GENEALOGICAL EVALUATION OF THARPARKAR CATTLE

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information on family members can aid in estimating the genetic merit of an individual.

Basically the aim of a cattle breeder is to increase the profitability of the dairy enterprise, which largely depends upon milk producing ability of the animals. However, as heritability of the trait is in general 0.2 to 0.4, the task of improving genetic potentiality of milk production becomes difficult. Development of potential for increasing lactational milk yield depends in part on identifying early in life dairy animals with high genetic value for milk production. This necessitates use of breeding values estimated from performance of ancestors and collateral relatives. So, in selecting young bulls, reliance must be placed largely on pedigree information. Little work has been done on evaluation methods to estimate genetic worth of females, whereas many more cows are available than bulls to study accuracy of pedigree estimates of breeding value. Selection on the basis of pedigree is the selection method which first can be applied.

The general problem of combining together the information in an animal's pedigree to give the best indication of its breeding value, has considerable practical importance in animal breeding. The estimation of true relative value of individuals from different generations in a pedigree is a rather complicated problem. The solution of the problem must be based on calculation of 'Weights' for each ancestor separately. There are two different methods for pedigree evaluation. The method of approach using the principles of quantitative genetics is well known (Lush, 1935) which later on was dealt with extensively by Le Roy (1958) and Skjervold and Odegard (1959) and rests in essence on the calculation of partial regression coefficients of the animal's breeding value on the separate items of information. The standard partial regression coefficients (expressed in standard deviation units) are estimated from each independent ancestor to the dependent variable. But from practical point of view this method is exceedingly cumbersome. The other method was developed by Robertson (1959). This method is based on so called "Standard progeny records" or "standard daughters". The information obtained from each member of the pedigree is expressed as the equivalent number of "standard daughters" defined as the first single lactation of one daughter. The method is first to get the scale of observations right, as information available is from different generations, and then to take their average, weighting each according to the amount of information it contributes.

The breeding value of an individual may be based on its own records plus those of its relatives. Predicted Breeding Value (PBV) of the individual is the estimate of the individual's genotype and should give genetic worth of an animal. The earlier it is known that which animal is likely to be less or more productive, the higher can be the impact of judicious selection that would result to enhance the productive performance of the herd.

An attempt has been made in the present study to predict the breeding value of Tharparkar animals on the basis of their pedigree records and their own records in case of cows and progeny performance in case of bulls to evaluate the genetic worth of the animals at the earliest possible.

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REVIEW OF LITERATURE

The early investigation by Copeland (1934) revealed that in studying the ancestory of a bull calf, the records of his sire's daughters were considerably more valuable than was the record of the dam alone. Further investigations revealed that the records of the daughters of the maternal grand sire were more closely related to the production of the grand son's daughters than were the records of the daughters of the paternal grandsire. In respect of cow evaluation, it appeared that if a cow had a production record herself, records of two or more tested daughters, and of number of tested daughters of her sire, the sum of this information gave a good index of her germ plasm composition and transmitting ability.

Lush (1935) and later on Le Roy (1958) developed methods of pedigree evaluation based on so called "standard partial regression coefficient" to assign values to paths from each of independent ancestors to the dependent progeny.

Legates and Lush (1954) reported a correlation coefficient of +0.073 between cow's own performance and that of her maternal sisters for fat yield and +0.120 with that of her paternal sisters.

Korkman (1958) found statistical correlation between F-numbers of the bull and of his sire (+0.296) and between the F-numbers of the bull and his dam's yield (+0.144) and therefore indicated that some attention should be paid to the parentage of the bull for its genetic evaluation.

Roder (1958) stressed that while evaluating cows, more accuracy could be obtained if "relative values" (deviations from herd mean) were used rather than absolute values. 'Accuracy of cow evaluation was increased by considering all lactation yields of a cow, and to evaluate a bull with reasonable accuracy the first yields of 30 daughters was a must.'

Varo (1958) found from progeny tests of sons of superior and inferior parents that the "relative evaluation method" (deviations from herd mean) was a more accurate guide to the breeding value of the sires for milk production than the actual average yield of his daughters.

Eisner (1959) presented a formula by which the expected milk yield of the daughters of a bull was calculated:

$$S+(M-S)0.2+(MD-S)0.1+(MM-S)0.1+(PS-S)0.45+(MD-S)0.4$$

Where,

S = Herd average,

M = Average yield of bull's dam,

MD & MM = Average yield of bull's grand dams,

PS = Average yield of bull's half-sisters,

MD = Average yield of the cows with which the bull was mated.

The above formula was used to evaluate several bulls and the expected yield of the daughters was found to be related to the actual yield.

Ermolaev (1959) obtained data over a 20 year period of Bestuzher cattle and found pronounced maternal effect on the butterfat content of the milk. Butterfat content of milk of cows was highly correlated with that of female ancestors in both high butterfat and low butterfat group. It was nevertheless revealed that careful matching of males and females was necessary to obtain higher butterfat content.

Fewson (1959) used LeRoy's "accuracy values" (which measure the degree of relationship between the actual genotype of an animal and its hereditary value as estimated on the basis of a selection index) to assess the relative reliability of various methods of determining breeding value. Choosing milk yield ($h^2 = 0.3$) and butterfat content ($h^2 = 0.7$) as indicators of performance, he concluded that when h^2 was low, the accuracy of prediction was greatly increased by taking into account all information on individual performance, performance of half-sisters and ancestors.

Gertenbach (1959) found out relationship between the yields of dams, daughters, grand dams and grand daughters. He reported that going further back added little to the accuracy.

Mutscheller (1959) made genealogical investigations on 2259 pedigree German Brown cows and found that unreliable estimates of breeding value were obtained if only female records were available, and inclusion of sire records was a valuable aid to breeding programme. He also emphasised that there was no use going further back than grand parental generation.

Taking into consideration that earlier methods of Lush and LeRoy were exceedingly cumbersome, Robertson (1959) presented a simple and general approximate method of pedigree evaluation that rested in essence on calculation of "standard progeny records" or "standard daughters" for information from each member of the pedigree. Information on all yields of females and 1st lactations of all daughters of bulls occurring in the pedigree was represented as deviation from the herd mean. Formulae had been derived for transferring "weights" from one generation to another (assuming $h^2 = 0.25$, $r = 0.50$ for milk production; $h^2 = 0.50$, $r = 0.60$ for fat content) as $\frac{5n}{n+20}$ and $\frac{7n}{3n+28}$ for the two traits respectively, where, n is the value of the weight. Finally "Predicted Breeding Value" (PBV) was calculated by regressing the "Expected Breeding Value" (EBV) of the animal to herd mean by a factor

$$\frac{0.25\ nh^2}{1 + (n-1)\ 0.25\ nh^2}$$

n = weight

h^2 = heritability

It was concluded that loss of available information using approximate method rather than using correct method was only 1% and was thus quite insignificant.

Skjervold and Odegard (1959) estimated breeding value on individual's own phenotype and ancestor merit (upto grand parents only). The results were quite in agreement in both cases and their different combinations. Same workers in 1960 showed that selection for litter size and piglets weight in pigs had to be based on ancestors alone.

Lorenz (1960) compared first annual yields of 5502 daughters with the average yield of their dams, and with average yields of dams + 2 granddams. He concluded that data on grand dams added little to the accuracy and that data on half-mates were of no importance.

Sebestyn (1960) found the coefficient of correlation between the average butterfat production in 4-6 lactations of an average of 9.4 daughters and 11.7 half-sisters representing 65-progeny groups was +0.64. It was concluded that a bull's transmitting ability for milk production should be based on his half-sisters production as well as on his dam's production. Same author in 1961 determined relationship between the milk yield of the daughters and their dams and paternal halfsibs. The milk yield of daughters showed more relationship to their halfsibs than to that of their paternal grand dams.

Osinga (1962) analysed data pertaining to 114 Friesian bulls and concluded that the breeding value of a bull could not be judged solely on the production of his female ancestors and that attention should also be paid to the transmitting ability of the sire and even of the grand sire.

Azgun (1963) analysed data relating to 266 Friesian bulls and obtained +ve correlation between sires and son's in hereditary transmission of milk yield (+0.37). Butterfat was correlated with both sire (+0.35) and dam (+0.44). No correlation was obtained for milk yield between production of dams and "Expected Transmitting Ability" (ETA) of sons.

Politiek and Vos (1963), for 527 bulls reported +ve correlation between dam and daughter for butterfat. Regression of mean fat of 2 year old dam and progeny was 0.5.

Deaton (1964) and Deaton and McGilliard (1965) found that multiple correlation of the cow index (based on information from ancestors) with the cow's genotype ranged from +0.50 to +0.73 depending on type and amount of information available from the relations. The correlation of a cow's index and an unselected daughter's record was 0.1666, and the correlation between the actual production of a cow and her daughter was 0.140.

Everett et al. (1964) reported for 1st lactation records, the correlation between records of the cow and

those of her daughters varied from -0.04 to 0.24. Dam's records were negatively correlated with son's progeny test and correlation between progeny test and the average production of the daughter's of the bulls dam was 0.26. The coefficient of correlations were greater when records on all lactations were used rather than only 1st lactation.

Henderson (1964) used records of 24,000 animals in 157 herds and found that gain in S.D. from using a large information on each cow compared with that from using only on individual's own records was small.

Searle (1964) concluded that for a $h^2 = 0.25$, a sire's progeny test based on indefinite number of daughters would give no more information about his son's true merit than that of progeny test of the son himself based on five of his own daughters.

Vos and Politiek (1964) obtained data on the progeny tested Dutch Friesian bulls and found no correlation between the son's milk index and the dam's milk yield (0.06), however, the correlation between the son's milk index and sire's milk index was 0.49. Considering dam's average yield/day along with sire index, the correlation was 0.38.

Engeler and Herzog (1965) found a low but significant correlation (0.2) between completed lactation yields of dams (min. 3 lactations) and daughters (average 31.2 per bull) of 436 Swiss Brown bulls. The authors in the same year compared 131 sire-son pairs of Swiss Brown bulls,

which gave correlation, based on an average of 1-3 lactations of their daughters, of 0.44 for milk production. Sires passed on good breeding characteristics to sons in 75% cases. They concluded that selection of young bulls on the basis of their sire's performance could be twice as reliable as based on their dam's performance over several years.

