[illegible] Selection Indices for [illegible] Tharparkar Herd at Patna

THE DEVELOPMENT OF SELECTION INDICES FOR IMPROVING THARPARKAR HERD AT PATNA

A THESIS

Submitted to the Faculty of Veterinary Science and Animal Husbandry, Magadh University, in partial fulfilment of the requirements for the Degree of Master of Science (Animal Husbandry)

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INTRODUCTION

" The key is man's power of accumulative selection: nature gives successive variation, man adds them up in a certain direction useful to them".

Darwin, 1920

Cattle population of India is 155 million (Anand, 1959) which is about 20 percent of the world population. But the average per capita human consumption of milk is only 46 Kgs. per annum as compared to 206 Kgs. in the United Kingdom and 253 Kgs. in the United States of America. Our low per capita consumption of milk is due to very low productivity of our cattle as compared to those of advanced countries.

The actual situation pertaining to the different countries would be clear from the following table:-

Name of country		National average milk yield per cow (in Kgs.)
1. Switzerland	...	3897
2. Netherland	...	3780
3. Japan	...	3646
4. Belgium	...	3560
5. Denmark	...	3340
6. United Kingdom	...	2830
7. U. S. A.	...	2420
8. Phillipine	...	1280
9. Pakistan	...	730
10. India	...	190

Anand(1959) as quoted by Ahmad(1961)

Another reason for low per capita milk consumption may be the increasing rate of human population. Human population in India is increasing by 2 percent per year whereas cattle population is increasing only 1.2 percent per year (Agri.Marketing,1956 as quoted by Ahmad, 1961).If this trend continues in future, per capita milk consumption will also decline. In order to prevent this decline in per capita milk consumption one will have to think either of increasing the cattle population more rapidly than the human population or increasing the production of the existing cattle. Increasing the per capita milk consumption by raising the productive efficiency of our cattle seems to be more logical as the existing level of production of our cattle is very low. In order to bring about improvement in the productivity of cattle,breeding methods on scientific basis have to be adopted.

Out of the three basic tools of Animal Breeders, viz Inbreeding,Cross-breeding and Selection, the latter i.e. selection seems to be encompass,directly or in-directly, the rest two that is in-breeding and cross-breeding. Differential reproduction of some individuals as compared to the rest of population constitutes in essentiality,what we speak of as 'selection'. Paraphrasing it, we may say that choosing the parents for the next generation is 'selection'.Whatever the criteria of selection may be,the ultimate objective is to effect genetic improvement in a trait or traits.We may strive to improve one trait of a population or many traits of that particular population at the same time. There can not be an intermediate objective on this score.

May be, we are interested in improving more than one trait of a population at a time. Then we are naturally forced to take to one of the three conventional methods of selection. (1) Independent Culling Level where a minimum level of performance is fixed for every trait and the animal falling short of the desired level in any trait is culled. (2) Tandem Method - where the traits are improved to a desired level, one at a time and (3) Total Score Method in which a relative weight is given to each trait depending upon its importance to fix a score (numerical figures like 10,20,30 and so on) for each animal. The animal showing the highest score is selected. Thus total score or "Selection Index" is just a numerical score assigned to each individual being considered for selection and the animal securing the highest score would obviously be the best for selection.

Hazel and Lush (1942) have reported that the selection of the animal on Total Score or Selection Index is more efficient than either of Independent Culling or Tandem Method. Total Score Method is $\sqrt{n}$ times more efficient than Tandem Method when taken separately, where n represents number of traits considered in selection. For two traits the selection index method would be 1.41, for four traits 2.0, for six 2.45 and for eight traits 2.83 times as effective as Tandem Method. The Tandem Method is by far the least efficient of the three. The efficiency of Independent Culling Level Method is always population or many traits of that particular population at the same time. There can not be an intermediate objective on this score.

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The most striking point in Total Score Method is that it gives opportunity to all economic characters for improvement. Thus this method prevents culling of animals which are outstanding in all but one trait. In other words we may say that this method accepts slight mediocrity in one trait in order to obtain high performance in others. This method balances all traits and thus helps in retaining the animals in the population who possess over all superiority.

The present study concerns, the development of Selection Indices in Tharparkar herd maintained at Government Cattle Farm, Patna. In this study four economic traits have been taken into consideration because the value of a cow does not necessarily depend only on her milk yield rather also upon other economic traits like Age at first calving, First calving interval, Lactation period, Productive life, Fat yield, Service period and Fat percentage etc.

The following economic characters were included in the study:-

(1) Milk yield (Life time production, in pound).

(2) Age at first calving (From birth to the date of First calving, in days).

(3) First calving interval (Interval between first & second calving, in days).

(4) Lactation period (Life time, in days).

These economic traits seem to be of utmost importance for cattle and require selection for their improvement.

Indian cattle in general are low yielders. They attain their maturity very late in comparison to foreign breeds of cattle and have long calving intervals. All these contribute to a great extent towards the low economic return from the cows in this country.

(1) <u>Milk yield (Life time production)</u>

Milk yield is the most important economic character. The value of a cow largely depends upon the quantity of milk she produces. Therefore, any attempt to increase the milk yield would be highly desirable. In the present study, life time milk production has been taken into consideration. This was done because milk yield is a quantitative character & is highly influenced by the environmental factors. Internal conditions of health are part of environment. The ultimate value of a cow would be determined by the total amount of milk she produces. Milk yield is a repeatable trait and several lactation records may be available on the same cow. Since milk production as observed, is conditioned both by genetic and environmental influences, the latter may introduce a definite amount of error if a single lactation is taken into account to assess the total productivity of the cow, irrespective of the correlation that exists between the first lactation and the life time production of the cow. It was, therefore, decided to base this study on the life time production and not on a single lactation record.

(2) Age at first calving:-

Age at first calving is also one of the most important economic traits. Though there are a number of non-genetic factors which affect milk yield like season of calving (Ragab et al., 1954), the Age at first calving is also a potent factor which influences the lactation yield (Dickerson and Chapman, 1940). It affects the life time production of the animal. An early age at first calving would reduce the unproductive period of our cattle. Tandon (1951) studied the age at first calving in Red Sindhi and Sahiwal cows and their crosses with Friesian bulls on selected Military Dairy Farm in India. He observed that the genes for early maturity are dominant over those for late sexual maturity. Johanson (1950) reported that early calvers give many more calves than late calvers and thus they are more economical than the latter. Hartmann (1953) also observed that fertility and life time production were highest in cows which had their first calving at an early age and that early calving did not affect the body size or growth of the animal. It is the lactation which taxes the heifer and not the burden of pregnancy.

(3) First calving interval:-

Calving interval also plays a significant role in the performance of dairy cattle. Gains and Palfrey (1931), Chapman and Casida (1935) as quoted by Prasad (1958) reported that optimum milk producing efficiency would be obtained in cows calving every 12 months or less. Thus any practice C.R.

LITERATURE REVIEW

Farm animals have been under domestication since the time immemorial and the breeding animals have been selected by methods known to the breeders. The goal of the breeders is to bring about improvement in the genetic constitution of their animals but the main drawback in achieving this goal is that the breeders do not know the exact genotype of their animals. With the advancement of time, when the art of animal breeding developed, it was thought that the improvement in the genetic make up of animals could be made by 'Selection'. This is done because the breeders at least have the choice to decide which of the animals will have more offspring. As reported by Hazel and Lush (1942) selection based on Total Score Method (Selection Index) is more efficient than either of Tandem or Independent Culling Level Method.

Estimates of phenotypic and genetic parameters like heritability, genetic correlation, phenotypic and genetic variances and co-variances are the guides in estimating the breeding worth of an individual. Consequently various workers have studied the different traits for estimating these values. Since development of an Index requires estimates of phenotypic and genetic parameters, it appears quite logical to review the literature under two sub-heads viz(a) Selection Indices (b) Estimates of phenotypic and genetic parameters.

(a) Selection Indices:-

It was for the first time that Smith(1936) applied this concept to plant selection which later on developed into selection index(Jakih, 1940). He developed indices for two varieties of Australian wheat and utilized the following characters:-

(a) Yield of grain,(b) Weight of grains(c) Number of heads and number of kernels per plant,(d) Average weight per kernal and (e) Weight of straw per plant.

V.S.Jakih(1940) developed an index in dairy cattle for the first time. He utilised the available information of 10820 Schwyz cattle and constructed a series of indices each intended for either of pure breed or their crosses. The one for pure breed was as follows:-

For the first lactation:-

I_1 = 1900.4 My + 391.9 Kg liveweight.

$I_2 I_3$ = 2557.9 My + 397.4 Kg bodyweight(for the 2nd and 3rd lactation)

Later on,Panse ~~xx~~(1940) constructed an index in cotton which is supposed to be the first index constructed in India.

In 1946,he developed an index in poultry for the first time in India. He included the following economic traits:-

(a) Body weight at first laying period.

(b) Egg weight.

(c) Age at first laying.

(d) Egg lay.

Hazel(1943) constructed three indices in pig, utilising the data from the Regional Swine Breeding Laboratory Iowa from the fall of 1937 through the spring of 1940. The history of the herd was given by Bywaters(1937) and more recently by Whatley(1942). He gave the genetic basis of constructing selection index. On the basis of his work he concluded that "the genetic gain which can be made by selection for several economic traits simultaneously within a group of animals is the product of (1) selection differential (2) miltiple correlation between aggregate breeding value and the selection index and (3) genetic variability. The first of these may be very small due to breeder's carelessness and is limited by the rate of phenotypic reproduction of each species while the third is relatively beyond man's control, hence the greatest opportunity of increasing the progress from selection is by insuring that second is as large as possible". He used the Multiple Correlation Method in constructing the index.

Hazel later on in the year, 1952 again developed three indices in beef cattle using the assumed values for necessary parameters. He included the economic traits like (a) Weaning weight (b) Weaning Score (c) Feed efficiency (d) Slaughter grade and (e) Rate of gain. The relative economic values of the traits were obtained as change in profit per unit change in the trait under consideration.

From the available information on producing ability of cows and its dam, average cow's daughter, maternal half-sibs and average of paternal half-sibs, Legates <u>et al.</u> (1954) developed an index in Jersey cattle for butter fat yield. The following parameters were computed for this purpose.

(a) Repeatability of records of the same cow.

(b) Correlation between fat records of paternal half-sibs.

(c) Correlation between fat records of maternal half-sibs.

(d) Heritability of fat production.

The progress made by using this index was estimated to be about 1.10 to 1.15 times greater than selecting on the cow's performance alone.

Tabler and Touchberry(1955 & 1959) constructed indices in Jersey and Holstein-Friesian cattle in Illinois utilising data from 2810 daughter-dam pairs obtained from 414 Jersey herd and 20024 daughter-dam pairs of Holstein-Friesian herd. They included the following economic traits:-

(a) Milk yield.

(b) Fat percent.

(c) Fat yield.

(d) Type classification.

They computed several indices and compared their relative efficiency. They concluded that index based on milk alone showed the maximum improvement in milk yield as well as in fat yield in both the breeds. These indices were more comprehensive than the index developed by Legates <u>et al.</u>(1954).

Lindholm and Stonaker(1957) using the procedure adopted by Hazel (1952), constructed an index in beef cattle based on (a) Weaning weight (b) Daily gain and (c) Feed consumption per lb of gain. The relative economic values were estimated in terms of paternal regression coefficient of net income per hunderweight of the animal on the several traits. The heritabilities were estimated by the use of paternal half-sibs intra-class correlations - $\frac{VS}{VS-VE}$ where 'VS' is the sire component of variance and 'VE' is the individual variance.

