For Ex Exam.

GENETIC STUDIES ON REPRODUCTIVE EFFICIENCY OF HARIANA FEMALES AT Indian Veterinary Research Institute

BY

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Certified that the research work contained in this thesis entitled "Genetic Studies on Reproductive Efficiency of Hariana Females at Indian Veterinary Research Institute" by Satish Kumar is an original work carried out by him under my supervision and guidance.

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C O N T E N T S

INTRODUCTION

The 1961 census put India's cattle population at 226.8 million. Giving allowance for the seven years which have elapsed since then, India's present cattle population can tentatively be taken at 250 million. This is about one fifth of the total cattle wealth of the world. Despite this richness of cattle wealth, the total milk production and per capita consumption of milk and milk products is distressingly low in India. An Indian, on an average, consumes only about five ounces of milk and milk products daily which is far below the 12 ounces recommended by F.A.O. for meeting the minimal requirements of a human body. This paradoxical situation owes its existence to the poor productivity and reproductivity of Indian cattle.

Milk production depends upon a number of factors out of which reproduction is one of the most important one. The number of times a cow freshens during her life time has a great bearing upon her total milk production.

According to Lush the variation in economic traits, including reproductive efficiency, is due to the net result of heredity, environment and to their interaction. The genetic variation within a breed, in the various constituents of reproductive fitness, is rather small but hereditary factors are definitely responsible for the variation that

REVIEW OF LITERATURE

Studies made on the reproductive efficiency of Indian cattle are very few. Most of the related work done on Indian breeds has been summarized hereunder, whereas the review of work done on European cattle had to be restricted only to those that had a direct bearing on the objective of this study.

Wegscheider (1939) reported that the reproductive disorders can be controlled by breeding as fertility is influenced by heredity. Wilson (1946) observed a seasonal variation in fertility of Zebu cattle in Nyasaland. Sexual activity was highest during September to December. Koort (1948) studied fertility in Swedish Red and White cattle and found that even if herd management was good the fertility was affected by age of the cow, the quality of her feed and by the occurrence of diseases but not by her production. Asdell (1952) observed very low estimates of heritability and repeatability for reproductive performance.

Wilcox *et al* (1956) measured fertility as the number of viable calves produced in the lifetime by Holstein-Friesian cows. Heritability of this fertility was estimated as 30 per cent.

Lindley *et al* (1958) reported that reproductive performance and age were correlated. Mahadevan and Hutchison (1964) concluded that within breeds, heredity played only a minor part in affecting variation in reproductive activity.

Gerdemann (1966) found that out of 174 cows with irregular lactation curves, 67.2 per cent showed fertility disturbances and 8.6 per cent were completely infertile. Corresponding figures in 147 cows with steep lactation curves were found to be 44.2 and 6.8 per cent respectively.

I. AGE AT FIRST CALVING

The averages of age at first calving in Indian and European cattle reported by different workers have been presented in Table 1.

Table 1

Age at First calving of some of the Indian, African and European Cattle

Breed	Average age at first calving (Months)	Reference
Indian		
Hariana	41.7-47.8	Amble *et al* (1958), Singh and Desai (1961), Ahmad (1961) etc.
Hariana	59.3	Kohli *et al* (1961)
Gir	47.3	Venkayya and Anantakrishnan(1956)

Table 1 (contd)

Breed	Average age at first calving (Months)	Reference
Sahiwal	41.1-42.8	N.D.R.I. Annual Report (1961), Singh and Choudhury (1961)
Tharparker	43.2-43.8	- do -
Red Sindhi	42.9	Venkayya and Anantakrishnan (1956)
Ayrshire, Red Sindhi crossbreds	35.1	- do -
African		
Native Egyptian	44.3	Asker et al (1958)
Butana	44.0	Alim (1962)
African Dairy Cows	42.9	Danasoury and Bayonmi (1962)
Small East African Zebu	42.7	Galukande et al (1962)
Indian x African crossbreds	42.3	Mahadevan (1962)
Nganda	42.0	Mahadevan and Marples (1961)
Boran and Jiddu	39.9	Mahadevan and Hutchison (1962)
Kenana	38.4	Alim (1960)
European and African crossbreds	37.4	Mahadevan and Hutchison (1964)
Egyptian cows	34.3	Ragab et al (1954)
European		
Friesian	33.5-34.0	Bonmi (1957) and Dassat (1953)
Brown Alpine	33.0-33.5	- do -

Table 1 (contd)

Breed	Average age at first calving (Months)	Reference
Swedish Lowland	32.5	Palsson (1952)
Aosta	32.4	Dassat (1953)
Pied Mont	32.4	-do-
Red and White Cattle	26.0-28.0	Hansson (1941)

Indian dairy breeds matures earlier than dual purpose breeds, the range of average age at first calving being 41.1 to 47.8 months for Indian cattle. European cattle between 26.0 to 34.0 months of age i.e. nearly fifteen months earlier. African cattle are intermediate between these two groups and calve at average ages of 37.4 to 44.3 months. They are definitely later maturing than European cattle.

Hansson (1941) reported the desirable age at first calving in Swedish Red and White cattle as about 26-28 months from economic point of view. The relation between production and feed consumption is greatly increased at this age of first calving.

Veiga, Chieffi and Paiva (1946) observed that the age at first calving of Nellore cows in Brazil was 41 months and 24 days while in India for the same breed it is much more as they reach sexual maturity only after 4 or 5 years of birth (Littlewood, 1936).

The age at first calving in Red Sindhi cattle was reported to be 36.9 months with a range of 30.7-47.2 months by Rigor (1949). He (1949) also studied the breeding activities of grade Ayrshire cows. His observations are summarized below.

Character studied	1/2 bred Ayrshire		3/4 grade Ayrshire		7/8 grade Ayrshire	
	Average (Months)	Range	Average (Months)	Range	Average (Months)	Range
Age at first fertile mating	29.2	14.4-51.2	33.9	13.2-68.6	39.5	23.6-74.9
Age at first calving	38.2	23.9-60.53	43.4	22.5-77.9	48.8	32.9-66.8

Tandon (1951) studied the age at first calving of Red Sindhi and Sahiwal cows and their crosses with Friesian bulls, on selected Military Dairy farms of India. He concluded that age at first calving has a threshold of expression and that the genes for early maturity are dominant over those for late sexual maturity.

Palsson (1952) observed the average age when Swedish Lowland (Swedish Friesians) cattle deliver their first calf as 32.5 months. Average age at first insemination was found to be 22.8 months.

Giuliani (1952-53), reviewing the literature, concluded that age at first calving of Friesian cows and of dual-purpose breeds (e.g. Brown Alpine) should not be less than 25 and 27 months respectively.

Aghina (1952-53) found the average age at first calving of 687 cows in Red Pied Aosta breed as 2 years and 7½ months.

Dassat (1953) at Piedmont, Italy reported the average age at first calving as follows :

Aosta	...	32.2 months
Pied Mont	...	32.4 "
Brown Alpine	...	33.5 "
Friesian	...	33.5 "

Hartmann(1953) analysed data on 1455 Black Pied Lowland herd book cattle from Altmark breeding area and found that more than 50% of the cows calved at an age of 2 3/4 to 3 years.

Average age of 177 Egyptian cows when they delivered their first calf was found to be 34.3 months by Ragab, Asker and Hilmy (1954).

Hofmann and Kleiber (1955) reported that out of 494 Yellow Franconian cattle more than half delivered their calves at the age of 31 months, majority of them had been served at 1½-2¼ years of age.

Venkayya and Anantakrishnan (1956) reported average ages at first calving of 216 Red Sindhi, 80 Gir and 241 Ayrshire-Red Sindhi crosses as 42.9, 47.3 and 35.1 months respectively.

Bonomi (1957) studied age at first calving in Brown Alpine and Friesian cattle in Italy and reported :

Breed	No. of animal studied	Average age at first calving
Brown Alpine	598	2 years and 9 months
Friesian	279	2 years and 10 months

Amble, Krishnan and Soni (1958) observed that village cattle calves at an older age (47 to over 50 months) in comparison with dairy cows (42 to 49 months) belonging to farms of State Government and Research Institutes.

Mainardi (1958) reported the average ages at first conception from 538 Friesian and 588 Brown Alpine cattle and reported it to be 25 and 27 months respectively.

Mc'Dowell, Fletcher and Johnson (1959) investigating age at first calving of Red Sindhi-Jersey crossbred cattle having different level of exotic blood found that this was not markedly affected upto 75% of Sindhi inheritance.

Danasoury and Bayonmi (1962) reported the average age at first calving of 184 dairy cows in Sudan as 42.9 ± 8.9 months whereas Horn et al (1965) on 632 crossbred cows having half Hungarian Brown and half Jersey inheritance calculated the average age at first calving of 27.5 months.

Maoli and MazziottiDicelso (1964) did not find any significant difference in age at first calving of Brown Alpine, Dutch Friesian and crosses of the two. The averages were reported to be 35, 36 and 35 months respectively.

Conev, Iocov and Angelov (1965) observed average age at first calving of Bulgarian Red heifers as 34 and 33 months at 25 collective and 3 State farms respectively.

Age at first conception was found to be 16-17, 21-22 and 21 months by Cjuralis (1965) in Dutch, Lithuanian and F_1 females of the two breeds respectively.

Heritable Variance Exhibited in Age at First Calving :

Many workers have estimated proportion of the total variance in age at first calving which is attributable to additive effect of genes. Some of these heritability estimates on Indian cattle are presented below :

Estimate of Heritability	Reference
0.39	Stonaker (1953)
-0.36	Singh (1957)
-0.09 to 0.66	Amble *et al* (1958a, b)
0.34	Singh and Desai (1961)
0.37	Ahmad (1961)
0.08 to 0.20	Mahadevan *et al* (1961-62)

Age at First Calving and Reproductivity :

Rognoni and Pasti (1955) observed an insignificant positive correlation ($r = 0.04$) between age at first calving and first calving interval in 576 Friesian cows in Piacanza district.

Hofmann and Kleiber (1955) studied age at first calving in relation to fertility in Franconian cattle and found a decrease in average number of calves produced per cow from 9.00 to 8.03; when age at first calving increased from 27 to 38-42 months.

Rognoni (1956) found a negative correlation ($r = -0.48$) in Brown Alpine cattle in Piacentino between age at first calving and first calving interval.

Lahousse (1960) reported that age at first calving was not correlated with first, second and third service periods in Friesians at Droogmans.

Venkayya and Anantakrishnan(1956) observed significant relationship between age at first calving and first calving interval in Red Sindhi and Ayrshire x Red Sindhi crossbred cows. The relationship was not significant in Gir cows.

Gautam, Tomar and Agrawala (1966) studied breeding efficiency in Hariana cows in relation to age at first calving. Breeding efficiency, which was estimated as $365\ (n-1) \times \frac{100}{D}$ where n = number of calvings and D = number of days from first to last calving, was affected significantly by age at first calving. It was found to be maximum i.e. 91.0 per cent at the first calving age between 36 to 39 months.

Singh and Sundaresan (1966) found phenotypic and genetic correlation coefficients as 0.091 and 0.701, respectively, between age at first calving and first calving interval in Tharparkar cattle. Their findings were based on 345 daughter-dam pairs from 22 sires.

Age at First Calving and Milk Yield :

Hartmann (1953) studied relationship between age at first calving and milk production of Black Pied Lowland cattle in Altmark breeding area. His findings are reported as follows :

1. Cows calving at an early age showed maximum lifetime production.

2. As the age at first calving increased, the lifetime production decreased.

3. Cows which calved at 2 3/4-3 years of age showed maximum annual yields.

4. Cows which calved over 3 years of age had maximum yields in their first lactations while cows which calved earlier than three years produced maximum yields in subsequent lactations.

5. Food taken per kilogram of milk production was also found less by earlier calvers.

Ragab, Asker and Hilmy (1954) reported in Egyptian cows an insignificant positive relationship between age at first calving and first lactational yield.

Hofmann and Kleiber (1955) also found no relationship between age at first calving and (i) first lactational yield, (ii) a 5-year average or (iii) the total average yield. Their findings were based on 494 Yellow Franconian cattle.

Venkayya and Anantakrishnan(1956) observed significant positive relationship between age at first calving and first lactational yield in three breeds of cattle. Their findings are summarized as below :

Breed	No. of animals included in the study	Coefficient of linear correlation
Red Sindhi	216	0.44
Gir	80	0.34
Ayrshire x Red Sindhi	241	0.19

Rognoni (1956) observed an insignificant positive relationship between age at first calving and total lifetime production, in Brown Alpine cows in Piacentino (r = 0.002). According to the findings of Ermolaev (1957) the Bestuzhev heifers produced highest yields in first lactations (1707-2115 kg) if they were bred at an age of 18-23 months whereas those bred before 18 months and after 23 months produced only 1634 kg and 1560 kg of milk in their first lactation respectively.

Holl (1959) reported in Czechoslovak Red Spotted heifers that 8½ years production of the heifers when bred at 27, 24, 21 and 18 months did not vary significantly. Hence heifers could be bred as early as at 18-19 months without any deleterious effects.

Lahousse (1960) reported an increase in first lactational yield of 138 Friesians at Droogmans farm when the age at first calving increased from 21 to 31 months. The relationship was found to be significant. When age at first calving increased from 32 to 40 months, the correlation was not significant. The author also reported a significant negative relationship between age at first calving and average monthly yields upto fourth calving.

Amble and Krishnan (1960), Kohli *et al* (1961), Alim

(1962) and Puri and Sharma (1965) all reported significant linear increases in first lactational milk yields with increase in age at first calving in Kangayam, Hariana, Butana, Tharparkar and Sahiwal cattle respectively.

Sundaresan et al (1954), Kohli et al (1961), and Puri and Sharma (1965) also reported that early first calvers were usually found to have the highest lifetime yields.

Danasoury and Bayonmi (1962) observed a highly significant correlation coefficient between first calving age and first lactational yield. It was 0.402.

Fiorentino (1965) reported that production increased from 847 kg to 1144 kg in Red Pied Aosta herd as the age at first calving increased from 26 to 38 months after which it declined.

In the study of crossbred Hungarian Brown x Jersey cows Horn et al (1965) observed a correlation coefficient of 0.222 at $P < 0.1$ per cent between age at first calving and first lactational yield. The coefficient of correlation varied from farm to farm, the range being from 0.082 to 0.361.

Gautam, Tomar and Agrawal (1966) observed a significant relationship between milk producing ability of Hariana cows and their age at first calving within the range of 39-51 months. The highest value for r = 0.26 was corresponding to the calving age below 39 months (particularly between 36-39 months). Milk producing ability was calculated using as herd average; deviation of a cow's average yield from the herd average; number of lactations completed and the repeatability of this character.

According to Guba (1966) Hungarian Spotted cows when bred first time at an age of 18 months had higher milk production in each of their first 4 lactations than of the cows that were first bred over 18 months of age.

Son, Ja (1965) observed that second lactational yield of Black Pied heifers increased over corresponding first lactational yield by 33.9 and 12.8 per cent, if the heifers were first bred at 15-17 months and 24 months respectively. Corresponding figures for Simmental heifers were 28.9 and 28.0 per cent. Optimum age when the heifers of both the breeds were bred was reported to be 18-20 months.

Singh and Sundaresan (1966) studied in Tharparkar cattle phenotypic and genetic correlations between age at first calving and first lactational milk yield. They reported these to be 0.038 and 0.795.

VanKov and Aleksiev (1967) divided into 7 groups, 203 Red Danish cows and 316 of their first crosses using various breeds. The grouping was according to the age at first calving between 27 and 37 months. In both groups i.e. purebred as well as crossbred, as the age at first calving increased upto 30 months, 300 day's yield also increased. Red Danish cows when first calved at 27-28 months produced highest milk yield per 100 kg body weight. Corresponding figures for the crossbreds of Red Danish was 29-30 months.

Asker *et al* (1958), Singh and Desai (1961), Singh and Choudhury (1961) and Puri and Sharma (1965) working with Egyptian, Hariana, Sahiwal, Tharparkar, Red Sindhi and crossbred cattle detected no effect of age at first calving on first lactational yields.

Effect of age at first calving on milk yield has been studied in a number of investigations; in some age at first calving exerted a significant influence on first lactational yield while in others the two were independent of each other. It can be concluded that herd differences account for a much larger portion of variability in age at first calving and in first lactational yields than do breed to breed differences.