Ernst (1965) concluded that progeny testing for sire evaluation was more effective than that based on records of female ancestors.

Herzog (1965) calculated correlation for milk yield between daughters of 131 progeny tested Swiss Brown sires and the daughters of their sons with only 1st lactation, second and third lactation records of 0.44 and 0.39. Correlation between the yield of 436 bull's dams with a minimum of 3 lactations, and those of bull's daughters were +0.205 and 0.216 depending upon method of assessing daughter's production. It was concluded that in bull selection, information of dam's production would be useful where other information was lacking.

Lampo and Willems (1965) studied the value of the production data of the bull's dam and her parents in estimating the breeding value of a young bull. Coefficient of determination of breeding value rose as number of lactations of bull's dam increased and as more data became available.

Nedelova (1965) used variance and multiple regression analysis on the records of two generations of

ancestors of 130 Red Danish and 141 Czechoslovak Red Spotted bulls. The Relative Breeding Value (RBV) of the son's was closely related to that of their sires. The milk production of a bull's dam was not related to that of his daughters.

Bekedam et al. (1966) calculated, on the basis of average daily milk yield for the 1st lactation only, correlation coefficient ranging between +0.18 to +0.33 between dam's performance and the breeding value of her son, the values being higher than those reported previously by workers on same herd (including Azgun, 1963) who used record on 1st three lactations of females.

Burkat (1966) concluded that selection of stud bulls on the production of sisters and half-sisters, or dams and grand dams was unsatisfactory and recommended crossing of outstanding lines for increasing milk production.

Gluscenko (1967) surveyed data on 71 Kostroma and 68 Yarostavl (males) and 19367 lactations of their daughters, half-sisters, dams and grand dams. For each breed the correlation between the daughter's yield and those of:-

(a) Sire's dam,

(b) Sire's half-sisters,

(c) Sire's dams + grand dams,

were lower than the correlation between the daughter's yield,

and, (d) Combined yield of sire's dam and half-sisters,

and, (e) Combined yields of the direct and collateral

relatives of sires in the parental and grand parental generations.

Holl (1967) found a correlation of +0.17 for RBV of sires and sons based on 319 sire-son pairs.

Basovskii and Fedorova (1968) analysed data on the daughters of 1500 bulls and found a correlation of +0.29 between the daughters of the bulls and their dams for milk production.

Nedelova (1968) found correlation between the R.B.V. of the sire-son as +0.381, +0.200, +0.242 in 175 pairs where both males had 40 daughters, in 131 pairs where both males had 40 daughters and R.B.V. 100% and in 195 pairs where R.B.V. was 100% and the number of daughters was not a criterion.

Nedelova (1968) constructed a selection index based on pedigree. Data on 450 Czechoslovak Red Spotted males were used to calculate correlation between the milk yield of the daughters of the individual males and those of daughters of their sires, of their dams and grand dams, and between those of their dams and grand dams; the closest correlations were +0.386 between the milk yield of the daughters of the individual bulls and that of daughters of their sire. Multiple regressions were used to produce selection indices. The same author in the same year analysed data on 159 Czeckoslovak Red Spotted sires and their 450 sons. It was concluded from 26 partial analyses that

selection on breeding value of sire could reduce R.B.V. of the son. No advantage was gained by using 25 effective (i.e. actual 40) daughters in a test.

Odegard (1968) in an attempt to find relationship between progeny tests of 37 fathers and 155 sons of Norwegian Red and White A.I. bulls for FCM (fat-corrected milk, $h^2 = 0.2$) found that regression of son's progeny test on sire was in agreement with heritability.

Skjervold (1968) estimated the breeding value on different combinations of individual performance, full-sibs, half-sibs, progeny and pedigree and included, c, the environmental correlation. The value of information from sibs dependent on c-effects. It was nearly zero when,

$$c^2 = 0.3708 - 0.4470h^2 + 0.0004m - 0.0007n$$

Where, m = number of fullsibs,

n = paternal halfsibs

He concluded that in cattle breeding, the expected breeding values of young bulls should be estimated mostly from paternal halfsibs i.e. progeny tests of sires. In ranking A.I.bulls, very little could be gained by including the pedigree.

Mocquot and Poutous (1969) analysed data on 186-sire-son pairs (at least 15 daughters per bull) and found that for milk production, correlation and its efficiency ($\frac{100r}{\text{Expected } r}$ in %) were +0.30 and 81%. In 52 pairs with at least 35 daughters per bull the corresponding figures were 0.52 and 118%.

VanVleck (1969) studied the information from 541 Holstein matings to find out weights of different relatives viz., paternal sisters, dams, paternal sisters' of dams, maternal sisters, maternal grand dams and maternal sisters' of dams. The average index of superiority for the 541 progeny ranged between 406-455 kg milk depending upon combinations of relatives used. He found that records of maternal relatives (grand dams, dams) received too much emphasis as compared to theoretical weights, which might be due to greater opportunity for selection.

Kovalcikova and Plesnk (1970), in 340 dam-daughter pairs found coefficient of correlation for milk yield as +0.15, +0.34, and +0.28 for second, first three and peak lactation respectively. All estimates were significant.

Mostager (1970) studied the value of information on ancestors in evaluating the additive genetic merit of an individual, for the case when the character was expressed in both sexes using any number of ancestor generations and the recurrence relation was developed for the case when the character studied was expressed only in females. The limit to the accuracy using upto 10 generations of ancestors was proved to be:

$$\frac{(1+h^2 = \sqrt{1+2h^2 - 2\ R^4})}{3h^2}$$

Where, h^2 = heritability

It was concluded that information from the infinite pedigree chart of a bull and from an average of 1.75 halfsib daughters of the bull was equally informative with respect to their breeding value when h^2 for milk production was taken as 0.25.

Ruzhevskii (1970) evaluated 359 Russian Black Pied bulls:

(1) according to the formula 2 x Dam's Average-Daughters average,

(2) based on the average of the rating of a bull's sire and his dam's average.

The correlation between the two methods was +0.43.

The dam-daughter and grand dam-grand daughter correlations were +0.50 and +0.29 respectively.

Thomson and Freeman (1970) evaluated effect of environmental correlations among records of ancestors of A.I. bulls with data recorded over a 10-year period comprising 1,58,336 records by 62,389 Holstein-Friesian cows. The environmental correlations among records of cows calving in the same herd and year-season, in the same herd but different year-season, as in the same year-season but different herds were +0.328, +0.226, and +0.028 respectively for M.E. and 0.0, 0.0 and +0.003 for similar estimates respectively for deviation records. Additional environmental correlation for half-sisters in the same herd were +0.005 and +0.102 for M.E. and deviation records respectively. Correlation between computed indexes of breeding value and

estimates from progeny performance of the bulls were near 0.0 for M.E. records and near +0.25 for indexes of deviation records.

Eugster (1971) gave a new method for gaining a provisional estimate based on milk yield of dam and both grand dams and on the progeny test results of sire and both grand sires of a young bull of estimates obtained and compared with later progeny tests, 25% were in good agreement.

Kenopka et al. (1971) made investigations on 112 Polish Black and White Lowland heifers and calculated breeding value by Robertson's method. A correlation of r+0.238 was obtained between the breeding value of heifer and their milk yield which was higher than that between production of heifers and production of dams.

Lampo and Willems (1971) tested more than 5400 East Flemish Red Pied heifers which were daughters of 80 sires and their 220 sons. Sire-son regression for milk yield for three progeny groups of 5-20, 21-40 and 40 daughters reached only 25, 75 and 90% of the theoretically expected values.

Syrstad (1971) used a cow index which included in addition to cow's own records, information on the P.B.V. of sire and dam. The index x expressed the RBV of cows. Data constituted 136,000 Red and White cows.

Borozdina (1972) tabulated data on the dairy performance of 3 types of female relatives of 5 Russian Brown bulls and compared with contemporaries. It was

concluded that evaluation on the performance of half-sisters was a useful procedure when carried out under standardised feeding.

Kushner et al. (1972) for 46 and 66 Red Stepple bulls and 44 Russian Simmental bulls at three farms, calculated correlation between the dairy performance of their daughters (1163, 2118 and 1354 females respectively) and that of various female ancestors and half-sisters of the bulls. None of the correlations in respect of the female ancestors was significant. A significant correlation of +0.35 between daughters and half-sisters was found in respect of milk yield on one farm.

Lindstrom and Vilva (1972) constructed a pedigree index for selection of bull calves for milk production based on sire, dam and maternal grand sire information. They checked reliability of the index against progeny test results for 113-361 Finnish Ayrshire bulls. The correlation between the two methods ranged from 0.24 to 0.32 and were significant.

Neumann and Fiegenbaum (1972) with data of 499-6259 German Black Pied dam-daughter pairs in 20-240 sire groups in 10 regions found dam-daughter genetic correlation for milk yield 0.13-0.72 and phenotypic correlation 0.06-0.16. All values 0.1 were highly significant.

VanVleck and Carter (1972) calculated Estimated Daughter Superiorities (EDS) of 240 Holstein-Friesian bulls from records of paternal sisters of the sire, dam and records

of daughters of maternal grand sire. Although response was not as large as predicted but it was concluded that selection of young bulls with high EDS is an effective method of finding a superior group of young bulls for further sampling.

Vinson, Freeman (1972) examined pedigree and performance data supplied by 7 major A.I.studs to evaluate the intensity of pedigree and progeny test achieved by using young Holstein-Friesian bulls for A.I. Pedigree selection was found to be less effective than expected.

B., R.; L., A. (1973) obtained results from 224 Brown Swiss bulls with 30 daughters having 1st lactation records and 192 bulls with daughters having 2nd lactation record. They found that accuracy of estimation of the bull's breeding value based on dam's first lactation, sire-proof and ancestor proof was 2.3, 11 and 21.9% respectively. Highly significant correlations between breeding value estimates from ancestor proofs and progeny-testing ranged from +0.43 for bulls with 30-40 daughters and 0.51 for bulls having 51 daughters.