The genetic variances and co-variances were obtained by dividing sire variances and co-variances by the same half-sib relationship. The genetic correlations were obtained by dividing genetic co-variances by the square root of the product of genetic variances.

Mishra(1960) carried on work on selection index in dual purpose cattle using the data from Southern Experiment Station,Waseca,Minnesota (U.S.A.).He included the following economic traits in his study:-

(a) Mean average production of the dam(m.e.* but not fat corrected).
(b) Mean annual production of half-sibs (m.e.* but not fat corrected).
(c) Growth rate on dam.
(d) Mean growth rate of half-sibs(corrected for sex).
(e) Mean dressing percentage of half-sibs.
(f) Growth rate on sire
(g) Mean butter fat of dam.
(h) Mean carcass grade of half-sibs.
(i) Mean butter fat of half-sibs.

The following parameters were obtained:-

(1) Phenotypic variance of milk production, butter fat percent, 12 months weight (males),12 months weight(females),dressing percentage, carcass grade and calving interval.
(2) Phenotypic co-variances between milk and growth,milk and calving interval, milk and butter fat percent, calving interval and growth, growth and butter fat percent,growth and dressing percentage,growth and carcass grade,dressing

m.e.* = Mature equivalent.

percentage and grade and calving interval and butter fat percent.

(3) Additive genetic variances of milk production,fat percent, calving interval and growth.

(4) Additive genetic co-variances between milk and fat percent, milk and calving interval,milk and growth,milk and dressing percentage, milk and carcass grade,fat percent and calving interval, fat percent and growth,fat percent and dressing percentage, fat percent and carcass grade,calving interval and growth, calving interval and dressing percentage, calving interval and carcass grade, growth and dressing percentage and growth and carcass grade. Variance - co-variance was the method employed to obtain the relative weight (b-value) for each trait.

O,Bleness <u>et al.</u>(1960) constructed several indices based on (a) Milk yield (b) breeding efficiency and (c)seven other variables and concluded that an index based on milk alone was no less efficient than the other indices.

Ahmad (1961) constructed three indices in India in Hariana cattle maintained at Izatnagar (I.V.R.I.) and included the economic traits like (a) Age at first calving(months) (b) First calving interval(in days) (c) Milk yield of first lactation,301 days(lb) (d) Body weight at first calving and (e) Fat percent in first lactation. The method employed in this study was 'multiple correlation'. The following parameters were estimated:-

(1) Heritability of all the traits used.

(2) Phenotypic correlation between all possible combinations.

(3) Genetic correlation between all possible combinations.

Besides, works of similar nature have also been carried out on pig and sheep by various workers which may be worth mentioning.

<u>Pig:-</u>

Bernard <u>et al.</u>(1954) constructed four indices in pig based on:-

(a) Number of pig per litter at birth - (X_1).

(b) Number of pig per litter at 154 days - (X_2).

(c) Litter weight - (X_3).

(d) Their body weight at 154 days - (X_4).

The four indices constructed were as follows:-

(a) For X_2 & X_4 :-

$$I_a = 0.950X_2 + 0.103X_4, \; RI_aH = 0.394$$

(b) For X_2, X_3 and X_4:-

$$I_b = 1.330X_2 - 0.003X_3 + 0.103X_4, \; RI_bH = 0.397.$$

(c) For X_1, X_2 and X_4:-

$$I_c = 0.070X_1 + 0.990X_2 + 0.103X_4 , \; RI_cH = 0.395.$$

(d) For X_1, X_2, X_3 and X_4 :-

$$I_d = 0.102X_1 + 1.459X_2 - 0.004X_3 + 0.103X_4, \; RI_dH = 0.399.$$

Robinson <u>et al.</u>(1960) developed four selection indices in swine utilising body measurements taken at 154 days of age combined with measures of production traits. They included the following economic traits :-

(1) Weight of dam (2) depth of chest (3) width behind shoulder (4) length of foreleg (5) Back fat at shoulder

(6) Back fat at loin (7) Number of pigs farrowed (8) Number of pigs in litter at 154 days and (9) Weight of the litter at 154 days. The following parameters were obtained for this purpose:-

(1) Heritability of each trait (Doubling the intra-sire daughter-dam regression).

(2) Genetic correlation.

(3) Relative economic value (on the basis that profitability in a swine can be defined in terms of gain, productivity and carcass quality).

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...p:-

Moreley(1956), Karam et al.(1953) and Karam (1959) ...ructed indices for Marinoes, Targhee and Rahmani breeds ...eep and utilised the economic traits like (a) Weaning ...t (b) Number of lambs reared upto 120 days (c) Body ...t (d) Fleece weight and (e) Typeratings.

...stimates of parameters (Phenotypic and Genetic):

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The best index was 'I_a' in which all the nine economic traits were included.

Sheep:-

Moreley(1956), Karam et al.(1953) and Karam (1959) constructed indices for Marinoes, Targhee and Rahmani breeds of sheep and utilised the economic traits like (a) Weaning weight (b) Number of lambs reared upto 120 days (c) Body weight (d) Fleece weight and (e) Typeratings.

(b) Estimates of parameters (Phenotypic and Genetic):

Estimates of heritabilities, repeatabilities, phenotypic variances and co-variances, additive genetic variances and co-variances and phenotypic and genetic correlations obtained by various workers on the traits being considered under this study have been listed in table 1, 2, 3, 4, and 5. The economic traits included in this study are milk yield, age at first calving, first calving interval and lactation period.

Table 1. Estimates of heritabilities.

Traits	Estimates of herita-bilities	d.f*	Method of analysis	Reference
Milk yield	0.37	-	-	Sikka (1934)
	0.5	-		Grown (1934)
	0.18	-	-	Plum (1935)
	0.21-.25	-	-	Seath (1940)
	0.38	1488	Regression of daughters on dam	Johanson & Hansson (1940)
	0.31	6887	Intra-sire corre-lation	Tyler and Hyatt (1947)
	0.36	-	-	Laben and Hartmann(1950)
	0.30	-	-	Rendels and Robertson(1950)
	0.24	-	-	Johanson (1950)
	-0.01	270	Daughter-dam regression	Chandrashaker,51
	0.21	667	"	Mahadevan (1951)
	0.25	186	"	Touchberry(1951)
	0.37	-	"	Mahadevan (1953)
	0.19	1101	"	" (1954)
	0.25	-	-	Stonaker (1953)
	0.58	-	-	Johanson (1954)
	0.28	162	Paternal half-sib correlation	Yao et al.(1954)
	0.71	122	Daughter-dam regression	" "
	0.25	2809	"	Tabler et al.,55
	0.26	2024	"	Tyler (1955)
	0.25	-	-	Robertson et al.,56

d.f.* refers to the total number of observations minus one.

Table 1. contd.

Trait	Estimates of herit-abilities	d.f.	Method of analysis	Reference
Milk yield	0.20-.26	-	-	Patel (1956)
	0.35	9549	Daughter-dam regression	EL-Shimy(1957)
	0.37	9549	Intra-class correlation	" "
	0.30	75	"	Johanson (1957)
	0.26	69	"	" "
	0.12-.25	-	Intra-sire regression	I.C.A.R.Team,57
	0.18	-	-	Chandramani(1958)
	0.34	182	Daughter-dam regression	Amble *et al.*,'58
	0.37	143	"	" "
	0.20	1248	Paternal half-sib correlation	Hartmann (1958)
	0.19	433	Daughter-dam regression	Bauer *et al.*,59
	0.27	20023	"	Tabler *et al.*,59
	0.43	-	-	O.Connor (1959)
	0.20	-	-	Singh (1959)
	0.22	-	Variance and Co-variance	Mishra (1960)
	0.58	308	Intra-sire regression of daughter on dam.	Amble *et al.* (1960)
	0.25	159	Intra-class co-rrelation of daughter on dam.	Ahmad (1961)
	0.14	187	Intra-sire regression	Sukhbir and R.N. Desai (1961)
	0.19	210	Half-sib correlation	" "

Table 1. contd.

Traits	Estimates of herita-bilities	d.f.	Method of analysis	Reference
Milk yield	0.42	645	Intra-sire regression of daughter on dam.	Johanson et al. (1961)
	0.36	381	"	" "
	0.37	209	"	" "
	0.40	103	"	" "
Age at first calving	0.10-0.15	-	Daughter-dam regression	Mahadevan(1951)
	0.32	90	"	Stonaker (1953)
	0.24	7	-	Agarwala (1955)
	-0.36	208	Intra-sire regression	Singh (1957)
	-0.30	-	Intra-sire correlation	" "
	-0.09	192	Daughter-dam regression	Amble et al. (1958)
	0.16	134	"	"
	-0.08	281	"	"
	-1.24	29	"	"
	0.66	41	"	"
	0.48	215	"	"
	0.05	-	Paternal half-sib correlation	Singh (1957)
	0.34	-	-	Singh (1959)
	0.37	146	Daughter-dam regression	Ahmad (1961)
	0.34	243	Intra-sire regression of daughter on dam.	Sukhbir et al. (1961)

Table 1. contd.

Traits	Estimates of herita-bilities	d.f	Method of analysis	Reference
Age at first calving	0.34	321	Paternal half-sib correlation	Sukhbir *et al.* (1961)
Calving interval	0.0	-	Intra-class co-rrelation	Dunbar *et al.* (1950)
	0.004	-	-	Dumboor and Handerson(1953)
	0.88	40	Daughter-dam regression	Stonaker(1953)
	-0.16	-	Daughter-dam correlation	Singh (1958)
	-0.18	58	Daughter-dam regression	Singh (1958)
	-0.08	155	"	Amble *et al.*,58
	0. 13	125	"	"
	0.11	223	"	"
	-0.37	23	"	"
	-0.31	25	"	"
	-0.01	204	"	"
	0.02	-	-	Dadlani *et al.* (1959)
	0.02	-	-	Singh (1959)
	0.5	-	-	Wheat *et al.* (1959)
	-0.04	-	Variance and Co-variance	Mishra (1960)
	0.22	165	Intra-class co-rrelation among paternal half-sib	Ahmad (1961)

Table 1. contd.

Traits	Estimates of herita-bilities	d.f.	Method of analysis	Reference
Lactation length	0.08	86	Intra-sire regression of daughter on dam.	I.C.A.R.Team (1957)
	0.04	182	"	Amble *et al.* (1958)
	0.13	304	"	Amble *et al.* (1960)
	0.32	189	"	Sukhbir *et al.* (1961)
	0.10	189	Half-sib correlation	"

Table 2.

Estimates of repeatabilities:-

Traits	Estimates of repeat-abilities	d.f	Method of analysis	Reference
Milk yield	0.40	3544	Intra-class co-rrelation	Plum (1935)
	0.38	1488	"	Johanson(1940)
	0.42	461	"	" (1947)
	0.40	2398	"	" (1949)
	0.39	1051	"	" (1949)
	0.49	788	"	Chandrashaker (1951)
	0.47	1304	"	Mahadevan(1951)
	0.52	308	"	"

Table 2. contd.

Traits	Estimates of repeat-abilities	d.f.	Method of analysis	Reference
Milk yield	0.58	-	Intra-class correlation	Mahadevan(1954)
	0.55	-	"	"
	0.65	-	"	"
	.40	-	"	"
	.51	598	"	Madden et al. (1955)
	.34	1248	"	Hartmann(1958)
	.61	921	"	Amble et al. (1958)
	..4	958	"	"
	..4	433	"	Bauer et al. (1960)
	[illegible]	187	"	Sukhbir et al. (1961)
	[illegible]	526	"	Johanson and Corley (1961)
Calvi[illegible] inte[illegible]	[illegible]	1488	"	Johanson(1940)
	[illegible]	461	"	" (1947)
	[illegible]	2398	"	" (1949)
	[illegible]	791	"	Amble et al. (1958)
	[illegible]	849	"	"
	[illegible]	129	"	"

47495

394419

4110000

Table 2. contd.

