparkar breed of cattle. However, the correlation coefficient between 10 years production and FLP is less than the figures reported by Sundaresan et al. (1954) as 0.855 in Red Sindhi, Singh et al. (1964) as 0.788 in Haryana cattle, Puri and Sharma (1965) as 0.696 in Tharparkar and Bhasin and Desai (1967) as 0.667 in Haryana breed of cattle. Variation in FLP, alone, would explain 34.65% of the variation in lifetime milk production (upto 10 years).

Regression of lifetime production on FCI was  $-4.435 \pm 2.081$  kg/day (Table 11). The estimate of correlation coefficient was  $-0.1399$  which is statistically significant ( $P/0.01$ ). The corresponding value reported by Puri and Sharma (1965) was as  $-0.050$  in Tharparkar breed of cattle. However, correlation between FCI and lifetime production (upto 10 years) was found to be non-significant by Sundaresan et al. (1954).

Multiple regression equation based on AFC and FLP would explain 46.98% of the variation in lifetime milk production upto 10 years. The  $R^2$  value was larger than that reported by Gopal and Bhatnagar (1972) as 40% in Sahiwal breed of cattle. However, it is smaller than that reported by Sundaresan et al. (1954) as 70.56% in Red Sindhi, Singh et al. (1964) as 76.30% in Haryana cows, Dutt et al. (1965) as 57.60% in Murrah buffaloes and Puri and Sharma (1965) as 86.40% in Tharparkar breed of cattle. Multiple regression equation,

based on AFC and FCI, to predict lifetime milk production (upto ten years) would explain 26.83% of the variation in lifetime milk production. Prediction based on FLP and FCI shown in table 9, would explain the variation in 10 years milk production by 37.53%.

Multiple regression equation based on all the three traits viz. AFC, FLP and FCI, to predict lifetime milk production would explain the variation in lifetime milk production by 52.05% as shown in the table. Additional increase in predictability of regression equation on addition of FCI to multiple regression based on AFC and FLP only, was not of much significance.

4.4.1. Predictability of lifetime milk production (upto 6 years of age) on the basis of selection index (Group-I):

Regression of six years' milk production on  $I_1$  (Index incorporating AFC and FLP) was  $12.547 \pm 0.940$  kg/rupee (Table 12). Correlation coefficient between lifetime milk production and total phenotypic score ( $I$ ) was 0.842. Thus, this index incorporating AFC and FLP would explain the variation in 6-year milk production by 70.93%. This value of  $R^2$  is slightly less than  $R^2$  value obtained for multiple regression equation (72.86%), as shown in the table.

The regression of 6 years milk production on Index- $I_2$ , based on AFC and FCI, would explain 21.38% of the variation in lifetime milk production (6 years). This value is much less than that obtained from multiple regression corresponding to same independent traits given in table 9.

Regression of lifetime milk production (6 years) on  $I_3$  was found to be  $5.657 \pm 1.539$  kg/rupee, as shown in table 12. The index based on FLP and FCI would thus explain 8.83% of the variation in lifetime milk production (upto 6 years). This  $R^2$  value was very low as compared to that (45.31%) obtained for corresponding multiple regression (Table 9).

Regression of lifetime milk production (upto 6 years) on  $I_4$ , index incorporating AFC, FLP and FCI was  $7.29 \pm 0.472$  kg/rupee (Table 12). Variation in  $I_4$  would, thus, explain 47.52% of the variation in lifetime milk production. This value is quite low as compared to  $R^2$  value obtained as 74.99% for multiple regression corresponding to the same independent traits (Table 9).

It was, thus, seen that the predictability of selection index for lifetime milk production (upto 6 years) was generally low as compared to that for multiple regressions. The surprising result was the very low predictability of index ( $I_4$ ), incorporating all the three traits, as compared to that incorporating AFC and FLP only ( $I_1$ ).