Cassel et al. (1973) analysed data on 336253 registered Holstein Friesian daughters of 1872 sire-son pairs. They found that regressions of son's progeny test on sire's progeny average were +ve for all traits.

Kakhikalo (1973) derived results from 37 sire-son pairs of Kurgan bulls. The correlations between the son's daughter performance and (a) sons' half-sisters,

(b) sons' dams in peak lactations, (c) the sons' dams on average, and (d) sons dam + half-sisters. Highest positive correlations were obtained for milk fat percent in groups c and d (0.26 and 0.31 respectively). All correlations for milk yield were negative.

Boev (1974) performed investigations that involved 13 dams selected on pedigree and 74 dams selected on their performance of Russian Simmental breed and found that for the two groups of dams respectively, milk yield averaged 4908 and 4191 kg.

Butcher (1974) used pedigree records of 340 Holstein-Friesian sons. Correlations of +0.43, +0.24, +0.21, +0.16 and +0.16 were obtained between sire-son, son-maternal grand sire, son-dam's 1st records, son-dam's 2nd record, and son-dam's 2nd record respectively. Correlation between son's breeding value and son's pedigree index computed by combining breeding value estimates, on sire, maternal grand sire and dam's first three records was found to be +0.47. He showed that predicting son's breeding value solely from first five records of dam gave larger regression coefficient for the dam's first record, indicating that it was a better predictor of son's breeding value than any other lactation of dam. An intercept of -325 kg was obtained for the regression of son's proof on son's pedigree index, indicating that the pedigree index was overestimating son's breeding value based on his progeny test.

McGilliard (1974) and McGilliard and Freeman (1976) analysed data on 10349 Holstein Friesians and found that Expected average transmitting ability (EATA) of dams (which estimated half the genetic worth of the cow from her records, and records of her dam, daughters, paternal and maternal sisters) was correlated with milk yield of daughter's 1st lactation by +0.18 compared with an expected value of +0.20. Multiple correlations indicated that dam and maternal sisters contributed less than expected to the accuracy of predicting daughter's yield.

Owen (1974) found that genetic progress by selecting young bulls on half sisters' records was similar to progeny testing but the cost was less.

Pilz and Schonmuth (1974) evaluated 500 bulls by dam-daughter regression and found a correlation +0.19 between milk yield of a sire's dam with his breeding value. They further found that for each one kg increase in flow rate of the max. 1-min. milk yield of sire's dam gave 0.04 kg increase in milk yield of his daughters.

Poutous _et al_. (1974) calculated three basic cow indexes based on:

(1) Cow's own performance,

(2) Performance of ancestors, and

(3) Combined information.

The accuracy of cow index as given by the squared correlation between the index and the true genetic

value was 0.42 and 0.47 for 1st and 2nd lactations when ancestor data was included and 0.27 and 0.39 when they were not.

Schonmuth and Pilz (1974) found correlation of son's breeding value with sire's breeding value and dam's breeding value was 0.23 and 0.19 respectively. Correlation of a young bull's classification with his breeding value at later assessment for milk yield was +0.17.

Schwarj (1974) calculated P.B.V. of a young bull, based on his sire's breeding value, dam's contemporary comparison and breeding value of dam's sire for 176 German Simmental bulls and found that for males with P.B.V. of ∠200, 200-349, 350-500 and 500 milk, the realised breeding values, based on their daughters' first lactation, averaged 47, 116, 141 and 369 kg respectively.

Vinnichuk (1974) described a method whereby the 1st lactation milk yield of a bull's daughter was estimated from the 1st lactation records of the sire's dam and the heifer's dam and maternal grand dam and the average 1st lactation yields of half-sisters of each of female ancestors. The average of the value of the each ancestor and the average value of her halfsibs was calculated for each female ancestor in the pedigree. A correlation of +0.58 was found between the actual 1st lactation yield and estimated yield. The difference between the estimated and actual yields was 79-84 kg V 55 kg based on dam-daughter comparisons among paternal halfsibs.

Vinson and Freeman (1974) compared progeny testing of young bulls with pedigree selection, for semen banking. He concluded that pedigree selection with semen banking produced slight to moderate, decrease in cost and increase in number of bulls tested. He further concluded that pedigree selection was most advantageous where a high proportion of bulls tested returned to service and where correlation between pedigree and progeny test evaluation was high.

Bray *et al.* (1975) used data on 150 Holstein Friesian pedigree bulls to develop pedigree indices for estimating P.D. for milk and 4% FCM and found that multiple correlation coefficients between actual and estimated P.D. were +0.357 and +0.293.

Eisner *et al.* (1975) estimated breeding value of bulls using performance data on his dam and paternal half-sisters by 'Duplex-Method'. Results showed that for 6 bulls with 1st lactation milk yield of daughters (11-42 daughters/bull) exceeded the yield predicted by "Duplex Method" by 3.3 to 10.1%.

Henderson (1975a,b,c,1976a,b,1977) and Henderson and Quass (1976) developed BLUP procedures for using relationship among sires to increase accuracy of sire evaluation, to find rapidly the inverse matrix of relationship due to OO ancestors and all relatives. He also gave simplified BLUP procedures for multiple trait

sire evaluation, with or without using relatives' records, and to find out of inverse of matrix of relationship without computing relationship matrix.

Novostavskii and Dolgobrod (1975) estimated breeding value of bulls based on pedigree using a multiple regression model using milk yield, fat percentage, fat yield of a bull's daughters, his dam, his sire's progeny, and his grand dam, and grand sire's progeny. In estimating breeding value for milk production, the independent variables milk yield of daughters and fat percent of other relatives were included. Multiple correlation coefficients were +0.544, +0.623, +0.421, +0.540 for records on 1st lactations, 2nd lactations, 3rd lactations and peak lactations.

Bratt and Elofson (1976) prepared a cow index mainly for selecting bull dams which was based on information on:-

(1) Individual's own yield,

(2) Breeding value of sire, and

(3) Cow Index of dam

However, the index could also be used for any cows.

Burnside (1976) collected information on 216 bulls, all of which had positive pedigree Index for average point score, only 38 percent had a positive progeny test score. Average progeny test proofs increased from -4.92 for bulls with a positive pedigree index to +3.01 for bulls with an index of 6.0, while average progeny test proofs

increased from -2.86 to +4.50 respectively. In both cases, number of positive bulls increased with predicted pedigree indexes.

Lindstrom and Sirkkomaa (1976) compared progeny tests for milk yield (adjusted for year) based on 20 daughter per bull in 1368 Ayrshire and 351 Finnish sire-son pairs. Pairs were in agreement in 80% cases in Ayrshire breed whereas in Finnish only 33.3% were in agreement for milk yield. Variation in sons accounted for by sires in both breeds was 25%. In both breeds sons of superior sires produced daughter groups with above average performance for milk yield and fat percentage.

McNaill et al. (1976) found that empirical correlation between son's type proofs and pedigree information were 76% of their theoretically expected values. The correlation between son's type proofs and information from dam was greater than expected. He concluded that selection of young bulls for progeny testing based on their pedigree evaluation for type should be an effective preliminary selection, although practically found less effective than expected.

Rindsig (1976) evaluated 201 Holstein bulls by various models (different combinations of ancestor information) for milk yield and fat using 23,500 1st lactation records. Estimates of all models were found to be highly correlated with each other.

Incorporating information on production of dams and sires' progeny, Robertson and Fairlie (1976) evaluated 1750 Ayrshire cows in 27 herds. The average value of all cows was +150 kg milk.

Stewart et al. (1976) found positive correlation between progeny performance and pedigree indices. Progeny performance for body confirmation was related to pedigree indices, sire-score, and an approximate index based on sire and maternal grand sire. In both cases, it was concluded that pedigree index was the best indicator of progeny performance.

Cassell and Norman (1977) used sire summary on 702 Holstein-Friesian bulls to develop a measure of daughter performance. P.D. of milk, fat and 72 other variables were independent variables for prediction of performance of additional daughters for milk and fat. The best predictive equation for performance of additional daughters for milk included PD for milk, fraction culled, and repeatability x contemporary Father's Modified Contemporary Deviation (MCD) for milk. PD for milk alone accounted for 93.4% as much of the predictive variation as did the entire predictive equation. PD for milk and fat from multiherd proofs appeared to be sufficiently accurate prediction of performance of future daughters to serve as the sole criterion for production in breeding programmes.

Chesnak (1977) used the idea of 'a priori' information using Henderson's BLUP method of 1975,1976. The

general deviation of a BLUP was given, together with two other methods leading to the same estimates. A comparison was made between the contemporary comparison (CC) and BLUP Methods for the estimation of breeding value of dairy sires.

Henderson (1977) presented review for the prediction of -

(1) The yields of future daughters of dairy sires,

(2) Future yields of heifers and cows, and

(3) a function of the yield of future progeny for three traits.

Best prediction, Best linear prediction and BLUP and efficient computations of the last two, were summarized, and various applications of BLUP were given.

Hornansky (1977) analysed milk production records of 1st, maximum, and average lactations of 195 Slovakian Pied bull dams and obtained data on R.B.V. for milk for 68 sire-son pairs. Whilst correlations of 1st and average lactation of dams with the son's R.B.V. for milk were -0.38 ($P < 0.01$) and -0.29 ($P < 0.05$) respectively, the correlations of son's R.B.V. with that of his sire was +0.32 ($P < 0.01$).

Powell *et al.* (1977) investigated appropriateness of P.D. of bulls, whether it was directly influenced by merit of its male ancestors and the accuracy of pedigree indices. Sire pedigree indices calculated from PD were

nearly as accurate as expected. Regression of average daughter performance (MCD) on pedigree index was near the expected 1.0. Correlations were reasonably close to the approximated values. Corresponding relationships between PD and pedigree index gave similar results.

Powell (1978) outlined a procedure which provided necessary weights for inclusion of records of dam and maternal grand sire of cow in USDA-DHIA cow indexes which previously utilized information only on cow herself and her sire. Procedure provided method of simple calculation of weights rather than by matrix inversion. It was concluded that by this method more accurate indexes could be calculated.