Traits	Estimates of repeatabilities	d.f.	Method of analysis	Reference
Milk yield	0.58	-	Intra-class correlation	Mahadevan(1954)
	0.55	-	"	"
	0.65	-	"	"
	0.40	-	"	"
	0.51	598	"	Madden et al. (1955)
	0.34	1248	"	Hartmann(1958)
	0.61	921	"	Amble et al. (1958)
	0.54	958	"	"
	0.24	433	"	Bauer et al. (1960)
	0.38	187	"	Sukhbir et al. (1961)
	0.47	526	"	Johanson and Corley (1961)
Calving interval	0.04	1488	"	Johanson(1940)
	0.10	461	"	" (1947)
	0.08	2398	"	" (1949)
	0.21	791	"	Amble et al. (1958)
	0.08	849	"	"
	0.17	129	"	"

Table 2. contd.

Traits	Estimates of repeat-abilities	d.f.	Method of analysis	Reference
Calving interval	0.19	1581	Intra-class co-rrelation	Amble et al. (1958)
	0.20	281	"	Wheat et al. (1959)
	0.08	1012	"	Amble et al. (1960)
	0.18	1662	"	Rennie (1954)
Lactation length	0.33	921	"	Amble et al. (1958)
	0.31	1231	"	Amble et al. (1960)
	0.27	189	"	Sukhbir et al. (1961)

Table 3.

Estimates of Phenotypic variances & co-variances:-

Traits	Estimates of phenotypic Variances	d.f.	Method of analysis	Reference
Milk Yield	201477.0	5619	Variance computation	Tabler et al. (1955)
	4749584.4	40045	"	"
	3944197.0	162	"	Yao et al. (1954)
	4110000.0	716	"	Mishra (1960)

Table 3. contd.

Traits	Estimates of phenotypic variances	d.f.	Method of analysis	Reference
Milk Yield	41610.00	392	Variance computation	Amble *et al.* (1960)
	1294363.98	159	"	Ahmad(1961)
	1490494.9	187	"	Sukhbir *et al.* (1961)
Age at first calving	106.4	197	"	Asker *et al.* (1958)
Calving interval	157.0	587	"	Asker *et al.* (1958)
	15.75	515	"	Mishra(1960)
	9201.4	165	"	Ahmad (1961)
Lactation length	15.9	843	"	Asker *et al.* (1958)
	Estimates of phenotypic co-variances			
Milk & calving interval	551.0	494	Co-variance computation	Mishra(1960)

Table 4.

Estimates of additive genetic variances and co-variances.

Traits	Estimates of additive genetic variances	d.f.	Method of analysis	Reference
Milk	495968	2809	Analysis of variance	Tabler and Touchberry(1955)
	1284288	40045	"	Tabler et al.,59
	8900150	118	Parent-off-spring co-variance	Mishra (1960)
Calving interval	-0.606	73	"	"
	Estimates of Additive Genetic Co-variances			
Milk & calving interval	636.76	186	Parent-off-spring co-variance	Mishra(1960)

Table 5.

Estimates of Phenotypic and Genetic correlations

Traits	Estimates of pheno-typic co-rrelations	d.f.	Method of analysis	Reference
Milk & age at first calving	0.44	215	Correlation	D.Venkayya et al. (1956)
	0.34	79	"	"
	0.19	240	"	"
	0.183	-	"	Ahmad (1961)

Table 5. contd.

Traits	Estimates of phenotypic correlations	d.f.	Method of analysis	Reference
Milk & age at first calving	0.46	63	Correlation	Erb et al. (1961)
	0.45	43	"	"
Milk & calving interval	0.257	-	"	Asker et al. (1958)
	0.233	-	"	Ahmad (1961)
Milk & lactation period	0.44	-	"	Mahadevan (1956)
	0.66	-	"	"
	0.731	-	"	Asker et al. (1958)
Age at first calving & calving interval	0.025	-	"	Singh (1957)
	0.56	215	"	Venkayya (1956) et al.
	0.20	79	"	"
	0.28	240	"	"
	0.109	-	"	Ahmad (1961)
	Estimates of genetic correlations			
Milk & age at first calving	-0.187	-	"	Ahmad (1961)
Milk & calving interval	-0.132	-	"	"
Age at Ist calving & calving interval	0.272	-	"	"

THEORY OF SELECTION INDEX

Selection Index is a numerical score assigned to an individual to estimate the breeding value. The concept of developing a selection index as an estimate of breeding value of an animal was first developed by Smith(1936) for plant selection. This was extended by Hazel(1943) to selection work in animals. Since then no addition has yet been made by any worker in the approach of Smith and Hazel and consequently all the workers have been following the same approach. The problem of developing selection index arises when more than one economic characters are under consideration and specially when the characters are genetically correlated. The greater this correlation the more speedy would be the genetic progress per generation through selection.

The net merit of a cow depends not only on one character but several economic characters viz age at maturity, age at first calving,calving intervals,lactation lengths and lactation yield etc. Thus in developing a selection index one will have to know the informations on these traits.For the purpose of computing selection indices, phenotypic measurements on these traits may be expressed in terms of X's, for example, phenotypic measurement on trait one would be indicated by X_1; that on trait number two by X_2 and so on. Since the relative importance of each trait may differ and all the traits together determine the value of the animal which we designate as index or Total Score, this becomes a conventional Multiple Regression Equation which may be represented as follows:-

$$I = b_1x_1 + b_2x_2 + \ldots + b_nx_n$$

Where,

I= Selection Index.

b's= Regression coefficient (relative weight given to a trait for selection).

x's= Phenotypic measurement of the traits.

The values of b's may be obtained from the following equations:-

$$b_1\sigma^2x_1 + b_2\sigma x_1x_2 + \ldots + b_n\sigma x_1x_n = \sigma x_1H \quad \text{(a)}$$

$$b_1\sigma x_1x_2 + b_2\sigma^2x_2 + \ldots + b_n\sigma x_2x_n = \sigma x_2H$$

$$b_1\sigma x_1x_n + b_2\sigma x_2x_n + \ldots + b_n\sigma^2x_n = \sigma x_nH$$

Where,

σ^2x_1 = Variance of x_1 (Trait No.1)

σx_1x_2 = Co-variance of x_1 with x_2 (Trait No.1 & 2).

σx_1H = Co-variance of x_1 with H (Between Trait No.1 and breeding worth).

Here b's are so determined that correlation between I & H (RIH) is maximum. The actual breeding worth(H) is the function of Additive gene effects and the relative economic weight of the trait in question. Its value may be obtained from the following linear functions:-

$$H = a_1g_1 + a_2g_2 + a_3g_3 + \ldots + a_ng_n$$

Where,

a's = Relative economic weights of the traits.

g's = Additive gene effect for the traits.

We can not know the value of H. We have to infer that from x's, since we study genotype with help of phenotype. Hence we want such a value of I that could be closest to H.

It would be worth while at this stage looking at the values of $\sigma x_i H$. In the form of a conventional model the phenotype x_1 may be expressed in terms of mean and effects as follows:-

$$x_1 = \mu + g_1 + e_1$$

Where,

μ = a general mean

g_1 = Genetypic effect for the trait number one.

e_1 = Environmental factor for the trait number one.

Now by taking the co-variance of the linear functions.

$$x_1 = \mu + g_1 + e_1$$

$$H = a_1 g_1 + a_2 g_2 + \dots + a_n g_n$$

Therefore,

$$a_1 \sigma^2 g_1 + a_2 \sigma g_1 g_2 + \dots + a_n \sigma g_1 g_n = \sigma x_1 H$$

Here μ being a constant drops out, and e_1 would prove to be random to each of the terms of H values and

and therefore would be equal to zero (following the rules for taking variances and co-variances of linear functions, Mishra (1960). Other co-variances on the right hand side of the equation ($\sigma x_1 H$) would follow the same patern of computation.

$$a_1 \sigma g_1 g_2 + a_2 \sigma^2 g_2 + a_3 \sigma g_2 g_3 + \ldots + a_n \sigma g_2 g_n = \sigma x_2 H$$

$$a_1 \sigma g_1 g_3 + a_2 \sigma g_2 g_3 + a_3 \sigma^2 g_3 + \ldots + a_n \sigma g_3 g_n = \sigma x_3 H$$

$$a_1 \sigma g_1 g_n + a_2 \sigma g_2 g_n + a_3 \sigma g_3 g_n + \ldots + a_n \sigma^2 g_n = \sigma x_n H$$

Thus,

$$b_1 \sigma^2 x_1 + b_2 \sigma x_1 x_2 + b_3 \sigma x_1 x_3 + \ldots + b_n \sigma x_1 x_n = a_1 \sigma^2 g_1 + a_2 \sigma g_1 g_2 + a_3 \sigma g_1 g_3 + \ldots + a_n \sigma g_1 g_n$$

$$b_1 \sigma x_1 x_2 + b_2 \sigma^2 x_2 + b_3 \sigma x_2 x_3 + \ldots + b_n \sigma x_2 x_n = a_1 \sigma g_1 g_2 + a_2 \sigma^2 g_2 + a_3 \sigma g_2 g_3 + \ldots + a_n \sigma g_2 g_n$$

$$b_1 \sigma x_1 x_3 + b_2 \sigma x_2 x_3 + b_3 \sigma^2 x_3 + \ldots + b_n \sigma x_3 x_n = a_1 \sigma g_1 g_3 + a_2 \sigma g_2 g_3 + a_3 \sigma^2 g_3 + \ldots + a_n \sigma g_3 g_n$$

$$b_1 \sigma x_1 x_n + b_2 \sigma x_2 x_n + b_3 \sigma x_3 x_n + \ldots + b_n \sigma^2 x_n = a_1 \sigma g_1 g_n + a_2 \sigma g_2 g_n + a_3 \sigma g_3 g_n + \ldots + a_n \sigma^2 g_n$$

Equation (a) was presented in different form by Hazel(1943) but both equations are basically the

the same. Thus to obtain the values of b's one will have to know the following information:-

(1) Phenotypic variances of all traits.

(2) Phenotypic co-variances of two traits in all possible combinations.

(3) Additive Genetic variances of all traits.

(4) Additive Genetic co-variances between two traits in all possible combinations.

(5) Relative economic values of all ~~the~~ traits.

A combination of all these informations provides a method of measuring the "Net Merit" of an animal. This combination is known as Selection Index (Lush, 1937).

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COMPOSITION OF PHENOTYPIC VARIANCES AND CO-VARIANCES

The phenotypic variance may be defined as the "average squared deviations of the individual from the population average". The square root of the variance is called standard deviation. The following symbols noted against each have been utilised in this study.

Traits	Symbol for phenotypic expression	Symbol for additive gene effect	Total phenotypic variance	Additive genetic variance
Milk yield	x_1	g_1	$\sigma^2 x_1$	$\sigma^2 g_1$
Age at first calving	x_2	g_2	$\sigma^2 x_2$	$\sigma^2 g_2$
First calving interval	x_3	g_3	$\sigma^2 x_3$	$\sigma^2 g_3$
Lactation period	x_4	g_4	$\sigma^2 x_4$	$\sigma^2 g_4$

In a random breeding population, parent-offspring co-variance of a trait is one half of the additive genetic variance of the trait in question plus a portion of epistatic variance which is not more than one-sixteenth of the epistatic variance. Likewise parent-offspring co-variance between a pair of traits is equal to one half of the additive genetic co-variance between the traits in question plus a portion of epistatic variance as mentioned above. In other situations the sire component of variance of a trait is one-fourth of the additive genetic variance

variance of that trait and a sire component of co-variance between a pair of trait is one-fourth of the additive genetic co-variance of the pair of trait in question (Kempthorne 1957). To illustrate the point more clearly, the following may be written.

