CHAPTER II

REVIEW OF LITERATURE
1. FACTORS AFFECTING PART LACTATION

Investigations on factors affecting part lactation milk yields in different breeds of cattle (Herefords, Red Polls, Lincoln Reds and Friesians, Friesian crosses, pedigree and non-pedigree Shorthorns, Park cattle, Jersey and Guernsey in Norfolk district of England) were made as early as 1930 by Sanders. He found that ratio between total lactation yield and the maximum weekly yield varied from 24.47 to 29.37 according to the month of calving.

Mahadevan (1951) studied the causes of variation in milk yield in Ayrshire cattle and found that the effect of month of calving on milk yield varied significantly between herds. The average difference in 180-day milk yield between the summer and winter calvers of all herds was about 10% in favour of winter calvers. The milk yield of a cow was found to be influenced both by the number of her previous lactations and also her age at first calving.

Dickman (1957, 1960) in Ayrshire, Holstein and Jersey cattle observed that seasonal variation in age corrected 180 days yield indicated that comparison among contemporary cows predicting total yield on the basis of 6 months performance was likely to eliminate the effects of season of freshen-
ing on yield from estimate of breeding values. His later study revealed that age and month of calving had significant effect on association between 180 days and 300 days yield.

Bogner and Schumann (1953) analysed 1444 lactation records of heifers which calved at 24-35 months of age in 25 districts of Bavaria. The authors reported that the average milk yield of the first three test milkings (i.e., during 90-110 days) of lactation was not affected by age at first calving but was affected by season of calving being lowest for those calved during July-September.

Jost (1959) obtained in 19000 Black Pied and 3000 Red Pied heifers a positive correlation between 305 days yield and part-yields (30-, 60-, 100-, 140-, 180-, 200- and 250-day yields). He found that the part yields were not influenced by the environmental factors such as age at first calving of heifers, first calving interval and differences in feeding and management. Month and year of calving influenced the correlation between part yields and total yields. The environmental influences were found to be not important in preliminary selection of bulls for breeding.

Fritz et al. (1960) using 11,420 records of four breeds (Holstein, Guernsey, Jersey and Brown Swiss) derived regression factors for estimating 305 days production from part lactations. Intra-herd factors for extending incomplete records were developed from the average regression coefficient of total on part lactation within herd, season,
lactation and age group. For comparison, extension factors disregarding herd, season, lactation number and age effects also were derived. However, the differences between inter and intra herd factors were not tested for significance. The marked similarity between the two estimates for Holstein breed suggested that herd had little or no influence on part to whole relationship.

Lamb and McAlliared (1960) in 12,551 Holstein, 2262 Guernsey, 990 Jersey and 459 Brown Swiss cows studied the effects of breed, herd, age, parity and season of freshening on the relationship between total and part records. They reported that the lactation number had larger influence on the total to part relationship than did age at freshening. Season of freshening also exerted an influence, but to a slightly lesser degree than either lactation number or age, while the effect of herd was small and unimportant. Differences between breeds existed both in the components of variance and in the total to part relationship. These workers hence advocated that while extending part records to 305 days, the effect of breed, age and season of freshening should be considered.

VanVleck and Henderson (1961a) found on 177,575 records of Holstein cows significant effect of age at first calving, season of calving and month of lactation on part lactation and total milk yield and fat production. It was concluded that while constructing ratio factors for extending
part lactations to complete lactation, simultaneous consideration to age at first calving, season of calving and month of lactation should be given both for estimating milk or fat production. VanVleck and Henderson (1961b) concluded on the basis of studies on the part lactation in Holstein cows that contemporary environmental conditions are more important during first and last stages of lactation, when genetic and permanent environmental differences between cows exert relatively more control over production. The authors (1961c) computed the regression coefficients for predicting complete lactation yield from part records ignoring the herd effects. It was concluded that prediction of complete lactation yield by regression ignoring herd effects was more practicable because of the computational advantages although the accuracy of prediction was slightly less in all situations for intra-herd predictions.

Turton (1952) observed that milk yield among White Mulani cattle was significantly affected by season of calving. The part and total lactation yields did not vary significantly due to lactation number.

McDaniel et al. (1957) studied the influence of breed, age and season of calving on cumulative and non-cumulative ratios of total to part lactation milk yield in Ayrshire, Guernsey, Holstein, Jersey and Brown Swiss cows. Average ratios were found for each of the ten test days, both individually and cumulatively for all the combinations of
breed, month of calving, age class and yield trait (milk and milk fat). Brown Swiss cows had the highest ratios throughout lactation, while Ayrshires had the lowest. Differences among other breeds were not significant. Ratios were uniformly high for 2 year old cows. Ratios among cows calving in July-September and October-December changed the least over the lactation while those for animals calving in April-June varied the most. Analysis of variance of Holstein data indicated that the influences of age, season and trait on both cumulative and non-cumulative ratios were significant.

Miller et al. (1957) computed age factors for placing monthly and cumulative monthly production on mature equivalent part lactation basis for Holstein breed. The later stages of lactation contributed smaller increase in production with age than the earlier stages. Cows calving in summer showed smaller rate of increase with age than cows calving in other seasons of the year. They hence advocated that extrapolation of cumulative part records to a 305-day basis should consider age at calving.

Appleman et al. (1969) observed the effect of age, season of calving, level of peak production and days pregnant on precision of production factors used in extending incomplete lactation records. They developed separate prediction factors taking 3 age groups and 4 levels of peak production in Holstein breed.

Singh and Acharya (1969) based on 482 first lactation records of Hariana cattle reported that age at
first calving and calving season did not significantly effect milk yield.

Finland et al. (1972) studied the influence of age and season of calving on milk characteristics at 122nd, 245th and 305 days of lactation in Israel Friesian cattle. Age of the cow had a highly significant effect on production of milk and fat corrected milk whereas all the three characters were significantly influenced by season of calving. The variance of lactation between age and season accounted for only 0.4% of total within herd-year variation.

Auran (1973) found that month of calving had relatively small effect on milk yield and accounted for 1.3 to 7.9 per cent of variation in the test day milk yield, age which accounted for the largest proportion of the variation (40%) in the first months of lactation, accounted for less than 2% in the last three months. Also the influence of herd was large throughout lactation accounting for 10-20% of the variation at the early and late stage of lactation and nearly 25% in the middle.

China (1975) in air cattle found that the period effects were highly significant in all monthly and cumulative partial lactation milk yield records. The effect of season was significant in case of ninth and tenth monthly yields. The age effect was not significant.

Kahaaja and Bhalaje (1977) investigated the data pertaining to monthly and cumulative records in Kariana and
its crosses and observed that season of calving, year of calving, age and body weight at first calving did not have significant effect on monthly or cumulative monthly yields.

Chhilar et al. (1979) in purebred Harianas and their crosses with Holstein Friesians found highly significant effects of farm, season of calving and age at first calving on cumulative monthly yield and a significant effect of these parameters on 300 days yield.

Varshney and Tomar (1982) in Hariana cattle reported that farm, year and age at first calving had significant effect on cumulative monthly yields.

Rayalu et al. (1984) observed year effects on cumulative milk yields to be significant in Friesian x Ongole halfbreds but not in Brown Swiss x Ongole crosses. Friesian crosses performed better than Brown Swiss crosses.

The literature reviewed indicates that farm, period, season of freshening and age at first calving affect the monthly, cumulative monthly and complete yields.

**Prediction of first lactation milk yield (300 days) and first lactation revenue.**

Ketha (1934) was the first to work on the prediction of total lactation yield from monthly yields in Indian purebred and crossbred cows. It suggested that the production in the 4th month of lactation provided the best prediction for total yield.