Sexual maturity of tropical cattle in general and of

Indian cattle in particular is later than that in temperate zone cattle. This character can be improved by selection as heritability estimates in most cases were positive. There is adequate evidence that the relationship between age at first calving and reproductivity varied from herd to herd as did the relationship between age at first calving and milk production. This later relationship is not so large that improvement in age at first calving should have any noticeable and adverse influence on milk production.

II. OPEN PERIOD

It has also been called by some workers as service interval or post-partum interval.

1. Season

Herman and Edmondson (1950) reported that season did not affect open period while Carman (1955) showed that open period of cows calving in March to May was shorter than that of cows that calved in other months.

Grekke (1967) observed 55.7 days as an average open period for females calving in winter. It was less than 30 days for females calving in April to July.

2. Other Factors

Herman and Edmondson (1950) reported that open period was influenced by age of the cow and by lactation number.

Biswal and Rao (1960) showed that in Red Sindhi cows in Orissa average open period was 110 days for cows whose calves were weaned and it was 157 days for the cows which suckled their calves.

3. Relationship with Fertility

A number of workers have reported that there exists a relationship between open period and fertility (as it is measured by the number of services required per conception) and the conception rate at each service.

Edward (1950), Swensson (1952), Shannon et al (1952), Olds and Seath (1954), Søgnen and Filseth (1958), Steklenev (1966) and Segling (1967) reported that conception rate increased by an increase upto a certain limit in the interval from calving to first service thereafter it declined. Cows bred at shorter interval after calving took more services per conception than those bred after long intervals (VanDemark and Salisbury, 1950 and Lindley et al, 1958). The former also reported that the departure from linearity was highly significant when the data were fitted to a curve by use of a second degree polynomial regression equation.

Kohli and Suri (1960b) reported from 576 normal calvings over a nine year period in a herd of Hariana cows that the average open period after first calving was 230 days. One hundred days was found to be the minimum interval for a satisfactory conception rate.

Foot et al (1960) in a study made on animals bred to first oestrus after calving found that conception rate at first service was affected significantly by the length of the open period. The coefficient of linear correlation between these two variables was 0.04 at $P < 0.05$.

El-Sheikh and El-Fouly (1963) observed average open period in 953 pregnancies of 435 Friesian cows as 88.6 days. The corresponding service periods for three groups of cows mated at various open periods were :

Open period	Service period
< 60 days	122 days
61-90 days	138 days
> 90 days	235 days

Khan (1955) and Logvinov (1966) in their studies reported that conception rates after short and after long open periods did not vary significantly.

Grekke (1967) found that the percentage of 120,000 cows in Moscow Province in 1965 conceiving to first insemination increased from 15.3 to 89.9 as the open period increased from less than 30 days to between 61 and 90 days.

4. Relationship with Milk Production

Herman and Edmondson (1950) and Carman (1955) did not observe any relationship between current production and current open period. However Lewis and Horwood (1950), Olds and Seath (1953) and Pavuna (1960) reported that open period was affected by current production. Only 0.9 per cent of the total variation in this period was attributable to milk production (Olds and Seath, 1953).

Lunka *et al* (1962) reported that earlier conception affected milk production in the corresponding lactation.

Heritability and Repeatability Estimates of Open Period

Olds and Seath (1953) reported that repeatability of open period was 29.0 per cent for single records of the same cow. Intra-sire regression of daughters on dam, using first available records, was 27 per cent and using all records it was 32 per cent. Heritability measured by paternal half-sib correlation, using single records, was small but it was 31 per cent when all records were used.

Carman (1955) reported heritability and repeatability estimates of open period as 0 and 0.15 to 0.27 respectively.

Rognoni and Betta (1960) found heritability and repeatability estimates of open period as 0.06 and 0.47 respectively.

III. INSEMINATION PERIOD

Lindley *et al* (1958) studied effect of season on this character and reported that this period was 13.2 days less in summer than in autumn-bred cows. They also found low estimates of heritability and repeatability for insemination period.

Lewis and Horwood (1950) and Carman (1955) found that the insemination period was influenced by high production in the current lactation. They also found a positive significant relationship (r = 0.15), between insemination period and current daily average lactational yield. Age, parity and year had no effect on this character.

A significant relationship between open period and insemination period was observed by Touchberry *et al* (1959). They further reported that insemination period decreased as open period increased from 0 to 127 days, after that a slight increase was found. Only 1.4 per cent of the total variance in insemination period was accounted due to open period.

While studying the inheritance of breeding efficiency Pou et al (1953) found that heritability and repeatability estimates of insemination period were 0.07 and 0.11 respectively.

From his findings on 1646 lactations of 763 Holstein-Friesian cows maintained in two different herds, Carman (1955) reported the average insemination period in one herd as 28 days and in another as 42 days. Heritability and repeatability estimates were -0.03 ± 0.18 and 0.08 ± 0.09, and 0.27 and 0.06 in the two herds respectively.

Service Period

The open period and insemination period comprise together what is called as service period. Work of some of the authors who studied this character has been reviewed as follows :

Schmidt (1948) reported an average service period in German Red cattle of 95.1 days.

Lambardt (1951) calculated the average of 18593 service periods of West Phalian herd-book cattle as 85.5 days. He had excluded 3434 service periods which were more than 125 days as they were considered abnormally long.

Ragab et al (1956) found average service period in Egyptian cattle as 119 days. Repeatability of the character was 0.051.

Prasad (1958) studied the interval from calving to conception using 1338 records from 365 Tharparkar cows and reported it to be 131 days, with a coefficient of variation of 61 per cent.

Kohli and Suri (1960a), Kohli and Acharya (1961) and Kohli et al (1961) found unusually long average service periods in Hariana cows, these being 263, 289 and 314 days respectively. From the same herd, Kohli and Suri (1960b) reported this interval after first calving to be 283 days and after second calving it was 239 days.

Average service period in cows of University of Khartoum was observed by Danasoury and Bayonmi (1963) as 129 days. Cjurlis (1965) found that average service period in Dutch, Lithuanian and F_1 females was 116.3, 120.9 and 107.8 days respectively.

Florschiitz (1967) showed that average service periods in Simmental and Red Pied Lowland cows were 84.9 and 129.5 days respectively.

Non-Hereditary Variables Affecting Service Period

1. Season

Schmidt (1948), Lambardt (1951) and Romba (1961) reported that service period was affected by season. Kohli and Suri (1960a) also found a significant effect of season on the service period. It was shortest for the period September to March. On the contrary Plocek (1959), Ødegard (1965) and Prasad (1958), did not observe any significant effect of season on the service period.

2. Sequence of Calving

Prasad (1958) in Tharparkar cows reported that sequence of calving had a significant effect on the interval between a calving and subsequent conception and it contributed 4 per cent of the total variance.

Plocek (1959) reported longest service periods after the first calving.

3. Relationship with Production

Sayer (1934) found that with special feeding and handling the service period in Pusa pedigree Sahiwal herd was reduced from 172 days in 1931-32 to 90 days in 1933-34. In

1934-35, Sayer (1937) found that the service period in this herd increased again from 90 to 159 days. The author suggested that as the service period appeared to be linked with yield it would seem necessary in a high yielding herd to establish an optimum service period according to the yield and other relevant factors.

Lambardt (1951) observed that service period of high yielders was increased to some extent. Plocek (1959) and Danasoury and Bayonmi (1963) also showed significant relationship between service period and milk production. Service period was also correlated with lactation length (r = 0.594) according to Danasoury and Bayonmi (1963). However, Schmidt (1948), Romba (1961) and Prasad (1958) and Ragab et al (1956) did not observe any significant relationship between milk production and service period.

Wilton et al (1967) reported that in Holstein-Friesian cattle differences in days open accounted for 4.5, 3.5 and 4.5 per cent of the intra-sire variance in milk production in the first, second and later lactations, respectively.

IV. NUMBER OF INSEMINATIONS PER CONCEPTION

A. Hereditary Variables

1. Effect of Sire

A considerable variation in fertility in some of the families by 22 Yellow Franconian bulls was reported by Kab (1937).

Trimberger and Davis (1945) analysed records of 20 cow families and indicated the inheritance for sterility and number of services per conception. One family showed an average of 2.92 services per conception and two with significantly low values (1.22 and 1.00). Overall, number of services taken per conception by daughters of all the sires was 1.70. Daughters of one sire took 2.25 services per conception which differed significantly from other groups.

Korkman (1947) reported that average number of services required per conception was 1.57 in Ayrshire cows in Southern Finland. Out of the total variation in this character only 4.72 per cent was due to heritable causes and 14 per cent of this variation was attributable to differences amongst sires.

Henle (1949) analysed records of 28 bull families in Allgau cattle and observed that 8 bulls had an unfavourable and 5 bulls a favourable influence on the fertility of their daughters.

Mares et al (1961) studied genetic factors affecting the conception rate in Holstein cows and reported that conception rate of heifers was affected significantly by the season of birth and by interaction of sire-line with the system of mating whereas the conception rate in cows was affected significantly by the sire-line ($P < 0.01$) and by the interaction of sire-line with the system of mating ($P < 0.05$).

Swensson (1963) reported that all the 5 daughter groups sired by the same bull had sub-normal fertility.

2. Dam's Influence

Erb et al (1940) on the basis of analysis of some of the important cow families reported that some families have a higher breeding efficiency than others.

Trimberger and Davis (1945) compared cow families of three different breeds of cattle and found significant differences among cow families for the number of services per conception.

Tabler et al (1951) found considerable but non significant differences among cow families in number of services per conception. Korkman (1947) reported that 4.72 per cent of the variance in number of services per conception was due to heredity and 43 per cent was associated with differences among paternal half-sisters.

Olds et al (1949) observed a statistically insignificant correlation between the breeding performance of eleven foundation cows and of their daughters using number of services per conception as an index of breeding performance. However, highly significant correlations were obtained between breeding efficiency of dam and of daughters (0.203) and in breeding efficiency of paternal half-sibs (0.176).

Heritability and Repeatability Estimates

Heritability estimates for conception rate have been calculated by different workers using either the number of services per conception or the proportion of non-returns to first service.

Trimberger and Davis (1945) reported that breeding efficiency at the next conception (i.e. the number of services required per conception) or during the whole lifetime of a cow can not be predicted on the basis of conception rate at her first conception nor the lifetime average of the daughter could be inferred from that of their dams. Similar findings were reported by Tanabe and Casida (1949) and Olds *et al* (1949).

Dunbar and Henderson (1953) analysed records of 1015 Holstein-Friesian cows from different herds located throughout New York State and estimated heritability and repeatability of non-returns to first insemination. Repeatability estimate was 0.027 from a population of half sisters and 0.05 from cows by different sires within the same herd. Heritability was estimated as 0.004 using the component of variance due to differences among sires. It was concluded that selection for fertility on the basis of non-returns to first service or on the basis of number of services per conception can not be very effective. Same conclusions were drawn by Pou *et al* (1953), as heritability and repeatability estimates obtained by them were very low (0.07 and 0.12, respectively). The heritability was calculated on an intra-herd basis and was corrected for seasonal effects, time trends and breed differences.

Legates (1954) estimated the heritability and repeatability for services per conception and reported the values 0.026 and zero respectively.

Carman (1955) reported, in *Holstein-Friesian* cows, heritability and repeatability estimates of the number of services per conception as 0 and 0.06 respectively.

Repeatability of services per conception was reported to be 0.002 in *Egyptian* cattle by Ragab *et al* (1956).

Rottensten and Touchberry (1957) estimated heritability of conception rate on first and second service in heifers of three breeds at Danish Progeny testing stations and reported it to be zero.

Intra-cow repeatability of services per conception was reported to be 0.01 by Ahmed and Tantawy (1959) in Egyptian cattle.

Schindler and Angel (1960) found that correlation between conception rates of successive pregnancies of the same cow was more or less zero in most of the herds. Only a few herds showed moderately high correlation.

Rognoni and Betta (1960) reported heritability and repeatability of number of services per conception in Friesian cows to be 0.04 and 0.06 respectively.

Heritability of conception rate at first insemination was estimated as 0.1 by LeRoy and Hahn (1963).

Rognoni *et al* (1966) reported the heritability of number of services per conception as 0.24. The estimate was obtained from 534 dairy cows sired by 9 bulls.

B. Non-Hereditary Variables

1. Age of the Bull

A number of investigators have studied the age of bull as a factor affecting number of services per conception and conception rate.

Yearling bulls in general take minimum services per conception and showed highest conception rate. A gradual but definite fall in the breeding efficiency of the bull accompanies increasing age (Morgan and Davis, 1938; Erb *et al*, 1940; Bowling *et al*, 1940; Hilder *et al*, 1944; Tanabe and Salisbury, 1946; Detkens and Malik, 1954; Ahmed and Tantawy, 1959).

Tanabe and Salisbury (1946) observed that the highest conception rate i.e. of 54 per cent was obtained with 4 to 6 year old cows with 1 to 3 year old bulls. Contrary to the above findings, Carman (1955) and Morrison and Erb (1957) found that age of the bull had little effect on number of services per conception.

Kohli *et al* (1965) reported that fertility rate varied significantly among *Hariana* bulls. Number of services per conception for the three age groups of bulls were as follows :

Age of bull	Services per conception
2-5 years	1.72
6-8 years	1.76
9-13 years	2.02

The range in the conception rate in these three age groups was between 40.0 and 63.8 per cent.

2. Age of the Dam

Gowen and Dove (1931) reported a progressive increase in the number of services per conception for females one year of age to females 16 years of age.

Heifers take more services than older or multiparous cows according to Hilder et al (1944) and Detkens and Malik (1954). However Morgan and Davis (1938) and Foot and Ridler (1949) showed that breeding heifers took less services per conception in comparison to older cows.

Tanabe and Salisbury (1946) observed that conception rate increased with the age of the cow and was maximal in 5 year old cows and then decreased upto 10 year olds.

Pou et al (1953) reported that age of the cow had little effect on this character.

Boyd and Reed (1961) observed conception rate for heifers as 60.5 per cent, which reached its peak value of 66.8 per cent at the third gestation and then declined progressively to 51.1 per cent in cows with more than 8 gestations.

3. Seasonal Variation

Morgan and Davis (1938) reported that season of insemination affected number of services per conception. Average number of services per conception was 2.28 from May to October and 2.14 from November to April.

Kumaran (1944) observed a seasonal variation in conception rate from natural matings. Conception was lowest in February and highest in April.

Seasonal variation in conception rate and number of services per conception was also reported by Trimberger and Davis (1945), Hilder *et al* (1944), Lindley *et al* (1958), Ahmed and Tantawy (1959), Paufler (1962), Stott and Williams (1962), Rognoni and Vismara (1962), Cicardi and Magnani (1963) and Ghiandoni *et al* (1966). Anderson (1966) reported that conception rate at first service was more in autumn mated cows than those mated in spring. On the contrary Pou *et al* (1953) and Kellgren *et al* (1963) found that season had little effect (if any) on female's fertility.

No effect of the season was found on conception rate in *Hariana* cows (Kohli and Suri, 1960).

4. Other Factors

Carman (1955) observed a positive significant correlation between current production and number of services to conception.

On the contrary Boyd et al (1954) and Currie (1956) failed to observe any relationship between current production and number of services per conception.

Brochart (1966) reported from his findings on Friesians, Normandy and Swiss Brown dairy herds that there was a highly significant correlation (r = 0.72) between the mean number of inseminations per conception and the maximum monthly decrease in milk production over the first five months of a lactation.

Johansson (1953) reported that conception rates on 10691 cows varied greatly according to the length of interval between calving and service as follows :

Interval between calving and service (in days)	Conception rate %
0-30	35.4
30-60	56.5
60-90	62.2

He concluded that the conception rate increased upto the interval of 210 days and then declined.

Tochberry et al (1959) found that number of services per conception were not affected by open period. It accounted for only 0.3 per cent of the variance in number of services per conception. Partial regression of the number of services per conception on open period for a constant butter fat production was -0.0034 ± 0.0023.

According to Mataserino and Nagarcenkar (1962), the mean number of inseminations per conception varied curvilinearly as a function of open period, the regression was found to be highly significant for natural services but not significant for artificial services.