σ (P.O.) $=\frac{1}{2}\sigma^2 g = \frac{1}{2}$ additive genetic co-variance.

$\sigma^2 s = \frac{1}{4}\sigma^2 g = \frac{1}{4}$ additive genetic co-variance,

Where, σ(P.O.)= Parent-offspring co-variance.

$\sigma^2 s$ = Sire component of variance.

The above mentioned relationships have been taken into consideration in estimating the Additive Genetic Variances and Additive Genetic Co-variances in this study.

(1) <u>Phenotypic Variances:-</u> ($\sigma^2 x_1$, $\sigma^2 x_2$, $\sigma^2 x_3$ and $\sigma^2 x_4$)

The phenotypic expression of a trait or a pair of traits is represented as a linear functions of mean and effects. Therefore, the variance of a trait and co-variance between a pair of traits have been computed from linear representation. The variance of a linear function was obtained by using the following procedure:-

(a) Constant was dropped.

(b) The function was squared.

(c) Squares were replaced by the variances of the variables and the products by the co-variances of the variables.

This may further be illustrated as follows:-

Phenotypic expression of milk production = x_1

Now x_1 may be expressed in terms of mean and effects. Therefore,

$$x_1 = \mu + g_1 + \bar{e}$$

Where,

μ = General mean of the population.

g_1 = Additive gene effect.

$\bar{e}$ = Average environmental effect.

Since, in this case μ is a constant, it drops out.

Therefore, $x_1^2 = g_1^2 + \bar{e}^2 + 2g_1\bar{e}$

or, $\sigma^2 x_1 = \sigma^2 g_1 + \sigma^2 \bar{e} + 2\sigma g_1 \bar{e}$

Since the co-variance between g_1 and $\bar{e}$ is zero, $\sigma^2 x_1$ would be equal to $\sigma^2 g_1 + \sigma^2 \bar{e}$ which is genetic variance plus environmental variance.

The genetic and environmental components of variances may further be divided into three and two components respectively viz (a) Additive genetic variance, (b) Dominance variance, (c) Epistatic variance, (d) Permanent environmental variance and (e) Temporary environmental variance. Thus the total phenotypic variance of a trait would be equal to :-

$$\sigma^2 p = \sigma^2 A + \sigma^2 D + \sigma^2 I + \sigma^2 Pe + \sigma^2 T_e$$

Where,

$\sigma^2 P$ = Total phenotypic variance.

$\sigma^2 A$ = Additive genetic variance.

$\sigma^2 D$ = Dominance variance

$\sigma^2 I$ = Epistatic variance

$\sigma^2 P_e$ = Permanent environmental variance

$\sigma^2 T_e$ = Temporary environmental variance

(2) Phenotypic co-variances:-

($\sigma x_1 x_2$, $\sigma x_1 x_3$, $\sigma x_1 x_4$, $\sigma x_2 x_3$, $\sigma x_2 x_4$ and $\sigma x_3 x_4$)

Six possible combinations of phenotypic co-variances were computed. The general procedure employed has been the same as in case of phenotypic variances. The only difference however, in this case is that after deletion of the constant only products were taken into consideration, for example:-

$$x_1 = \mu + g_1 + e$$

$$x_2 = \mu + g_2 + e$$

Therefore,

$$\sigma x_1 x_2 = \sigma g_1 e + \sigma g_2 e + \sigma g_1 g_2 + \sigma^2 e$$

(3) Co-variances of x_n with H ($\sigma x_n H$):-

Here x_n are the phenotypic expressions of nth traits and H is the breeding worth of the individual to be estimated by selection index.

$H = a_1 g_1 + a_2 g_2 + \ldots + a_n g_n$ (see chapter, theory of S.I.)

Where, a_n and g_n are the relative economic values and additive gene effects of the nth traits respectively. The co-variance of a trait with the breeding worth of an animal would be as follows, following the previous procedure.

$$\sigma x_1 H = a_1 \sigma x_1 g_1 + a_2 \sigma x_1 g_2 + a_3 \sigma x_1 g_3 + a_4 \sigma x_1 g_4$$

The main problem in computing the co-variance between phenotypic expression of a trait and breeding worth of an animal is that one variable is of phenotypic expression while the other variable can not be expressed phenotypically (breeding worth). The breeding worth of an animal is the effect of interaction between relative economic value and additive gene effect. Under this circumstance, one can not estimate the co-variance between phenotypic expression and breeding worth directly. Since the co-variance between a particular x and H is to be estimated, this x may be reduced to the genetic plane as follows:-

$$x_1 = \mu + g_1 + e_1$$

$$H = a_1 g_1 + a_2 g_2 + a_3 g_3 + a_4 g_4$$

As the μ is constant, it drops out, the product between e_1 and the set of terms denoting H would be random to each other, therefore, the co-variances of e_1 with all the terms of H would be equal to zero.

Hence,

$$\sigma x_1 H = a_1 \sigma^2 g_1 + a_2 \sigma g_1 g_2 + a_3 \sigma g_1 g_3 + a_4 \sigma g_1 g_4$$

Similarly other co-variances with x's and H can be computed. They would be as follows:-

$$\sigma x_2 H = a_1 \sigma g_1 g_2 + a_2 \sigma^2 g_2 + a_3 \sigma g_2 g_3 + a_4 \sigma g_2 g_4$$

$$\sigma x_3 H = a_1 \sigma g_1 g_3 + a_2 \sigma g_2 g_3 + a_3 \sigma^2 g_3 + a_4 \sigma g_3 g_4$$

$$\sigma x_4 H = a_1 \sigma g_1 g_4 + a_2 \sigma g_2 g_4 + a_3 \sigma g_3 g_4 + a_4 \sigma^2 g_4$$

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MATERIALS AND METHODS

Sources and preparation of data:-

Data used in this study were obtained from the Tharparkar herd maintained at Government Cattle Farm, Patna. This herd was established in the year 1927 with a foundation stock of 52 Tharparkar and 10 Sahabadi cows. Tharparkar cows were purchased from Sindh province. Seven Tharparkar bulls were also purchased from Karnal Farm for stud purpose. In 1934, eight more cows with seven calves were purchased from Sindh province. The purchases from outside however were spread only for first ten years of the establishment of the Farm but later on that is since 1936 no addition was made from outside in the female stock. Since then only Tharparkar cows are being maintained at the Farm.

The original purpose of establishing the Farm was to breed Tharparkar cattle under the climatic conditions of the state, to grade up Sahabadi cows with Tharparkar bulls and also to provide certain teaching facility to the students of Bihar Veterinary College, Patna.

The usual practice of feeding the adult animals at this Farm is to feed them in groups. Adult animals are given six pounds of dry fodder, 66 pounds of green fodder and 2 pounds of concentrate mixture as maintenance. Production allowance constitutes one pound of concentrate mixture for every three pounds of milk. In addition, animals are also given 2 ozs of salt and 1 oz of mineral mixture per day.

The composition of the concentrate mixture is as follows:-

Groundnut cake - 33%

Gram crushed - 40%

Wheat bran - 27%

The dry fodder includes paddy straw and hay. The green fodders are Napier,para,jowar,maize,teosinte,berseem and silage. Napier and para being perennial grasses,are fed throughout the year whereas jowar,maize and teosinte are fed during rainy season. During winter season berseem and silage are fed. Animals are allowed to graze twice a day, just after morning and evening milking. This schedule has continued throughout the existance of this Farm.

Cows are housed in pucca byres. In general,twice hand milking per day is practised but the high yielders (above 15 pounds of milk per day) are milked thrice in day. The weaning is being practised with all animals at present. In the past, there have been at times some exceptions.

Since the inception of this Farm, natural mating has been practised till quite recently. Since 1961,cows are being inseminated artificially. Heifers are being inseminated at their first heat but the milch cows are inseminated at the second heat after parturition.

In the present study four traits viz milk yield(life time production), age at first calving,first calving interval and lactation period(life time) were used. The data included for the present study covered for a period of 22 years(from 1939 to 1960).

For all the traits under consideration, January was taken as dividing line between years that is the period from first January to 31st December was treated as one year.

Milk Yield:-

Data on milk yield of 440 cows with 1529 lactations records were used in this study. The maximum milk yield in one lactation was 4500 lbs and the minimum was 1001 lbs; the range being 3499 (4500-1001). The number of lactations during the life time of a cow ranged from 1 to 11 in the present study.

The following table will show the distribution of lactations per cow used under this study:-

No. of cows	No. of lactations per cow	Total lactation records
99	1	99
104	2	208
52	3	156
53	4	212
41	5	205
40	6	240
20	7	140
15	8	120
12	9	108
3	10	30
1	11	11
Total: 440	-	1529

Age at first calving:-

Records on age at first calving of 396 cows were used in this study. The maximum age at first calving (in days) was 1850 and that of minimum 1151; the range being 699 days (1850-1151). The following table will show the distribution of the records of age at first calving:-

Age at first calving(in days)	Number of cows
1151-1250	34
1251-1350	48
1351-1450	66
1451-1550	95
1551-1650	75
1651-1750	48
1751-1850	30
Total:-	396

First calving interval:-

Records on first calving interval of 350 cows were obtained. The maximum and the minimum calving intervals were 550 days and 300 days respectively. The range was 250 days (550-300). The following table will show the distribution of the records on first calving interval:-

First calving interval (in days)	Number of cows
300-350	70
351-400	117
401-450	69
451-500	56
501-550	38
Total:-	350

Lactation period:-

Data on lactation periods of 451 cows having 1602 lactation periods were used in this study. The maximum and the minimum length of lactations (in days) were 380 and 181 respectively, the range being 199 days (380-181). The following table will show the distribution of lactation periods per cow used under this study:-

No. of cows	No. of lactation periods per cow	Total no. of lactation periods
102	1	102
90	2	180
71	3	213
53	4	212
36	5	180
36	6	216
31	7	217
15	8	120
10	9	90
5	10	50
2	11	22
Total: 451	-	1602

The above data on the four traits under study were subjected to Bartlett's test for homogeneity of variance as described by Snedecor (1957) and it was found to be homogenous at 1% level for all the traits.

The frequency distributions of the records used in this study are presented in figures 1,2,3 and 4 for Milk yield, Age at first calving, First calving interval and Lactation period respectively. It will be seen that only about 15% of the total lactation yield taken fell below 1501 lbs per lactation and 4% went beyond 4000 lbs while 81% of the total lactations ranged between 1501 to 4000 lbs. About 8% of the heifers calved at an age below 1251 days and about 7% calved at an age over 1751 days while 85% of of the total heifers calved between 1251 to 1750 days of age. About 11% of all the first calving intervals were above 500 days and about 89% of the calving intervals were within 300 to 500 days. Nearly three-fourth of all the lactation lengths were within the limits of 221 and 340 days.

Analysis of variance was done to test the year effects on all the four traits under study. It was found that the year effect was highly significant at both 1% and 5% level in respect of all the four traits. These estimates are listed in table 6,7,8 and 9.

In order to use the data for analysis, year correction was made on the basis of year means (Mishra, 1960). For this purpose average of each year in each trait($\bar{\bar{Y}}i$) was computed. The grand average ($\bar{y}$) of all the years was also computed. Then each observation was corrected by subtracting ($\bar{Y}i-\bar{y}$) from each of them, where $\bar{Y}i$ is the average of each year and $\bar{y}$ is the grand average of all the years (Mishra, 60).

The relative economic values of all the four traits under study were determined from the records of the Government Cattle Farm, Patna.