4.4.2. Predictability of lifetime milk production (upto 8 years of age) on the basis of selection index (Group-II):

Regression of lifetime milk production (8 years) on  $I_1$  was  $15.95 \pm 1.312$  kg/rupee (Table 13). The correlation between LTP (8 years) and  $I_1$  was high, positive and statistically significant ( $P/0.01$ ). The predictability of  $I_1$  for lifetime milk production (8 years) was 62.70%, which is almost equal to

that for corresponding multiple regression model (Table 10). Predictability of  $I_2$  (AFC and FCI only) was 17.53% (Table 13) which is much less than the value of  $R^2$  (36.95%) for multiple regression model corresponding to the same traits (Table 10).

Regressions of lifetime milk production (8 years) on  $I_2$ ,  $I_3$  and  $I_4$  (Table 13) also gave lower values of  $R^2$  for prediction of lifetime production (8 years) as compared to corresponding multiple regression models (Table 10).

Thus, it is evident that the predictability of lifetime milk production (8 years) on the basis of selection index would be quite low as compared to multiple regression incorporating the same traits.

4.4.3. Predictability of lifetime milk production (upto 10 years of age) on the basis of selection index (Group-III):

The regression of lifetime milk production (upto 10 years of age) on  $I_1$  was  $16.79 \pm 1.528$  kg/rupee (Table 14). Variation in  $I_1$  would explain 51.23% of the variation in lifetime milk production (upto 10 years).

Regressions of lifetime milk production (upto 10 years of age) on  $I_2$ ,  $I_3$  and  $I_4$  alongwith standard errors were as given in table 14. Predictability of lifetime production (10 years) was 12.04% for  $I_2$  and 5.93% for  $I_3$ .

Regression of lifetime production (upto 10 years of age) on  $I_4$  was  $9.24 \pm 1.177$  kg/rupee (Table 14). Variation in  $I_4$  would explain 30.74% of the variation in lifetime milk production (10 years).

On comparison of table 11 and table 14, it is evident that predictability of lifetime milk production (upto 10 years) on the basis of selection index with the exception of  $I_1$ , was fairly low as compared to that obtained by fitting multiple regression equations on the same independent traits.

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Table 4. Effect of variation in relative economic value of first calving interval (FCI) on selection index

Index No.	Vector of Relative economic values			Vector of Index coefficients			Relative weightage to AFC and FCI		Accuracy	Vector of genetic gain in individual traits			Total genetic gain H	Change in $\Delta H$ (%)
	$a_1$	$a_2$	$a_3$	$b_1$	$b_2$	$b_3$	$b_1^*$	$b_3^{**}$	$r_{HI}$	$\Delta G_1$	$\Delta G_2$	$\Delta G_3$		
(1)	(2)			(3)			(4)		(5)	(6)			(7)	(8)
I <sub>1</sub>	-100.00	0.50	-3.50	-16.80	0.190	-1.196	-88	-6	0.5053	-0.382	26.12	-5.86	71.8	-11.9
I <sub>2</sub>	-100.00	0.50	-4.00	-17.04	0.189	-1.319	-90	-7	0.5063	-0.377	23.89	-6.29	74.8	-8.2
I <sub>3</sub>	-100.00	0.50	-4.50	-17.28	0.188	-1.443	-92	-8	0.5072	-0.371	21.78	-6.67	78.1	-4.2
I <sub>4</sub>	-100.00	0.50	-5.00	-17.52	0.187	-1.566	-94	-8	0.5080	-0.365	19.80	-7.01	81.5	0.0
I <sub>5</sub>	-100.00	0.50	-5.50	-17.77	0.186	-1.689	-96	-9	0.5084	-0.359	17.95	-7.31	85.0	4.3
I <sub>6</sub>	-100.00	0.50	-6.00	-18.00	0.185	-1.813	-97	-11	0.5092	-0.353	16.21	-7.56	88.8	8.9
I <sub>7</sub>	-100.00	0.50	-6.5	-18.25	0.184	-1.937	-99	-11	0.5097	-0.347	14.59	-7.79	92.6	13.7

$$b_1^* = b_1/b_2$$

$$b_3^{**} = b_3/b_2$$

Table 7. Effect of changes in the estimates of genetic correlations on selection index (assuming that relative economic values, genetic variances and phenotypic variance and covariances are unaffected)