El-Sheikh and El-Fouly (1963) studying records of Friesian cows in U.A.R. concluded that number of services per conception and conception rate varied according to the length of open period. They reported as follows :

Open period (in days)	Number of services per conception	Percentage of cows conceived to first service
< 60	2.89	48
61-90	2.55	70
> 90	2.62	76

A considerable increase in the conception rate was found by Belling (1963) when the open period increased to 60 days or more. Similar findings were also reported by Segling (1967) and Grekke (1967).

V. CALVING INTERVAL

A. Hereditary Variable (Breed)

Calving intervals in days in Swedish Red and White cattle observed by Johansson and Hansson (1940) were, first 396 days; second to fourth 380-390 days; fifth to eighth 390 to 400 days and ninth to tenth 400-410 days.

Østergaard (1942) based on 970 Red Danish herd book cows, showed that first and second calving intervals were 407 and 392 days, respectively. After the second, the calving interval tended to increase upto the ninth when it averaged 423 days.

Korkman (1947) reported that average calving interval of Ayrshire cows maintained in Southern Finland from 1931 to 1937 was 382 days.

Rigor (1949) reported the calving intervals of Red Sindhi cows from 1932 to 1940 as follows :

	Average (days)	Range (days)
Imported Red Sindhi	446 ± 7	286 to 872
Alabang borned Sindhi	448 ± 8	307 to 628

Average calving intervals reported by Lewis and Horwood (1950) in different breeds of dairy cattle at

Michigan State College were as follows :

Guernsey	...	12.1 months
Ayrshire	...	12.6 "
Jersey	...	12.6 "
Brown Swiss	...	13.0 "
Holstein-Friesian	...	13.2 "
Overall average of 365 calvings	...	12.7 "

Rennie (1952) calculated the average calving interval of 1663 Holstein-Friesian cows as 413 ± 78 days with the mode in 360 to 380 days class.

Herman *et al* (1953) analysed data of 310 Jersey and 410 Holstein calvings from 1900 to 1949 in Missouri dairy herd and observed that the average calving intervals were 15.5 and 14.4 months respectively. Percentage of cows that calved within 12 months interval was 77.5 and 85.1 in the respective breeds.

According to investigations made by the Agriculture Department of Jamaica, first to the fifth calving intervals averaged 423, 412, 462, 427 and 393 days respectively.

Detkens and Iwanicka (1954), Legates (1954) and Arnold and Becker (1956) reported average calving intervals of 378 days, 406 days and 437 days in Black and White Lowland cows of Lower Silesia, cattle of North Carolina State herds and cattle of Florida station respectively.

Pegg (1957) conducted a survey in Queensland on 19,971 cows representing 43 per cent of the recorded cows in that State which were in other than their first lactation during 1955 to 1956 herd recording year. Out of those cows 18.4 per cent recalved in less than 11 months and 16.5 per cent after more than 13 months.

Morrison and Erb (1957) observed the average calving interval from 9994 reproductive periods of 2607 Holstein-Friesian cows to be 424 days.

Bonomi (1957) found the average calving interval in 689 Brown Alpine and 246 Friesian cattle as 12.3 and 12.5 months respectively.

Amble *et al* (1958a) reported that the average calving interval in 6 dairy herds in India which belong to the State Governments, Research Institutions and to villages was between 15 and 18 months. The average calving intervals of Red Sindhi at Hosur and Bangalore were observed by Amble *et al* (1958b) as 546 ± 10 and 447 ± 8 days respectively.

Rigor and Nelmida (1959) reported the average calving intervals of 510.4 ± 20.1 and of 511.7 ± 10.6 days in 16 Red Sindhi and 17 Jersey x Red Sindhi crossbreds from Tarlac breeding centre.

Rigor et al (1959) and Plocek (1959) found 433 ± 2.6 and 438.7 ± 9.0 days as the average calving intervals in imported and locally bred Sahiwal cows. Whereas in Red Spotted cattle it was 393.8 days.

According to El-Sheikh and El-Fouly (1962), 359 Friesian cows in United Arab Republic had averages of first four calving intervals as 474.2 ± 6.2, 399.3 ± 5.6, 392.8 ± 8.0 and 344.5 ± 8.8 days respectively.

Belling (1963) in four naturally served herds of cows and Danasoury and Bayonmi (1963) in dairy cows at University of Khartoum observed the average calving intervals of 363 and 416 days respectively.

Maoli and Mazziotti (1964) did not observe any significant difference in calving intervals of Brown Alpine, Dutch Friesian and crosses of these two. The average intervals were 394, 398 and 386 days respectively.

Anderson (1966) observed average calving intervals of 394.0 and 380.5 days in Red Danish and Black Pied Danish cattle.

Calving intervals of some of the Indian and African cattle are summarized in Table 2.

Table 2

Calving Intervals of Some Indian and African Cattle

Breed	Location	Calving interval in days	Reference
Indian			
Hariana	Izatnagar	432(First)	Ahmad (1961)
"	Mathura	458(")	Singh (1959)
"	Hissar	530(")	Kohli and Suri (1957)
"	Mathura	458	Singh and Desai (1962)
Sahiwal	Karnal	460	N.D.R.I. Report (1961)
Tharparkar	"	441	-do-
Red Sindhi	"	437	-do-
"	Hosur	546	Amble et al (1958b)
"	Bangalore	447	-do-
African			
Kenana	Sudan	395	Alim (1960)
Butana	"	416	Alim (1962)
Boran and Jiddu	Tanganyika	382	Mahadevan and Hutchison (1964)

Calving intervals of Indian cattle being about 14 months or more were longer than those of even African breeds. Even within a breed, large variations exist among herds.

Heritability and Repeatability of Calving Interval

A number of workers have estimated heritability and repeatability values for calving interval. These estimates suggest that variation in the calving interval is entirely due to non-genetic causes. Some of these estimates are presented in Table 3.

Table 3

Estimates of Repeatability and Heritability of Calving Interval

Breed	Repeatability	Heritability	Reference
Holstein-Friesian	0.175 to 0.184	Low	Rennie (1952)
-	0.07	-	Asdell (1952)
Holstein-Friesian	-	0	Dunbar and Henderson (1953)
Red Danish	0.13	-	Østergaard (1942)
Red Danish and Black Pied Danish	0.089 to 0.103	0.012 to 0.056	Anderson (1966)
Norwegian Red	-	0	Ødegard (1965)

Table 3 (contd)

Breed	Repeatability	Heritability	Reference
Angus beef cattle	0	0	Brown et al (1954)
Native cattle	0.080	-	El-Itriby and Asker (1956)
Crossbred cattle	0.089	-	-do-
Tharparkar (i) Uncorrected data	0.226	-	Singh (1958)
(ii) Corrected data	0.282	-0.16 to-0.18	-do-
Red Sindhi	-	0.88	Stonaker (1953)
Hariana	-	0.02 ± 0.448	Dadlani et al (1959)
"	-	High	Acharya (1966)
"	0.224	-	Ahmad (1961)
Indian breeds	0.08 to 0.21	-0.08 to 0.13	Amble et al (1958)

B. Non-Hereditary Variables Affecting Calving Interval

1. Age of the Cow

Schmidt (1933) reported that calving interval increased with the age of the cow. It was less than 12.9 months in cows upto 7 years of age and 13.9 months in 12 years old cows.

Lewis and Horwood (1950) did not observe any effect of age on calving intervals of Ayrshire, Brown Swiss, Guernsey, Jersey and Holstein-Friesian cows. First calving interval did not differ significantly with others, upto the 9th interval, after which it increased reaching an average of 14.4 months. Only 10.3 per cent of the total variation in calving interval could be attributed to age of the cow (Rennie, 1952).

Investigations in Department of Agriculture, Jamaica (1954) showed that in Bodles herd, the effect of age on calving interval was not found upto the fifth lactation.

Schmidt and Koriath (1956), investigating the German cattle, found that calving interval was affected by age. Each successive interval, except the second, increased by two days. The first interval was 386.9 days and the second being 379.6 days.

Morrison and Erb (1957) observed a significant linear negative relationship between age of the cow and calving interval from 3 to 14 years. The regression being 8.72 days per year increase in age. They concluded that at about 6 years of age the interval was minimum.

Plocek (1959) did not observe any effect of age on calving interval while Belling (1963) reported a significant effect. Upto four years this interval was 353 days and from 10 to 16 years it became 384 days.

2. Season of Calving

Lindley et al (1958) reported that calving interval was 7 days less in summer and autumn bred cows than at other time.

Singh et al (1958) reported the following averages for calving intervals of Hariana cows :

Period	Average calving interval (days)
December to April	488
May to June	514
July to November	464

The overall average of the calving interval was 484 days and the first interval was highest, differing significantly from the second.

The Livestock Bureau of Scotland (1959) reported that pedigreed Ayrshire cows which calved for the first time in summer (July) or autumn (October) had longer calving intervals than those that first calved in spring (April) and winter (January).

Ødegard (1965) studied effect of season of calving on fertility of Norwegian Red and White heifers and observed that December to March calvers had significantly shorter calving intervals in comparison to August to November calvers.

Anderson (1966) observed that calving intervals of Red Danish and Black Pied Danish cows which first calved in May, July and September did not vary significantly.

3. Other Factors

Rennie (1952) reported that in Holstein-Friesian cows, out of the total variation in calving interval, 11.7 per cent was accounted by intra-herd intra-year variability and 4.8 per cent due to yearly environmental differences.

Brown *et al* (1954) studied variation in calving interval of beef cattle from a large Angus herd maintained under range conditions having year round calvings. Year and sequence of calving accounted 17.5 and 6.7 per cent of the total variance respectively, and they differed significantly from zero.

Singh (1958) reported that calving interval was affected both by year and calving number in Tharparkar cattle. Calving interval was affected more by management and nutrition than by high production (Guba and Illes, 1959).

El-Sheikh and El-Fouly (1962) and Danasoury and Bayonmi (1963) found that calving interval and service period were significantly correlated. Estimates of r were 0.766 and 0.964 respectively.

Cows nursing heifer calves had shorter calving intervals than cows nursing male calves (Belling, 1963). Ødegard (1965) observed that service period was correlated with first and second calving interval.

Khan (1965) reported in Dajjal cattle at Qudirabad that excessively long calving intervals after first, second and fourth calvings were due to long service periods viz. 196, 186 and 134 days respectively.

4. Relationship with Milk Production

Rennie (1952) reported that in Holstein-Friesian cows genetic correlation between milk production and calving interval was more than one. Intra-herd and intra-year regressions were such that for each increase of 10 days in the current calving interval, an increase of 73.5 pounds of milk could be expected and for the same increase in the preceding calving interval an increase of 60.9 pounds could be expected.

Johansson (1953), at Animal Genetics Institute, calculated the successive calving intervals as follows :

First	...	14 months
Second	...	13 "
Third and further	...	12 "

He concluded that the first calving interval was more due to (a) Flatter first lactation curve, (b) Persistant milk production or as (c) heifers were not fully grown up.

Pegg (1957) observed no appreciable increase in production by calvings at intervals greater than 12 months, and there was a definite drop when cows calved at 9 or 10 months after the previous calving date.

Poly and Vissac (1958) analysed data on 1108 calving intervals of Normandy and French Friesians from third to sixth lactations and found that low production was followed by shorter calving intervals. The association of calving interval and milk production varied with the level of production in each herd. No significant relationship was found between the current production and the preceding calving interval. Guba and Illes (1959) found large calving intervals in high yielders.

A significant linear increase in milk yield with increasing the length of first calving interval was observed in Hariana cows by Kohli *et al* (1961).

Danasoury and Bayonmi (1963) also found a significant relationship between first calving interval and first lactational milk yield (r = 0.394) while Ødegard (1965) reported that the first calving interval was significantly correlated with the second lactational yield (r = 0.211).

Toeplitz (1965) studied milk production of Black Pied Lowland cows in relation to fertility. Cows which yielded 3000 to 4000 kilos showed shortest calving intervals (14.9 months) and cows which yielded 5000 to 6000 kilos had longest calving interval (16.3 months). Fiorentino (1965) reported that in Red Pied Aosta cattle, milk yield increased by increasing length of calving interval. The increase being greater between 11 and 13 months than between 13 and 21 months.

According to Robertson (1966) "over the normal range of calving intervals, a reduction in calving interval will always lead to an increase in the average daily yield between calvings". Amongst cows which had long lactations, for each day increase in lactation length there was an increase of almost 3 gallons in milk yields.

Acharya (1966) observed in Hariana cows a positive phenotypic correlation between milk yield and first calving interval. Genetic correlation was negative.

Horvath (1966) found a correlation of 0.23 between average daily milk production and the current calving interval.

Singh and Sundaresan (1966) observed a significant phenotypic correlation (r = 0.304) between first lactational yield and first calving interval in Tharparkar cows. The genetic correlation was 0.777.

Genetic studies made on calving interval, showed that variation exhibited by this character is mostly environmental. Heritability and repeatability estimates are mostly zero. Environmental variables which affect it are year, age of the cow, season, sequence of calving, and milk production etc.

VI. NUMBER OF HEATS MISSED

Tandon (1958) studied the average of the expected number of heats missed in the insemination period before first conception in Red Sindhi x Jersey crossbred cows. He found that as the Jersey blood increased upto 50 per cent the average number of heats missed decreased.

Some of the authors have tried to evolve an expression for the breeding efficiency which could have wider implications than the various individual measures which could be called its components and which have been reviewed above.

Lowe (1938) evolved an index for fertility known as "value index" which is equal to the ratio of Position Index and the Calving Index where

Position Index = Age of the cow in month at first successful mating, and

Calving Index = Total number of births (Multiple births are treated as one).

Wilcox *et al* (1957) evolved a formula for measuring breeding efficiency of *Bos taurus* cattle on the basis of calving intervals. According to them

$$\text{Breeding Efficiency} = \frac{(n-1)\ 365 \times 100}{D}$$

where, n = Total number of calvings;

D = Number of days from first to last calving.

This compares the observed calving interval with 365 days, assuming that 365-day interval is an achievable ideal.

Dohy (1960) expressed fertility as

$$T = 100 - (K_1 + 2_i)$$

where T = Fertility index

K_1 = Age of the cow at first calving in months

i = Average calving interval in months.

This takes into account age at first calving and calving index. Fertility is indicated by index value, when it is 48, fertility is good, average when index value lies between 41-47 and poor when it is 40 or less.

Current reproductive status of a herd can be measured by the formula given by Johnson *et al* (1964) :

$$\text{Herd Reproductive Status or HRS} = 100 - \left[\left(\frac{Co}{Tc} + \frac{Do}{Tc \times 0.11 \times 305} \right) / 2 \right] \times 100$$

Where Co = Number of cows not pregnant for > 100 days

Do = Total number of days of non-pregnancy for cows not pregnant for > 100 days in the herd

Tc = Number of cows in the herd.

A HRS of 100 per cent indicates that either all the cows in the herd are pregnant or not-pregnant for less than 100 days. The relationship between HRS and the average number of days of non-pregnancy per cow in a herd was found to be negative and significant.

Tomar (1965) estimated breeding efficiency in *Zebu* cattle as :

$$\frac{[n\,(365) + 1020]\,100}{Ac + Ci}$$

Where n = Number of calving intervals

Ac = Age at first calving in days

Ci = Days between first and last calving

1020 = Optimum age at first calving in days.

Kubkowski (1965) suggested the use of Morozow's formula for finding out proportion of the non-pregnancies in a herd in any period of time. According to him :

$$\text{Proportion of non-pregnancies} = \frac{P}{2.85 \times A_1}$$

Where P = Total days of barrenness for all cows

A_1 = Herd size i.e. number of cows.

All these indices have the limitation of defining apriori an ideal pattern of reproduction for a herd. They also give an overall codification simultaneously of more than one of the constituents that make up reproductive efficiency. No attempt is thus made to combine these constituents in order of their genetic variability or any other related value.

THE PRESENT INVESTIGATION

Source of Data

The breeding and calving records of _Hariana_ cows of the dairy herd of Indian Veterinary Research Institute, Izatnagar, Uttar Pradesh, India, were used for this study. The foundation stock of this _Hariana_ herd, which was established in October 1937 came from a cattle breeding farm at Karnal. These animals were maintained and housed at first along with those in the Division of Biological Products. Later in 1946, these were transferred to the Division of Animal Genetics. Since then the increase in the foundation stock was made by purchasing gradually animals from the Hariana tract. The last purchase was made in 1955, since when the herd has been a closed herd.