Methods of Analysis :-

(1) Analysis of variance to test the year effects :- This analysis was done for ~~kmx~~ all the four traits under study. The idea of this analysis was to know whether the variations between the years were significantly different or not. For this purpose, original data (without correction) were used. The year effects were found to be significant in all the four traits and consequently corrections for year were made in all cases on the basis of year means. The following is the set up of the analysis :-

Sources of variation	d.f.	Total S.S.	Mean sqr.	F
Total	N-1	X	-	
Between years	Y-1	P	$(\frac{P}{Y-1})$	$\frac{(\frac{P}{Y-1})}{(\frac{Z}{N-Y})}$
Within year or Error	N-Y	Z	$(\frac{Z}{N-Y})$	

Where,

N = total number of observation.

Y = total number of years.

X = total corrected sum of wquare.

P = Between years corrected sum of square.

Z = Error sum of squares.

(2) Phenotypic variances:-

Milk Yield:- In estimating the total phenotypic variance of milk yield,only year-corrected-data were used. No correction was made for lactation period and thus all the data on milk yield between 1001 to 4500 lbs were utilised irrespective of the length. The analysis was done according to the following formula:-

$$\sigma^2 x_1 \text{ (variance of milk yield)} = \frac{\Sigma x_1^2 - \frac{(\Sigma x_1)^2}{N}}{N - 1}$$

Age at First Calving:- Year-corrected-data as in case of milk yield were used. Records on age at first calving between 1151 to 1850 days were used and the estimate was obtained by running an analysis of variance. The formula used in this case also was the same as in case of milk yield.

First Calving Interval & Lactation Period:- Year-corrected-data were used. The analysis of variances of first calving interval and lactation period were also done as in previous cases.

(3) <u>Phenotypic Co-variances:-</u> Phenotypic co-variances between all six possible combinations as mentioned under "Composition of variances and co-variances" were estimated by the following formula:-

Co-variance between x_1 and x_2

$$\sigma x_1 x_2 = \frac{\Sigma x_1 x_2 - \frac{(\Sigma x_1)(\Sigma x_2)}{N}}{N - 1}$$

Where,

x_1 = Milk yield

x_2 = Age at first calving

For this purpose also, only year-corrected-data were used. The following are the possible combinations:-

(a) Milk yield and age at first calving - ($\sigma x_1 x_2$)

(b) Milk yield and first calving interval- ($\sigma x_1 x_3$)

(c) Milk yield and lactation period ------ ($\sigma x_1 x_4$)

(d) Age at first calving and first calving interval -------------- ($\sigma x_2 x_3$)

(e) Age at first calving and lactation period ------------------- ($\sigma x_2 x_4$)

(f) First calving interval and lactation period --------------------($\sigma x_3 x_4$)

(4) <u>Computation of Additive Genetic Variances and Co-variances (by Parent-offspring Co-variance method):-</u>

Estimates of co-variances between dams and

and daughters were obtained to get the estimates of Additive Genetic variances and co-variances. As stated under "Composition of phenotypic variances and co-variances", there is relationship between phenotypic parent-offspring co-variance and Additive Genetic variance and co-variance. The relationship is to the effect that the phenotypic parent-offspring co-variance is half of the additive genetic variance, if the same trait is taken on both dam and daughter and also half of the additive genetic co-variance, if a pair of traits are taken. Then co-variances in all possible combinations were computed. Thus there were twelve possible combinations for estimating the additive genetic co-variances and only six possible combinations for estimating the additive genetic variances. The data employed for the dam were average of all her records for the trait in question. Similarly the data employed for the daughter were average of all the records of all the daughters of a particular cow in question. In order to estimate the additive genetic co-variances the weighted average of the phenotypic parent-offspring co-variance was taken and then it was doubled to obtain the final estimate. But for the estimate of additive genetic variances,parent-offspring co-variances were directly doubled as the variables were the same in both sides i.e. with daughter and dam. For example,the additive genetic co-variance between milk yield and age at first

first calving in the present study would be :-

Dam	Daughter	Parent-offspring co-variance
Milk yield	Age at first calving	11322.1460
Age at Ist calving	Milk yield	6264.8490

Weighted average co-variance = 8860.62976

Therefore, the additive genetic co-variance would be equal to 8860.62976x2 = 17721.25952. The additive genetic variance of milk yield on the other hand would be twice the parent-offspring co-variance directly i.e. 14734.2677 x 2 = 29468.5354 where, 14734.2677 is the parent-offspring co-variance of milk yield.

(5) Phenotypic Correlations:- The phenotypic correlations between two traits in all possible combinations were obtained by dividing the estimates of phenotypic co-variances by the square root of the product of the estimates of phenotypic variances of the same two traits. The following formula was used:-

$$r_{x_1x_2} = \frac{\sigma_{x_1x_2}}{\sqrt{\sigma^2_{x_1}.\sigma^2_{x_2}}}$$

Where,

x_1 = Milk yield

x_2 = Age at first calving

(6) Heritability of different traits:- The heritability estimates of all the four traits under study were also

also computed. This was obtained by dividing the additive genetic variance of a trait by phenotypic variance of the same trait. The following formula was used for this purpose:-

$$h^2 = \frac{\sigma^2 g_1}{\sigma^2 x_1}$$

Where,

h^2 = Heritability

$\sigma^2 g_1$ = Additive genetic variance of trait number one.

$\sigma^2 x_1$ = Total phenotypic variance of the trait number one.

The estimates of phenotypic variances, phenotypic co-variances, parent-offspring co-variances, additive genetic variances and co-variances, phenotypic correlations and heritabilities are listed in tables 10, 11, 12, 13, 14 and 15 respectively.

Table 6.

Analysis of variance (Milk yield) to test the year effect.

Sources of variation	d.f.*	Sum of square	Mean square	F(Estimated)	Tabler 'F' at 1% level
Total	1528	1023735747.72	-		
Between years	21	76441297.25	3640061.7738	5.79**	1.85
Within year or (Error)	1507	947294450.47	628596.184		

* Denotes the total number of observations minus one.

** Denotes significant at 1% level.

Table 7.

Analysis of variance (Age at first calving) to test the year effect

Sources of variation	d.f.*	Sum of square	Mean square	F(Estimated)	Tabler 'F' at 1% level
Total	395	10558893.55	-		
Between years	21	1429309.91	68062.3766	2.78**	1.85
Within year (Error)	374	9129583.64	24410.6514		

* Denotes the total number of observations minus one.
** Denotes significant at 1% level.

Table 8.

Analysis of variance (First calving interval) to test the year effect.

Sources of variation	d.f.*	Sum of square	Mean square	F(Estimated)	Tabler 'F' at 1% level
Total	349	1365132.47	-		
Between years	21	156716.84	7462.7066	2.02**	1.85
Within year (Error)	328	1208415.63	3684.1939		

* Denotes the total number of observations minus one.

** Denotes significant at 1% level.

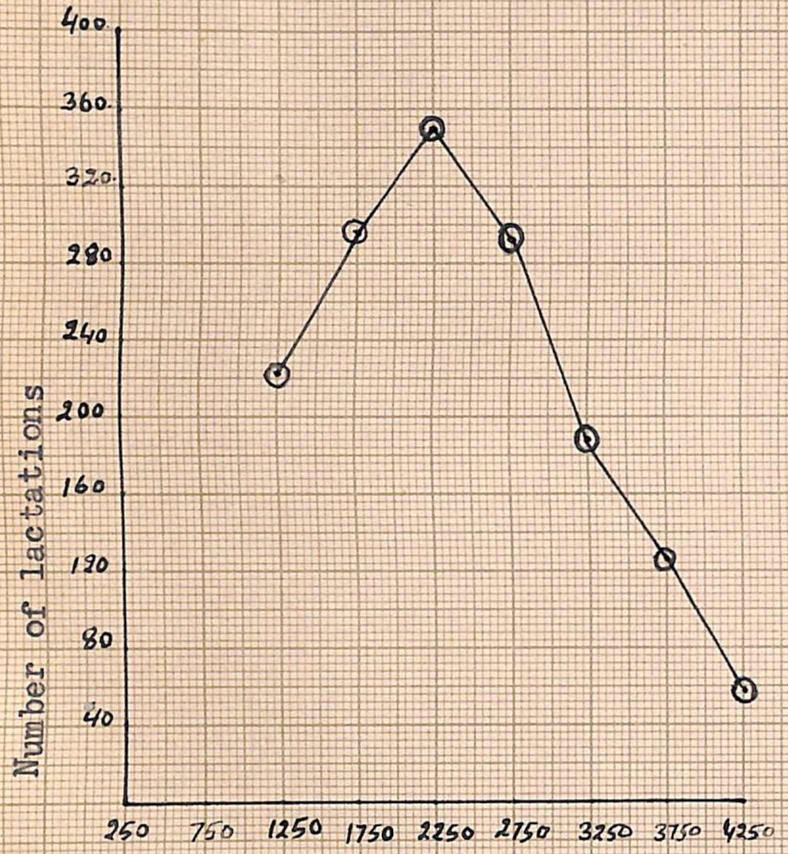
Table 9.

Analysis of variance (Lactation period) to test the year effect

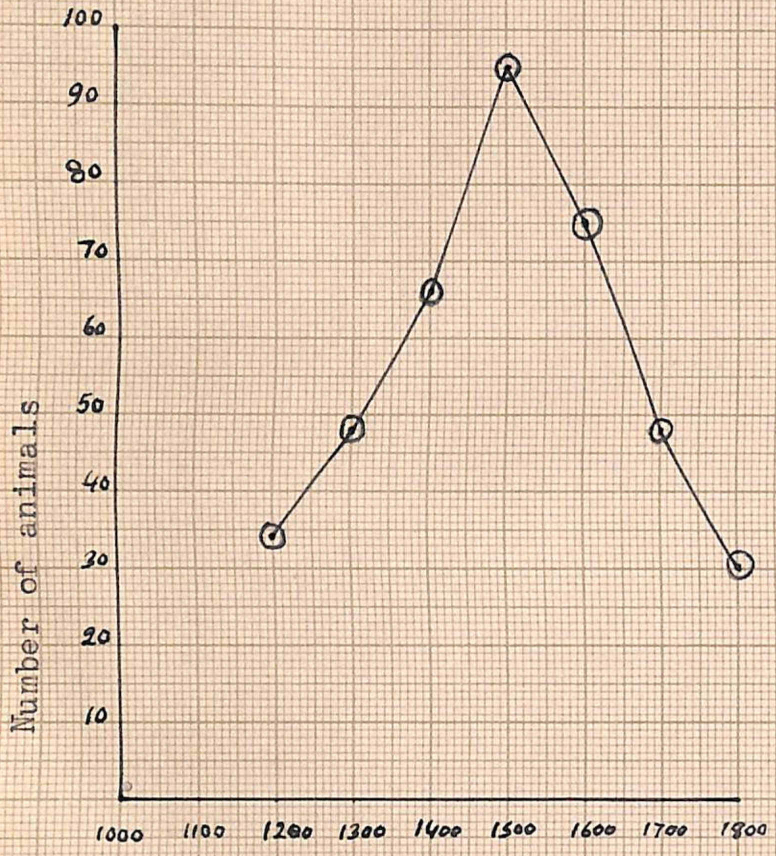
Sources of variation	d.f.*	Sum of square	Mean square	F(Estimated)	Tabler 'F' at 1% level
Total	1601	4126055.33	-		
Between years	21	178207.05	8486.05000	3.39**	1.85
Within year	1580	3947848.28	2498.63815		
(Error)					

* Denotes the total number of observations minus one.