Pedigree index values were compared with actual proofs for various traits in some of the Holstein Friesian sires by Schaeffer and Burnside (1978) for 20 bulls with indices 6 BCA for milk yield, out of which half had actual proofs above their index values. Similar results were obtained for 26 bulls with milk yield indices of 2 BCA, only 1 bull in this group had an actual proof 6, and also for 21 bulls with indices $\angle 0$.

Spike and Freeman (1978) studied information of 25,843 cows in 693 herds and concluded that both inclusion of more information from relatives and Herd Mate averages improved the association of herd production with estimates of breeding value.

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MATERIALS AND METHODS

The data presented in this investigation were collected from available records of the Tharparkar herd maintained at the National Dairy Research Institute, Karnal (Haryana). The herd was established in 1923, when 61 animals were purchased from West Punjab (now Pakistan). History of this Tharparkar herd had been extensively detailed (Kumaran, 1956; Sundaresan *et al.*, 1965 and Bhatnagar *et al.*, 1976).

The breeding programme of Tharparkar cows at Karnal was to raise the pedigree Tharparkar bull calves for distribution to different state governments for upgrading their livestock. Since 1971, the Tharparkar females are being crossed to exotic bulls of three breeds viz., Holstein Friesian, Jersey and Brown Swiss for raising crossbreds. Subsequently, triple-crosses (Holstein x Brown Swiss x Tharparkar; Holstein x Jersey x Tharparkar) have also been obtained.

Pedigrees of Tharparkar females crossed to potent exotic sires were traced as far as possible. The performance records of 474 cows, 83 sires and their 1094 daughters constituted the material for this study. Informations on percentage, date of birth, first 305-day lactation yield (kg) and lifetime 305-day production (kg)

were collected from the available records from 1923 to 1978. Informations on first 305-day yield (kg) and lifetime 305-day yield (kg) for all the daughters of the sires occurring in the pedigrees were also collected. Lactations, whose length were less than 100 days, were considered abnormal and, thus, were excluded from this investigation. Data on lactations of less than 305-day standard length, incomplete due to accidents (death, culling, transfer), were also not considered. If an animal produced milk for any number of days between 101-305, the lactation was considered to be 305-day. On the other hand, if an animal produced milk for more than 305 days, the first 305-day production was accounted.

Milk records in pounds were converted into kilograms.

The breeding value, the average effect of parental genes that determine the mean genotypic value of its progeny, was calculated by the method based on 'standard progeny records' or 'standard daughters' (Robertson, 1959). The information obtained from each member of the pedigree was expressed as the equivalent number of standard daughters, defined as the first single lactation record of one daughter.

In order to evaluate the breeding value of an individual on the basis of its pedigree, the

following four items of information were required:-

1. The phenotypic value.

2. A scaler factor which equalises phenotypic value from different generations.

3. A "weight" which expresses the accuracy of the phenotypic breeding value (based on the amount of information an animal contributed).

4. A conversion factor which transfers "weights" from one generation to another.

1. Phenotypic Value

Instead of absolute yield, the yield relative to the herd average was used. In respect of bulls, the progeny testing result was expressed in relative terms. Age correction factors were not applied as they were invariably confounded with year effects and because even small errors in age correction factors derived from other sources could create a serious bias in the estimates (Rendel and Robertson, 1950; Henderson, 1958; Tajane, 1975).

2. Scale factor

The phenotypic values were transferred from one generation to the previous or subsequent generation by multiplication by two. The reason being that progeny is expected to differ from the herd mean by half the deviation of the breeding value from the mean of the animal in question. So, to consider the progeny on the same scale, it was essential to multiply the deviation by two. The same applied to the members of the previous generation also,

because they too had half the genes in common with the animal in question.

3. Weight

The weight was expressed as standard progeny record.

(a) Bull:- A bull whose breeding value was estimated on the basis of the first lactations of n daughters was given a weight 'n'.

(b) Cow:- The correlation between the cow's own performance and her breeding value was $h(\sqrt{h^2})$. The correlation for the average performance of m daughters was:

$$\frac{1/4mh^2}{1+1/4(m-1)h^2}$$

Where,

m = no. of daughters,

h^2 = heritability of the trait.

This for equivalence:

$$m = \frac{4 - h^2}{1 - h^2}$$

The breeding value of such a cow, having one lactation record, was given a weight 5 ($h^2 = 0.25$). Knowledge of more than one lactation yield increased the accuracy of the breeding value assessment (calculation of $h_n^2 = \frac{nh^2}{1+(n-1)r}$). This increase in accuracy could be fixed at 50% when second lactation was taken into

consideration in addition to first lactation, when the third lactation was included, the accuracy increased with another 25% and so on. However, six lactations almost gave complete information. The weights for the breeding values of the cows with different number of lactations have been summarised in table I.

4. Conversion factor

The following conversion factor was used when a given weight was transferred from one generation to another (previous or subsequent).

$$b = h^2_{\text{progeny test}} = \frac{0.25\, nh^2}{1+(n-1)0.25h^2}$$

$$= \frac{n}{n + \frac{4 - h^2}{h^2}} = \frac{n}{n + a}$$

where,

$$a = \frac{4 - h^2}{h^2}$$

$$b = \frac{n}{n + 15} \qquad (\text{when, } h^2 = 0.25)$$

If a sire had n daughters, the equivalent number of son's daughters, m, was got by equating two bits of evidence with the son's breeding value, i.e.

$$r_{A_s F_d} = \tfrac{1}{2}\sqrt{\frac{0.25\, nh^2}{1+(n-1)0.25h^2}} = \tfrac{1}{2}\sqrt{\frac{n}{n + a}}$$

in the first case, where,

$r_{A_s F_d}$ = Correlation between sire's daughters and son's breeding value.

$$\text{and } r_{A_s F_s} = \sqrt{\frac{0.25\, mh^2}{1+(m-1)0.25h^2}} = \sqrt{\frac{m}{m+a}}$$

in the second case, where,

$r_{A_s F_s}$ = Correlation between son's breeding value and its daughters.

Equating these two:

$$1/2\sqrt{\frac{n}{n+a}} = \sqrt{\frac{m}{m+a}}$$

$$m = \frac{na}{3n+4a}, \text{ for equivalence.}$$

So, Conversion factor $= \dfrac{a}{3n+4a}$

It means that in order to transfer a weight 'n' to a previous or subsequent generation, a multiplication with the conversion factor $\dfrac{a}{3n+4a}$ was required (Robertson, 1959). Table I and Table II summarise some equivalent standard daughter records for females and males respectively.

Table I. Number of equivalent standard daughter records

No. of Records (Lactations)	Equivalent standard daughters On Cow Herself	On Daughter
1	5	1
2	7.5	1.3636
3	8.8	1.5278
4	9.4	1.5986
5	9.7	1.6330
6 or more	10.0	1.6667

Six lactations give almost complete information.

The factor to transfer weight from one generation to another is $\frac{5n}{n + 20}$, Where, n = number of standard progeny records (heritability = 0.25; repeatability = 0.50).

Table II. Information given by a sire's progeny test on the breeding value of his son in terms of the equivalent standard daughters records of the latter

Sire's daughters	Equivalent number of son's daughters
5	1.0000
10	1.6667
15	2.1429
20	2.2500
25	2.2778
50	3.5714
100	4.1667

Prediction of breeding value

Having combined all the evidence from pedigree information to the animal in question, the breeding value of such an animal was predicted by regressing the average deviation back to the population mean by a factor:

$$\frac{0.25\ nh^2}{1 + (n-1)\ 0.25\ nh^2}$$

$$= \frac{n}{n + \frac{4 - h^2}{h^2}}$$

$$= \frac{n}{n + a}$$

$$= \frac{n}{n + 15} \qquad (\text{for } h^2 = 0.25)$$

Where,

n = total value of the evidence,

h^2 = heritability of trait,

$$a = \frac{4 - h^2}{h^2}$$

So, the predicted breeding value of the animal in question would be:

PBV = b x Estimated breeding value.

Where, estimated breeding value is the breeding value of the animal estimated by the actual records available on animal itself and its pedigree information.

$$\text{PBV} = \frac{\sum(\text{Converted weight} \times \text{Transferred breeding value}}{(\text{Converted weight} + 15)}$$

In simple words, it can be stated that to finally predict the breeding value, the animal is started off with 15 hypothetical daughters at the herd mean (having zero deviation) and working out the average performance of the daughters including the hypothetical ones (Robertson, 1955).

Accuracy of the Estimate

The weight (the accuracy) as already stated is, b.

$$b = \frac{n}{n + 15}$$

Where,

n = total value of the evidence.

Correlation

The correlation coefficient between different variables was calculated as product moment correlation using the method described by Snedecor and Cochran (1967). The correlation coefficient was calculated by the formula:

$$r_{XY} = \frac{\sum_{i=1}^{n} X_i Y_i}{\sqrt{\sum_{i=1}^{n} X_i^2 \sum_{i=1}^{n} Y_i^2}}$$

Where,

X and Y are two traits,

n = No. of observations,

X_i^2 = Squares of deviations from the mean for X,

Y_i^2 = Squares of deviations from the mean for Y,

$X_i Y_i$ = Cross products of deviations from the mean of the two traits.

Standard error of the correlation was calculated by the formula:

$$S.E.(r) = \frac{\sqrt{1 - r^2}}{\sqrt{n - 2}}$$

To test its significant 't' test was applied (Snedecor and Cochran, 1967).

$$t = r\sqrt{\frac{n-2}{1-r^2}} \quad , \text{ at } n-2 \text{ d.f.}$$

Regression

The regression coefficient between different variables was calculated by the formula:

$$b_{YX} = \frac{\sum_{i=1}^{n} X_i Y_i}{\sum_{i=1}^{n} X_i^2}$$

and, its standard error -

$$S.E.(b) = \sqrt{\frac{\sum_{i=1}^{n} Y^2 - \frac{\sum_{i=1}^{n} XY}{\sum_{i=1}^{n} X^2}}{(n - 2) \sum_{i=1}^{n} X^2}}$$

(Becker, 1975)

Multiple Regression Equation

The multiple regression equation of Predicted Breeding Value of dam and Predicted Breeding value of sire with Predicted Breeding Value of daughter was estimated:

Model:-

$$Y_{ij} = a + b_1 X_1 + b_2 X_2$$

Where,

Y = the predicted breeding value of daughter,

a = Constant,

b_1 = Partial regression coefficient of Y on X_1 (Predicted Breeding Value of Dam),

b_2 = Partial regression coefficient of Y on X_2 (Predicted Breeding Value of sire).