Cannon et al. (1942) calculated the regression of total lactational yield on monthly yields in a lactation
and formulated the regression equations to predict full lactational yield from part records of 1 to 9 months in Friesian cows. The coefficient of phenotypic correlations between the monthly and 305 days yield ranged from 0.37 to 0.91. On these basis the authors concluded that the fifth month yield was the most appropriate for predicting 305 days yield and prediction was less accurate when the test was made during the first or the last months of lactation than when it was made during middle months.

Kennedy and Beath (1942) also reported that the production of Jersey and Holstein heifers during the first four months of 1st lactation was a good index of the complete first lactational milk yield and was of slightly less value comparable to that based on complete records for predicting production during the 2nd lactation.

Madden et al. (1959) developed ratio of the total to cumulative part production for Holstein Friesian cows. They felt that ratio method might underestimate total production of low producing cows and overestimate total production of high producing cows.

Fritz et al. (1960) derived the regression factors for estimating 305 days production from monthly yields in Holstein, Guernsey, Jersey and Brown Swiss cows. It was observed that correlation between cumulative part and 305 days milk production were not less than 0.7 for the first month, increased steadily as the lactation progressed
and were 0.9 by the fifth test day for all breeds. The authors suggested that production records of only one or two months were valuable guide to what a cow would produce in that lactation.

VanVleck and Henderson (1961d) carried out regression studies on part lactations in Holstein cows and concluded that the single month's yields best suited for estimating complete lactation milk yield were 4th, 5th and 6th monthly yields. The correlation value between predicted and actual complete record was 0.85. The multiple correlation estimates of first five, six and seven months lactation with complete lactation were 0.92, 0.94 and 0.96 respectively. The correlation of the sum of the first seven monthly test yields with total production was of the order of 0.95.

Aarstad (1964) in Norwegian red and white cows tabulated ratio factors for converting incomplete first records to complete lactation basis. The factors he found increased with increasing herd production level indicating that persistency increased as production level increased.

Dutt et al. (1964) in Mariana cattle derived the regression factors for predicting the 305 days yield from part records up to 15th, 75th and 135th day of lactation. The regression factors were 7.33, 2.54 and 1.38 respectively. The prediction equations for determining total lactation yield from part lactation were as follows:

\[
Y = 1234 + 7.63X_1
\]

\[
Y = 174 + 2.54X_2
\]
\[ Y = -142 + 1.58X_3 \]

where, \( Y \) = predicted complete lactation milk yield.
\( X_1, X_2, X_3 \) were milk yields for 15, 75 and 135 days of lactation.

Aulerich and Macilliard (1965) stressed the necessity of using different ratios for extending the voluntary terminal incomplete records to 305-day records than those used for in-progress and involuntary terminal incomplete records.

Lamb and Macilliard (1967b) estimated ratio factors for extending milk records for each of ten monthly test days and from cumulative test-day production. Separate ratios were presented for different ages, seasons of freshening and breeds as these factors were found to affect part whole relationship.

Baptist (1972) based on 10,000 records of German Black Pied, German Red Pied and Anglo-Friesian cows applied Harvey's modified regression method for estimating 305 days yield from part lactation and recommended it in comparison to only ratio method or only regression method for estimating total lactation yield.

Miller et al. (1972a) used modified regression method for extending part records in Holsteins and found that error in prediction by this method was less than by ratio method. The modified regression method was developed by one of these workers, Harvey.
Miller et al. (1972b) compared four methods of extending part lactation records. They were (1) ratio, (2) multiple regression, (3) modified regression, and (4) regression of the remainder of the lactation on the last test. Errors of multiple regression estimates and regression estimates on the last test were least, those of modified regression were intermediate, while errors of ratio estimates were largest.

Powell et al. (1973) suggested that voluntarily terminated records should be extended by special factors.

Auran and Cocquot (1974) compared the various methods of extrapolating part yields to predict total lactation yields using data on Norwegian Red breed and was of opinion that ratio method underestimated poor yields and overestimated good yields but gave the estimate of variance close to the actual variance, whereas regression methods were more accurate as regards correlation between estimated and actual values but they were inferior as regards variance of estimates. Simple regression was easy to apply and almost as accurate as multiple regression.

Cocquot and Auran (1975) found that multiplication of last test day yield by a coefficient related to stage of lactation was of greater accuracy than multiplicative factors and was almost equivalent to multiple regressions or simple regressions on last test day yield.

Patel and Patel (1975) analysed the lactation records of Jersey cattle and gave the equation for predicting
the 305 days milk yield in the first lactation as:

\[ Y = 2021.6 + 2.3593x \]

where, \( x \) is the cumulative milk yield for the first 60 days of lactation.

Auran (1976) used multiple regression equation which gave estimates with the smallest variance of the deviation from actual lactation yield. Regression or ratio equations including only yield on last test were as accurate as multiple regression equation. Part lactation yield was inferior to yield on last test day for estimating total yield.

Dommerholt (1975) found extrapolation of future yield, from yield at the last test day more accurate than linear regression of lactation milk yield on part lactation yield in Dutch Black Pied cows. Suzuki and Kishimoto (1976) carried out comparison studies of extension by ratio factors, simple regression and regression method referred to as method P and the last method was found to be the most precise followed by simple regression.

Smirnov (1975) found highly significant correlation of 0.56, 0.67, 0.75 and 0.82 between the actual 305 days lactation milk yield and 305 days milk yield estimated from the milk yields in the first 30, 60, 90 and 120 days of lactation respectively.

Wiggins and VanVleck (1975) reported that prediction error variance was 21% smaller for 50 to 60-day records and 38% smaller for 200 to 201-day records when remaining milk yield was predicted from last sample day
production compared with using cumulative yields. Higgans and VanVleck (1979) developed a function based on last sample production for extending partial records of milk and fat yields in Holstein-Friesian as

\[ \hat{Y}_{305} = Y_n + \left[ (b_1 + b_2n) + (b_3 + b_4\sqrt{n}) \right] / L_P \times (305-n) \]

where, \( \hat{Y}_{305} \) is the estimated 305-day lactation yield, \( n \) is the length of the partial record, \( Y_n \) is the cumulative yield to day \( n \), \( L_P \) is the last sample production and \( b_1, b_2, b_3 \) and \( b_4 \) are coefficients estimated by least squares within 3 lactation stages (\( \geq 55, 65 \) to 245, \( > 245 \) days in milk), 4 ages at calving (\( \leq 34, 34 \) to 48, 49 to 60, and \( > 60 \) months, 3 herd yield levels (\( \leq 5900, 5900 \) to 7000, and \( > 7000 \) kg) and 6, two monthly calving seasons. Error variance of difference between estimated and actual lactation yield was lower using last sample production factors than by using cumulative yield factors.

Chilar et al. (1980) in 801 lactation records on 299 purebred Mariana (M), \( \frac{1}{2} \) Holstein-Friesian \( \times \frac{1}{2} \) Mariana (\( \frac{1}{2} \) HF) and \( \frac{1}{4} \) Holstein-Friesian \( \times \frac{1}{4} \) Mariana (\( \frac{1}{4} \) HF) developed regression coefficients on different part records to develop prediction equations. The earliest accurate prediction equation was from 100 days record for which the correlations with lactation yields were 0.82-0.93 in Mariana, 0.78-0.89 in \( \frac{1}{2} \) HF and 0.79-0.90 in \( \frac{1}{4} \) HF.
Næs and Sundararajan (1980) analysed the first lactation records of 884 Sahiwal, 157 Brown Swiss × Sahiwal and 255 Friesian × Sahiwal for estimating 300 days yield from part records of 13, 17, 21, 26 and 30 weeks by four methods (regression, ratio, gamma and inverse polynomial function). The authors found that the ratio and regression methods were similar in accuracy but were superior to both gamma and the inverse polynomial function.