** Denotes significant at 1% level.

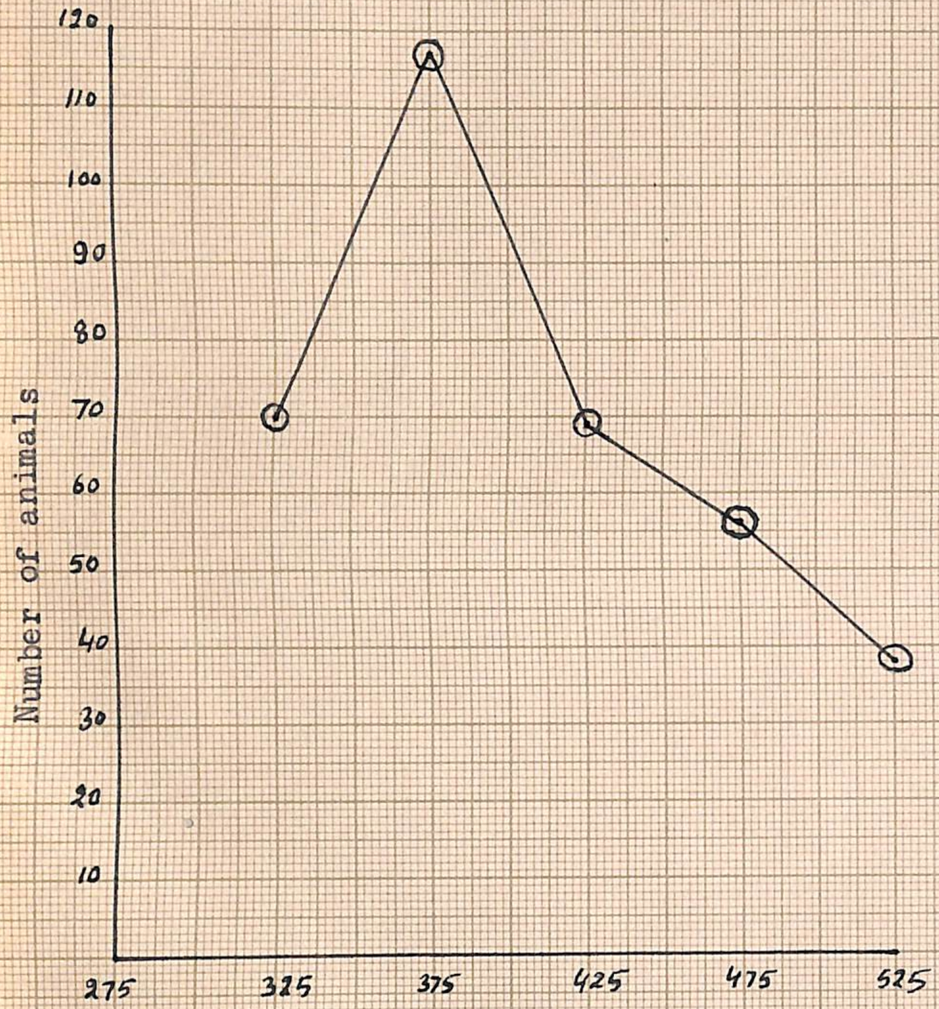


Mid- class point of lactation yield (lb)
fig.1- Frequency - Polygon showing the yields of 1529 lactations of Tharparkar cows.



Mid-class point of Age at First Calving (days)

Fig.2- Frequency-Polygon showing the Age at First calving of 396 Tharparkar cows.



Mid-class point of First Calving Interval(days)
Fig.3- Frequency-Polygon showing the First Calving Interval of 350 Tharparkar cows.

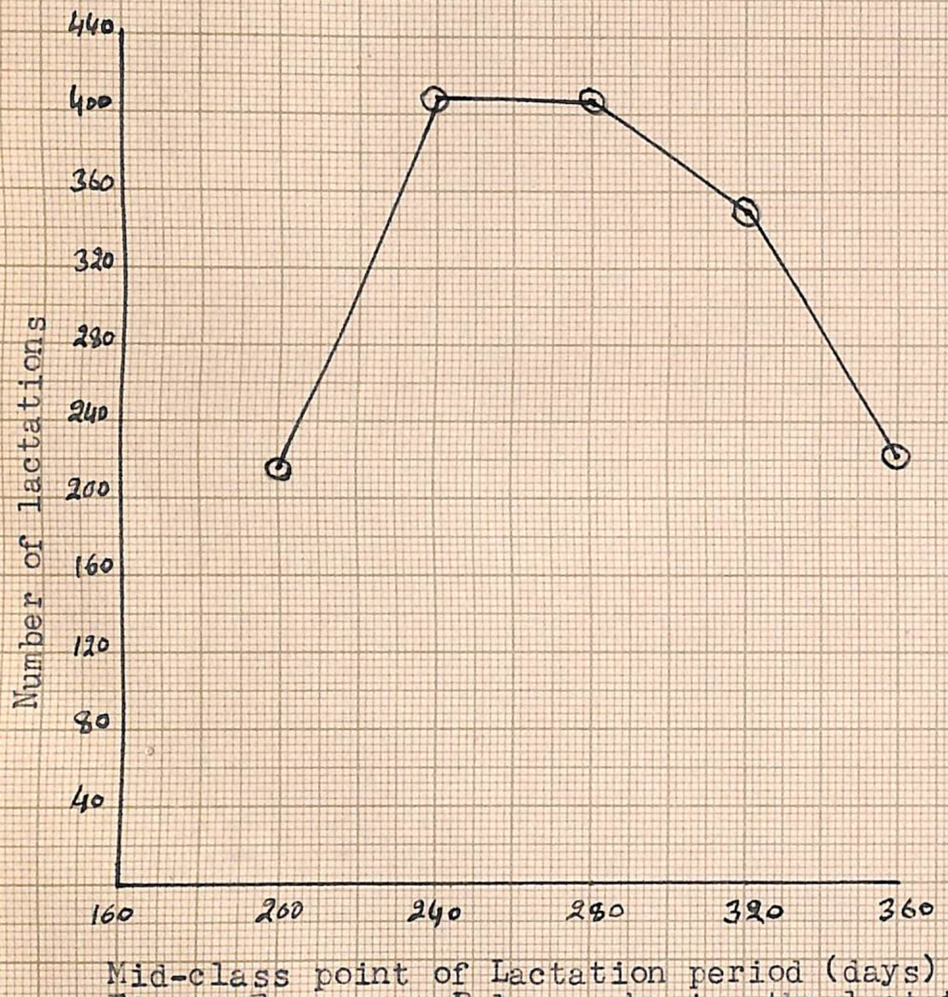


Fig.4- Frequency-Polygon showing the lactation lengths for 1602 lactations of Tharparkar cows.

ESTIMATES OF PHENOTYPIC AND GENETIC PARAMETERS

Table 10.

Estimates of total phenotypic variances

Name of trait	d.f.*	Mean	M.S.(total phenotypic variance)	S.E.	Coefficient of variation	Method
Milk yield(Pounds)	1528	2414.36	643071.4505	20.5	33.2%	Analysis of variance
Age at first calving(days)	395	1498.77	23305.4277	7.7	10.2%	"
First calving interval(days)	349	407.55	3461.4509	3.1	14.4%	"
Lactation period(days)	1601	278.88	2364.0610	1.2	17.5%	"

* Denotes total number of observations minus one.

Table 11.

Estimates of Phenotypic co-variances

Possible combinations	d.f.*	Estimates of phenotypic co-variances	Method
Milk yield and age at first calving	349	12800.38702	Co-variance computation
Milk yield and first calving interval	326	1539.40152	"
Milk yield and lactation period	407	9808.25145	"
Age at Ist calving & first calving interval	304	421.47836	"
Age at Ist calving & Lactation period	358	1419.23304	"
First calving interval & Lactation period	331	180.98	"

* Denotes total number of observations minus one.

Table 12.

Dam-daughter co-variances (Estimates of one half of the Additive Genetic variances and co-variances)

Dam	d.f.	Daughter	Estimates
Milk yield	122	Milk yield	14734.2677
"	115	Age at Ist calving	11322.14609
"	113	Ist calving interval	726.1595079
"	124	Lactation period	-15.033537
Age at Ist calving	104	Age at Ist calving	888.390284
"	109	Milk yield	6264.849052
"	100	Ist calving interval	-860.176877
"	111	Lactation period	950.534069
Ist calving interval	90	Ist calving interval	26.151198
"	96	Milk yield	-8013.464093
"	94	Age at Ist calving	282.371340
"	99	Lactation period	-267.279111
Lactation period	127	Lactation period	105.2457858
"	124	Milk yield	809.647134
"	118x	Age at Ist calving	466.423496
"	116	Ist calving interval	112.9120

Table 13.

Estimates of Additive Genetic variances and co-variances (twice the weighted average of the parent-offspring co-variance in case of additive genetic co-variance and twice the parent-offspring co-variance directly in case of additive genetic variance).

Dam	d.f.	Daughter	Estimates (Additive Genetic variances and co-variances
Milk yield	122	Milk yield	29468.5354
"	224	Age at Ist calving	17721.2595
"	209	Ist calving interval	-6583.1642
"	248	Lactation period	794.6136
Age at Ist calving	104	Age at Ist calving	1776.7805
"	194	Ist calving interval	-612.7814
"	229	Lactation period	1402.2873
Ist calving interval	90	Ist calving interval	52.3023
"	215	Lactation period	-124.5825
Lactation period	127	Lactation period	210.4915

Table 14.

Estimates of phenotypic correlations

Possibile combinations	Estimates
Milk yield and age at first calving	0.105
Milk yield and first calving interval	0.041
Milk yield and lactation period	0.222
Age at Ist calving & Ist calving interval	0.048
Age at Ist calving and lactation period	0.190
Ist calving interval & lactation period	0.063

Table 15.

Estimates of heritabilities

Trait	Additive Genetic variances	Phenotypic variances	Estimates
Milk yield (life time)	29468.5354	643071.4505	0.05
Age at Ist calving	1776.7805	23305.4277	0.08
First calving interval	52.3023	3461.4509	0.01
Lactation period (life time)	210.4915	2364.0610	0.09

RELATIVE ECONOMIC VALUES OF TRAITS(a's).

The relative economic value of a trait is the amount of change in net profit which is due to a unit change in the trait in question. Thus the relative economic values of different traits at the same time and the same trait from time to time will vary depending upon the market price. Therefore, it was considered desirable to take a long time average of the market rates to obtain these values (a's).

(1) a-value of Age at first calving:-

For a period beginning from the April,1951 to March,1961, appropriate records were available on daily wages paid to the employees,number of workers employed to raise the calves and heifers, quantity and type of feeds given, average price of feed, expenditure on medicines per annum and other miscellaneous items.During this period 134 heifers were born and raised upto the age xk at first calving under the Farm conditions. On this basis, average expenditure incurred in raising a heifer upto the age at first calving was calculated. This expenditure does not include the expense incurred in construction of buildings and pay of the officers. This amounted to Rs.32.39 (Rupees thirty two and N.P.thirty nine) only per month.The unit of rearing period in this case was taken as one month. Therefore,the economic value per unit of age at first calving was found to be Rs. 32.39 only.

(2) a-value of first calving interval:-

A unit in this case also was taken as one month. The average first calving interval of this herd was estimated to be 407.55 days and for that of the average lactation period was 278.88 days. The lactation period was subtracted from the calving interval, the idea being to know the unproductive period. Since in calculating the relative economic value of first calving interval, it was decided to find out the total expenditure incurred on retaining a cow for one additional month in her first calving interval, the productive period was excluded. Therefore, all the expenditures incurred on workers on daily wages, feeds, medicines and other miscellaneous items during the period begining from date of drying to date of second calving were calculated. During this period i.e. from April, 1951 to March, 1961, 120 animals were raised upto the age at second calving under Farm conditions. On this basis average expenditure for retaining a particular cow for one additional month in her first lactation was calculated. This amounted to Rs. 42.50 (Rupees forty two and N.P. fifty) only per month. Hence the economic value of unit change in first calving interval was taken as Rs. 42.50 only.