The coefficients a, b_1, b_2 were estimated by minimizing the quantity $(Y - \hat{Y})^2$ representing the residual variation as given by Snedecor and Cochran, 1967 (by inverse-matrix method).

The accuracy of prediction (R^2) of dependent variable based on the independent variables using the multiple regression method was obtained as:

$$R^2 = \frac{b_1(\Sigma YX_1 - \frac{\Sigma Y.\Sigma X_1}{n}) + b_2(\Sigma YX_2 - \frac{\Sigma Y.\Sigma X_2}{n})}{\Sigma Y^2 - \frac{[\Sigma(Y)]^2}{n}}$$

The square root of R^2 was calculated to obtain the multiple correlation of dependent variable with the independent variable considered in fitting the multiple regression equation.

Standard error of multiple regression coefficients was calculated by the formula:-

$$S.E.(b_i) = \sqrt{C_{ii}} \cdot \sqrt{\frac{\Sigma Y^2 - (b_i \Sigma YX_i + b_j \Sigma YX_j)}{n - 2}}$$

Where,

C_{ii} = element of inverse-matrix corresponding to b_i.

Table III. Expected gain in weight from one generation with differential amount of information from the two parents.

Number of daughters	Weight	Number of lactations					
		1	2	3	4	5	6
		Weight 1.0000 w	Weight 1.3636 w	Weight 1.5278 w	Weight 1.5986 w	Weight 1.6330 w	Weight 1.6667 w
5	1.0000	2.0000	2.3636	2.5278	2.5986	2.6330	2.6667
10	1.6667	2.6667	3.0303	3.1945	3.2653	3.2997	3.3334
15	2.1429	3.1429	3.5065	3.6707	3.7415	3.7759	3.8096
20	2.2500	3.2500	3.6136	3.7778	3.8486	3.8830	3.9167
25	2.2778	3.2778	3.6414	3.8055	3.8763	3.9107	3.9444
50	3.5714	4.5714	4.9350	5.1002	5.1710	5.2054	5.2391
75	3.9474	4.9474	5.3110	5.4752	5.5460	5.5804	5.6141
100	4.1667	5.1667	5.5303	5.6945	5.7653	5.7997	5.8334
1000	4.9020	5.9020	6.2650	6.4298	6.5006	6.5350	6.5687

w = weight

T-test of significance was applied to test the significance of partial regression coefficients (Snedecor and Cochran, 1967).

$$t = \frac{b_i}{S.E.(b_i)}, \text{ at } n-2 \text{ d.f.}$$

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RESULTS AND DISCUSSION

The mean, standard error and coefficient of variation of 1st 305-day lactation production of 1094 daughters of 83 Tharparkar sires, used for breeding from 1923 through 1971 are presented in table 1. The highest sire index was attained by GAMA sire (2667.50±332.33) while the lowest was of sire number 808 (845.67±227.80). These sire indices were based on four and three daughters standard first lactation yield respectively. The coefficient of variability among 83 sires studied ranged from zero to 68.56 percent. The minimum and maximum values of coefficient of variability for sire having five daughters were 16.04 (Sire 286) and 58.22% (Sire Shabir). In general coefficient of variation was between 20-40 percent.

Predicted Breeding Value (P.B.V.) of these sires, calculated by their pedigree information and their own performance (daughters' average as deviation from herd mean) are also presented in table 1. P.B.V's are represented as deviations from herd mean. All the calculations are based on "relative values" and not on absolute yields so as to minimize environmental correlations in the members of the pedigree, as reported by

Thomson and Freeman (1970). It is evident from table 1 that highest P.B.V. (+785.18) was recorded for Alam sire, based on 24 daughters and lowest (-965.15) for Bringmore sire based on 16 daughters. They were used during the years 1938-1945 and 1930-33 respectively. Out of eighty-three sires used for breeding 58% (48) had positive and 42% (35) had negative predicted breeding values i.e. their 'standard daughters' were expected to produce more or less than the herd average respectively by the quantity shown. The negative predicted breeding value varied from -965.15 (sire Bringmore) to -1.43 (Sire 371) and positive predicted breeding value varied from +0.12 (Sire Iqbal) to +785.18 (Sire Alam). It is noteworthy that 60% of the bulls that showed negative P.B.V. had lactating daughters after 1953 and 20% had lactating daughters before 1935. These results are in accordance with yearly herd-average which are markedly less than the overall herd average (2130.09 kg) after 1963 and before 1935 (Bhatnagar et al., 1976). Weights (number of 'standard daughter' records on which P.B.V. is based) and accuracy of the prediction are also tabulated. Weight is, simply, a measure of accuracy of an index of germ plasm composition and transmitting ability of the animal. The accuracy of prediction of P.B.V. of sires ranged between 0.1477 for Sire Bahadur who had limited pedigree information without daughter records and 0.8327 for Sire Nabha who had a record of 70 tested daughters on himself and adequate pedigree

information also. It was observed that pedigree information of the bulls, having a number of tested daughters themselves, added little to the accuracy of the prediction or the value of prediction as had already been stated by different workers (Lush, 1931, 1935; Searle, 1964; Ernst, 1965; Skjervold, 1968; Mostager, 1970; Owen, 1974; Vinson and Freeman, 1974). However, pedigree information was quite important for sires having little or no information of their own. Information on as many as 6-7 'standard daughters' could be added if the bull had a sire with a number of tested daughters and if adequate information was available from maternal side also. This was in accordance with earlier investigations by various workers (Copeland, 1934; Korkman, 1958; Mutschellar, 1959; Osinga, 1962; Engler and Herzog, 1965; Herzog, 1965; Lempo and Willems, 1970; VanVleck and Caster, 1972; Vinson and Freeman, 1974; McNeill et al., 1976; Stewart et al., 1976).

The results obtained on daughters' average of sires of same herd by Chander (1977) were little higher than the present ones owing to the fact that in the present study first lactation (100 days) records of all daughters were used while Chander probably used selected number of daughters of 37 breeding bulls as being evident from the number of daughters.

The parent's P.B.V. would be of great help in preliminary selection of future breeding bull at birth or even before birth.

Table 1. Phenotype (based on daughters' 1st 305-day lactation) and P.B.V. of 83 Tharparkar sires that occurred in different pedigrees from 1923-1978.

Sire	Mean±SE	C.V.(%)	Weight (n)	Accuracy (n/n+15)	Predicted Breeding Value (P.B.V.)
(1)	(2)	(3)	(4)	(5)	(6)
ALAM	2568.54±120.25 (24)	22.93	29.1913	0.6606	+785.1824
AZAD	1982.33±242.77(12)	42.42	16.7954	0.5282	+202.7959
BAHADUR	-	-	2.5986	0.1477	+75.4717
BALWANT	2186.27±179.52(22)	38.52	26.0449	0.6416	+368.4044
BRINGMORE	1284.06±159.83(16)	49.79	17.6667	0.5408	-965.5157
CHANDAN	1589.91±141.77(22)	41.82	27.6236	0.6485	-309.4185
CHANG	2263.75±430.80(4)	38.06	7.5527	0.3353	-28.5054
CHIRANJI	1190.67±321.75(3)	46.81	7.5388	0.3315	-52.2594
DALIP	1784.00±118.59(8)	18.80	13.8254	0.4796	+72.4598
DILBER	2025.25±533.22(4)	52.66	9.0173	0.3755	+229.8058
DILDAR	1947.85±363.00(7)	17.93	11.6751	0.4377	+73.9481
EJAJ	2411.65±182.44(17)	31.19	20.6253	0.5790	+419.8362
EKKA	2195.67±429.31(3)	33.87	6.9331	0.3161	+172.3573
FAIRHOPE	1782.75±104.95(13)	29.22	13.0000	0.4643	-5.8154

.....contd.

(1)	(2)	(3)	(4)	(5)	(6)
FAISAL	2192.86±152.39(14)	26.00	19.7521	0.5684	+302.1895
FIRSTHOPE	1520.20±245.33(5)	36.09	5.0000	0.2500	-21.2590
GAMA	2667.50±332.33(4)	24.92	8.6589	0.3660	+518.6116
GOPE	1861.86±215.87(7)	30.68	10.9901	0.4229	+38.1428
HAKIM	2419.12±194.83(17)	33.21	22.7005	0.6021	+350.1985
INAM	1769.43±312.47(7)	46.72	12.3550	0.4517	+171.1456
IQBAL	1646.50±6.50(2)	0.56	3.6330	0.1950	+0.1156
JAWAN	1957.60±389.56(5)	44.50	10.4009	0.4095	+28.1992
JUNG	2234.00±196.20(12)	30.42	15.3408	0.5056	+188.1528
KAMAL	1338.00(1)	-	3.8095	0.2025	+482.3905
KATNOL	1857.50±240.50(2)	18.31	3.6630	0.1966	+45.4116
KAURA	1756.75±524.67(4)	59.73	7.6991	0.3392	+37.3992
KURWELL	1693.63±155.94(7)	22.28	7.0000	0.3182	-11.4432
KURNOL	1642.06±157.79(7)	31.19	7.0000	0.3182	-13.7875
KULWANT	1945.46±96.96(38)	30.72	43.9490	0.7455	+81.9407
LAKHAN	2156.50±419.98(4)	30.95	9.4009	0.3917	+103.3344

....contd.