Higgen (1980) assessed the accuracy of several models for projecting partial production records to 305 days from sample day production records of 15 036 Holstein-Friesian cows. The author studied the effects of including 305-day, 2%, mature equivalent herd average yield, production on the most recent sample day, days since conception and average daily yield for the part lactation yield in the models. Regression analysis indicated that production on the most recent sample day was the most important factor in predicting 305 days yield.

The literature reviewed indicates that fourth, fifth and sixth monthly yields are sufficient for predicting complete yields and similarly first two, four and five months among cumulative yields. Underestimating poor yield and overestimating high yield are pointed out to be inherent with ratio method. Multiple regression on separate monthly yield is very precise but cumbersome. Simple regression on cumulative yield is easier to apply. Regression of remaining yield on the last test day is argued to be the best. Records up to the middle of lactation give good prediction.
Karthe (1934) found the correlation coefficients of 300 days lactation yields with 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th and 9th monthly milk yield in 157 crossbred cows as 0.87, 0.90, 0.92, 0.93, 0.91, 0.87, 0.83 and 0.71 respectively.

Linichenko (1935) observed a correlation coefficient of 0.769 ± 0.017 between first 30 days yield and 300 days yield during first lactation and the correlation coefficient between 130 days yield and 300 days first lactation yield was of the order of 0.92 ± 0.060.

Daseat (1934) analysed 166 first lactation records of Piedmont cows and estimated correlation value of 0.617 between milk yield of first 90 days and that of the whole lactation of 280 days. He maintained that 90 days yield would, for various reasons including those of time and money, be preferable to the lactation yield as a basis for progeny testing of bulls.

On studying 599 lactation records of Holstein cows, Madden (1934) concluded that repeatability of monthly yields ranged from 0.26 for 9th month to 0.50 for 2nd month of milk production. Repeatability for cumulative lengths ranged from 0.51 for the first 305 days to 0.61 for the first 90 days of milk production. Heritability estimates for monthly yields by intra sire regression ranged from -0.03 for 10th
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month to 0.40 for the 5th month of milk production. The
standard errors were of the order of 0.13 to 0.22. Herit-
ability estimates of cumulative yields ranged from 0.44 for
first 120 days to 0.63 for first 174 days of milk production.
Genetic correlation between cumulative part lactation yields
and whole lactation production using 1st records only in many
cases approached or exceeded unity. This led him to conclude
that mass selection based on part lactation records could
cause noticeable genetic improvement in milk production.

Hadden et al. (1953) observed the average increase in
daughter dams regressions for monthly and the cumulative
monthly yields being 0.15 and 0.25 in Holstein cows. Genetic
correlation between cumulative monthly milk yields with lacta-
tion yield was above 0.9.

Giulani (1959) reported the coefficient of
correlation for 307 animals in Brown Alpine and Friesian
cows between milk production during 300 days lactation and
production during the first 180 days as 0.97 and 0.99
respectively and the same values were obtained for butterfat
production. Correlation between the first month and first
180 days milk production were 0.93 and 0.39 respectively.
It was concluded that milk recording might with advantage
be limited to the first 6 months or even to the first
month of lactation.

Mandel et al. (1957) while studying six cattle
breeds (Ayrshire, Friesian, Guernsey, Jersey, Red Poll and
short horn) of England and Wales, estimated heritability of 70 days yield as 0.39 ± 0.06 and that of 305 days lactation yield as 0.43 ± 0.06. The correlation of 70 days yield with 305 days first lactation yield was 0.74, 0.61, 0.58, 0.54, 0.34 and 0.76 for respective six breeds. Phenotypic and the genetic correlation of pooled data for first lactation was 0.80 and 0.76 respectively.

Negroni and Brambilla (1957) reported that the coefficient of correlation between milk yield during 70 days of lactation and the first 305 days lactation and the total lactation yield as 0.67 and 0.52 respectively for Ayrshire heifers and 0.68 and 0.66 for Brown Swiss heifers. The authors concluded that the milk yield during the first 70 days of lactation is an adequate index of the milking capacity of heifers.

Jayne and Woodruff (1959) obtained a correlation of 0.97 between the average yield of the first three test milkings and 180 days yield and concluded that the average of the first three test milkings could be utilized for preliminary selection of bulls.

O'Connor and Stuart (1958) analysed the data on Ayrshire heifers and reported within herd coefficient of correlation between 180 and 305 days yield to be 0.94 ± 0.019. Hickman (1950) in Yorkshire and Holstein cattle reported the simple correlations between 180 and 300 days yield as greater than 0.90. The genetic correlation among successive 90 days period of lactation, 180 days yield and 300 days yield was
all close to 1.00 and the lower limit of the genetic correlation between 180 and 300 days yields was estimated as 0.94.

Johnson and Corley (1961) estimated heritability for first lactation in Brown Swiss cattle of 8413 HR records as 0.42 for milk, 0.37 for butterfat and 0.30 for percentage of butterfat for 1st lactation. Using partial (100-, 200-, 305-day) 1st lactation records, the estimates were of the order of 0.30 and 0.34 for 100- and 200-day yields respectively, whereas for percentage of butterfat the values were 0.44 and 0.63 respectively. In selecting for production traits in Brown Swiss cattle, 1st records appear to be as valuable as any other single record or average of records. Partial 1st records of 100 or 200 days in length will be almost as effective in improving milk and fat yield as selection based on 305 days 1st records.

Pirchner (1961) in 991 Austrian Brown and 295 Oberinutal (Grey) cattle reported the heritability coefficient for 2, 3 and 4 months yield slightly lower than that for 305-day yield ($h^2 = 0.49$) and that of 5 and 6 months as approximately equal to it. High phenotypic and genetic correlations between part yields and whole lactation indicated that selection based on part records as almost as efficient as that based on complete lactation records.

Searle (1961a) found that heritability estimates of monthly fat yields decrease as lactation progresses. The estimates of genetic correlation of monthly yields with lactation yield show approximately the same trend over the
lactation as heritability estimates, i.e., increase up to 3rd month (0.93) followed by a general decline. This indicated that environment played an increasingly important role as lactation progressed. The set of genes determining total yield and end of lactation yields were not altogether same. The genetic correlation values estimated among monthly yields were higher among early months of lactation than among later months and also higher than the genetic correlation between early and late months. The same author (1963) in his study of Jersey cattle found a wide variation of -0.03 to 0.92 with respect to genetic correlation values between monthly milk yield and complete lactation milk records.

VanVleck and Anderson (1961b) found that the heritability estimate of first four months cumulative milk production in Holstein cattle by paternal halfsib method was 0.22. They further reported in the same breed of cattle the heritability estimates of monthly part records up to tenth month of lactation as 0.11, 0.17, 0.22, 0.19, 0.19, 0.14, 0.14, 0.14, 0.12 and 0.03 respectively. The phenotypic correlations of monthly consecutive yields with total yield were 0.58, 0.76, 0.81, 0.85, 0.85, 0.85, 0.78, 0.66 and 0.53 respectively. The genetic correlation between monthly cumulative milk records and complete lactation milk yield of first lactation was found to be 0.89, 0.93, 0.89, 0.92, 0.94, 0.97, 0.98, 0.99, 1.00 and 1.00 for the first month, first two months, first three months and so on up to first ten months milk record. The same authors in the same
breed also found similar values for monthly consecutive milk records up to tenth month part record and these estimates were 0.89, 0.79, 0.94, 0.95, 1.01, 0.98, 0.99, 0.88, 0.94 and 0.71 respectively. The high genetic correlation between part and complete lactation records indicates that the genetic progress by selection of A.I. sires on the basis of partial records was as efficient as on the basis of complete records.