variance and covariances are unaltered											
Index Change in value No. of genetic correlations	Index coefficients			Relative weightage for AFC and FCI		Accu- racy	Genetic gain in individual traits			Total gain in H	Change in $\Delta H$ (%)
	$b_1$	$b_2$	$b_3$	$b_1^*$	$b_3^{**}$	$r_{HI}$	$\Delta G_1$	$\Delta G_2$	$\Delta G_3$	(7)	(8)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)				
I <sub>1</sub> No change	-17.52	0.187	-1.566	-94	-8	0.5080	-0.365	19.80	-7.01	81.5	0.00
I <sub>2</sub> +10% $r_{G12}$	-17.99	0.197	-1.579	-91	-8	0.5142	-0.381	21.89	-6.86	83.3	2.3
I <sub>3</sub> +20% $r_{G12}$	-18.46	0.207	-1.591	-89	-8	0.5204	-0.397	23.94	-6.71	85.2	4.6
I <sub>4</sub> +30% $r_{G12}$	-18.92	0.217	-1.603	-87	-7	0.5268	-0.413	25.95	-6.56	87.1	6.9
I <sub>5</sub> +10% $r_{G13}$	-17.94	0.189	-1.603	-95	-8	0.5094	-0.378	19.68	-7.22	82.6	1.4
I <sub>6</sub> +20% $r_{G13}$	-18.35	0.190	-1.639	-96	-9	0.5179	-0.386	19.29	-7.33	84.9	4.2
I <sub>7</sub> +30% $r_{G13}$	-18.77	0.192	-1.676	-98	-9	0.5228	-0.396	19.05	-7.49	86.6	6.2
I <sub>8</sub> +10% $r_{G23}$	-17.56	0.179	-1.530	-98	-9	0.5022	-0.365	18.20	-6.88	79.9	-1.9
I <sub>9</sub> +20% $r_{G23}$	-17.60	0.171	-1.494	-103	-9	0.4963	-0.364	16.59	-6.76	78.5	-3.7
I <sub>10</sub> +30% $r_{G23}$	-17.64	0.164	-1.452	-108	-9	0.4906	-0.363	14.99	-6.64	76.9	-5.5

$$b_1^* = b_1/b_2$$

$$b_2^{**} = b_2/b_3$$

$r_{G12}$  = Genetic correlation between AFC and FLP

$r_{G13}$  = Genetic correlation between AFC and FCI

$r_{G23}$  = Genetic correlation between FLP and FCI

Table 8. Average age at first calving (AFC), first lactation production (FLP), first calving interval (FCI) and lifetime milk production in Tharparkar cows

Group No.	Cows having records on lifetime milk production upto	No. of animals	Age at first calving (months)		First lactation milk production (kg)		First calving interval (days)		Lifetime production of milk (kg)	
			$\bar{X} \pm S.E.$	C.V. (%)	$\bar{X} \pm S.E.$	C.V. (%)	$\bar{X} \pm S.E.$	C.V. (%)	$\bar{X} \pm S.E.$	C.V. (%)
I	six years of age	557	40.43 $\pm$ 0.295	17.20	2159.69 $\pm$ 28.92	31.61	464.33 $\pm$ 4.73	24.09	5585.77 $\pm$ 93.23	39.39
II	eight years of age	342	40.33 $\pm$ 0.375	17.18	2204.32 $\pm$ 34.74	29.15	467.45 $\pm$ 6.09	24.10	9589.30 $\pm$ 155.34	29.96
III	ten years of age	238	40.19 $\pm$ 0.462	17.72	2278.73 $\pm$ 42.05	28.47	465.90 $\pm$ 6.97	23.08	14029.62 $\pm$ 220.34	24.23

Table 9. Prediction of lifetime production (upto 6 years) on the basis of age at first calving (AFC), first lactation production (FLP) and first calving interval (FCI)