(3) a-value of lactation period:-

In this case also the unit of time was taken as one month. The average lactation period of this herd was 278.88 days and the average milk production per lactation (on life time production basis) was 2414 lbs. To find out the relative economic value of lactation period, total expenditure incurred on daily wages, feeds, concentrates, medicines and other miscellaneous items per lactation was calculated. Since the lactation period is a productive period of a cow, the relative economic value of lactation period would be "selling cost - production cost". In this case the selling cost would be the total price of average lactation yield whereas the production cost on the other hand would be the average expenditure incurred in maintaining a cow for one lactation period. On this basis the total cost incurred during one average lactation period was calculated. This amounted to Rs. 456.35 NP. (Rupees four hundred fifty six and N.P. thirty five) only. The cost of 2414 lbs of milk @ 30 N.P. per pound amounted to Rs. 724.20 N.P. (Rupees seven hundred twenty four and N.P. twenty) only. The production cost subtracted from the selling cost gave the total net profit per lactation. From this information the economic value of lactation period was worked out. This turned out to be Rs. 28.80 NP. (Rupees twenty eight and N.P. eighty) only. Hence the relative economic value of lactation period was found to be Rs. 28.80 N.P.

(4) <u>a - vale of milk yield:-</u>

The first requirement is to express profit from milk production. In finding out the relative economic value of milk yield, it was assumed that costs other than cost for feed do not vary with milk production. As for example, a cow previously giving 10 lbs of milk a day, if now gives 12 lbs of milk a day. This increase of 2 lbs of milk will not affect the expenditure on labourers, medicines, maintenance and other miscellaneous items. But this increase of 2 lbs of milk per day will certainly necessiate feeding more concentrates. Selling rates of milk and concentrates were available from 1953 to 1961. A consideration of these rates gave the average selling price of milk and that of concentrates. The average selling price per lb of milk came to 30 N.P. only. Average cost of concentrate was found to be Rs. 11.63 (Rupees eleven and N.P. sixty three) only per md. Since every three pounds increase in milk needs 1 lb of extra concentrate, the total cost for production of 1 lb of milk was calculated. This amounted to 5 N.P. only (five N.P.). The production cost subtracted from the selling cost gave the relative economic value of milk yield. This amounted to Re 0.25 (twenty five N.P.) only. Hence the relative economic value per unit of milk yield was assessed as 25 NxRx N.P. only. Nxxxx This means that for every pound increase in milk production there would be a profit of Re 0.25 and for every pound decrease in milk production, there would be a loss of Re 0.25.

The relative economic values of all the four traits under study were assigned positive value. This was

was done considering that early age at first calving, lesser first calving interval, increase in milk production and increase in lactation period were economically desirable. For example, reduction of one month age at first calving and first calving interval would give Rs. 32.39 NP. and Rs. 42.50 NP. net profit respectively. On the other hand increasing 1 lb of milk and one month lactation period would give Re 0.25 and Rs. 28.80 NP. net profit respectively. These values are listed in table 16.

Table 16.

Table showing the relative economic values of the traits under study

Traits	Unit of measurement	a-values
Milk yield	1 lb	Re 0.25
Age at first calving	1 month	Rs. 32.39
First calving interval	1 month	Rs. 42.50
Lactation period	1 month	Rs. 28.80

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COMPUTATION OF b-VALUES, CONSTRUCTION OF SELECTION INDICES AND THE USE THERE OF

The b's are the multiple regression coefficients for the traits under consideration chosen so as to make RIH as large as possible. These values are the main guide in assessing the real merit of an individual. There are two methods for obtaining the b-values viz (a) Correlation technique and (b) Variance and co-variance technique. The basic principle involved in obtaining these values by use of variance and co-variance technique, is the same as multiple correlation technique, illustrated by Hazel (1943). These values were obtained from a set of simultaneous equations. In obtaining the b-values required for constructing selection indices, the following constants were computed:-

(1) Total phenotypic variances of all traits.

(2) Total phenotypic co-variances between two traits in all possible combinations.

(3) Additive Genetic variances of all traits.

(4) Additive Genetic co-variances between two traits in all possible combinations.

(5) Relative economic values of all traits.

Utilising the estimates listed in tables 10, 11,13 and 16, three sets of b-values were obtained.

The detailed procedure has already been discussed under the chapter "Theory of Selection Index". In one set of b-values, all the four traits were considered. In the second set x_1, x_2 and x_4 and in the third set only x_1 and x_2 were considered. The idea of obtaining three sets of b-values was to observe the variation in b's under these situations. Thus there were four sets of simultaneous equations in the first, three in the second and only two in the third. These values are listed in table 17. It was seen that there was great variation in b-values in different situations. The general trend of b_1-values in different situations was that as the number of traits increased its value decreased, which was quite contrary tothe value of b_4 in which case the value increased as the number of variables increased. It was interesting enough to note that the value of b_2 showed altogether a different trend. When only two variables were considered its value was minimum. It was maximum when three variables were taken up but when all the four variables were considered its value fell in between the other two situations.

Another three sets of b-values were also obtained from a reasonable assumed genetic correlations. This was done to see the error of estimation because some of which were found to be beyond normal range. The following assumed values were taken into consideration for further

further computation:-

Possible combinations	Estimates of genetic correlations
Milk yield and age at first calving	0.4
Milk yield and first calving interval	-0.3
Age at Ist calving & Ist calving interval	-0.2
Age at Ist calving & lactation period	0.1
Ist calving interval & lactation period	-0.2

On the basis of above assumed values, additive genetic co-variances were estimated and three sets of b-values were obtained. These values are listed in table 18.

Construction of Selection Indices:-

Using the b-values listed in table 17, the following three indices were constructed:-

For all the four traits (x_1, x_2, x_3 and x_4)

$$I_1 = 0.204x_1 + 2.206x_2 - 7.946x_3 + 18.073x_4$$

For three traits (x_1, x_2 and x_4)

$$I_2 = 0.613x_1 + 2.990x_2 + 17.500x_4$$

For two traits only (x_1 and x_2)

$$I_3 = 0.862x_1 + 2.112x_2$$

Where,

x_1 = Milk yield (Life time production)

x_2 = Age at first calving

x_3 = First calving interval

x_4 = Lactation period (life time)

When all the three indices were constructed, a pertinent question arose as to which one was more efficient. For this purpose, the relative efficiency of all the three indices were measured. This was done by estimating the correlation between the aggregate genotype and the selection index in question because RIH gives the accuracy of identifying the genotype.. The following procedure as described by Bogart(1959) was adopted in estimating RIH:-

$$RIH = \sqrt{\frac{\sigma^2 I}{\sigma^2 H}}$$

Where ,

RIH = Correlation between breeding worth(H) or aggregate genotype and selection index(I)

$\sigma^2 I$ = Variance of selection index (I)

$\sigma^2 H$ = Variance of breeding worth(H) or aggregate genotype of an animal.

$\sigma^2 I$ and $\sigma^2 H$ may further be expanded as follows:-

$$I = b_1x_1 + b_2x_2 + \ldots + b_nx_n$$

$$I^2 = b_1^2x_1^2 + b_2^2x_2^2 + 2b_1b_2x_1x_2 + \ldots + b_n^2x_n^2 + 2b_1b_nx_1x_n + 2b_2b_nx_2x_n$$

$$\sigma^2 I = b_1^2\sigma^2 x_1 + b_2^2\sigma^2 x_2 + 2b_1b_2\sigma x_1x_2 + \ldots + b_n^2\sigma^2 x_n + 2b_1b_n\sigma x_1x_n + 2b_2b_n\sigma x_2x_n$$

$$H = a_1g_1 + a_2g_2 + \ldots + a_ng_n$$

$$H^2 = a_1^2g_1^2 + a_2^2g_2^2 + 2a_1a_2g_1g_2 + \ldots + a_n^2g_n^2 + 2a_1a_ng_1g_n + 2a_2a_ng_2g_n$$

$$\sigma^2 H = a_1^2\sigma^2 g_1 + a_2^2\sigma^2 g_2 + 2a_1a_2\sigma g_1g_2 + \ldots + a_n^2\sigma^2 g_n + 2a_1a_n\sigma g_1g_n + 2a_2a_n\sigma g_2g_n$$

The variances of selection indices ($\sigma^2 I_i$) were obtained by utilising the estimates of phenotypic variances of all traits and co-variances between two traits in all possible combinations and b-values listed in tables 10,11 and 17 xx respectively. The variance of breeding worth ($\sigma^2 H$) on the other hand was obtained by utilising the estimates of additive genetic variances of all traits, additive genetic co-variances between all possible combinations of two traits at a time and the relative economic values of the traits listed in tables

tables 13 and 16 respectively. The correlation coefficient thus obtained between breeding worth (H) and selection indices (I_i) are listed in table 19.

Use of Selection Index:-

As discussed above three indices were constructed in Tharparkar herd maintained at Government Cattle Farm, Patna. Now question arises which index is most suitable for using it as a basis of selecting individual. The deciding factor appears to be the correlation coefficient between the aggregate genotype (H) and Selection Index (I) in question. The RI_iH values are listed in table 19. It was found that the selection index no.1 (I_1) was more efficient than either of two indices constructed (I_2 and I_3). The efficiency of I_2 fell in between I_1 and I_3 and for that of I_3 it was minimum. Therefore, selection index no.1 (I_1) is more suitable for the use of selecting breeding animals. An illustration on how to use this index is given below:-

$$I_1 = 0.204x_1 + 2.206x_2 - 7.946x_3 + 18.073x_4$$

Cow No.	Milk yield lb	Age at Ist calving (days)	Ist calving interval (days)	Lactation period (days)	Indices
96/1	3381	1651	459	255	5273
63/4	2164	1201	378	300	5509
86/6	3753	1197	309	300	6373

Table 17.

Table showing the estimates of b-values

Traits	Symbol	Ist set (b-values using all the four traits)	2nd set (b-values using three traits)	3rd set (b-values using only two traits)
Milk yield	b_1	0.204	0.613	0.862
Age at first calving	b_2	2.206	2.990	2.112
First calving interval	b_3	-7.946	-	-
Lactation period	b_4	18.073	17.500	-

Table 18.

Table showing the estimates of b-values on the basis of assumed normal genetic correlation:

Traits	Symbol	Ist set (b-values using all the four traits)	2nd set (b-values using three traits)	3rd set (b-values using only two traits)
Milk yield	b_{11}	0.103	0.121	0.109
Age at first calving	b_{22}	2.338	2.415	2.423
First calving interval	b_{33}	-0.499	-	-
Lactation period	b_{44}	1.303	1.551	-

Table 19.

Table showing the correlation coefficient between breeding worth(H) and Selection Indices(I_i)

S.N.	Selection Index	Symbol	RIH
1.	$0.204x_1+2.206x_2-7.946x_3+18.073x_4$	I_1	0.657
2.	$0.613x_1 + 2.990x_2 + 17.500x_4$	I_2	0.565
3.	$0.862x_1 + 2.112x_2$	I_3	0.540

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Table 20.