Váchal (1961) reported in Czechoslovak Red Spotted cattle correlation values between 60, 90, 120, 180 and 300 days lactation yield. All values were found to be significant the estimates ranging from 0.475 to 0.827, the one with 180 days yield being the highest.

Turton (1962) observed in White Fulani cattle highly significant correlation of 0.74 to 0.77 between total lactation yield and 70 days and 120 days yields respectively.

Zavertjaev (1963) in Latvian Red and Black Pied cattle found that the correlation between milk yield in the first 30, 60, 90 and 120 days and the complete lactation increased progressively from 0.48 and 0.86. The author also concluded that the production in the first 90-120 days of first lactation could be used in progeny testing.

In his studies on Italian Friesian cattle, Nagarcenkar (1964a) found highly significant correlation 0.833 ± 0.01 between 120 days part lactation and complete first lactation yield. The genetic correlation between partial and complete milk record was 0.777 ± 0.355 during first lactation. The heritability values reported by
Nagarconkar (1964b) in the same herd for milk yield by intra-sire daughter dam regression, intra-sire correlation between daughter dam pairs, between half-sibs without elimination of year effects and intra-class correlation between half-sibs after elimination of year effects for 120 days milk yield as 0.192 ± 0.108, 0.220 ± 0.120, 0.936 ± 0.306 and 0.352 ± 0.144, total lactation yield 0.424 ± 0.132, 0.520 ± 0.150, 1.060 ± 0.391 and 0.280 ± 0.148 respectively.

Decking (1964) observed in Brown Swiss cattle a phenotypic correlation of 0.87 between 100 and 200-days yield and 0.82 between 100 and 305-days yields and corresponding genetic correlation were 0.96 and 0.92. Heritabilities of 100-, 200- and 305 days yield were all over 0.22 and did not differ significantly. These figures indicate that the same group of genes are operating for the different part performance of milk production.

VanVleck (1964a) analysed the data of five breeds by dividing them into two groups depending on age at freshening and estimated the heritability estimates from between and within sire groups, analysis of deviation from herdmate average in case of both the age groups. Heritability estimates of 150 days' milk yield for the first (age at freshening <35 months) and second (age at freshening >35 months) age groups were found to be 0.40 and 0.20 for Ayrshire, 0.03 to 0.14 for Guernsey, 0.27 and 0.15 for Holstein, 0.20 to 0.07 for Jersey, and 0.39 to 0.21 for
Brown Swiss breed. The genetic correlation between 150 days and 305 days milk production for the two age groups were 0.95 and 0.93 among Ayrshire, 0.66 and 0.68 among Guernsey, 0.95 and 0.89 among American Holstein, 0.88 and 1.02 among Jersey, and 0.91 and 0.93 among Brown Swiss breed.

Dutt et al. (1964) on 103 lactations of Mariana cattle reported significant correlation of 0.50, 0.74 and 0.86 between 305 days lactation and partial yields upto 15th, 75th and 135th day of lactation respectively.

Basovskii (1955) found correlation between 300 days lactation milk yield with 30, 90 and 180 days of 870 daughters of 20 Black Pied bulls as 0.650, 0.903 and 0.975 respectively.

Kuwoski (1965) reported correlation coefficient of 0.89 and 0.93 between 100-day and 305-day production and 200-day and 305-day milk yield and suggested that part records might be useful to reduce the time required for bull evaluation. Bdirigevic and Truskiciv (1956) in Red Steppe cattle observed correlation between milk yield in completed lactation and that in 30, 60, 90, 120, 150 and 180 days as 0.35-0.59, 0.64-0.77, 0.73-0.78, 0.67-0.84, 0.72-0.86 and 0.75-0.88 respectively. It was considered that preliminary evaluation of bulls can be carried out on 90 days lactation results of their daughters as there was a good agreement between ranking of bulls on 90 days and completed lactation records of their daughters.
Malossini (1966) on 246 lactations of Brown Alpine cows observed the relationship of total lactation yield to 90 and 180 days yield to be linear but the linear relationship was not maintained in 30 days milk yield and maximum daily yield. Total yield was correlated with 90 days yield (0.936) and 180 days yield (0.964).

Henley (1966) observed that the heritability of monthly and cumulative monthly production ranged from 0.06 to 0.21 and 0.20 to 0.23 on the basis of 735 daughter-dam pairs in Holstein breed. Genetic correlation between cumulative parts of lactation and total yields were close to or greater than one.

Lamb and McGilliard (1967a) estimated heritability for monthly and cumulative monthly records for various lactations. The heritability of monthly production of milk increased steadily with each successive month during the first lactation, reaching to 0.25 by the 10th month. Heritability of the cumulative monthly milk yield increased gradually with each added month of full lactation to 0.22 for the total lactation. The genetic correlation between monthly and total milk production were generally 0.9 or higher, while the phenotypic correlation of monthly with total milk production in the same lactation were highest from 4th to 5th month of lactation (0.81-0.86).

Singh et al. (1967) analysed the data on 186 first lactation records in Hariana cattle and reported that the genetic correlation between 305 days milk yield
and part lactation milk yields of 15, 75 and 135 days were 0.73 ± 0.25, 0.96 ± 0.04 and 0.98 ± 0.02 respectively. The heritability estimates were 0.22 ± 0.19, 0.39 ± 0.22, 0.63 ± 0.27 and 0.32 ± 0.21 respectively.

Stolzman (1967) analysed the data of 1757 lactations of Black and white Lowland heifers in order to estimate the correlation between 305 days milk yield and 90-, 120-, 150- and 181-days yield, the correlation coefficients were 0.34, 0.83, 0.91 and 0.94 respectively. Singh and Acharya (1969) in Mariana breed reported heritability of monthly yields which ranged from negative value (first and the tenth month) to 0.46 ± 0.13 (fifth month) by daughter-dam regression method, the values of heritability by paternal half-sib correlation method ranged from 0.12 ± 0.12 (third month) to 0.33 ± 0.05 (fifth month). The corresponding values for cumulative yields were 0.16 ± 0.13 (first cumulative part) to 0.43 ± 0.14 (eight cumulative part) and 0.31 ± 0.15 (second cumulative part) to 0.47 ± 0.17 (fifth cumulative part) respectively. The phenotypic correlations for single monthly milk yields ranged from 0.36 for the first month to 0.79 for the sixth month and those for cumulative monthly milk yields ranged from 0.50 for the first two months to 0.97 for the first nine months. The genetic correlations of monthly yields with total yields were close to or greater than unity. These correlations indicate that most probably the same genes control the part and total lactation production.
Ivanov et al. (1959) reported the possibility of the part lactations in purebred and crossbred Danish Red cows for determination of lactation yield. The part lactation yields were for 30, 60, 90, 120, 150 and 200 days. The correlation estimates of these part records with 300 days milk yield were 0.71, 0.73, 0.79, 0.80, 0.85 and 0.85 respectively in pure breeds and 0.75, 0.80, 0.72, 0.85, 0.91 and 0.93 in crossbreds.

Nazarenko (1959) correlated first 120 days and 180 days yield with 300 days production in Red Steppe cows at two different farms. The correlation for former was found to be 0.79 and 0.83, and 0.83 and 0.89 for later one, on respective two farms.

Konicek and Kolech (1971) reported the correlation in Czech Pied heifers between the milk yield recorded for the first, second, third, fourth, fifth, sixth and seventh months of lactation and that for the total lactation as 0.80, 0.75, 0.81, 0.83, 0.87, 0.90 and 0.91 respectively.

Todorov (1971) estimated correlation of 300 days yield with 30, 60, 90 and 120 days yields. The correlation coefficients were 0.64, 0.73, 0.77 and 0.81 respectively. These correlations were significant.