Traits considered	Regression coefficients			Constant of Regressions (bo)	Multiple correlation coefficient (R)	R <sup>2</sup> (%)
	b <sub>1</sub>	b <sub>2</sub>	b <sub>3</sub>			
AFC	-211.93 ± 14.081			14430.999	-0.6998	48.972
FLP		2.111 ± 0.168		1104.191	0.6342	40.221
FCI			-3.793 ± 1.283	7681.777	-0.1889	33.568
AFC and FLP	-177.58 ± 10.566	1.670 ± 0.116		9246.192	0.8536	72.857
AFC and FCI	-208.03 ± 14.076		-2.071 ± 0.933	15238.894	0.7073	50.023
FLP and FCI		2.154 ± 0.161	-4.535 ± 0.970	3119.777	0.6731	45.312
AFC, FLP and FCI	-171.08 ± 10.267	1.714 ± 0.112	-2.967 ± 0.664	10266.433	0.8659	74.992

Table 10. Prediction of lifetime production (upto 8 years of age) on the basis of age at first calving (AFC), first lactation production (FLP) and first calving interval (FCI)

Number of animals taken = 238

Traits taken	Regression coefficients $b_1$	$b_2$	$b_3$	Constant of Regression (bc)	Multiple correlation coefficient (R)	$R^2$ (%)
AFC	-244.35±21.395			19820.613	-0.5966	35.597
FLP		2.905±0.224		3381.834	0.6454	41.654
FCI			-5.159±1.735	12404.862	0.1900	3.610
AFC and FLP	-194.54±16.669	2.422±0.103		12300.847	0.7941	63.062
AFC and FCI	-238.35±21.381		-3.185±1.417	21063.507	0.6078	36.951
FLP and FCI		2.963±0.214	-6.180±1.294	6127.762	0.6842	46.817
AFC, FLP and FCI	-184.71±16.254	2.489±0.178	-4.487±1.051	13843.794	0.8107	65.731

Table 11. Prediction of lifetime production (upto 10 years of age) on the basis of age at first calving(AFC), first lactation production (FLP) and first calving interval (FCI)

No. of animals taken = 238

Traits taken	Regression coefficients			Constant of Regression (bo)	Multiple correlation coefficient (R)	R <sup>2</sup> (%)
	b <sub>1</sub>	b <sub>2</sub>	b <sub>3</sub>			
AFC	-244.11±26.685			23789.261	-0.5140	26.424
		3.104±0.279		6896.329	0.5887	34.651
FLP			-4.435±2.061	16055.969	-0.1399	1.957
FCI				15617.417	0.6860	46.976
AFC and FLP	-180.38±22.258	2.458±0.247		24563.459	0.5180	26.834
AFC and FCI	-239.52±26.969		-2.053±1.800	9307.754	0.6126	37.531
FLP and FCI		3.149±0.274	-5.387±1.647	16892.542	0.7215	52.053
AFC, FLP and FCI	-187.25±22.526	2.713±0.246	-3.393±1.457			

Table 12. Prediction of lifetime production (upto 6 years of age) on the basis of selection index incorporating AFC, FLP and FCI

Number of animals taken = 238					
Index No.	Traits taken	Regression of lifetime production(6 years) on Index	Constant of Regression	Correlation coefficient	R <sup>2</sup> value (%)
I <sub>1</sub>	AFC and FLP	12.547±0.940	7188.2110	0.8422	70.9287
I <sub>2</sub>	AFC and FCI	5.033±0.707	12008.7204	0.4623	21.3765
I <sub>3</sub>	FLP and FCI	5.657±1.538	8284.3276	0.2971	8.8272
I <sub>4</sub>	AFC, FLP and FCI	7.297±0.472	13125.7236	0.6893	47.5197

Table 13. Prediction of lifetime production (upto 8 years of age) on the basis of selection index incorporating AFC, FLP and FCI

Number of animals taken = 238

Index No.	Traits taken	Regression of lifetime production (8 years) on Index	Constant of Regression	Correlation coefficient	R <sup>2</sup> -value (%)
I <sub>1</sub>	AFC and FLP	15.955±1.3127	11620.7504	0.7918	62.7022
I <sub>2</sub>	AFC and FCI	16.164±0.9582	17464.8185	0.4187	17.5301
I <sub>3</sub>	FLP and FCI	7.729±1.6786	13238.6366	0.3001	9.0062
I <sub>4</sub>	AFC, FLP and FCI	0.174±0.8678	19067.8622	0.6409	41.0708