(1)	(2)	(3)	(4)	(5)	(6)
LATIF	2175.96±120.14(25)	27.61	30.7403	0.6721	+502.2122
LEAR	1893.57±252.62(14)	16.49	16.5137	0.5240	-36.6334
MAHESH	2211.25±123.10(12)	19.29	16.7348	0.5273	+461.1574
MAHARAJA	2531.66±130.87(32)	29.24	35.2883	0.7017	+610.1920
MAHANT	2390.40±389.56(5)	21.05	10.6685	0.4156	+590.0925
NABHA	2036.57±75.72(70)	31.11	74.6760	0.8327	+214.6481
NARENDRA(79)	1446.77±192.43(13)	47.96	16.6253	0.5257	-438.2646
NASEER	2611.00±217.69(3)	14.44	8.0173	0.3483	+464.6633
NETA	2034.00±174.55(4)	17.16	9.6700	0.3920	+443.7942
OMEGA	2250.00(1)	-	6.2173	0.2930	+470.7122
PARTAP	1663.93±112.16(29)	36.24	33.6127	0.6914	-143.5415
PATHAN	2151.29±221.62(7)	27.26	9.2865	0.3824	+174.6179
PRINCE	2128.17±246.57(6)	28.38	7.7177	0.3397	+49.0313
QAIS	2455.74±149.40(23)	29.14	28.5729	0.6557	+545.2048
RAJA	1565.75±230.21(8)	41.59	12.1073	0.4466	-1.9347
PURAN	1768.00(1)	-	6.3967	0.2990	+279.6996

.....contd.

(1)	(2)	(3)	(4)	(5)	(6)
RANJIT	1939.00±99.95(48)	35.71	52.7795	0.7787	+38.4773
RANFURLY	2012.56±112.72(50)	39.60	59.0009	0.7973	+18.7762
RUDRA	1813.90±120.08(42)	42.90	47.5191	0.7601	+29.7210
SIKANDAR	2088.17±206.43(12)	34.25	17.6528	0.5406	+149.7446
SHABIR	1690.57±371.98(7)	58.22	12.0099	0.4463	+341.4465
SARDAR	1767.50±219.86(4)	24.88	6.8241	0.3127	-222.6190
TIKKA	2415.06±102.32(49)	29.66	54.1913	0.7832	+734.4159
THAKUR	2196.25±556.48(4)	50.68	9.0619	0.3766	+528.7571
UMPIRE	2364.00±228.90(4)	19.37	9.2588	0.3817	-69.8486
WARYAM	2246.22±236.11(9)	31.53	14.0816	0.4842	+539.2329
E-1	1284.25±145.68(20)	50.73	20.0000	0.5714	-18.8894
223	1545.60±295.39(5)	42.74	11.0678	0.4246	+58.1551
286	1955.85±86.99(13)	16.04	18.9497	0.5582	+194.4684
349	1632.75±334.57(4)	40.98	8.0667	0.3497	+102.4781
353	1787.50±230.50(2)	18.24	6.9331	0.3161	+172.3573
357	1674.74±09.92(31)	29.89	36.3679	0.7080	-303.8726

.....contd.

(1)	(2)	(3)	(4)	(5)	(6)
359	1500.56±213.04(9)	42.59	13.4963	0.4736	-234.1915
360	1355.25±432.98(4)	63.90	9.1085	0.3778	-239.3310
361	1308.00±445.79(3)	59.03	7.0397	0.3194	+98.3878
371	1339.33±349.35(3)	45.18	8.5705	0.3636	-1.4283
398	1436.50±388.31(4)	54.06	8.3357	0.3572	-228.4916
426	1831.63±114.43(19)	27.23	24.2149	0.6175	-18.9038
478	1501.79±101.48(29)	36.39	34.4054	0.6964	-512.7214
532	1670.11±169.67(9)	30.53	13.4255	0.4723	-209.4999
535	-	-	5.0438	0.2516	+121.2862
580	1336.90±215.91(10)	51.07	13.6304	0.4762	-336.2171
599	1337.33±194.76(6)	35.67	9.1436	0.3787	-145.6763
610	1551.67±280.61(6)	44.30	11.2654	0.4289	-190.5280
613	1425.50±252.85(8)	50.17	12.1629	0.4478	-273.5218

....contd.

(1)	(2)	(3)	(4)	(5)	(6)
619	1734.40±146.77(10)	26.76	15.3714	0.5052	-75.3752
627	1538.75±120.26(8)	22.11	12.9437	0.4632	-137.2716
630	1160.00±157.49(7)	35.92	10.5426	0.4127	-380.0054
652	1380.00±669.00(2)	68.56	6.9299	0.3160	-62.3670
710	1238.08±182.59(13)	53.18	18.2355	0.5487	-557.8360
711	1063.80±125.17(10)	37.21	14.8240	0.4970	-508.9672
718	1292.00±451.75(3)	60.56	8.4175	0.3595	-240.3324
808	845.67±277.80(3)	56.92	6.7174	0.3093	-331.8646

The numbers in parentheses indicate the number of daughters per sire.

n = total value of the evidence

P.B.V. of cows

The Predicted Breeding Values of 93 Tharparkar cows that have been used to produce crossbred progeny since 1971 and their dams is presented in table 2 alongwith the 'accuracy of the predictions'. Only 16% (15) out of these cows showed positive PBV, while 84% (78) had negative PBV. Predicted Breeding Value of cows ranged between -585.04 (Cow 693) to +262.01 (Cow 369). Eighty-five of these cows had commenced lactation after 1964, the year from which a marked decline in herd average was witnessed as shown by yearly herd averages (Bhatnagar et al., 1976). For their dams PBV ranged between -420.5558 (Cow 594) to +609.5837 (Cow 565). In the case of dams 43% (40) had positive PBV while 57% (53) had negative predicted breeding value. The accuracy of prediction varied from 0.1219 (Cow 512) to 0.5107 (Cow 425) for daughters, whereas for their dams, it varied between 0.1664 (Cow 857) and 0.5175 (Cow 514). By observing weights of the predictions, it is concluded that information on animal would be attained equivalent to 6-7 standard daughters of a good pedigree if records of her own performance were lacking. It is also observed that more weight was exhibited in case of the animals whose sires had large quota of information (on standard daughters), cow had production records herself, besides having adequate maternal information also. Similar inferences were drawn by Copeland (1934); Fewson (1959);

Table 2. PBV and its accuracy of Tharparkar cows and their dams, former having been used for crossbreeding from 1971 with exotic sires (Brown Swiss; Holstein Friesian and Jersey).

Animal	Dam	Sire	on Animal itself			Animal's dam		
			Weight	Accuracy	PBV	Weight	Accuracy	PBV
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
19	565	Partap	15.3340	0.5055	+42.0091	15.7037	0.5135	+609.5837
29	776	-do-	15.1181	0.5020	-191.7332	13.1451	0.4670	+70.5888
333	607	Kulwant	2.1651	0.1261	+4.8243	11.6342	0.4368	+334.7592
340	799	Dalip	14.1917	0.4862	-237.2200	15.0638	0.5011	-234.0751
363	904	Kulwant	15.2274	0.5038	-263.6355	14.3769	0.4892	+68.6800
369	897	-do-	15.6088	0.5099	+262.0095	15.3669	0.5060	-8.5132
382	938	Chandan	14.8845	0.4981	-259.6975	13.1594	0.4673	+12.8313
388	625	Kulwant	15.4847	0.5079	+176.7797	13.8799	0.4806	+290.4365
425	759	-do-	15.6571	0.5107	-221.8306	15.9814	0.5158	+236.4697
431	863	NK	12.1245	0.4470	-162.5475	14.7771	0.4963	+243.1575
465	752	Partap	15.3234	0.5053	-93.3100	15.3234	0.5053	+150.7555
483	979	Chandan	15.1153	0.5019	-129.4992	15.9082	0.5147	-43.0528

.....contd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
486	947	Chandan	14.9005	0.4985	-194.1034	13.4258	0.4723	+137.6062
488	40	223	13.8312	0.4797	-62.5756	13.8985	0.4809	-233.1000
512	E-163	286	2.0824	0.1219	-52.8182	11.6330	0.4368	+9.5382
515	366	286	14.1479	0.4854	+165.7918	10.4445	0.4105	+375.5900
520	353	286	14.3670	0.4892	-141.2630	12.6199	0.4569	-367.9800
522	888	286	14.5256	0.4920	+37.4268	14.4002	0.4898	-47.1815
525	13	360	13.9039	0.4810	-104.6506	15.8254	0.5134	-63.9743
559	729	361	13.3163	0.4703	+230.8267	13.4959	0.4736	+258.6005
566	999	357	15.4253	0.5070	-207.3189	15.7061	0.5115	+3.7942
577	359	371	12.5647	0.4558	+27.2773	5.4091	0.2650	-53.3830
582	431	357	15.1000	0.5018	-95.1325	12.1245	0.4470	-162.5475
578	471	371	13.6505	0.4765	-139.3534	15.0953	0.5016	-351.9246
583	810	426	14.0725	0.4979	+125.3646	14.8943	0.4982	+355.5585
587	467	426	14.3175	0.4004	+50.6653	15.4509	0.5074	+68.9100
602	379	426	14.2914	0.4079	+120.2681	9.0181	0.3755	+92.7629
626	419	357	14.9971	0.5000	-4.8258	10.9712	0.4224	-95.3279
629	698	426	14.8838	0.4901	+88.4315	15.0326	0.5005	+548.1900

....contd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
630	488	NK	11.4429	0.4327	+155.2537	13.8312	0.4797	-62.5784
632	512	357	15.3083	0.5051	-195.7674	14.2747	0.4876	-50.7185
635	424	350	1.7075	0.1022	-64.0914	10.3716	0.4088	-128.1832
648	985	426	13.7486	0.4782	-191.0281	15.8465	0.5137	-119.7085
658	906	478	15.3641	0.5060	-66.1452	15.7422	0.5121	+125.9690
661	519	478	14.0375	0.4834	-378.9121	8.3733	0.3582	-74.7082
665	29	478	14.1144	0.4848	-504.6485	15.1181	0.5020	-191.7332
666	19	478	15.0318	0.5005	-143.6183	15.3340	0.5055	+42.0091
680	766	478	15.3339	0.5055	-106.3317	15.3610	0.5059	+219.9932
682	994	357	14.2117	0.4865	-320.5496	15.5344	0.5088	+50.0463
685	431	478	14.0490	0.4836	-154.2995	12.1245	0.4470	-162.5475
687	454	478	14.6335	0.4938	-399.2216	14.1480	0.4854	-333.0233
693	987	478	12.3745	0.4520	-585.0411	10.4196	0.4099	+508.7075
696	557	478	13.8440	0.4800	-285.0808	12.0728	0.4459	+36.2085
704	924	478	14.1816	0.4860	+35.7009	15.9670	0.5156	+312.6933
705	425	478	15.3614	0.5060	-164.0989	15.7079	0.5115	-7.2108

....contd.