Animals were fed according to the following schedule :

Daily ration for adult animals included 2 kgs dry or 8 kgs green fodder or a mixture of the two, (according to availability), per 100 kgs body weight. One and a half kilo concentrate mixture was given as maintenance allowance per adult animal per day. Production allowance was given at the rate of one kilo concentrate for every 2.5 kgs of milk. Pregnant animals were given daily one kilo concentrate extra for the foetus.

The concentrate mixture comprised of 40 parts wheat bran, 20 parts gram-husk, 10 parts crushed gram, 10 parts rape-cake and 20 parts ground-nut cake. In addition to this each animal was also fed 1 oz of salt and 2 oz of mineral mixture daily. The concentrate mixture given above was fed to the animals until July 1964 only. Afterwards the concentrate and mineral mixture was replaced by a commercially compounded Nandi cattle feed manufactured by Nandi Provender Mills.

Before 1952, the major portion of green fodder available was kans grass (Saccharum spontaneum), dry fodder supplied at that time was also unchaffed. Afterwards i.e. since 1952 fodder given to these animals has comprised of :

Jowar and bajra	-	July to September
Berseem, jowar and kadbi	-	December to March
Wheat bhoosa	-	Rest of the year

Since 1966 fodder given to these animals has been :

Berseem, oats and lucerne	-	January to May
Green maize and jowar silage	-	June and July
Cow-pea, jowar and maize	-	August to December

Cows are housed in pucca byres and they are milked twice a day at 2.30 A.M. and 2.00 P.M.

Pregnant cows which may continue in milk upto two months before they are due to calve are dried. Since then they are kept in the calving shed.

All the females are being bred artificially in this herd since 1945. Heifers are not bred until they either are over two and a half years of age or have normal oestrus and have their genitalia fully developed.

Heats are detected by the behaviour and activity of the cows in the herd during grazing or in side paddocks. It is confirmed afterwards by rectal palpation. All the females in the herd were kept until they died or were culled due to : (a) senility, (b) incurable diseases, (c) incurable breeding disorders, (d) poor yield or (e) off type to breed.

The study covers a period of 22 years extending from 1946 through 1967. Normal breeding and calving records of 553 lactations from 262 cows sired by 16 bulls were used for this investigation. Data pertaining to abortion, dystokia, where it was detected and other pathological conditions due to which breeding was affected, were excluded.

As the data used cover a long period; the animals whose records are used in the study must have been raised under varying environment and management. The sires were also used over that period. As independent measurement of the environmental effect is not possible from these data, the differences among sires, if taken as such, are sure to be confounded with environmental differences for the periods when the sires were used. To get rid of this difficulty data, for each measure of the reproductive efficiency studied were grouped into three periods such that sires whose daughters were contemporary came within one period only. Confounding of the genetic and environmental differences was attempted to be minimise thereby analysing the data within period.

Year of the birth of heifers was used for grouping heifers for age at first calving. The three periods formed for this character were :

Period designation	Years
I	1946 - 1950
II	1951 - 1957
III	1958 - 1963

Grouping of data for calving interval and open period were done according to the year of earlier calving as this may relate most to permanent environmental effects of that period. The periods thus constituted were :

Period designation	Years
I	1949 - 1953
II	1954 - 1960
III	1961 - 1966

For the remaining components of breeding efficiency grouping was done according to year of earlier service. The groups thus were :

Period designation	Years
I	1949 - 1953
II	1954 - 1959
III	1960 - 1966

Reproductive efficiency in this study has been measured in terms of :

(a) Age at first calving (in months).

(b) Open period (in days) : It is the interval between calving and first insemination given to a cow subsequently. The day of calving was not counted in the interval.

(c) Insemination period (in days) : It was calculated by substracting the open period from the interval between calving to fertile service. It ranged between zero and maximum value.

(d) Number of services per conception.

(e) Calving interval (in days) : This was calculated as the interval between two successive calvings. Only one calving date was included in the interval.

(f) Number of heats missed by each cow in one insemination period were calculated as follows along the method used by Tandon (1958) :

[(Insemination period ÷ 21)+1]- Number of services given to the cow in the insemination period

Statistical Methodology

The following model was used for the estimation of components of variances :

$$Y_{ijk} = \mu + p_i + s_{ij} + e_{ijk}$$

where $i = 1, 2, \ldots\ldots m$

$j = 1, 2, \ldots\ldots s_i$

$k = 1, 2, \ldots\ldots p_{ij}$

Y_{ijk} is the observation on any of the measures of reproductive efficiency studied on the k^{th} cow of the j^{th} sire of the i^{th} period; p_i, s_{ij} and e_{ijk} are random variables normally and independently distributed with means zero and variances σ^2_p (between periods), σ^2_s (between sires), and σ^2_e (between half-sibs) respectively.

As there were m periods, and the i^{th} period had s_i sires; and a random sample of p_{ij} offspring was studied from each sire, the mean squares and their expectations will be as given in Table 4.

Table 4

Mean Square and their Expectations in the Model Followed

Source of variation	d.f.	S.S.	M.S.	E.M.S.
Between periods	m-1	$\sum_i \frac{Y^2_{i..}}{p_{i.}} - \frac{Y^2_{...}}{p_{..}}$	A_1	$\sigma^2_e + K_2\sigma^2_S + K_3\sigma^2_P$
Between sires within periods	$\sum_i (s_i - 1)$	$\sum_{ij} \frac{Y^2_{ij.}}{p_{ij}} - \sum_i \frac{Y^2_{i..}}{p_{i.}}$	A_2	$\sigma^2_e + K_1\sigma^2_S$
Within sires within periods (Between paternal half-sibs)	$\sum_{ij}(p_{ij} - 1)$	$\sum_{ijk} Y^2_{ijk} - \sum_{ij} \frac{Y^2_{ij.}}{p_{ij}}$	A_3	σ^2_e

The estimates of σ^2_P and σ^2_S can be obtained by substituting the values of K_1, K_2, and K_3 in the E.M.S., which can be estimated as under :

$$K_1 = \frac{1}{\sum_i (s_i - 1)} \left[p_{..} - \sum_{ij} \frac{p^2_{ij}}{p_{i.}} \right]$$

$$K_2 = \frac{1}{(m-1)} \left[\sum_{ij} \frac{p^2_{ij}}{p_{i.}} - \sum_{ij} \frac{p^2_{ij}}{p_{..}} \right]$$

$$K_3 = \frac{1}{(m-1)} \left[p_{..} - \sum_i \frac{p^2_{i.}}{p_{..}} \right]$$

Estimation of Heritability of Different Measures of Reproductive Efficiency

The word 'Heritability' was coined by Lush to denote the relative importance of heredity in accounting for the variation that takes place in the expression of a character as contrasted with environment.

In the broad sense it is the fraction of the phenotypic variance exhibited in a character which is attributable to the variation in the heredity. In the narrow sense heritability is the raio of additively genetic variance to the phenotypic variance i.e.

$$h^2 = \frac{V_A}{V_P}$$

h^2 is the symbol used for heritability. It derives itself from Wright's (1921) terminology.

Heritability of a character varies from herd to herd and from time to time. Its estimate gives an idea of how much improvement is possible due to selection for a particular trait. It also helps in making up a breeding plan.

The principle involved in estimating heritability is to compare the degree of phenotypic resemblance between relatives knowing their genetic relationship. The former can be done either by analysis of variance or analysis of covariance; or by regression or correlation coefficient analysis. A method can be choosen depending upon the type of data available.

Methods used in this study to find heritability estimates were as under :

1. Resemblance Between Paternal Half-Sibs

Intra-class correlation among the paternal half-sibs was calculated by using the following components of variances : σ^2_s and σ^2_e which are between sires and between half-sibs components respectively. They can be estimated as given in Table 4. Thus

$$\text{Intra-class correlation among paternal half-sibs} = \frac{\sigma^2_s}{\sigma^2_s + \sigma^2_e}$$

The intra-class correlations for each measure of reproductive efficiency will have to be multiplied by 4 in order to get an estimate of heritability.

These estimates also include a small fraction of epistatic component in addition to the additively genetic variance. In multiplying the intra-class correlation by 4, the sampling errors of the heritability estimates become large. This is a serious limitation of this method.

The standard error of heritability estimate thus obtained was given by Robertson (1959)

$$\text{S.E. } h^2 = \left(h + \frac{4}{n}\right) \sqrt{\frac{2}{N}}$$

where n = Average number of progeny per sire

N = Total number of sires and

h^2 = Heritability of the trait.

Heritability estimates for all the measures of reproductive efficiency were estimated by this method.

2. <u>Intra-Sire Regression of Daughters on Dams</u>

As the genetic relationship between offspring and its dam is half, heritability was obtained by doubling the intra-sire correlation coefficient. By calculating the regression of daughters on dams within sires any environmental relationship that may exist gets discounted.

Heritability estimate for age at first calving was obtained by this method also in addition to the estimate using half-sib correlation coefficient.

Genetic and Phenotypic Correlations

Genetic correlation coefficients between characters were estimated by doing analysis of covariances and variances.

The details are briefly presented in Table 5.

Sire components of variances and covariances can be obtained from such table by substituting the values of K_1's that can be estimated as given earlier. The coefficients of genetic and phenotypic correlations can thus be obtained as under :

$$\text{Genetic } r_{XY} = \frac{\sigma_{SXY}}{\sigma_{SX} \cdot \sigma_{SY}}$$

where $\sigma_{SX} = \sqrt{\sigma^2_{SX}}$ and $\sigma_{SY} = \sqrt{\sigma^2_{SY}}$

Table 5

Expected Components of Variances and Covariances for Computing Coefficients of Genetic Correlations

Source of variation	d.f.	Mean square (X)	Cross product (X.Y)	Mean square (Y)
Between periods	m-1	$\sigma^2_X + K_2\sigma^2_{S_X} + K_3\sigma^2_{P_X}$	$\sigma_{XY} + K_2\sigma_{S_{XY}} + K_3\sigma_{P_{XY}}$	$\sigma^2_Y + K_2\sigma^2_{S_Y} + K_3\sigma^2_{P_Y}$
Between sires within periods	$\sum_i (s_i - 1)$	$\sigma^2_X + K_1\sigma^2_{S_X}$	$\sigma_{XY} + K_1\sigma_{S_{XY}}$	$\sigma^2_Y + K_1\sigma^2_{S_Y}$
Within sires within periods (Among paternal half-sibs in a period)	$\sum_{ij} (p_{ij} - 1)$	σ^2_X	σ_{XY}	σ^2_Y

$$\text{Intra-period Phenotypic } r_{XY} = \frac{\sigma_{SXY} + \sigma_{XY}}{\sqrt{(\sigma^2_{S_X}+\sigma^2_X)\,(\sigma^2_{S_Y}+\sigma^2_Y)}}$$

Repeatability Estimates

Repeatability of a character in statistical terms can be defined as the correlation among several determinations of a character on the same individual. It expresses the proportion of the variance in a character that is due to permanent differences. It includes both genetic and permanent environmental portions.

Estimation of repeatability in this study was made by the use of variance components as under :

The model :

$$X_{ij} = \mu + w_i + e_{ij}$$

where $i = 1, 2, \ldots\ldots b$

$j = 1, 2, \ldots\ldots n$

X_{ij} is the j^{th} observation on the i^{th} cow. w_i and e_{ij} are random variables normally and independently distributed with mean zero and variances σ^2_w (between cows) and σ^2_e (between records of the same cow).

The mean squares and their expectations were obtained as given in Table 6.

Table 6

Analysis of Variance for Estimating Repeatability

Source of variation	d.f.	S.Sq.	M.Sq.	E.M.S.
Between cows	b-1	$\sum_i \frac{X^2_{i.}}{n_i} - \frac{X^2_{..}}{N}$	MS_w	$\sigma^2_e + K\,\sigma^2_w$
Between records within cows	N-b	$\sum_{ij} X^2_{ij} - \sum_i \frac{X^2_{i.}}{n_i}$	MS_e	σ^2_e
Total	N-1	$\sum_{ij} X^2_{ij} - \frac{X^2_{..}}{N}$		

Where $K = \frac{1}{b-1}\left(N - \frac{\sum_i n^2_i}{N}\right)$

Estimating σ^2_e and σ^2_w from Table 6, repeatability was obtained as :

$$\text{Repeatability} = \frac{\sigma^2_w}{\sigma^2_w + \sigma^2_e}$$

Other statistical estimates like arithmetic averages and measures of dispersion etc. were calculated as described by Snedecor (1956).

RESULTS

I. AGE AT FIRST CALVING

Fig. 2 shows the frequency distribution of 262 ages at first calving grouped in class-intervals of six months. Skewness in the distribution is pronounced. The modal class was 48-54 months and about 74 per cent of the cows calved between 36 and 54 months.

Average age at first calving from 262 *Hariana* females at Indian Veterinary Research Institute was 50.0 months with its standard error and coefficient of variation of 0.5 month and 17.3 per cent respectively.

Components of Variation and Heritability of Age at First Calving

Analysis of variance for age at first calving has been presented in Table 7.

Out of the total variation in age at first calving 21.5 per cent was associated with period to period differences which were significant at 1 per cent level. Differences amongst sires within period were statistically not significant and they explained only 5.3 per cent of total variance in this character.

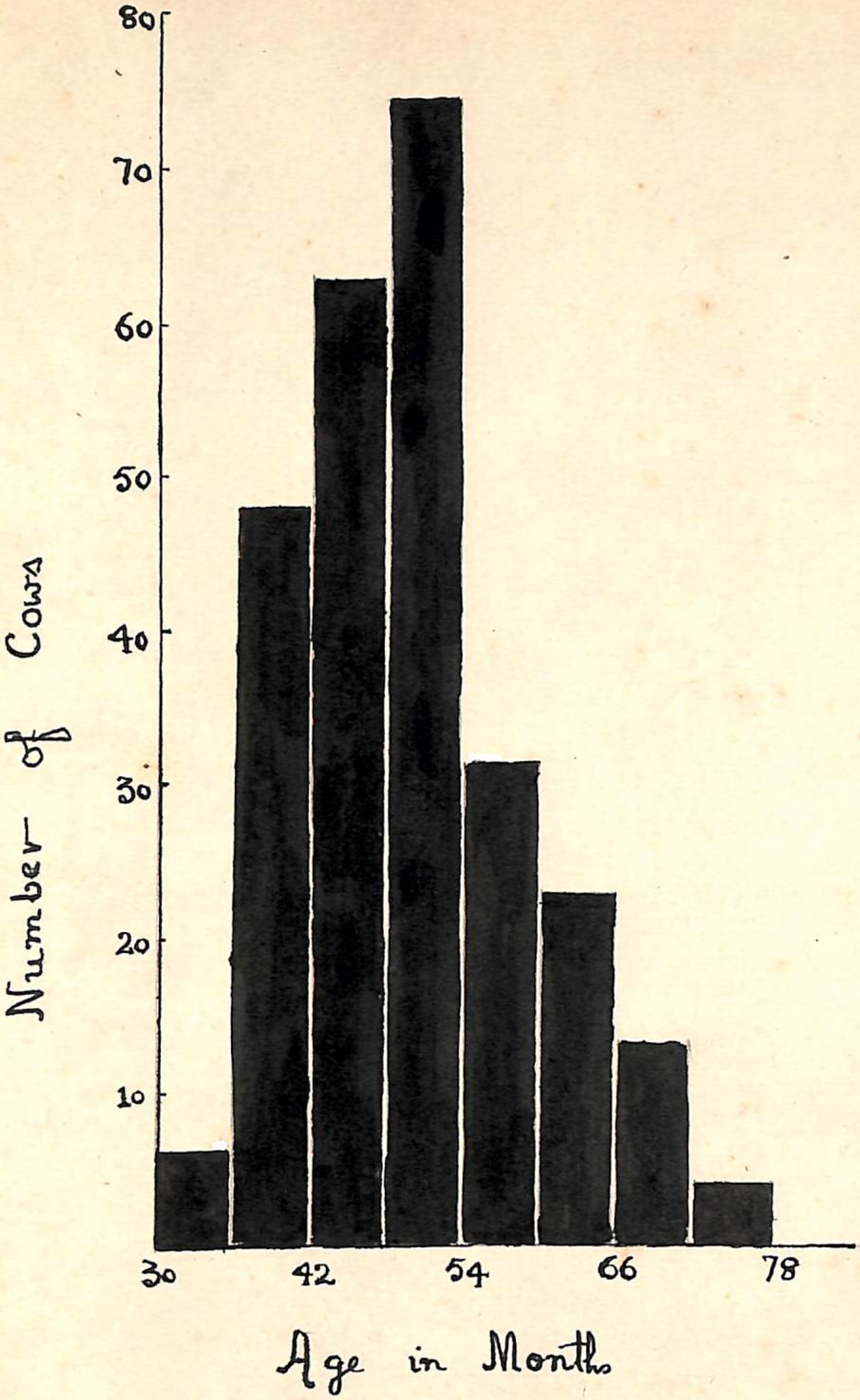

Fig. 2 DISTRIBUTION OF AGE AT FIRST CALVING IN HARIANA COWS AT I.V.R.I.