Khan and Ahmed (1972) reported on the study of 212 Sahiwal cows that correlation values between 1st, 2nd, 3rd, 4th and 5th monthly yields with 305 days milk yield
as 0.81, 0.90, 0.91, 0.90 and 0.95 respectively. The multiple correlation was found to be 0.97.

Chhina (1975) in dairy cattle found the genetic, phenotypic and environmental correlation between 300 days first lactation milk production and different partial milk yield records and cumulative milk yield records of the first lactation as highly significant and positive. The heritability values by intra-sire regression of daughter on dam of monthly consecutive part records were in the range of 0.161 ± 0.108 for the ninth month to 0.330 ± 0.103 for the third month and for cumulative part records these ranged from 0.483 ± 0.113 for the first 30 days record to 0.364 ± 0.105 for the 270 days records respectively. The heritability values by paternal half-sib correlation method of monthly consecutive and cumulative part records were in the range of 0.180 ± 0.207 (tenth month) to 0.484 ± 0.227 (fifth month) and the estimates for cumulative first 30 days to 270 days record were in the range of 0.373 ± 0.198 for first 30 days to 0.701 ± 0.281 for 240 days respectively. Mozentseva (1975) estimated in Khohomogor cows correlation between 30, 90, 120 and 180 days part lactation milk yields with 300 days yield as 0.39, 0.64, 0.94 and 0.94 respectively.

Aliya and Christensen (1975) reported in Finnish Ayrshire, Danish Red and Holstein Friesian cows that the cumulative yields between the first six months were highly correlated with total first lactation yields which ranged from 0.93 to 0.91.
Menadovin and Simic (1976) estimated highly significant phenotypic correlations between 305-days milk yield and the first 100 days lactation yield as 0.94, 0.92 and 0.97 respectively in Yugoslav herds.

Rajheja and Salaine (1977) analysed lactation records of 160 Hariana purebreds and crossbreds consisting of 38 Brown Swiss, 70 Friesian, 27 Jersey and 23 Danish Red crossbreds (all with 50% Hariana inheritance). They found the correlation of milk yield in the first month of lactation with total lactation yield as 0.43, 0.76, 0.59, 0.65 and 0.42 respectively for purebreds and the 4 crossbred strains. The estimates for the first two months with total yield were 0.87, 0.82, 0.75, 0.99 and 0.61 respectively.

Mera et al. (1980) in 306 Hariana cows located at three farms estimated the genetic, phenotypic parameters of the monthly, cumulative part time and 300 days first lactation productions. The pooled heritability estimates were obtained by half-sib correlation method for each month separately. The highest estimate was obtained for the 3rd month's (0.89 to 0.19) production. The pooled heritability estimates were also obtained for 60 days, 120 days, 180 days, 240 days and 300 days production which ranged from 0.281 ± 0.11 (60 days) to 0.393 ± 0.25 (240 days). The estimates of genetic, phenotypic and environmental correlations of part time production with 300 days production were all positive and high. The authors indicated that records of 3rd month can be utilized for selection.
Sharma et al. (1980) in Bariana cattle reported the correlation of monthly yields with 300 days yields which ranged from 0.77-0.99 (7/101). The heritabilities of 1st, 2nd, 3rd, 4th, 5th, 6th, 7th and 8th month of lactation were found to be 0.63, 0.58, 0.71, 0.57, 0.72, 0.83, 0.45 and 0.69 respectively.

Sikka and Taneja (1981) on 419 daughters of 28 sires in Sahiwal cattle estimated the heritability for lactation yield, monthly milk yield and cumulative monthly yields. The highest estimates were for yield in the 3rd month (0.37±0.18) and cumulative 90 days yield (0.42±0.19). Genetic correlation of lactation yield with monthly yields up to 5th month were 0.90±0.15 to 0.97±0.02. All genetic correlations were high (0.85±0.25 to 0.98±0.02).

Varshney and Tomar (1982) in Bariana cattle on 373 daughters of 38 bulls comprised cumulative and monthly test yields from 30 to 300 days of first lactation found that the heritability of milk yield from paternal half-sib correlations increased with advancing stage of lactation from 0.44±0.19 at 90 days to 0.53±0.21 at 300 days. By intra-sire regression of daughter on dam the highest estimate was at 210 days (0.60±0.13). Phenotypic and the genetic correlation of cumulative part lactation yield among themselves and with total milk yield were positive and highly significant.

Naksimov (1983) found the correlations of 30- and 90-day milk yields with 305-day yield of first lactation
as 0.79 ± 0.04 and 0.81 ± 0.02 respectively for 247 cows in Russia.

Singh and Tomar (1983) in Mariana cows, observed that heritability of 150-days first lactation yield was 0.36 ± 0.18. The correlation estimates of 90-, 120- and 150-days milk yields with 300-days yield were significant being 0.76 ± 0.25, 0.78 ± 0.23 and 0.85 ± 0.15 respectively.

Rayalu et al. (1984) estimated the heritability of cumulative partial yields of 30, 60, 90, 120 and 150 days as 0.013, 0.065, 0.201, 0.156 and 0.250 in halfbred (Friesian x Ongole) and 0.127, 0.272, 0.381, 0.290 and 0.162 in Brown x Ongole crosses respectively.

It is thus evident from the literature cited above that phenotypic and genetic correlations of part and cumulative part records with complete milk yield records are positive and high. In general the phenotypic, genetic correlations and heritability values of part and cumulative yields are high from 3 to 6 months.

**Selection Efficiency in Improving Additive Genetic Merit of Total Lactation Milk Production**

Madden et al. (1955) worked on American Holstein cattle and found that the relative efficiency of selection based on cumulative milk production ranged from 0.74 to above unity. The authors indicated that first 60- to 90-day production should be considered in preference to selection on a longer record, until the longer record was 6 months or more in length.
Rendel et al. (1957) on analysis of the pooled data on six British breeds, i.e., Guernsey, Jersey, Friesian, Ayrshire, Red Poll and Shorthorn, found the estimated value of selection efficiency on 70 days milk production as 0.696.

VanVleck and Henderson (1961b) conducted a study on the data of Holstein cattle and estimated value of relative genetic progress in the additive genetic merit of first lactation milk yield on the basis of selection of various partial lactation records and complete records. They found that the third or fifth months milk yield record would provide 92% as much genetic gain as on the basis of complete lactation yield. The estimate of selection efficiency was 0.88 on the basis of four months cumulative milk production. The linear function of the first five months would be 97 percent as effective and the cumulative six months milk yield 95 percent as effective as ten months lactation milk yield. The authors concluded that the use of more than nine months milk yield records was not warranted.

Searle (1961b) reported in case of New Zealand Jersey cattle that the estimates of selection efficiency were found to be as high as 0.97, 0.98 and 1.02 on the basis of four, five and six months of butterfat production.

Mahadevan (1955) has also reported in case of Red Sindhi cattle that as high as 50% of the cows completed their lactation before 300 days and 10% of the cows ended the lactation even within the period of 200 days.
Nagarcenkar (1964a) studied the production records of a large herd of Italian Friesian cattle and found that the estimation of selection efficiency varied within the range of 0.524 to 0.878 for the first 120 days milk production. On reviewing the available research work he pointed out that selection of cows for high milk production could be based on the criteria of two traits, i.e., age at first calving and partial lactation milk records having high efficiency of selection, since both the traits were found to be fairly heritable and significant phenotypic and genetic relationships were found to exist between partial and complete lactation milk records. While highlighting the usefulness of part lactation records in selection programme, Nagarcenkar (1964a) also stated that earlier part lactation milk records in adequate number can be used because majority of the cows abort or are culled after completing the first 120 days period of lactation. On the other hand, the availability of complete lactation milk yield records in sufficient number may not be possible for sound selection in dairy cattle.

Chhina (1975) in Gir cattle found that the selection efficiency in earlier part of lactation was quite high for second monthly milk yield (83.1%) and for cumulative 60 days it was 98.9%.