Table 14. Prediction of lifetime production (upto 10 years of age) on the basis of selection index incorporating AFC, LFP and FCI

Number of animals taken 4 238

Index No.	Traits taken	Regression of lifetime production(10 years) on Index	Constant of Regression	Correlation coefficient	R <sup>2</sup> -value (%)
I <sub>1</sub>	AFC and LFP	16.789±1.5287	15733.8219	0.7157	51.2334
I <sub>2</sub>	AFC and FCI	5.946±1.1161	21229.1556	0.3469	12.0362
I <sub>3</sub>	LFP and FCI	7.302±1.9545	17088.3167	0.2436	5.9330
I <sub>4</sub>	AFC, LFP and FCI	9.239±1.1775	23160.5486	0.5544	30.7371

## SUMMARY AND CONCLUSIONS

The available data on milk production of Tharparkar cows at National Dairy Research Institute, Karnal since 1930 upto date, which had records on milk yield upto ten years of age, was compiled along with the information on age at first calving (AFC), first lactation milk production (FLP), first calving interval (FCI) and lifetime production of milk (LTP) upto production of six, eight and ten years of age.

Effect of variation in relative economic values, heritability and genetic correlations, on selection index coefficients, accuracy of selection index, genetic gain in individual traits and expected genetic gain in net hereditary merit due to selection being based on selection index was studied. The predictability of lifetime production (LTP) was judged by estimating the regression of LTP separately on three early economic traits viz. AFC, FLP and FCI and by fitting multiple linear regression of LTP on all possible combinations of the three traits taken two at a time and all the three at a time. The predictability of selection index for LTP was calculated by estimating the simple linear regression of LTP on selection index, constructed on the basis of considering all possible combinations of two traits taken at a time and three taken at a time. Predictability of selection index for LTP was compared with that for multiple regression model incorporating the same traits.

In the index constructed on the basis of all the three traits, the weightages assigned to AFC and FCI were found to be -94 and -8 times the weightage given to FLP. The accuracy of selection index was estimated to be 0.5080. Expected genetic gain per generation of selection was estimated to be -0.365 months in AFC, 19.80 kg in FLP and -7.01 days in FCI. Expected genetic advance in net hereditary merit was calculated to be Rs.81.50 per generation of selection.

The results indicated that when the relative economic value of a trait was increased, the greater weight was found to be given in the index to that trait and an expected increase in total advance made in net hereditary merit. Among the three traits considered a given percent change in relative economic value of AFC had more impact on total genetic gain in net hereditary merit, followed by FCI and FLP. Also, when there was simultaneous change in the relative economic value of the three traits, by 30%, there was almost no change in index coefficients, the accuracy and the expected genetic gain in the component traits but the change in expected genetic gain in net hereditary merit was affected to the same extent. With the increase in heritability estimate of any trait in the index, the absolute value of weight in the index for that trait was increased, the absolute value of expected genetic gain for that trait increased with increased expected genetic gain in aggregate genotypic score (H). Gain in net hereditary merit was highest when the heritability of FCI was increased followed by that for FLP and AFC. Total gain in net hereditary merit was found to be maximum when there was increase in genetic

*X AFC and FLP while increase in cond. between*

correlation between FLP and FCI lowered the expected genetic gain in FLP and expected genetic gain in net hereditary merit.

Correlations of lifetime production (upto 6, 8 and 10 years of age) with AFC and FCI were negatively significant in all the three groups of cows. Correlations of lifetime production with FLP were positively significant in all the three groups. Additional increase in the predictability for lifetime production, while adding FCI to multiple regression equation based on AFC and FLP only, was significant in none of the three groups. Predictability of selection index for lifetime milk production was generally low as compared to that obtained by fitting multiple linear regression equations on the three traits. However, when selection index was constructed on the basis of AFC and FLP, the predictability of selection index for lifetime production was almost of the same order as was obtained by fitting multiple linear regression.