Heritability estimate of age at first calving calculated by intraclass correlation among paternal half-sibs was 0.30 ± 0.27. It was also calculated by intra-sire regression of daughters on dams, using 166 daughter-dam pairs and the estimate came to 0.24 ± 0.16. Statistically both these estimates were non-significant.

II. OPEN PERIOD

Frequency distributions of the first open period and that of the remaining ones, second to the fifth, are presented in Fig. 3. Both the distributions were skewed on the right side. First open period in about 77 per cent of the cows was less than 140 days while corresponding percentage of the cows for remainder of the open periods was 88 per cent.

Averages of the open periods following first to fifth calvings along with their standard errors and coefficients of variation are presented in Table 8.

Average open period was of the order of 90 days. It decreased upto the third open period and thereafter it increased.

Table 7

Analysis of Variance of Age at First Calving of Harianas at I.V.R.I.

Source of variation	d.f.	M.Sq.	E.M.S.	F	Components of variance as % of the total
Between periods	2	1251.50	$\sigma^2_e + 12.67\ \sigma^2_S + 44.98\ \sigma^2_P$	8.78**	21.5
Between sires within period	12	142.45	$\sigma^2_e + 9.17\ \sigma^2_S$	1.75	5.0
Within sires within period (Among paternal half-sibs in a period)	133	81.38	σ^2_e		73.5

$$\sigma^2_P = 24.14$$
$$\sigma^2_S = 6.65$$
$$\sigma^2_e = 81.38$$
$$h^2 = 0.30 \pm 0.27$$

** Probability less than 1%

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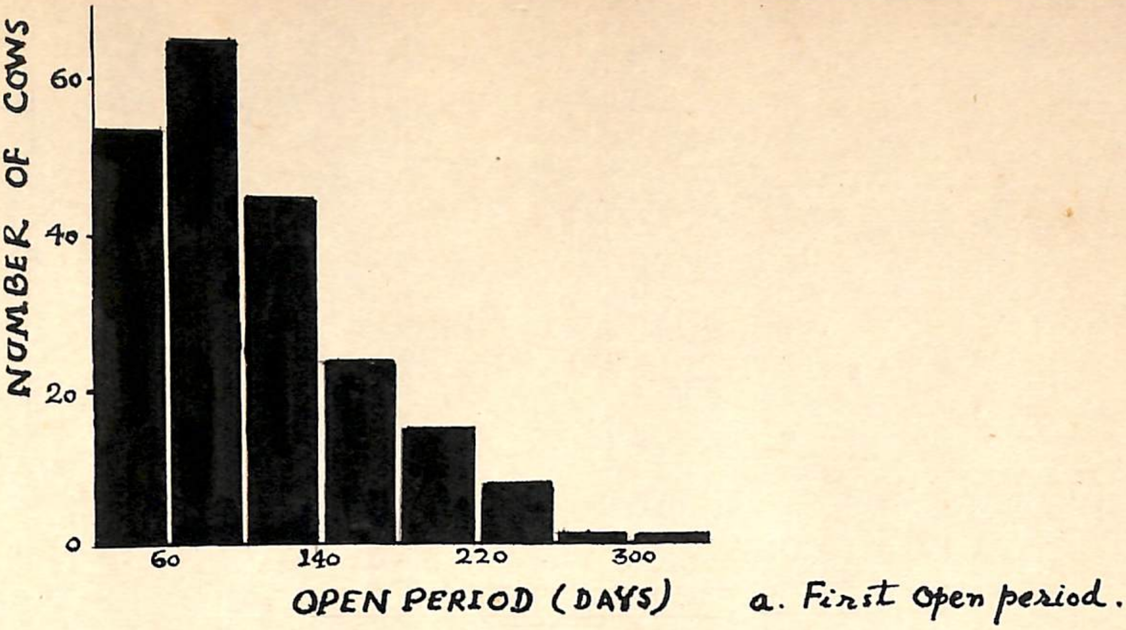


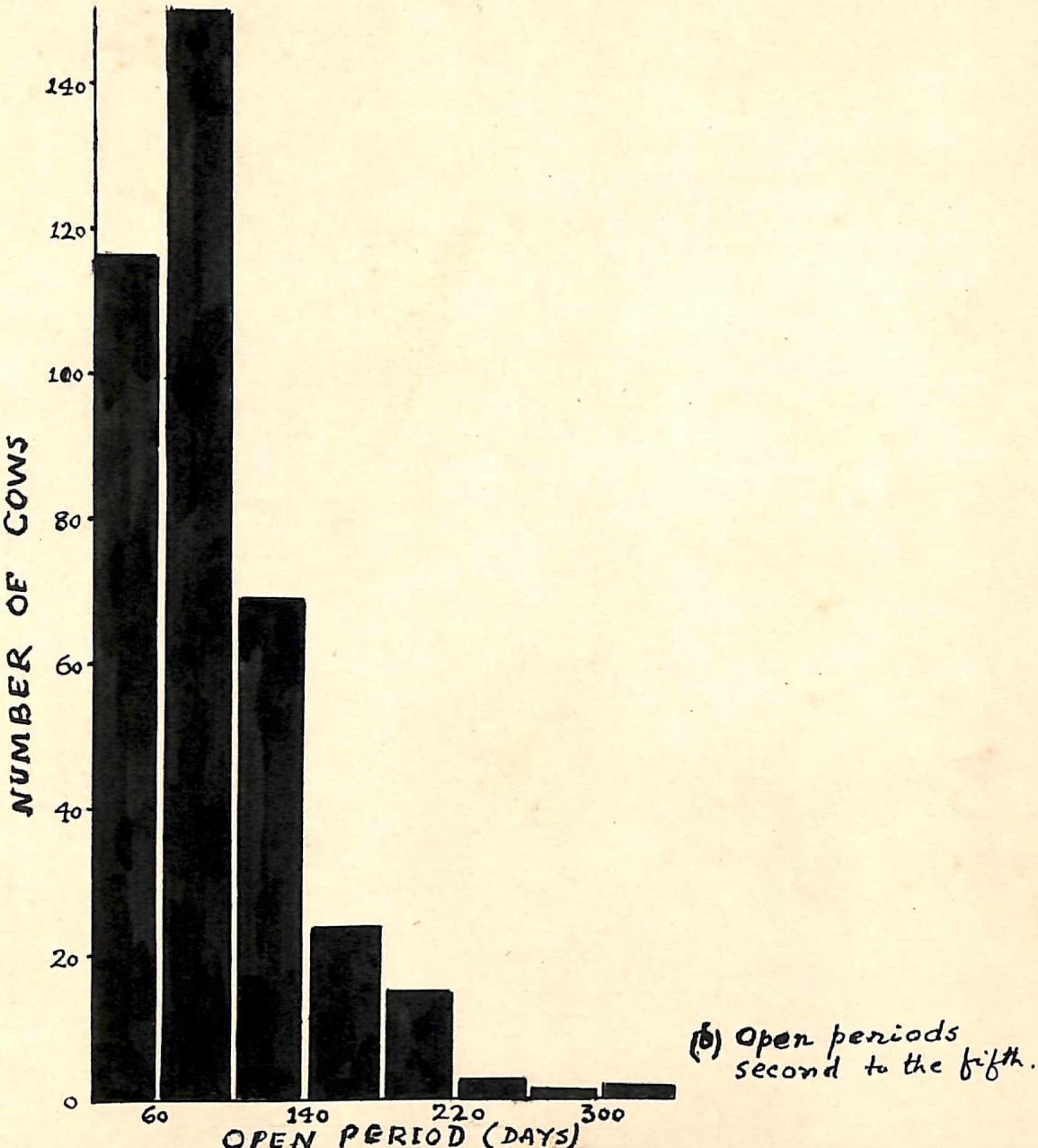


Fig 3. DISTRIBUTION OF OPEN PERIODS IN HARIANA COWS AT I.V.R.I.

Table 8

Averages, Standard Errors and Coefficients of Variation of Open Periods of Hariana Females at I.V.R.I.

Sequence	Number of observations	Arithmetic average (days)	Standard error (days)	Coefficient of variation %
I	194	105	4	54
II	149	92	4	56
III	96	81	4	51
IV	64	91	6	50
V	37	86	6	45

These differences were highly significant statistically as shown by analysis of variance in Table 9.

Table 9

Analysis of Variance of Open Periods

Source of variation	d.f.	M.Sq.	F
Between open periods	4	10147.90	3.99**
Within period	535	2538.31	

**Probability less than 1%

Components of Variation, Heritability and Repeatability Estimates

As large enough numbers were available only for the first open period, they were further analysed and results are shown in Table 10.

Heritability of first open period was thus estimated as 0.10. Only 2.6 per cent of the total variation was attributable to differences amongst sires. Period to period differences were even less important, accounting for only 0.9% of the total variation. These components were not significant.

Data on first five open periods from 198 cows as analysed have been presented in Table 11. The repeatability of this character was 0.18 being significant at 1 per cent level.

Table 10

Analysis of Variance of First Open Periods of Hariana Females at I.V.R.I.

Source of variation	d.f.	M.Sq.	E.M.S.	F	Components of variance as % of the total
Between periods	2	10024.27	$\sigma^2_e + 15.21\,\sigma^2_S + 49.00\,\sigma^2_P$	1.44	0.9
Between sires within period	12	6950.11	$\sigma^2_e + 10.84\,\sigma^2_S$	1.28	2.6
Within sire within period (Among paternal half-sibs in a period)	160	5402.39	σ^2_e		96.6

$\sigma^2_P = 50.00$

$\sigma^2_S = 142.77$

$\sigma^2_e = 5402.39$

$h^2 = 0.10 \pm 0.17$

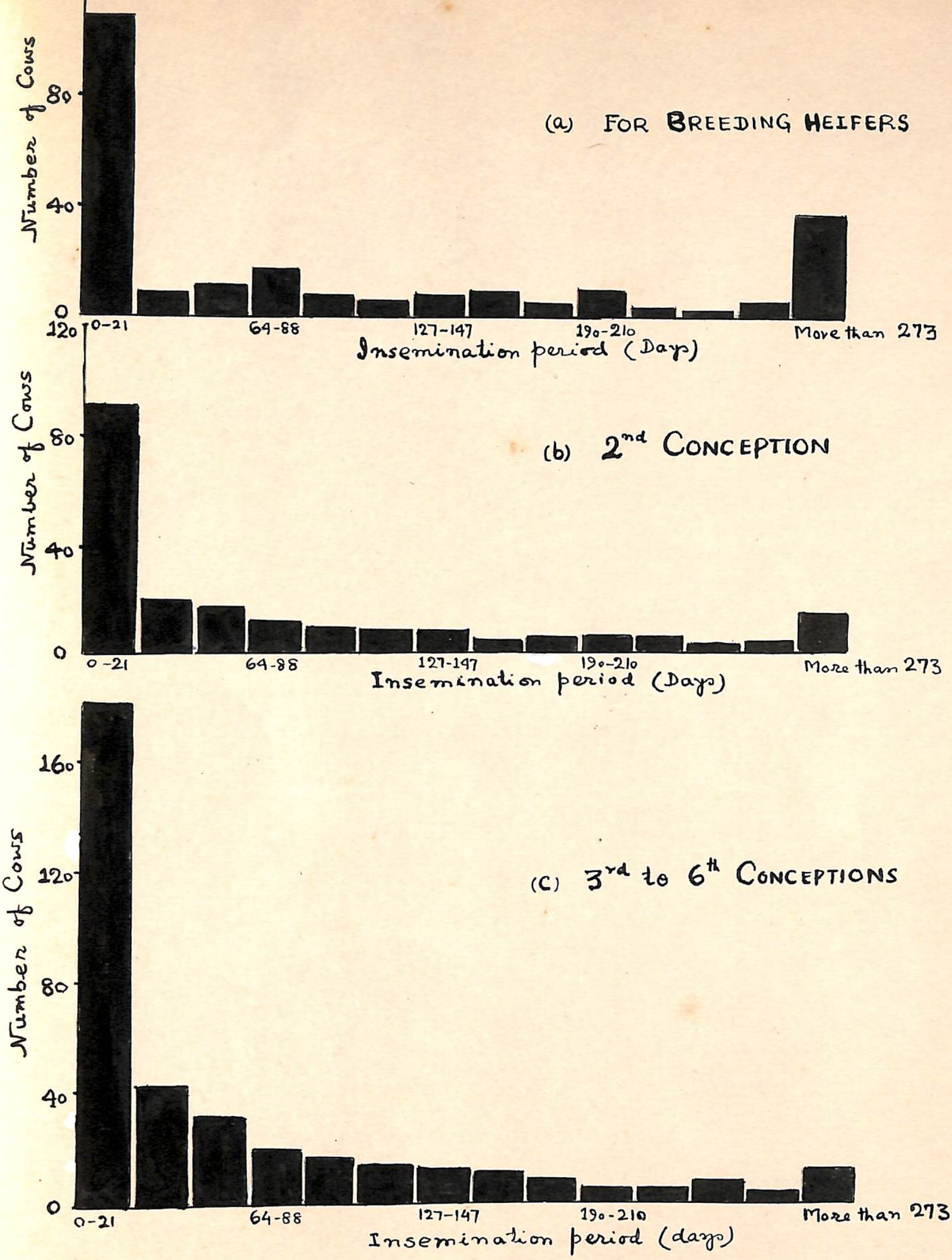


FIG. 4 DISTRIBUTION OF INSEMINATION PERIODS OF HARIANAS AT I.V.R.I.

and of cows in their first to the fifth calvings have been presented in Table 12 along with corresponding standard errors and coefficients of variation.

Table 12

Averages, Standard Errors and Coefficients of Variation of Insemination Periods of Harianas at I.V.R.I.

Order	Number of observations	Arithmetic average (days)	Standard error (days)	Coefficient of variation %
Breeding Heifers	233	105	10	139
After first calf	198	72	6	126
After second calf	149	54	7	155
After third calf	100	64	10	149
After fourth calf	68	58	10	135
After fifth calf	38	39	9	134

Insemination period was longest in breeding heifers. It declined sharply until after the second calf and then it increased slightly. In comparison with other measures of reproductive efficiency, this character was much more variable. The coefficient of variation was more than 100 per cent in each of the six periods. The differences among average insemination periods of cows were not significant statistically. However the heifers had significantly long insemination periods as shown in Table 13.

Table 13

Analysis of Variance of Insemination Periods

Source of variation	d.f.	M.Sq.	F
Breeding heifers Vs. cows	1	307998.00	24.32**
Among periods within cows	4	12662.74	1.09
Within period	780	11656.47	

** Probability less than 1%

Components of Variation, Heritability and Repeatability Estimates

Insemination periods after the first calf were used to estimate heritability. It was estimated as 0.04 using intra-class correlation among paternal half-sibs. Pertinent information for its calculation is presented in Table 14.

Table 14

Analysis of Variance of Insemination Periods following First Calving of Harianas at I.V.R.I.

Source of variation	d.f.	M.Sq.	E.M.S.	F	Components of variance as % of the total
Between periods	2	2374.34	$\sigma^2_e + 15.46\ \sigma^2_S + 48.93\ \sigma^2_P$	< 1	0
Between sires within period	12	9732.07	$\sigma^2_e + 10.73\ \sigma^2_S$	1.09	0.9
Within sire within period (Among paternal half-sibs in a period)	159	8880.01	σ^2_e		99.1

$$\sigma^2_S = 79.40$$

$$\sigma^2_e = 8880.01$$

$$h^2 = 0.04 \pm 0.15$$

The differences among periods were absent and only 0.9 per cent of the total variation in the insemination period following first calf could be accounted by differences among sires, as is shown in Table 14.