Table showing expected progress in net worth per cow per lactation per generation of selection

S.I.	Symbol	Sets of $\sigma x_i H$				Z (Expected progress)
		$\sigma x_1 H$	$\sigma x_2 H$	$\sigma x_3 H$	$\sigma x_4 H$	
$0.204x_1 + 2.206x_2 - 7.946x_3 + 18.073x_4$	I_1	33.0802	53.7778	-126.3061	19.6214	38.51
$0.613x_1 + 2.990x_2 + 17.500x_4$	I_2	61.6056	72.1280	-	21.8611	25.12
$0.862x_1 + 2.112x_2$	I_3	45.4173	2.6595	-	-	6.69

that in most cases the K-value comes to one. So, in the present study while measuring the net gain expected from the use of these indices, the selection differential measured in terms of standard deviation was assumed to be one. The Z-values were obtained under different situations which are summarised in table 20. It will be observed that the index developed considering all the four economic traits under study was more effective while the index developed on the basis of two traits only was least effective. The expected progress in net worth per lactation per cow per generation of selection was expressed in terms of Rx rupees. For example, value 38.51 listed in table 20 means that expected gain in net worth per cow per lactation per generation of selection would be Rs.38.51 (Rupees thirty eight and N.P. fifty one) only.

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DISCUSSION

The average life time milk production per lactation of the Tharparkar herd was 2414.36±20.5 lbs with 32.2 percent coefficient of variation. No literature on average life time per lactation yield could be available.

The average age at first calving of this herd was 1498.77± 7.7 days with 10.2 percent coefficient of variation which is in agreement with the earlier reports on this herd by Amble et al.(1958) who found it to be 49.4 ± 0.4 months. Reported estimates of Singh (1957) is slightly less (1461 ± 14.5 days).

The average interval between First and Second calvings of this herd was 407.55±3.1 days with 14.4 % coefficient of variation which agrees with the previous findings of Singh(1957) who reported the same to be 433.9±7.3 days. This slight difference may be due to the fact that in the previous report data were included only upto 1954 (1932 to 1954) but in the present study the period was extended upto 1960 (1939 to 1960).

The average life time lactation length of this herd was 278.88 ± 1.2 days with 17.5% coefficient of variation. No other report on this aspect could be found.

The phenotypic variances of all the four traits under this study were worked out. These values are listed in table 10. The magnitude of these values appears to be quite reasonable. Since the phenotypic variances represent the true picture of the individual variation, it requires no discussion. These values may however differ from time to time but to a reasonable degree.

The phenotypic co-variances between two traits in all possible combinations were estimated by running analysis of co-variance. These values are listed in table 11. These estimates also require no comment, because these values are also the phenotypic estimates which show the true picture of the inter-relationship among the traits. They also seem to be reasonable.

The additive genetic variances of all the four traits under this study were computed by Dam-Daughter co-variance method. These values are summarised in table 13. Since these values represent the variance of the aggregate genotype of an individual which can not be estimated with certainty, require special attention. These values are the subject to greater error of estimation. The best way of interpreting these values would be in terms of heritability in as much as the heritability is the ratio of additive genetic variance and phenotypic variance of a trait in question. For this purpose heritabilities of all the four traits were obtained by dividing the additive genetic variances listed in table 13 by the phenotypic variances listed in table 10.

The following estimates were obtained:-

Characters	Estimates of heritability
Milk yield (life time)	0.05
Age at first calving	0.08
First calving interval	0.01
Lactation period	0.09

The heritability of milk yield(life time production) was 0.05, showing thereby that the additive genetic variance in life time milk yield of this herd is extremely low in comparison to the phenotypic variance. This suggests that selection would not be effective in improving this trait since the improvement per generation of selection is equal to selection differntial times heritability. This estimate is slightly lower than that reported by I.C.A.R. Team (1957) who found it to be 0.12. They have further reported, "about 45% of the variation in lactation yield appeared to be due to genetic causes. When the records of cows not in the current herd were included the heritability for the lactation yield fell down to 0.12". This value was obtained by intra-sire regression of daughters on dam. In the present study the heritability was obtained by variance and co-variance technique. The slightly lower estimate in the present study appears to be due to the following reasons.

1. Technique used in obtaining the estimates of additive genetic variances is different from the usual methods of obtaining heritability. This is likely to make some error.
2. Life time production records were considered instead of only first lactation records as reported by the I.C.A.R. Team (1957).
3. Only those data which were corrected for year effects were used. No correction was made for the length of lactation period. Thus all the data on milk yield within a limit of 1001 lbs to 4500 lbs per lactation were considered irrespective of the length. The only consideration regarding the lactation length was minimum 101 days and maximum 300 days. Since estimates of genetic parameters are subject to greater error of estimation, use of data with such a wide range is likely to introduce a conceivable amount of error.

The heritability of age at first calving was 0.08 indicating that this character too can not be profitably handled by selection. This estimate is in good agreement with that of Mahadevan (1951) and Amble et al. (1958) who reported it to be 0.10 to 0.15 and -0.09 to .66 respectively. Singh (1957) worked out heritability of age at first calving in this herd and reported it to be -0.361 ± 0.099, -0.305 ± 0.083 and 0.048 by intra-sire regression of daughters on dam, intra-sire correlation and half-sib correlation method respectively. This suggests that the additive genetic variance of this trait is also too low.

The heritability of first calving interval$\not{s}$ was 0.01 which is in good agreement with that of Singh(1959) and Dadlani <u>et al.</u>(1959) who reported it to be 0.02 and 0.02 respectively. Singh (1958) reported the heritability of first calving interval of this herd to be -0.18± 0.145 and -0.16± 0.132 (by Intra-sire Regression of Daughters on Dam and Correlation method respectively). This suggests that the additive genetic variance of this trait is also negligible in comparison to the phenotypic variance and hence no reasonable amount of improvement can be expected by selection.

The heritability of lactation period (life time) was 0.09 which agrees well with the earlier report of I.C.A.R.Team (1957) who reported it to be 0.08. The reports of other workers also compare well with this estimate. Amble <u>et al</u>.(1958 and 1960) and Sukhbir <u>et al.</u>(1961) reported it to be 0.04,0.13 and 0.10 respectively. This estimate also suggests that the additive genetic variance for this character is low.

Additive genetic co-variances between two traits in all possible combinations were estimated by daughter-dam co-variance method. These values are listed in table 13. The magnitude of these estimates seems to be too high in comparison to the additive genetic variances discussed above. The reason may be the sampling error or the errors for genetic estimates discussed earlier or both.

The relative economic values of all the four traits under this study were obtained from the appropriate information available. These values were Re 0.25, Rs. 32.39, Rs. 42.50 and Rs. 28.80 for milk yield , age at first calving, first calving interval and lactation period respectively. It should be noted that the unit of measurement for milk yield was 1 lb while for the remaining variables it was one month. These values are in good agreement with that of Ahmad (1961) who reported them to be Re 0.27, Rs. 1.30 and Rs. 1.45 for milk yield, age at first calving and first calving interval respectively in which case the unit of measurement for age at first calving and first calving interval was one day.

Three sets of b-values were obtained. These values are listed in table 17. The general trend of b-values was that as the number of variables decreased the b_1-value increased which was just contrary to b_4 in which case the value decreased. It was interesting enough to note that altogether a new trend existed with b_2 in which case the highest value was obtained when three variables were included and the value was the minimum when only two variables were considered. When all the four variables were considered its value fell in between the remaining

remaining two situations. This suggests that b-values vary a great deal.

Three selection indices were constructed viz I_1,I_2 and I_3. In I_1, all the four traits, in I_2 three traits (x_1,x_2 and x_4) and in I_3 only two traits (x_1 and x_2) were considered. The relative efficiency of all these indices was also calculated. It was calculated in terms of correlation coefficient x between the aggregate genotype and selection index. These values are listed in table 19. It would be seen that I_1 was more efficient in comparison to I_2 and I_3. There was slight difference in the efficiency of I_2 and I_3 and that I_2 was slightly more efficient than I_3. No literature on these lines was available for Temperate Zone cattle. In India, Ahmad (1961) constructed three indices in Hariana herd maintained at I.V.R.I. Izatnagar on these lines. The maximum correlation coefficient between aggregate genotype or breeding worth (H) and selection indices (I_1) was found to be 0.657 in the present study which is higher than that of Ahmad (1961) who found it to be 0.625 only.

The matter of immediate interest is the amount of progress expected when these indices are used as a basis of selection. The expected progress in net worth under different situations were

were computed. These values are listed in table 20. It would be seen that K-value (selection differential measured in terms of standard deviation) was assumed to be one. This assumption was made on the basis that usually in practice this K-value comes to one (Mishra, 1960). The expected progress in net worth listed in table 20 are shown in terms of Rs rupees per lactation per cow per generation of selection. For example, value 38.51 shown in table 20 means that net profit per cow per lactation per generation of selection would be Rs. 38.51 (Rupees thirty eight and N.P. fifty one) only, if I_1 be used as a basis of selection. It would be seen from table 20 that maximum profit in terms of rupees per cow per lactation is from I_1 and the minimum from I_3. The relative efficiency also showed the same trend in which case the correlation coefficient between breeding worth and selection index was highest with index I_1 and the lowest with I_3. I_2 fell in between the two indices in both the situations. Consequently, I_1 appears to be the most suitable for use. An illustration to this effect has been shown under chapter, "Computation of b-values, construction of selection indices and the use thereof".

It would be seen that cow numbered 86/6 was better xmxkx in all respect, hence the question regarding her merit for selection did not arise. The actual matter of consideration laid in case of cow number 96/1 and 63/4. This situation would certainly prove that this method prevents culling of animals outstanding in all but one trait. It was apparent that the cow number 96/1 was high yielder in comparison to cow number 63/4 but when all the traits were taken into consideration her index came lower than the index of 63/4. Thus in over all merit cow number 63/4 was superior to 96/1 even though the latter was a high yielder.

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SUMMARY

Data included for the construction of selection indices were obtained from Tharparkar herd maintained at Government Cattle Farm, Patna. The period covered was 22 years (1939-1960).

The economic characters included in the present study were:-

(a) Milk yield (life time production)

(b) Age at first calving

(c) First calving interval

(d) Lactation period (life time)

The average life time per lactation yield was 2414.36 ± 20.5 lbs with 32.2% coefficient of variation. The average age at first calving of the herd was 1498.77± 7.7 days with 10.2% coefficient of variation. The average first calving interval was 407 ± 3.1 days with 14.4 % coefficient of variation. The average lactation period (life time) was 278.88 ± 1.2 days with 17.5% coefficient of variation.

The phenotypic and genetic variances and co-variances were computed. The additive genetic variances and co-variances were computed by Dam-Daughter co-variance method.

From these estimates of additive genetic variances and phenotypic variances, the heritabilities for milk yield (life time production), age at first calving,

first calving interval and lactation period were computed. These estimates were 0.05, 0.08, 0.01 and 0.09 respectively.

The relative economic values of milk yield, age at first calving, first calving interval and lactation period were worked out. These values were Re 0.25, Rs.32.39, Rs.42.50 and Rs.28.80 respectively. The unit of measurement in case of milk yield was 1 lb while in the remaining it was one month.

Three sets of b-values were obtained. In one set all the four traits, in second three traits and in third set only two traits were considered.

Based on these values, three indices were constructed. The relative efficiency and also the effectiveness of selection indices were calculated. The three indices constructed are given below with their efficiency and effectiveness.

Index	Efficiency	Effectiveness
$I_1 = 0.204x_1 + 2.206x_2 - 7.946x_3 + 18.073x_4$	$RI_1H = 0.657$	$Z_1 = 38.51$
$I_2 = 0.613x_1 + 2.990x_2 + 17.500x_4$	$RI_2H = 0.565$	$Z_2 = 25.12$
$I_3 = 0.862x_1 + 2.112x_2$	$RI_3H = 0.540$	$Z_3 = 6.69$

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