708	407	478	14.8152	0.4969	-214.1725	9.8798	0.3971	-373.3249
710	994	478	12.8477	0.4614	-415.6184	15.5344	0.5088	+50.0463
712	553	478	9.4602	0.3868	-474.2601	7.0146	0.3186	-402.1325
718	915	NK	11.5537	0.4351	-32.4795	15.1332	0.5022	+412.2669
720	971	357	12.4438	0.4534	-358.7000	10.4680	0.4110	+80.0059
733	561	Kamal	7.9240	0.3457	145.3295	14.7705	0.4961	+406.5235
739	766	532	15.5797	0.4752	-45.5811	15.3256	0.5054	+162.5175
741	567	580	11.6214	0.4365	-278.6594	14.4139	0.4900	-95.0421
749	515	580	13.7988	0.4791	-50.6836	14.1479	0.4854	+70.9425
755	564	580	14.0641	0.4839	-164.9210	13.7490	0.4782	-114.0807
759	924	619	14.0113	0.4830	+115.6550	15.9670	0.5156	+312.6933
761	897	580	13.5997	0.4755	-135.1932	15.3670	0.5060	-8.5125
764	502	599	8.6531	0.3658	-331.0678	14.2977	0.4880	-187.1883
777	546	613	11.4272	0.4324	-198.6971	3.4389	0.1865	+80.1373
779	906	NK	9.7022	0.3928	-44.4274	13.3844	0.4715	-269.5306
784	518	613	12.6086	0.4567	-185.6292	12.4447	0.4534	-163.7901
811	475	610	8.5825	0.3639	-325.8020	11.0642	0.4245	-308.7671

....contd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
814	340	610	8.8769	0.3718	-441.8216	14.1917	0.4862	-237.2200
817	580	610	2.8612	0.1602	-186.9790	5.3784	0.2639	-216.5782
827	514	627	3.9691	0.2092	-182.1914	16.0873	0.5175	+449.1111
848	382	627	9.0979	0.3775	-512.2424	14.8844	0.4981	-267.5059
853	557	630	13.0080	0.4644	-172.0771	12.0728	0.4459	+36.2085
859	428	630	3.0066	0.2024	-278.8255	14.2545	0.4873	-241.8869
864	665	627	11.5332	0.4347	-524.8723	14.1144	0.4878	-792.8821
867	539	627	9.0312	0.3758	-291.5746	14.0913	0.4844	+167.1606
870	531	610	11.1313	0.4260	-319.1064	11.5431	0.4349	-137.6765
884	525	711	11.6789	0.4378	-520.2370	13.9039	0.4810	-104.6506
885	594	718	3.2072	0.1798	-301.5476	11.3102	0.4299	-420.5558
887	454	630	3.7749	0.2011	-289.8479	13.8867	0.4807	-265.5760
893	479	619	9.3352	0.3836	-196.1237	15.2395	0.5040	-162.2810
895	577	619	4.1021	0.2147	-21.7939	12.5643	0.4558	+27.2777
906	460	710	13.1421	0.4670	-366.4397	12.8680	0.4617	-189.7209
909	502	710	4.4690	0.2295	-331.1871	14.2977	0.4880	-187.1833
915	611	710	13.2606	0.4692	-516.6117	14.1994	0.4863	-399.7662
920	465	711	4.2974	0.2227	-257.8942	15.3230	0.5053	-71.9653

....contd.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
923	639	711	4.2620	0.2213	-119.0236	14.886	0.4981	+241.2000
927	967	710	9.5794	0.3897	-458.9941	15.6478	0.5106	+70.9560
936	345	711	4.2802	0.2220	-283.2871	15.1099	0.5018	-128.6081
937	857	710	9.3537	0.3841	-101.1824	2.9932	0.1664	-42.1939
942	710	710	4.3402	0.2244	-432.9027	12.8477	0.4614	-415.6184
946	483	652	3.4309	0.1865	-87.7751	15.1153	0.5788	-129.4992
948	601	711	11.7416	0.4391	-909.2502	14.6405	0.4939	-88.0959
967	681	630	8.6875	0.3668	-359.8155	12.9117	0.4626	-70.1252
970	560	710	9.3531	0.3841	-235.8250	12.9871	0.4640	-125.9077
972	583	711	9.2608	0.3817	-377.4653	14.8725	0.4979	+127.4475
996	545	808	8.2703	0.3554	-358.2425	13.4806	0.4733	-40.3660
997	435	808	10.9271	0.4215	-419.2255	15.3357	0.5055	-166.0944
1001	579	808	3.3932	0.1845	-270.3030	14.9174	0.4986	-265.4228

NK = Not known

Mutochellar (1959); Deaton and McGilliard (1965); Syrstad (1971); Van Vleck and Caster (1972); Poutous et al. (1974); Bratt and Elofson (1976). However, some other workers found little or no significance of pedigree information in case of cow evaluation for milk yield (Henderson, 1964; Kakhikalo, 1973).

Correlations:

Coefficients of correlation were calculated between different variables to perceive their relative dependence on each other. Following correlations were calculated:-

1. Cow's PBV and its actual performance.
2. PBV of cow and PBV of its dam.
3. PBV of cow and PBV of its sire.
4. PBV of cow and average of Sire + Dam (Midparent) PBV.
5. Actual performance of cow and PBV of its dam.
6. Actual performance of cow and PBV of its sire.

The results alongwith standard errors of the estimates and number of paired observation is presented in table 3.

The correlation coefficient between cow's PBV and its actual performance was found to be positive and highly significant. Its value was found to be 0.7037±0.0572. Using Robertson's method, Konopka et al. (1971) found a significant correlation of +0.238 between the breeding

Table 3. Correlations and Regressions

Variables X	Variables Y	r ± S.E.	b_{XY} ± S.E.	R^2
Cow's PBV	Dam's PBV	+0.4965±0.0773(93)	+0.4195±0.1060(93)	0.2465
Cow's PBV	Sire's PBV	+0.5860±0.0692(90)	+0.5044±0.0986(90)	0.3434
Cow's PBV	Average of Sire+Dam's PBV	+0.5551±0.0725(90)	+0.5862±0.0830(90)	0.3082
Actual performance	Cow's PBV	+0.7037±0.0572(79)	+0.3046±0.0351(79)	0.4951
Actual performance	Dam's PBV	+0.1572±0.1104(79)	+0.0628±0.0536(79)	0.0247
Actual performance	Sire's PBV	+0.1547±0.1135(75)	+0.0728±0.0544(75)	0.0239

Figures in parentheses indicate the number of observations.

value of heifer and their milk yield. Vinnichuk (1974) estimated 1st lactation yield of a cow on the basis of 1st lactation of its dam, its sire's dam and maternal grand dam. He found a correlation of +0.58 between the estimated and actual yield of cow, which is little less than the present estimate. However, Bray (1975), working on bulls, calculated predicted difference of bulls on the basis of pedigree indices and found a correlation coefficient of +0.357 between actual and estimated PD for milk and +0.293 for 4% FCM. Such high correlation, as obtained under present study, may be attributed to the fact that predicted breeding value of cows are based on records on their own performance in addition to ancestral records. So, it can be easily concluded that if a cow has production record herself (however limited) and adequate pedigree information, the estimate of breeding value based on sum total of this information gives a good index of her phenotype. In present study, PBV of cows could not be compared with their subsequent (additional) lactation records, as the latter were not available till the time of submission of this study.

Coefficients of correlation between predicted breeding value of cow with that of

(i) Dam's PBV

(ii) Sire's PBV

(iii) Average of Sire + Dam (Midparent)PBV,

were found to be $+0.4965 \pm 0.0773$, 0.5860 ± 0.0692, and

0.5551±0.0725 respectively. All results were positive and highly significant. However, these results were lower than correlation between cow's PBV and her actual performance as found by Konopka *et al.* (1971).

Neumann and Fiegenbaum (1972) calculated genetic correlation between daughter and dam and found it to be ranging between +0.13 to +0.72. The mid-value is quite in correspondence with correlation found here between cow's and dam's PBVs. Although there had been numerous studies on sire-son correlations of breeding value (Holl, 1967; Nedelova, 1968; Pilz and Schonmuth, 1974; Butcher, 1974; Hornansky, 1977), no such estimate was found in literature for sire-daughter or mid-parent daughter. Positive and highly significant correlations indicated that transmittable genetic worth of the dams and daughters, sires and daughters or midparent values and daughters were highly at par i.e. the genotype of sire, dam or mid-parent was highly reflected in the genotype of daughters, under present study. This would suggest that we could predict the genotype or genetic worth or breeding value of the cows on the basis of genotype or genetic worth or breeding value of their sire or dam or midparent. Further, if there were no pronounced environmental effects or severe environmental fluctuations between the two generations, records of sire and dam should be reliable predictors for the future performance of their daughters. That is daughters of good sires and dams, in general, in Tharparkar

herd at N.D.R.I., Karnal were expected to produce good daughters. However, correlation of PBV's of grand daughter with any of its grand parents was not found to be significant. All values were near zero and thus were considered unimportant.