It is thus indicative from the literature reviewed that the second, third, fourth or fifth part yields and first 60 to 150 days would provide as much expected gain as in the whole yield.
Roget's (1957) stated that the optimum structure of the population and the probable genetic superiority of the chosen groups are dependent on the testing ratio, K (the ratio of the number of individuals which can be measured each generation to the number of sires which are to be selected), the heritability, and the genetic relationship within groups. The author found that the probable genetic superiority was within ten percent of its maximum when the heritability ranged from 0.01 to 0.25 and the size of the chosen group of daughters raised from 10 to 20.

Wearden (1959) using a procedure based on the probability of detecting real genetic differences among sire groups, calculated adequate number of progeny needed per sire for varying number of sires (7 to 25) for estimates of heritability ranging from 0.10 to 0.60, by assuming the probability as 0.75 and the rejection levels as 0.05 and 0.01. With 25 sires and moderate $h^2$ value of 0.30 for the trait, the number of progeny calculated as required was 12 and 17 at the rejection level of 0.05 and 0.01 respectively, whereas the number of progeny per sire was computed as 5 (when $\lambda = 0.05$) and 8 (when $\lambda = 0.01$) with the same number of sires but a high heritability value of 0.60.

Zorin (1959) compared the milk and butterfat yields in the first lactation of group of 10, 20, 30, 40 and 50 daughters of each bull compared with those of other bulls in Swiss breed at 2 studs in Tula Province. Taking into
consideration differences in the yields of the dams of the daughters, the degree of significance between yields of daughter groups was used to indicate superiority. It was concluded that, in general, 30-40 daughters were sufficient to determine the value of a bull.

Ruzskii (1961) observed that the average of 20 daughters was close enough to that of 30 to 40 daughters and recommended the use of 20 daughters for determining the breeding value of a sire.

Searle (1961b) indicated that under New Zealand conditions records accumulating up to a specified test day early in lactation (4th, 5th and 6th month) are suitable for progeny testing in Jersey and Jersey crossbred cows. Approximately 40, 60 and 80 daughters in sire proofs using part records give the same information about lactation yield as a proof using complete lactation yield on 30, 40 and 50 daughters respectively. Proofs on both kind of records for the same group of sires were highly correlated and part lactation proofs were just as repeatable as those based on lactation yields.

VanVleck and Henderson (1961e) studied large data on American Holstein cattle and estimated the number of part records required to predict the breeding value of a sire for ten months' total lactation yield with an accuracy equal to prediction on the basis of 20, 30, 40, 50, 100, 150 and 200 complete ten months milk records. The results found by them have been tabulated in Tables 1 and 2.
Table 1. Number of single month of lactation records need to have accuracy as on different number of complete lactation records

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VanVleck (1962) presented the results of an evaluation of Ayrshire, Guernsey, Holstein and Brown Swiss sires in New York State on the basis of the 150-day records of their A.I. daughters and compared these with those based on 305-day records of other daughters. It was found that except in case of Guernsey breed (probably a technical difficulty) the correlation between 305 days and 150 days evaluation increased as the number of daughter records in each group increased.

Searle (1964) developed a method based on the equations which lead to the estimation of the number of daughters required for sire proving on the basis of milk production records. The efficiency of this method in determining minimum number of daughters required for sire proof is measured by the correlation between sire's true additive genetic merit (g) and estimated genetic merit (\( \hat{g} \)). The efficiency of \( \hat{g} \) as an estimate of a sire's true genetic merit is further dependent on (1) estimation of environmental trends in daughter records, (2) number of daughters available, and (3) heritability of the trait concerned. The author found that for increase in the number of daughters, the correlation between g and \( \hat{g} \) approaches 1.00 more rapidly for high heritability estimates than it does for low. The values of this correlation have been given in Table 3.

Another useful equation was developed by Searle (1964) for the calculation of number of daughters required in a progeny test, when the heritability value of the trait
Table 3. Correlation between the estimated and true additive genetic merit of a sire

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Correlation, \(r_{\hat{g}, \hat{g}} = \sqrt{nh^2/A + (n-1)h^2}\)

where, \(n\) = the number of daughters per sire, and
\(h^2\) = the heritability of the trait
as well as the correlation between the estimated and true merit of the sire (which would be predetermined magnitude) are known. The Table 4 illustrates the usefulness of this method.

An optimum progeny size of 40 daughters and of 20-50 daughters per bull in Guernsey breed was recommended by Schuman (1964) and VanVleck (1964b) respectively. In another study, Seerle (1964) observed that accurate genetic estimation of breeding value for milk production of a sire's son is possible from using 5 daughters or more, 7 daughters or more, 14 daughters or more for heritability values of 0.25 or lower.

Sassin (1968) reported the correlations of the milk yields of the first 10 daughters of bulls with those of the first 20, 30 and 50 daughters as 0.75, 0.31 and 0.32 respectively. It was concluded that 10 daughters are sufficient for evaluation when these are in the same herd.

Ruzevskii and Pavlenko (1969) found no significant correlation between milk yield of all available daughters and that of sample of 5, 10 and 15 daughters. However, the correlations of sires breeding values based on all daughters with those based on 20, 25 and 30 daughters were 0.50, 0.99 and 0.85 respectively. It was concluded that in progeny testing, 20 daughters are required in testing for milk yield.

Nazarenko (1970) calculated the correlations of the performance of all daughters with that of the first
Table 4. **Number of daughters required to estimate the additive genetic merit of a sire**

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Number = \( r^2 (A/h^2 -1)/(1-r^2) \)
5, 10, 15, 20, 25, 30, 40 and 50 daughters of 2939 Red Steppe 
and 1166 Russian Simmental females, the daughters of 65 and 
26 bulls respectively. For 5 daughters, the correlation was 
high in respect of fat content and body weight. In progeny 
tests for milk yield 15–20 daughters test was recommended 
by the author and for fat content and body weight 10–15 
daughters.

Anisimov (1972) recorded the milk yields for the 
first 90, 150 and 300 days of lactation for the daughters 
of 6, 7 and 4 bulls at 3 farms (3–47 daughters/bull) and 
ranked the bulls according to average production of their 
daughters. The correlation between ranking based on a 
300 days lactation and that based on the first 90 days of 
lactation was 1.00, 0.89 and 0.80 at the 3 farms respectively. 
The correlation between ranking based on 300 days and 150 days 
records were also 1.00, 0.89 and 0.80 respectively. It is 
concluded that benefits from obtaining a sire's proof 150-210 
days earlier outweighs the slight loss of accuracy of evalua-
tion.

Chhina (1975) found that early sire proving 
with adequate accuracy and efficiency could be done with 
10 daughters per sire and the production records of first 
60 days lactation milk yield of their daughters in Gir breed 
within a herd basis.

The literature reviewed indicates that increasing 
the number of daughters would increase the accuracy of estimation of breeding value. But as more number of bulls sampled
would give a higher selection intensity an optimum progeny size would have to be considered. Sire proofs based on 5th monthly test day records require a few additional observations to be as accurate as proofs based on 10 months total lactation yield. Obtaining sires proofs earlier outweighs the slight loss of accuracy of evaluation of sires. The literature reviewed further reveals that the number of daughters needed for estimating the breeding value varied with the method applied and ranged between 5-50 daughters, as per various investigations reviewed above.

**BREEDING PLANS AND ECONOMIC RETURNS**

An excellent and exhaustive review was made by Miller (1977) on economics of selection programs for artificial insemination. He was of view that early research failed adequately to assess the economic impact of selection alternatives while later work demonstrated that maximum genetic gain resulted in less than maximum economic returns. He advocated that exchange of semen at international level would be more worthwhile and that the use of elite proven bulls both as sires of herd replacements and as sires of sons for future testing would increase selection intensity.