Repeatability of insemination period for first to fifth calvings from 199 cows was estimated as 0.09 being significant at $P < .05$. This has been presented in Table 15.

Table 15

Analysis of Variance of Insemination Periods for Estimating Intra-Cow Repeatability

Source of variation	d.f.	M.Sq.	F	E.M.S.
Between cows	198	8755.61	1.28*	$\sigma^2_W + 2.77\ \sigma^2_b$
Within cows (error)	354	6835.72		σ^2_W

$$\sigma^2_b = 693.10$$
$$\sigma^2_W = 6835.72$$

Repeatability = 0.09

* Probability less than 5 per cent

IV. NUMBER OF SERVICES REQUIRED PER CONCEPTION

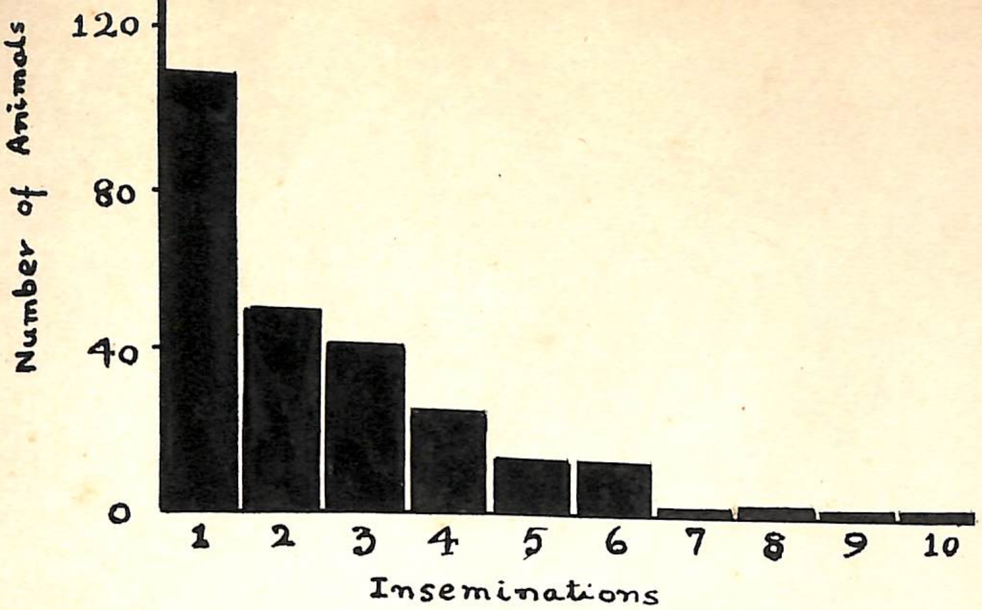
Frequency distributions of the number of inseminations required for conception in breeding heifers, for second conception and also for conceptions third to the sixth have been presented in Fig. 5. In all the three cases distribution was not normal. Percentage of animals conceived in four or less inseminations was 86, 83 and 89 for breeding heifers, second conception and conceptions third to the sixth respectively.

Average number of service required per conception along with its standard error and coefficient of variation is presented in Table 16.

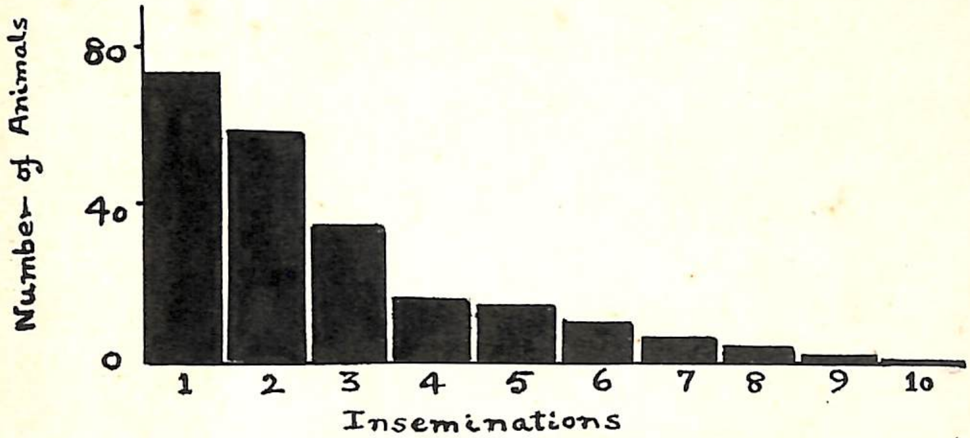
Table 16

Averages, Standard Errors and Coefficients of Variation of Number of Inseminations Per Conception of Hariana Females at I.V.R.I.

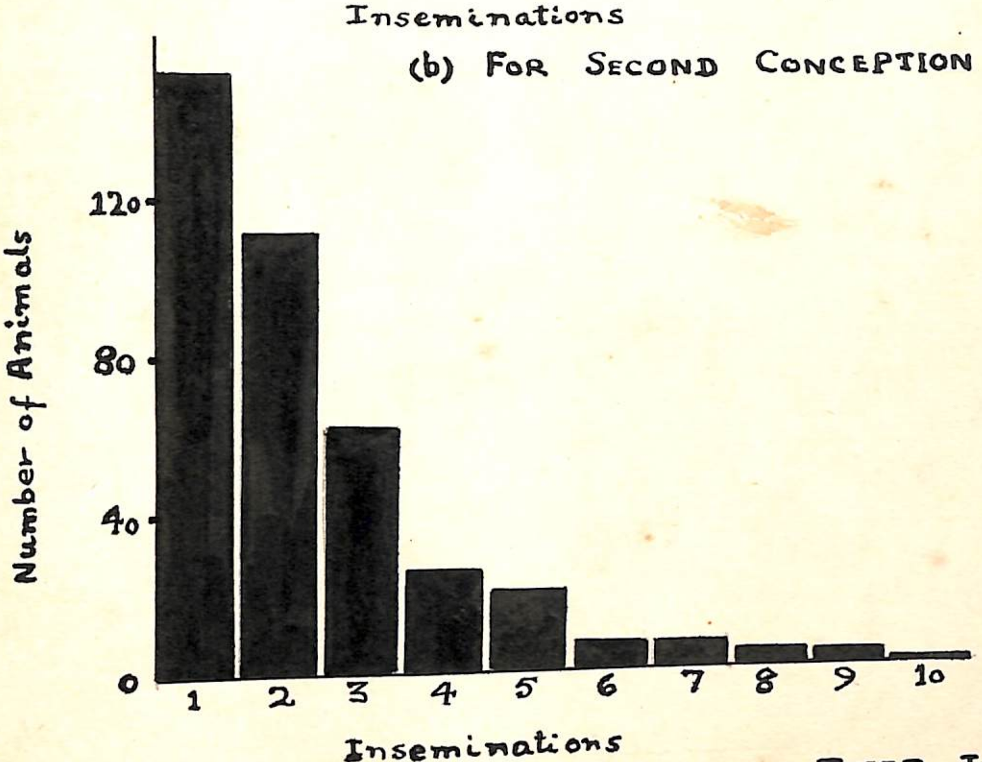
Sequence	Number of observations	Average	Standard error	Coefficient of variation %
Ist conception	239	2.73	0.14	79
IInd "	197	2.59	0.16	70
IIIrd "	145	2.13	0.11	62
IVth "	101	2.60	0.20	78
Vth "	70	2.42	0.20	71
VIth "	38	2.28	0.26	71



(a) For Breeding Heifers



(b) For Second Conception



(c) For Conceptions Third to the Sixth.

Fig 5. DISTRIBUTION OF NUMBER OF SERVICES REQUIRED PER CONCEPTION IN HARIANA COWS AT I.V.R.I.

Heifers took the maximum number of inseminations to conceive. As the calving sequence advanced the cows showed a tendency to conceive with fewer inseminations. Smallest number of inseminations were taken to conceive by cows in their third reproductive cycle. However these differences were statistically not significant as shown in Table 17.

Table 17

Analysis of Variance of Number of Inseminations Per Conception for Hariana Females at I.V.R.I.

Source of variation	d.f.	M.Sq.	F
Between conceptions	5	7.49	2.12
Within conceptions	784	3.52	

Components of Variation, Heritability and Repeatability Estimates

Analysis of variance of number of services required per conception after first calving has been presented in Table 18.

Heritability of this character was estimated as 0.13 using intra-class correlation among the paternal half-sibs. Most of the variation exhibited in this character was attributable to environmental factors. Variation due to periods was not detected and sire differences contributed only 3.1 per cent of the total variation.

On the basis of analysis shown in Table 19 repeatability of number of services per conception was estimated at 0.19 and it was statistically significant at $P < 0.01$.

Table 19

Analysis of Variance of Number of Inseminations Per Conception for Estimating Intra-Cow Repeatability

Source of variation	d.f.	M.Sq.	F	E.M.S.
Between cows	239	4.92	1.65**	$\sigma^2_w + 2.83\ \sigma^2_b$
Within cows	442	2.97		σ^2_w

$\sigma^2_b = 0.689$

$\sigma^2_w = 2.97$

Repeatability = 0.19

** Probability less than 1 per cent

V. CALVING INTERVAL

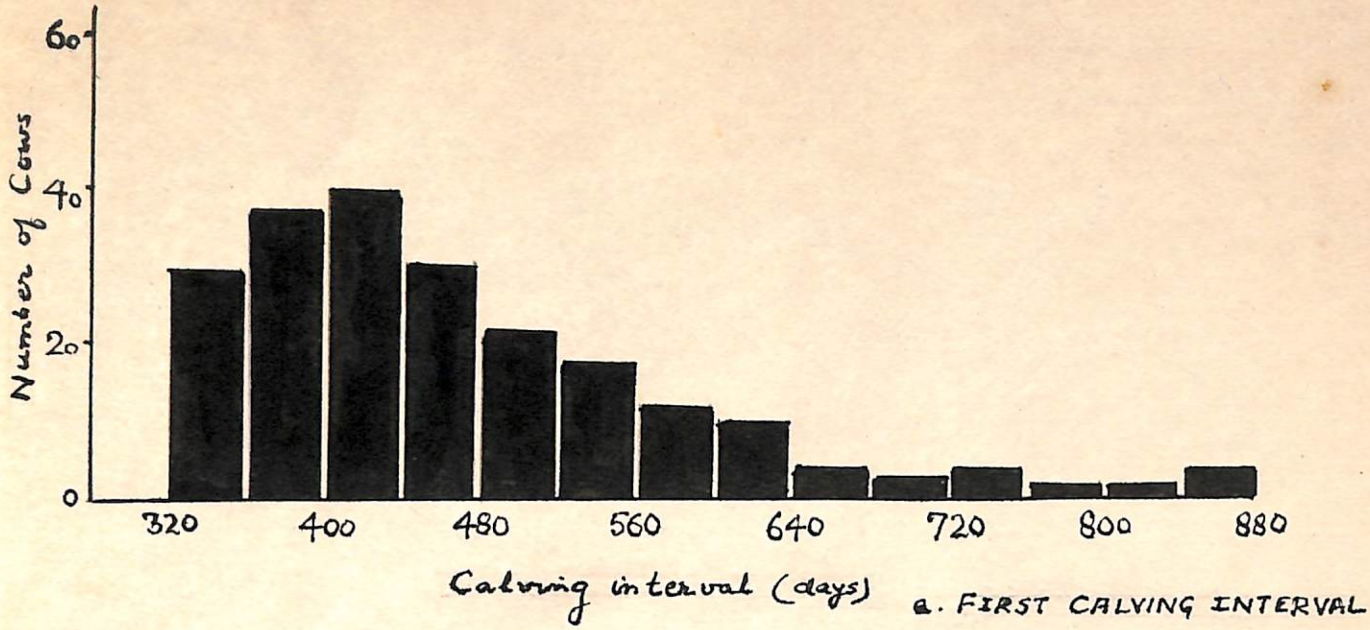
Frequency distribution of first calving interval and that for intervals second to the fifth combined are presented in Fig. 6. Skewness in the distribution is pronounced on the right side. The modal class was 400-440 days for first calving interval and 360-400 days for the remaining intervals. First calving intervals, in about two third of the cows were between 320-480 days and in remaining intervals 78 per cent of the cows calved before 480 days.

The averages along with their standard errors and coefficients of variations are presented in Table 20.

Table 20

Averages, Standard Errors and Coefficients of Variation for First to Fifth Calving Intervals of Harianas at I.V.R.I.

Sequence	Number of observations	Arithmetic average (days)	Standard error (days)	Coefficient of variation %
I	194	467	8	24
II	142	428	8	21
III	90	443	13	27
IV	59	437	13	23
V	35	399	9	13



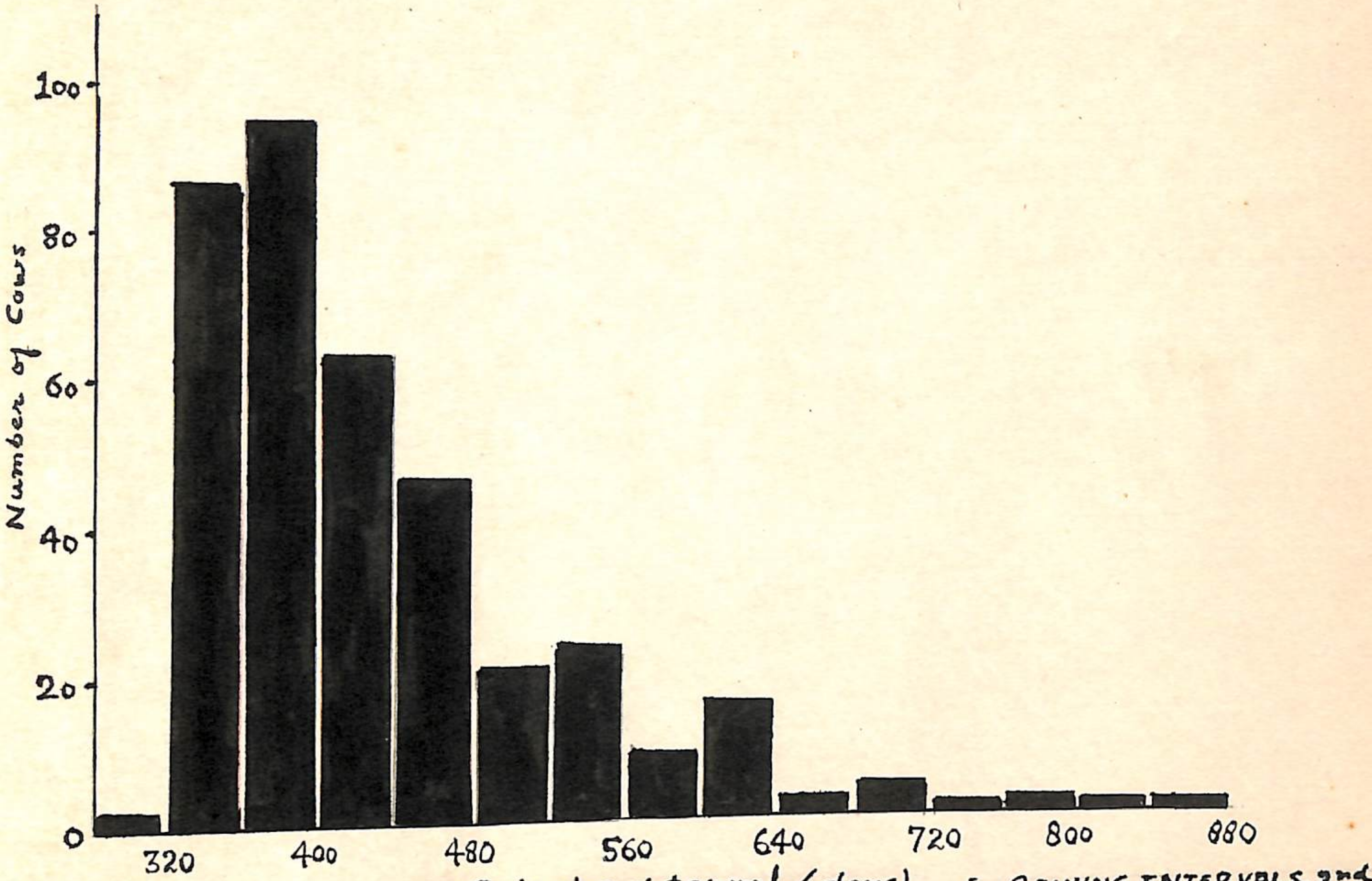


FIG. 6. DISTRIBUTION OF CALVING INTERVALS OF HARIANAS AT I.V.R.I.