Coefficient of correlation of sire's PBV on actual performance of their daughters was found to be +0.1547±0.1135 based on 75 paired observations. The estimate was positive but non-significant ($P \angle 0.05$). B.R.; L.A. (1973), on the other hand, found highly significant correlations between breeding value estimates from ancestor proofs of bulls and their daughters which ranged from +0.43 for bulls with 30-40 daughters and 0.51 for bulls having 51 daughters. Pilz and Schonmuth (1974) found similar results to the present study. They found, for 500 bulls, that corralation of a young bulls classification with his later assessment (daughters' performance) was +0.17. It is observed that, whereas, correlation of breeding values of sire and daughter was found to be positive and highly significant, the correlation between sire's breeding value and daughter's actual production performance was positive but statistically non-significant and was quite low. Above said observations are conclusive of the fact that, whereas, genotype of sire is a good predictor of daughter's genotype, the phenotype of the daughter cannot be directly predicted by the genotype of her father. It may be owing to the

fact that sires contribute less than expected to the accuracy of predicting daughters' yield. Or predicted breeding value of father is not at all responsible for the phenotype of the daughter and as such no selection can be practiced for daughters on the basis of the Predicted Breeding Value of their sires.

An attempt was made to find out correlation between predicted breeding value of dams and actual performance of their daughters. A positive correlation of $+0.1572 \pm 0.1104$ was obtained which was non-significant ($P \not< 0.05$). Deaton (1964) and Deaton and McGilliard (1965) found the correlation between cow index (based on information from ancestors) and an unselected daughter's record was 0.1666, which was quite close to the present values. Engler and Herzog (1965) found a low but significant correlation (+0.2) between complete lactation yields of dam (minimum three lactations) and daughters (average 31.2 per bull) of 436 Swiss Brown bulls. Kovalcikova and Plesnk (1970) in 340 dam-daughter pairs found coefficient of correlation for milk yield as +0.15, +0.34, +0.28 for second, first three and peak lactation respectively. All estimates were significant. However, McGilliard (1974) and again McGilliard and Freeman (1976) analysed data on 10349 Holstein-Friesians and found that Expected Average Transmitting Ability (EATA) of dams (which estimated half the genetic worth of the cow from her records, and records of her dam, daughters, maternal

and paternal sisters) was correlated with actual milk yield of daughter's first lactation by +0.18 compared with an expected value of +0.20. It may be concluded that Predicted Breeding Value of dam is not responsible for the phenotype of its daughter and that effect of the environment is a major factor contributing to the actual performance of the daughters. As such a selection for the phenotype of the daughter cannot be predicted on the basis of Predicted Breeding Value of their dams.

As correlation of daughter's actual yield with Predicted Breeding Value of its either of the parents were found to be quite low and non-significant, it was not considered worthwhile to go further back and find out correlations between daughters production records and genetic worth of members of its grand parental generation i.e. maternal and paternal grand sire and maternal and paternal grand dams.

Regressions:

The regression of daughter's predicted breeding value on that of its dam, sire, and midparent were found to be +0.4195±0.1060, +0.5044±0.0998 and +0.5862±0.0830 respectively (Table 3). Accuracy of the estimates (R^2) was found to be 0.2465, 0.3434 and 0.3082 for the three regression coefficients respectively. Politiek and Vos (1963) found that regression of average fat yield of dam and its progeny was +0.5. On the basis of above estimates of regression coefficients, it can be concluded that

predicted breeding values of dam, sire and mid-parent are good indicators of predicted breeding value of their daughters. Such a prediction was feasible and accuracy of prediction was highest for sire while that for dam was significantly lower. So, predicted breeding value of sire was definitely a better predictor for daughter's predicted breeding value. Regression coefficients of cow's PBV with any of its grand parents were not found to be significant. Values were quite near to zero with high standard errors. Regression of actual performance of cow on its predicted breeding value was found to be +0.3046±0.0351. The accuracy of prediction was 0.4951. Powell et al. (1977) found that regression of average daughter performance, as calculated by Modified Contemporary Deviations' on its pedigree index was near the expected unity. The estimate made here is quite low, probably because of the fact that environment played a greater role in deciding the phenotype of the animal. However, as accuracy of the prediction being quite high, it can be concluded with reasonable accuracy that we can predict the actual performance of cow on the basis of its predicted breeding value using the estimate of regression.

Regressions of actual performance of cow and PBV of its dam, and sire were both found to be quite low (0.0628±0.0536; +0.0728±0.0544 respectively). Accuracy of the estimates was 0.0247 and 0.0239 respectively. Results are thus non-significant and of little practical

importance, whatsoever. It may be again emphasised that because of greater role of environment in predicting phenotype of daughters, the PBV of sire or dam are not good predictors for the phenotype of the daughters.

Partial Regressions

The partial regression coefficients were calculated between daughter's predicted breeding value as dependent variable and dam's predicted breeding value and sire's predicted breeding value as independent variables. These estimates alongwith their standard errors have been given in table 4.

Table 4. Estimates of partial regression coefficients and multiple correlation coefficient.

Dependent variable (Y)	Partial Regression Coefficients		R^2	Multiple correlation coefficient
	$b_{Y X_1 . X_2}$	$b_{Y X_2 . X_1}$		$R = \sqrt{R^2}$
PBV of cow	0.3179** ±0.0694	0.4116** ±0.0709	0.4639	0.6811

**Highly significant (t-test at P<.01)

Where, X_1 = PBV of Dam, X_2 = PBV of sire.

Partial regression coefficient of PBV of cow on PBV of Dam was found to be +0.3179±0.0694 whereas that with PBV of sire was 0.4116±0.0709. Similar results

were obtained by Powell *et al.* (1977) who obtained regression of average daughter performance (Modified Contemporary Deviations) on pedigree index.

Prediction equation

While fitting the prediction equation an intercept of -445.2216 kg was obtained. Butcher (1974) obtained an intercept of -325 kg for the regression of son's proof on pedigree index using records of 340 Holstein-Friesian sons.

The prediction equation was:-

$$Y = -445.2216 + 0.3179X_1 + 0.4116X_2 \quad (R = 68.11\%)$$

Estimates of partial regression coefficients indicated that prediction of daughters breeding value on the basis of PBV of sire was more reliable as partial regression coefficient was greater and so more reliance could be put on PBV of sire while predicting the PBV of daughter. The estimate with Dam's PBV was a bit low but it was also highly significant and thus reliable. Accuracy of prediction was quite high ($R^2 = 0.4639$). Highly significant multiple correlation coefficient ($R = 68.11\%$) of sires' and dams' PBV with daughters PBV suggests that these characteristics provide a sufficient knowledge of daughters' PBV. Attempts were not made to go back to grand parental generation as correlation coefficients between cow's PBV and members of its grand parental generations were insignificant and low.

It can thus be concluded that good prediction of daughter's breeding value can be made even at the time of choosing its parents, on the basis of their predicted breeding values, using above prediction equation. Since predicted breeding value of animal is highly correlated with its actual yield (+0.7), it would be possible to predict the production potential of an animal, very early, in its life. Such judicious selection might be, thus, expected to boost the milk production and thus profitability of dairy enterprise.

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SUMMARY AND CONCLUSIONS

Performance records of 474 Tharparkar cows, 83 sires and their 1094 daughters from 1923 through 1978 at the National Dairy Research Institute, Karnal constituted the material for this study. Predicted breeding values were calculated using the method described by Robertson (1959).

Data on parentage, date of birth, first 305 days lactation yield, and lifetime 305-day lactation yields were collected and analysed for calculation of Predicted Breeding Value of animals.

The influence of parents' Predicted Breeding Value on Daughters' Predicted Breeding and Daughters' actual performance was investigated. In addition to this, the effect of animals' Predicted Breeding Value on their own actual performance was also traced.

It was revealed from average daughters' performance that more of the sires showing negative Predicted Breeding Value were used before 1935 and after 1964, the years where yearly herd average was less than the overall herd average. In case of cows, it was again found that most of the cows having lactation performances after 1964 had negative Predicted Breeding Values.

For both males and females information on as many as six to seven standard daughters was achieved by virtue of solely good pedigree records. Significance of pedigree information decreased as information on animal's own performance increased. However, if an animal had production record itself, its sire had a number of tested daughters and adequate information from maternal side was also available, the sum total of this information proved to be a good index of animal's Predicted Breeding Value. Pedigree information in case of animals lacking production records themselves was found to be quite valuable.

The correlation coefficient between cow's PBV and actual performance (+0.7037±0.0572) was found to be highly significant. Coefficients of correlation between Predicted Breeding Value of daughters and that of their dams, sires and midparent (+0.4965±0.0773, +0.5860±0.0692 and +0.5551±0.0725 respectively) were also found to be highly significant. However correlations between daughters' actual performance and Predicted Breeding Values of their sires and dams (+0.1572±0.1104 and +0.1547±0.1135) were found to be non-significant. Similarly correlations between Predicted Breeding Values of grand parents and actual performance of daughters as well as predicted breeding values of daughters were found very low and statistically non-significant.

Regression coefficients of daughters' Predicted Breeding Value on Predicted Breeding Values of its female, male and midparent (0.4195±0.1060; 0.5044±0.0998 and +0.5862±0.0830 respectively) were found to be significant. Accuracy of estimates (R^2) was found to be 0.2465, 0.3434 and 0.3082 respectively. Highest accuracy (0.7036) was obtained for regression of daughters' actual performance on its Predicted Breeding Value (+0.3046±0.0351) which was also highly significant ($P < 0.01$). However, regression coefficients of daughters' actual performance on Predicted Breeding Values of their dams and sires were both (+0.0628±0.0536 and 0.0728±0.0574 respectively) found to be non-significant with low values of accuracy (0.0247 and 0.0239 respectively).

Partial regression coefficients between daughters' Predicted Breeding Value and Predicted Breeding Values of dams and sires were found out to be +0.3179±0.0694 and +0.4116±0.0709 respectively. Both were highly significant. While fitting the prediction equation an intercept of -445.2216 kg was obtained which showed that base production of the herd of present generation was quite lower than overall herd average. Prediction equation was fitted as:-

$$Y = -445.2216 + 0.3179X_1 + 0.4116X_2 \quad (R = 68.11\%)$$

It is concluded that good prediction of animals' Predicted Breeding Value could be made using the

records of Predicted Breeding Value of their parents. As such prediction could be made even at the time of the deciding the parents of future offspring. It is further pointed out that this would probably help in early culling of 'would be' low producing animals and thus help in enhancing production average of the herd.

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