The early work by Robertson and Rendel (1950) and Rendel and Robertson (1950) marked the advent of research to develop efficient procedures for utilizing the new tool of A.I. for genetic improvement.
The key concept introduced was the elucidation of the four pathways for the transmission of genetic improvement. Sires of sons, sires of herd-replacements, dams of sons and dams of herd-replacements, Robertson and Rendel (1950) pointed out how the relative importance of these paths changes depending upon the characteristic of the breeding plan. The factors studied were population-size, number of young bulls progeny tested per year and the proportion of milk recorded cows bred to young bulls. They showed that opportunity for genetic gain is at least twice as large through A.I. compared to that in a closed herd using natural service. They also showed that size of breeding unit has an important bearing on potential for genetic improvement.

Specht and Mcilliard (1950) studied the effects of varying population-size, proportion of recorded cows bred to young bulls, selection-intensity and the number of young bulls tested. They found that, for recorded cows' population of 10,000 peak efficiency resulted when 30% to 50% of the cows were bred to young bulls. When the additional requirements for providing service to a large population of untested cows were introduced, the optimum proportion of the production tested cows to be bred to young bulls rose to 50-70%. Optimum selection intensity was found to be 1:10.

Poutous and Vissac (1962) applied economic criteria in choosing an optimum breeding plan. In addition they were first to account for the "ripple effect" of a
selection decision through generations subsequent to the offspring generation. The unique economic concept introduced by them was the idea of discounting the economic value of future genetic gain.

Skjervold (1963,1966) reported his finding for a genetic optimum for the trade off between the progeny group size and the number of young bulls that could be tested. Earlier he (1964) considered the effects of inbreeding depression on the genetic optimum. Population sizes considered were 2,000 to 400,000 cows. His conclusions were (a) the genetic optimum is to breed about 50% of the recorded cows to young bulls and to aim at a progeny group size of 50 to 55 daughters, (b) the most important vehicle of genetic improvement is the path of sire to son (44%) and only two sires of sons should be selected annually, (c) increasing magnitude of inbreeding depression requires increase in progeny group size and consequently decreasing the proportion of the recorded cows bred to young bulls.

VanVleck (1954b) presented a report in which certain costs of an A.I. progeny test programme were considered in choosing an optimal plan. The costs were for sampling and maintaining bulls during progeny testing and the extra feed cost incurred by lactating progeny to produce additional milk. He also considered the diffusion of genetic improvement over time (50 years). In a population of 110,000 with 100,000 first services, five proven bulls and a proven
buck replacement rate of 20%, the economic optimum with respect to net return per cow per year was to breed 75 to 80% of recorded cows to proven bulls, with 20 to 50 recorded offspring per sampled bull. Genetic optima were similar to the economic optima.

Cunningham (1966) simulated 3000 alternatives in which the following factors were varied: (a) use of progeny tested bulls, (b) cost of proving bulls (cost of bull purchased, maintenance, milk recording and progeny test evaluation), (c) proportion of recorded cows bred to young bulls, (d) number of progeny per tested bull. Discount method was not applied but rather average annual marginal income over feed cost was calculated for each alternative. His conclusions were: (a) maximizing rate of genetic improvement in milk yield may require systems which result in an economic loss due to cost of testing too many bulls, (b) in a population of 400,000 cows, 20% should be bred to young bulls, 20% of proven bulls should be replaced each year, and (c) a selection intensity of 1:4 should be practiced and a progeny group size of 40 should be achieved.

Soller et al. (1966) studied the effect of performance testing of young bulls on growth and milk production of their offspring. Among the economic factors introduced were relative prices of milk and meat, feed costs and rearing and maintenance costs. Their conclusions for the conditions studied (relative value of meat:milk ranging from 5:8:1 to 10:1) were: (a) progeny-testing for milk is the most profitable
aspect of an optimum selection plan (70% of total economic gain), (b) performance testing young-bulls for rate of gain can contribute significantly to overall economic gain (combined with dairy progeny test, increases to 93% of economic maximum), (c) under certain conditions, progeny test for rate of gain may be economically worthwhile, (d) optimum relative emphasis to milk and rate of gain is not affected drastically by realistic changes of relative values of meat and milk.

Lindhe (1968) made a stimulation study in which 10,800 breeding alternatives were computed for 400,000 cows of a dual purpose breed. The factors varied were proportion of milk recorded cows mated to young bulls, size of progeny group, the number of deep frozen semen doses, proportion of young bulls selected on performance test for growth rate, and heritability of milk yield. In his economic analysis, he considered the costs of bull maintenance, computation of progeny test results, rate of interest on funds expended, preparation, processing and storing frozen semen and bull calves retained. The author concluded that maximizing rate of genetic gain is not a rational economic decision. He found that it is more advantageous to increase the number of units of semen frozen per bull than to increase the number of bulls tested with a lower number of units produced per bull. All costs were discounted to 72 months of age of bulls.

Hinks (1970) studied the economic aspect of progeny testing of bulls. The economic factors considered
were (i) interest rate (8%), (ii) bull purchase price (£200 per bull calf), (iii) bull maintenance cost (£125 per bull per annum), (iv) data processing cost (£50 per bull), and (v) payment for attaining milk record on test offspring (£3 per completed daughter record), (vi) cost of semen processing (£0.05 per dose), (vii) cost of semen storage (£0.002 per dose per annum). He made different alternatives by varying the number of young bulls, number of progeny per bull in the progeny test, number of units of semen collected per bull, proportion of males selected on the basis of milk progeny test and population size. The costs and returns were discounted. He considered first and second generation descendants of selected bulls going to 25 years after a mating. He concluded that variables were minimized by saving all bulls until they were evaluated and then heavily utilizing the superior bulls over the remainder of their semen productive life span. He also found that a selection intensity of 1:4 to 1:6 was economically sound in spite of resulting higher testing costs. Optimum progeny group size was 65 to 75 when 30% of the population mated to young bulls in cow population of 10,000 to 800,000.

Hill (1971) described the discounted cash flow procedure for evaluating the returns on investment and also considered the factor of crossing a portion of the dual-purpose herds to beef bulls. The young bulls are selected for growth rate in a performance test, which precedes the
progeny test for milk production in the dairy breed. He demonstrated that a long "break-even-time" is required subsequent to the initiation of a selection scheme (10 years for beef, 15 years for dairy). With the parameters, costs and assumptions used, rate of return in the dual-purpose breed was 16% and 27% in the small beef population.

Hinks (1971) worked on the financial consequences of progeny testing. Total gross monetary value of selection response was estimated as the product of selection response, number of lactations in which it was expressed and its gross market price (assumed to be £35 per 100 kg of milk). This value was discounted according to appropriate discount factor and number of lactations involved. The extra cost of A.I. for the additional bulls needed to practice selection, was additional purchase cost assumed to be £200 per bull calf and additional maintenance cost of £125 per bull per annum. All other operational costs of A.I. service including the large cost of semen processing, storage and distribution incurred whether selection is practised or not were ignored. Conclusions were that capital investment in bull progeny testing for milk production was likely to be profitable under most economic conditions. The most important determinants of profitability were intensity of selection and ratio of milk price to feed price.

Hunt et al. (1972) simulated annual genetic gain for milk yield for an A. I. population of 115,000 dairy
cows for different values of the following variables, superiority of bulls dams, number of sires of sons per year, percent of sires of sons replaced annually, proportion of cow population that is milk recorded, percent of milk recorded cows bred to young bulls, progeny group size, number of first services in milk recorded herds to obtain test daughter, number of semen units collected annually from proven sires, and the proportion of progeny bulls replaced annually. Their conclusions were (a) relatively large declines in annual genetic progress occur when the number of sires of sons per year increases from 2 to 8, (b) 25 to 50% of all proven bulls for siring sons should be replaced annually, (c) genetic gain is enhanced by reducing progeny group size from 60 to 30, (d) when a low proportion of the population is milk recorded, genetic gain is enhanced by breeding a relatively high fraction of the tested cows to young bulls, (e) A.I. organisations can significantly affect rates of genetic improvement through the proportion of their proven stud which is replaced annually. No economic analysis was conducted.