Average of calving intervals was 444 days (i.e. close to 15 months). There was a gradual decrease in these from the first to the fifth calving, with the exception of the second which became unusually small. The analysis of variance for this character has been presented in Table 21.

Table 21

Analysis of Variance of Calving Intervals

Source of variation	d.f.	M.Sq.	F
Between calving intervals	4	52565.07	4.85**
Within calving interval	515	10834.34	

** Probability less than 1 per cent

The difference in the length of intervals between successive calving was highly significant.

Components of Variation, Heritability and Repeatability Estimates

As large number of observations existed for first calving interval, heritability of this character was estimated by paternal half-sib correlation and it was found to be 0.0006 ± 0.13. Pertinent information for its calculation is given in Table 22.

Table 22

Analysis of Variance of First Calving Interval of Harianas at I.V.R.I.

Source of variation	d.f.	M.Sq.	E.M.S.	F	Components of variance as % of the total
Between periods	2	1956.73	$\sigma^2_e + 16.12\ \sigma^2_S + 50.07\ \sigma^2_P$	< 1	0
Between sires within period	12	16837.04	$\sigma^2_e + 10.75\ \sigma^2_S$	1.00	0.02
Within sire within period (Among paternal half-sibs in a period)	161	16807.90	σ^2_e		99.98

$$\sigma^2_S = 2.71$$

$$\sigma^2_e = 16807.90$$

$$h^2 = 0.0006 \pm 0.1350$$

Only 0.02 per cent of the total variance was accountable by sire to sire differences. Variation due to periods was also negligible.

Repeatability was estimated by including first to the fifth calving intervals from 196 cows. The estimate was 0.03 as given in Table 23.

Table 23

Analysis of Variance of Calving Intervals for Estimating Intra-Cow Repeatability

Source of variation	d.f.	M.Sq.	F	E.M.S.
Between cows	195	11771.21	1.09	$\sigma^2_w + 2.64\ \sigma^2_b$
Within cows	324	10785.68		σ^2_w

$$\sigma^2_b = 373.70$$

$$\sigma^2_w = 10785.68$$

Repeatability = 0.03

The season at the time of first calving did not show marked difference in these animals as assessed by a frequency distribution among months.

VI. NUMBER OF HEATS MISSED

Averages, standard errors and coefficients of variation of number of heats missed by cows in their insemination periods are presented in Table 24. Maximum number of heats were missed during the insemination period of breeding heifers. This character was the most variable one as shown by the coefficient of variation.

Table 24

Averages, Standard Errors and Coefficients of Variation of Number of Heats Missed in Different Insemination Periods of Harianas at I.V.R.I.

Order	Number of observations	Arithmetic average	Standard error	Coefficient of variation %
Breeding Heifers	235	3.29	0.41	189
After First calf	197	1.95	0.22	158
After Second calf	147	1.27	0.20	189
After Third calf	98	1.56	0.31	194
After Fourth calf	70	1.48	0.28	161
After Fifth calf	38	0.74	0.12	201

The differences among average heats missed in different conceptions of cows were not significant statistically. However heifers missed significantly more heats as shown in Table 25.

Table 25

Analysis of Variance of Heats Missed

Source of variation	d.f.	M.Sq.	F
Breeding heifers Vs. cows	1	494.52	28.97**
Among conceptions within cows	4	17.07	1.16
Within conceptions	779	14.65	

** Probability less than 1 per cent

Component of Variances, Heritability and Repeatability Estimates

The magnitudes of different components of variation for number of heat missed by *Hariana* cows have been presented in Table 26.

Variation from period to period in this character was not present and only 5.7 per cent of the total variation could be attributed to sire differences. Using intra-class correlation among the paternal half-sibs the heritability was thus calculated as 0.23 ± 0.22.

Table 26

Analysis of Variance of Number of Heats Missed in the Insemination Period After First Calf of Harianas at I.V.R.I.

Source of variation	d.f.	M.Sq.	E.M.S.	F	Components of variance as % of the total
Between periods	2	1.15	$\sigma^2_e + 15.45\,\sigma^2_S + 48.64\,\sigma^2_P$	< 1	0
Between sires within period	12	15.76	$\sigma^2_e + 10.89\,\sigma^2_S$	1.65	5.7
Within sire within period (Among paternal half-sibs in a period)	161	9.50	σ^2_e		94.3

$$\sigma^2_S = 0.57$$

$$\sigma^2_e = 9.50$$

$$h^2 = 0.23 \pm 0.22$$

Repeatability of number of heats missed upto fourth calving from 197 cows with 442 records was estimated at 0.11 and was statistically non-significant as shown in Table 27.

Table 27

Analysis of Variance of Number of Heats Missed for Estimating Intra-Cow Repeatability in Hariana Females

Source of variation	d.f.	M.Sq.	F	E.M.S.
Between cows	196	9.46	1.27	$\sigma^2_w + 2.24\ \sigma^2_b$
Within cows	245	7.43		σ^2_w

$$\sigma^2_b = 0.906$$

$$\sigma^2_w = 7.43$$

Repeatability = 0.11

Phenotypic and Genetic Relationships Among Different Measures of Reproductive Efficiency

Phenotypic correlation coefficients between pairs of different measures of reproductive efficiency as also with milk production are presented in Table 28.

Table 28

Estimates of Coefficient of Phenotypic Correlation Between Pairs of Certain Measures of Reproductive Efficiency in Hariana Females at I.V.R.I.

Trait	First calving interval	First open period	Insemination period after first calf	No. of inseminations upto conception after first calf	Number of heats missed after first calf	First lactational yield in 301 days
Age at first calving	-0.147	0.053	-0.104	0.004	-0.105	0.049
First calving interval		0.581**	0.466**	0.496**	0.495**	0.343**
First open period			-0.130	-0.156	-0.090	0.104
Insemination period after first calf				0.738**	0.868**	0.251**
Number of inseminations upto conception after first calf					0.506**	0.202*
Number of heats missed after first calf						0.225*

** Probability less than 1 per cent
* Probability less than 5 per cent

The scatter diagram as given in Fig. 7 showed that the relationship between the first lactational yield and first calving interval was curvilinear. A second degree polynomial was fitted to these data (Snedecor, 1956). The departure of this fit from linearity was statistically significant at $P < 0.01$ as shown in Table 29.

<u>Table 29</u>

Test of Significance of Departure from Linear Regression

Source of variation	d.f.	S.Sq.	M.Sq.
Deviation from linear regression	162	26585269.39	
Deviation from curvilinear regression	161	24216628.96	150413.84
Curvilinearity of regression	1	2368640.43	2368640.43

$$F = \frac{2368640.43}{150413.84} = 15.74^{**}$$

** Probability less than 1 per cent

The following regression equation was obtained :

$$Y = -1522.85 + 8.059\,X - 0.00631\,X^2$$

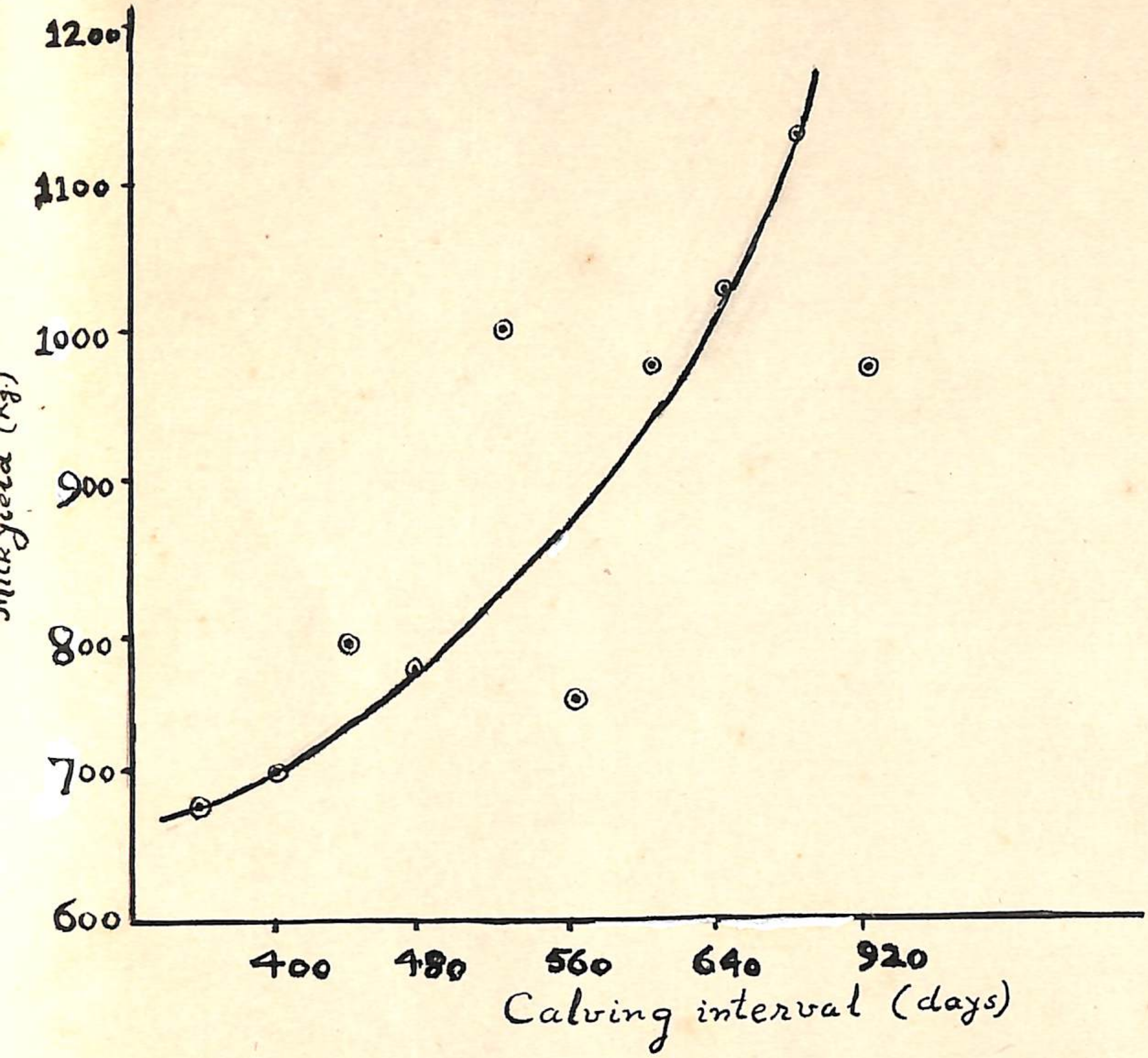


Fig. 7 JOINT DISTRIBUTION OF FIRST LACTATION-AL YIELD AND FIRST CALVING INTERVAL IN HARIANAS AT I.V.R.I.

Where X = Calving interval in days

Y = Lactational yield of 301 days in kilograms

All the phenotypic correlation coefficients between first calving interval and the other measures of reproductive efficiency as also with first lactational yield were positive and highly significant at 1 per cent level of probability with the only exception of the correlation coefficient between age at first calving and first calving interval which was negative and statistically non-significant. Highly significant positive correlation coefficients were also observed between insemination period after first calf and number of services per conception, number of heats missed as also with first lactational yield. Correlation coefficients between number of services per conception after first calf and first lactational yield as also with number of heats missed were positive and statistically significant. Correlation coefficient between number of heats missed and first lactational yield was also statistically significant. Rest of the phenotypic relationships were statistically non-significant.

Genetic relationships between different measures of reproductive efficiency are presented in Table 30.

Table 30

Estimates of Coefficient of Genetic Correlation Between Pairs of Certain Measures of Reproductive Efficiency in Hariana Females at I.V.R.I.

Trait	First calving interval	First open period	Insemination period after first calf	Number of inseminations upto conception after first calf	Number of heats missed after first calf	First lactational yield in 301 days
Age at first calving	2.150	2.140	0.145	0.984	0.663	0.347
First calving interval		0.773	1.020	1.220	0.126	0.804
First open period			-0.270	0.190	-0.647	1.300
Insemination period after first calf				0.575	1.110	0.822
Number of inseminations upto conception after first calf					0.690	-0.065
Number of heats missed after first calf						-0.358

All the genetic correlation coefficients were positive except the correlation coefficients between first open period and insemination period after first calf as also with number of heats missed which were found to be negative. Genetic relationships between first lactational yield of 301 days and number of insemination required after first calf as also with number of heats missed were also negative. Most of the correlation coefficients were of high magnitude and some of these even exceeded unity. These correlations showed that there exists genetic relationship between these measures of reproductive efficiency though the magnitude is variable.

DISCUSSION

I. AGE AT FIRST CALVING

Age at first breeding is the earliest measure of reproductive efficiency in dairy cattle though only after first calving productive cycle commences in them. Age at first calving is closely related to generation interval and thus to progress due to selection.

Average age at first calving in *Hariana* cows at Indian Veterinary Research Institute was 50.0 ± 0.5 months. This is in agreement with the findings of Ahmad (1961) and of Chandiramani *et al* (1959) who reported it in the same herd as 47.8 and 45.0 months respectively. Average age at first calving in other herds of *Hariana* cows ranged between 43.2 and 50.0 months (Johri and Talpatra, 1956; Singh, 1959 and Singh and Desai, 1961) except at Hissar farm where cows delivered their first calf at the age of 59.3 months.

Age at first calving of *Harianas* is more than that of cattle from temperate regions who first calve from 27 to 33 months (Turner, 1932; Chapman, 1940; Johonsson and Hansson, 1941 and Bonomi, 1957). There are herd as well as breed differences in this character. Heritability of age at first calving calculated in this study, using intra-class correlation among paternal half-sibs, was 0.30 ± 0.27. It was 0.24 ± 0.16 when estimated by intra-sire regression of daughters on dams. These estimates indicate that some improvement in the character can be made by selection. Ahmad (1961) reported heritability of age at first calving in the same herd as 0.37. The difference between these two estimates from the same herd at different times may be an expression of large sampling errors or it may indicate varying managemental practices or other environmental fluctuations.

Conception rate at first service in breeding heifers was found to be 40 per cent in this study while Luktuke and Subramaniam (1961) found it to be 38 per cent for Hariana heifers.

Phenotypic and genetic correlations between age at first calving and each of the other measures of reproductive efficiency as also with milk production were presented in Tables 28 and 30. All the phenotypic correlation coefficients were non-significant, the ones between age at first calving and, first calving interval, insemination period and number of heats missed were negative and the others positive.

Ragab *et al* (1954) in Egyptian cows, Singh and Desai (1961) in Hariana, Singh and Choudhury (1961) in Sahiwal and Tharparkar, Puri and Sharma (1965) in Red Sindhi and crossbreds and Singh and Sundaresan (1966) in _Tharparkar_ did not observe any significant relationship between age at first calving and first lactational yield as was the finding in this study. On the contrary Amble and Krishnan (1960), Kohli _et al_ (1961), Alim (1962) and Puri and Sharma (1965) observed a significant linear relationship between first lactational yield and age at first calving.

Relationship between age at first calving and first calving interval was non-significant in this study which is in agreement with the findings of Rognoni and Pasti (1955), Singh and Sinha (1960), Singh and Choudhury (1961) and Singh and Sundaresan (1966). However, Venkayya and Anantakrishnan (1956) in _Red Sindhi_ and _Red Sindhi_ x _Ayrshire_ crosses and Kohli _et al_ (1961) in _Hariana_ cows found a significant linear relationship between these two variables.

No significant relationship could be assessed between age at first calving and milk production or with reproductivity. Measures to reduce the age at first calving would not cause any deleterious effect on lactational yields or on reproductivity of the cows. The magnitude of variability of this character and the estimate of heritability obtained indicate some room for genetic improvement in it. In addition managemental or environmental improvements might also yield encouraging results.

II. <u>OPEN PERIOD</u>

Average open period for all the calvings in this study was found to be 94 days while after first calving it was 105 ± 4 days. Kohli and Suri in 1960 in their study on open period of *Hariana* cows reported an excessively long average interval of 230 days.