Brascamp (1973a) gave results of a study in which economics of alternative plans were appraised. Factors varied were proportion of cow population bred to young bulls, progeny group size and number of semen units frozen per young bull. Offspring were tested through four generations. Economic costs and returns were discounted.
He also concluded that the genetic path of sires to sons is
more important from a genetic than from an economic viewpoint. For the path "dam to breed daughter," the opposite was the case. A decrease in population at a constant rate had large effects on the economic value of genetic improvement.

Brascamp (1973b) studied the effect of costs of A.I. breeding on optimization of the breeding plan. Total of 12 cost alternatives were considered. Two management systems were compared, the waiting-bull system (B) and storage of deep frozen semen with slaughtering of bulls early in life (A). The variable factors were population size, proportion of the population recorded, annual semen production per adult bull, number of doses sampled per adult bull, progeny group size and proportion of the population inseminated with young bulls. Net return was used to select optimum and sub-optimum breeding plans. For most cost alternatives optimum and sub-optimum breeding plans were found for system (A) with high number of doses per bull except being alternatives with high costs of semen preparation and storage and low costs of management and feeding. Net returns for optimum and sub-optimum plans increased as population size increased, but the model was too simple to indicate an optimum population size.

Lane et al. (1973) evaluated the effect of variations in certain economic factors. Factors varied were bull purchase price, housing and maintenance costs, fees for first services and bull-dam superiority for an artificial insemination population of 115,000 cows. They reported when
purchase price ranged from $1,500 to $10,000 per bull least cost programme required sampling the minimum number of young bulls annually required to achieve a specified rate of genetic improvement. Purchase price and housing and maintenance costs had great impact on progeny testing costs, particularly when maximum genetic gain was approached because of very large number of young bulls required. When budgets were fixed, programs involving purchase of larger number of bulls at reduced prices yielded the highest rates of genetic improvements.

Petersen et al. (1973) studied progeny test for growth and milk in dual purpose breed. Factors varied were: (a) selection intensity for (b) number of semen units stored per bull being progeny tested and (c) selection intensity for milk. The costs and returns were discounted. The optimal plan (maximum net returns) called for one bull to sire sons each year and for maximum semen storage per young bull tested (50,000 units per bull). The plan was estimated to produce 1.56% annual genetic gain in milk and 0.42% annual genetic gain in growth. Under these conditions, milk yield increase accounted for 76% of economic gain and 24% rate of growth.

Hinks (1974) suggested that designed milk progeny tests must be needed in breeds of numerically smaller size to make best use of population of recorded animals.

Hunt et al. (1974) gave results of a study of plans for population ranging from 15,000 to 1,500,000 cows.
Variation in numbers of sires of young bulls used each year, percentages of cows milk recorded and bred to young sires and numbers of progeny in the test group were examined. They concluded that genetic gain was enhanced in all populations when the numbers of sires of sons had annually decreased from 8 to 2, the percent of cows bred to young bulls increased, rate of genetic progress with greater advantage occurred in smaller populations, large population size increased possibilities for further genetic advance, especially from 15,000 to 50,000. When population size is small (15,000 cows), maximum genetic gain requires sampling a large number of young bulls by reducing the progeny group size to 20, with a large population (750,000) progeny size should be 40 to 60.

McClintock and Cunningham (1974) defined a standard unit for a trait as one progeny expressed in the year in which the insemination is carried out. They developed a method for summarising the total genetic consequences of an insemination in these standard units. It takes account of the timing of the insemination, the number of years over which the evaluation is carried out, a discount factor, the dilution of the bull's genotype in his descendants, the female replacement rate, the calf survival rate, the probability that a surviving calf becomes a dairy cow. It applied equally to selection of young bulls for general use and for use in planned matings to produce young sires for testing.
Oltenacu and Young (1974a) presented a methodology to find the optimum intensity of selection among progeny tested bulls and optimum fraction of cow population used for progeny testing to maximize genetic progress. They concluded that genetic gain can be increased by increasing the fraction of the population on test or by increasing the usage of proven sires. They also emphasized that smaller group size should be used. The optimum selection was, 100 bulls tested per year, 23 daughters per bull and 5 bulls selected as proven sires.

Oltenacu and Young (1974b) gave results for several alternative plans. Three alternative ways of increasing the rate of selection among progeny tested bulls were (i) increasing the fraction of recorded cows bred to young bulls so that more bulls could be tested, (ii) decreasing progeny size, (iii) increasing utilization of proven bulls so that fewer bulls would be required. Economic factors were feed cost for producing increasing milk, interest rate, milk price and variable costs of sampling programme (cost of bulls purchase £1000, bull maintenance £400/bull/year independent of age of the bull, semen processing £0.05 per ampule, semen storage £0.25 per ampule/year). Variables were (a) progeny group size, (b) number of young bulls tested, (c) number of bulls selected, (d) interest rate. Population size was 200,000 cows with 20% of cows on test, 43% of proven bulls replaced every year. The conclusions were (a) improvement in bull utilization will permit increasing the selection
pressure without much increase in costs and appear also to
extend the limits of profitable selection. (b) In all three
methods of increasing bull selection, the optimum programme
for maximum profit was sub-optimal for genetic progress,
(c) intensity of selection profitable for bull selection
generally increases up to 1/5 to 1/7, depending on method
and discount rate.

Mangurkar and Gokhale (1979) estimated the annual
 genetic gain by simulation procedure for crossbred cattle
population of 20, 50, 100, 300 and 1,000 thousands with
progeny group sizes of 10, 20, 30, 40 and 50 respectively.
Forty percent of the cow population was milk recorded and
young sires were sampled on 40% of the recorded cow popula-
tion. Economic factors were: bull purchase price, bull
maintenance cost, semen processing and storage cost, cost of
A.I. to the stud, cost of recording per daughter and analysis
of data. They concluded that (a) semen collection period
appreciably affected the cost of testing a bull, (b) increase
in progeny size and consequent reduction in number of sampled
bull to economise in the testing programme and to achieve
maximum gain per unit of cost input, (c) a testing programme
which yields maximum genetic gain may not necessarily be
optimum on economic considerations.

Jain et al. (1984) computed rates of annual
 genetic gain for herds of 600, 300, 200 and 150 breedable
females separately for indigenous zebu breed, crossbred cattle
and buffaloes under progeny testing for alternative combina-
tions of tested and untested sires in use in each cycle.
The progress was at peak when selection intensity was for
2 or 3 top progeny tested bulls in each batch and depended
upon the amount of inbreeding depression. In a herd of 150
breedable females progeny testing gave better genetic
progress than the use of young bulls selected on the basis
of dams’ yield or no progeny testing. Progeny testing in
view of small gains and heavy cost involved, may not be of
much use in small herds they stated. However, they recommen-
ded that the best course, in such a situation would be to
coordinate breeding programme through exchange of semen of
bulls of the same breed among herds.

The literature cited above reveals the
characteristics of optimum breeding plans for improvement
of artificially inseminated populations by varying the
population sizes, number of young bulls progeny tested and
the proportion of cows bred to young bulls. It also
indicated that selection intensity should be at least 1:4
and about 20% of the tested cows should be bred to young
bulls. The review of literature further indicated that
maximizing genetic gain often results in less than maximum
economic returns if future productive improvement is dis-
counted to present value.

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