A gradual continuous fall was apparent in the open periods following successive calvings indicating that reproductive efficiency increased with the increase in age of the cow. Effect of calving sequence on open period was statistically significant at one per cent. Herman and Edmondson (1950) had also reported that open period was influenced by the age of the cow and by her lactation number.

Effect of period of years and of sires was not found to be significant and these contributed only 0.9 and 2.6 per cent to the total variance of the character.

Low estimate of heritability (0.10) of open period in this study is similar to that reported by Carman (1955) and Rognoni and Betta (1960). Selection of good sires or dams will, therefore, not cause a rapid improvement in this character but, management could play a major role. The estimate of repeatability of open period was 0.18, being statistically significant at P less than five per cent. Carman in 1955 had reported, for two herds studied by him, repeatability estimates of 0.15 and 0.27. In comparison to these, estimates obtained by Olds and Seath (1953) and Rognoni and Betta (1960) were high, being 0.29 and 0.47 respectively.

A positive phenotypic correlation coefficient significant at one per cent level was found between first calving interval and first open period. The relationship is spurious as open period is one of the components of calving interval.

Negative phenotypic correlation between open period and insemination period and also with number of services per conception indicated that as open period increased the other two measures decreased. The coefficient of linear regression of services per conception on open period was -0.0043 service per day indicating that an increase of one hundred days in the open period would decrease the services per conception by only 0.43. Everett _et al_ (1966) reported a decrease of 0.17 service per conception for every hundred days increase in the open period while Touchberry _et al_ (1959) showed that partial regression of services per conception on open period was as high as 0.50 for each hundred days increase in the open period. Trimberger (1954) also found that services per conception decreased as the open period increased.

The coefficient of linear regression of insemination period on open period was 0.17 indicating that one hundred day's increase in the open period would decrease the insemination period by 17 days only.

A positive but non-significant correlation coefficient was found between open period and current milk production in first lactation which is similar to the findings of Herman and Edmondson (1950). Everett *et al* (1966) reported insignificant negative relationship between 120 day's milk production and current open period. On the contrary Lewis and Horwood (1950), Olds and Seath (1953) and Pavuna (1960) all reported that open period was affected by current milk production.

III. INSEMINATION PERIOD

Similar to open period this period is an integral component of the calving interval.

Average insemination period for all the calvings studied was 75 days whereas the insemination period in breeding heifers was the longest, being 105 ± 10 days. A continuous decline took place in this character with successive calvings. The difference between first insemination period and others was statistically significant. Carman (1955) had reported insemination periods in two herds of Holstein-Friesian cows as 28 and 42 days respectively. Obviously these cattle were much more efficient in their breeding performance than are Indian cattle. There was some improvement in reproductive efficiency as age advanced as was indicated by this character. These findings do not agree with those of Lewis and Horwood (1950) and Carman (1955) who failed to observe an effect of age and parity on this character. This may be another expression of the genetic differences between *taurus* and *indicus* cattle in their reproductive efficiency.

Heritability of the insemination period was estimated as 0.04 ± 0.15. It indicated that most of the variation in the character is due to environment and that genetic improvement in it due to selection can not be much. Pou *et al* (1953), Carman (1955) and Lindley *et al* (1958) also reported very low heritability estimates for this character. Estimates of components of its variance showed that variation due to periods of years was not present in the insemination period and variation due to differences amongst sires accounted for only 0.9 per cent of the total variation.

Predictability of subsequent insemination periods on the basis of previous records can not be high as indicated by a low estimate of repeatability of the character. It was measured as 0.09. Repeatability estimates for this character reported by Pou _et al_ (1953) was 0.11 and it was 0.27 and 0.06 in the two herds of _Holstein-Friesians_ studied by Carman (1955).

A highly significant positive phenotypic coefficient of correlation equalling 0.738 was found between insemination period and the number of services per conception. This is automatic as both are measures of the same variable. Corresponding genetic relationship between these two measures was 0.575. Everett _et al_ (1966) had reported the phenotypic correlation coefficient between these two measures as 0.83 to 0.84.

A positive statistically significant phenotypic correlation coefficient of 0.251 was found between insemination period and milk production in the first lactation. Lewis and Horwood (1950) also reported a similar positive correlation between insemination period and current lactation production. Everett _et al_ (1966) on the other hand had observed a non-significant negative relationship between these two characters.

IV. NUMBER OF SERVICES PER CONCEPTION

Average number of services taken per conception for different calvings were presented in Table 16. It is evident from the table that breeding heifers took maximum services for conception, their average being 2.73 ± 0.14 whereas the average for all the calvings was 2.52. The number of services required in the third reproductive cycle was the lowest viz. 2.13. Cows at about that age showed maximum reproductive efficiency in terms of all the components studied. Number of services for fourth calving increased and afterwards again a gradual decline took place upto the sixth calving. These findings agree with those of Hilder et al (1944) and Detkens and Malik (1954) who also reported that heifers took more services for conception that did older or multiparous cows.

Gowen and Dove (1931), Morgan and Davis (1938) and Foot and Ridler (1949), however showed that younger cows took less services per conception than did older cows.

Estimates of components of variation indicated that period of years had negligible effect on the number of services required per conception. Differences among sires accounted for only 3.1 per cent of the total variation, thus indicating that the character is highly affected by environment.

Heritability of the number of services per conception was estimated as 0.13. Such a low estimate of heritability indicated that there was not much scope for improving this character by selection. Also future performance of a cow can not be predicted on the basis of her past performances in number of services per conception, as is indicated by its low repeatability estimate which was 0.19. Trimberger and Davis (1945), Tanabe and Casida (1949) and Olds et al (1949), Dunbar and Henderson (1953), Pou et al (1953), Legates (1954), Rognoni and Betta (1960) and Carman (1955) also reported low heritability and repeatability estimates for this character.

A positive, highly significant phenotypic correlation coefficient of 0.202 between number of services for second conception and milk production in first lactation was observed. It indicates that high yielders took more services for their second conception than was taken by low yielders. Genetic relationship was negative and small indicating that the two characters could be controlled by distinct sets of genes. Carman (1955) and Brochart (1966) had also reported positive significant relationships between current production and number of services per conception.

V. CALVING INTERVAL

Regularity of breeding and an optimal calving interval is an essential requirement for an economic dairy industry.

The average first calving interval in this study was 467 ± 8 days with a coefficient of variation of 24 per cent. These are close to the findings of Bhattacharya et al (1957), Dadlani et al (1959) and Ahmad (1961) who from the same herd reported it to be 444, 427 and 432 days respectively. Kohli and Suri (1957), Amble et al (1958) and Singh and Desai (1962) reported the average first calving intervals of 530, 501 and 450 days respectively for Hariana at Hissar and Mathura farms and in the villages.

There was a sharp fall in the second calving interval which averaged 428 days. The reason for this might be that having attained physical and productive maturity at that age, the cows showed maximum reproductive efficiency in their third cycle. The third interval, consequently, increased a little.

Calving intervals were found to be affected significantly ($P < 0.01$) by the sequence of calving. This agrees with the findings of Singh (1958) who also reported significant effect of the sequence on the calving intervals of Tharparkar cows.

Components of variation estimated in this study indicated that nearly all the variation in the character was due to non-genetic causes. Variation due to periods was not present. This is supported by the findings of Rennie (1952) whereas Brown *et al* (1954) and Singh (1958) had shown that year effect on calving interval was significant.

The heritability estimate of first calving interval was 0.0006 in this study which is not different from zero. Similar observations were also reported by Dunbar and Henderson (1953); Brown *et al* (1954); Legates (1954); Singh (1958); Amble *et al* (1958); Singh and Desai (1962); Ødegard (1965); Anderson (1966) and Rognoni *et al* (1966). Dadlani *et al* (1959) and Ahmad (1961) had reported estimates of heritability as 0.02 ± 0.45 and 0.22 ± 0.21 respectively for the same herd.

Low heritability estimate of this character indicates the absence of a large hereditary variance in it in this herd or presence of a much larger environmental component. Thus improvement in this character is not quickly possible with selection.

Even repeatability of this character was found to be low (0.03) indicating that prediction of future performance on the basis of previous or present calving interval is not likely to be dependable.

Highly significant positive phenotypic correlation coefficients were found between first calving interval and other measures of reproductive efficiency with the exception of age at first calving. These relationships measure the association of a part and its whole (as other characters actually make up the calving interval as was shown on page 4). These findings agree to those of Everett et al (1966) who also reported significant correlation coefficients between calving interval and its components e.g. open period, insemination period and number of services required per conception.

Genetic correlation coefficients between calving interval and its components were positive and high and in a few instances these exceeded unity possibly because genetic variances which go into the denominator and which are estimated by sire components were negligibly small. There is some indication that the genotypic relationships among these characters may not be zero since the covariance terms were all positive.

A highly significant positive phenotypic correlation coefficient was also found between first calving interval and first lactational yield. This is in agreement with the reports of Poly&Vissac(1958), Kohli et al (1961), Danasouri and Bayonmi (1963), Toeplitz (1965), Acharya (1966) in Hariana cows, Singh and Sundaresan (1966) and Horvath (1966).

Calving interval of Hariana females can be reduced primarily by improving managemental practices. The two important traits namely first calving interval and current lactational yield were significantly and positively correlated, therefore further investigation is warranted to ascertain the most economical length of the calving interval at which milk yield in current lactations as well as in the total lifetime could be maximized.

VI. NUMBER OF HEATS MISSED IN AN INSEMINATION PERIOD

Number of heats missed by cows during the insemination periods of different reproductive cycles are presented in Table 24. Breeding heifers missed maximum number of heats during their insemination period, this averaged to 3.29 ± 0.41. After the first calving, there was a decline in the number of heats missed followed by a small increase in the third and fourth lactations.

Heritability of this character was estimated as 0.23, indicating that among all the components that make up reproductive efficiency this is the only component which offers some promise of improvement due to selection. However future performance of a cow cannot be predicted on the basis of her past performances in number of heats missed as is indicated by its low estimate of repeatability which was 0.11.

Tandon (1958) reported that the number of heats missed in the Red Sindhi and its crosses with Jersey decreased as the Jersey blood increased upto fifty per cent and simultaneously other components of reproductivity also improved. From his results as well as those found presently it can be concluded that gene frequency of this character, as possibly of others making up reproductive efficiency, is low in Indian cattle and therefore genetic variance is low. It increased by crossing them with exotic breeds.

Combination of various components into a single index of breeding efficiency, as had been attempted by a number of authors, will cover up these detailed manifestations of each character which are important if Indian dairy cattle are to be improved.

On the basis of results obtained in this study, for improving reproductive efficiency of Hariana cattle, the following components deserve primary consideration :

a) Age at first calving.

b) Insemination period.

c) Number of heats missed.

Relationships of these with milk production needs to be examined in detail to ascertain the optimum levels for them at which lactational as well as lifetime milk productions could be maximized.

It deserves mention here that in the first and the last of these three measures, there is indication of existence of substantial genetic variability. Therefore attempts should be made to improve them by selection within breed and also within herd.

As *taurus* animals are much superior to *indicus* animals in various constituents of reproductive efficiency, fast and ultimate solution might be in utilization of genes from *taurus* groups. This will give rise to a larger genetic variability which could be exploited by the breeders. Until then selection between populations rather than within a population should be resorted to.

SUMMARY

This study was made on Hariana females maintained over a period of 22 years in the breeding herd of Indian Veterinary Research Institute, Izatnagar, U.P. Normal breeding and calving records of first six reproductive cycles from 262 Hariana cows, sired by 16 bulls, were used in the investigation. Totally they made up 553 lactational records. The measures of reproductive efficiency studied were :

(a) Age at first calving,
(b) Open period,
(c) Insemination period,
(d) Number of insemination per conception,
(e) Calving interval, and
(f) Number of heats missed in an insemination period.

The analysis was done within periods of years over which all the daughters of a bull were born. It was thus expected to minimise the confounding of the genetic and environmental differences.

I. (a) Age at First Calving

Average age at first calving in the herd was 50.0 ± 0.5 months with a coefficient of variation of 17 per cent. Its heritability was estimated as 0.30 ± 0.27 by intra-class correlation among paternal half-sibs and 0.24 ± 0.16 using intra-sire regression of daughters on dams. Both the

estimates were non-significant. Period to period differences accounted for 21.5 per cent of total variation. Differences amongst sires within period explained only 5.3 per cent of the variance. There is thus scope for genetic improvement by selection in this character.

(b) Open Period

Average open period was of 94 days while after first calving it was 105 ± 4 days. A gradual fall was apparent in the open periods after successive calvings. Differences among periods and those among sires within period were not significant. They contributed only 0.9 and 2.6 per cent to the total variation in the character. Heritability estimate of this character was low i.e. 0.10 ± 0.17 and repeatability was 0.18 so that selection could not make rapid improvement in this character.

(c) Insemination Period

Average insemination period was of 75 days and it was significantly longest among breeding heifers. Its coefficient of variation was more than 100 per cent. Period to period variation was not present and variation due to sires contributed only 0.9 per cent of the total variation. Heritability was 0.04 ± 0.15 while repeatability of this character was 0.09

indicating that most of the variation is non-genetic. Reproductive efficiency improved as age advanced, as was indicated by this character.

(d) Number of Services Per Conception

Breeding heifers took maximum services to conceive, average being 2.73 ± 0.14, whereas the overall average was 2.52. Minimum services viz. 2.13 were required for conception in the third reproductive cycle. Period to period variation was not present and sire differences accounted for only 3.1 per cent of the total variation. Heritability and repeatability estimates of this character were low being 0.13 ± 0.37 and 0.19, respectively. There is thus not much scope to improve this character by selection and future performance of a cow can also not be predicted on the basis of her past performances.

(e) Calving Interval

Average calving interval was 444 days i.e. nearly 15 months while first calving interval was 467 ± 8 days with a coefficient of variation of 24 per cent. Variation due to period of years was negligible and only 0.02 per cent of the total variation was due to differences amongst sires. Heritability estimate was 0.0006 ± 0.1350 and therefore this character can not be improved by selection. Repeatability of the character was 0.03 and calving intervals were affected significantly by the sequence of calving.

(f) <u>Number of Heats Missed</u>

Breeding heifers missed maximum number of services in their insemination periods, the average number being 3.29 ± 0.41. The heifers missed significantly larger number of heats in comparison to cows. This character was most variable amongst all those studied. There was a small decline in this character in the first and second calvers and the differences in heats missed among different insemination periods of cows were not significant statistically. Differences due to periods were also not present and sire differences accounted for only 5.7 per cent of the total variation. Heritability estimate of this character was 0.23 ± 0.22 which indicates that amongst all the components that make up reproductive efficiency, only number of heats missed offers some scope of improvement due to selection. Its repeatability was estimated at 0.11.

In terms of most of the components of reproductive efficiency maximum reproductive efficiency was attained around the third reproductive cycle.

II. Phenotypic and Genetic Relationships Between Pairs of Different Measures of Reproductive Efficiency as also With 301-days Milk Production in First Lactation

The phenotypic correlation coefficients between first calving interval and each of the other measures of reproductive efficiency as also with 301-days first lactational yield were positive and significant. Only the coefficient between first calving interval and age at first calving was negative and non-significant. Correlation coefficients between first insemination period and number of services for second conception, as also with heats missed after first calf, and with first lactational yield were all positive and statistically significant. Similarly phenotypic correlation coefficients between heats missed and number of services per conception and that with first lactational yield were positive and significant. The remaining ones were non-significant.

All the genetic coefficients between pairs of different measures of reproductive efficiency as also with 301-day's lactational yield have been presented in Table 30. All the correlation coefficients were positive except those between first open period and the first insemination period, as also with heats missed after first calf, and those between first lactational milk yields and number of services for second conception and with heats missed after first calf.

These were negative. Most of these coefficients were large and some of them even exceeded unity as sire components for some of these measures were extremely small. Nevertheless these relationships gave an indication that there seems to exist a genetic relationship between these measures.

Results of this study reveal that out of the different components studied, the following deserve special attention for improving reproductive efficiency of Hariana cattle :

(1) Age at first calving.
(2) Insemination period.
(3) Number of heats missed.

The first and last of these three measures could be improved by selection within breed and within herd. Detailed investigations are required to find out the optimum levels of the above three measures at which lactational as well as lifetime production are maximised.

For rapid improvement of reproductive efficiency of Indian cattle, *taurus* genes might need to be utilized to increase genetic variability in various components which could later be exploited by selection as the existing genetic variability is negligibly small.

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