THE INHERITANCE OF FERTILITY IN DAIRY CATTLE

by

ARLESS ASMAN SPIELMAN

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APPROVED:

[redacted]

Professor of Dairy Husbandry

In Charge of Major

[redacted]

Head of Department of Dairy Husbandry

[redacted]

Chairman of School Graduate Committee

[redacted]

Chairman of State College Graduate Council

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INTRODUCTION

In technical writings, as in the popular press, there is confusion regarding the exact biological connotation of the term "fertility". It is oftentimes used as identical and therefore interchangeable with "fecundity" and "prolificacy". A differentiation will be adhered to in this dissertation.

Fecundity designates the innate potential capacity of the individual to produce functional germ cells. In the female, fecundity will depend upon the production of ova, and in the male upon the production of spermatozoa.

Fertility is the ability to bring forth young when mated to the opposite sex. In popular usage, it usually refers to large numbers of young.

The number of young resulting from a given mating, or produced by an individual during its lifetime, is referred to as prolificacy. It is usually applied only to females or to groups such as herds and breeds.

Sterility is the negation of fertility. It denotes the inability to produce any young. Sterility is absolute. Fertility is relative, being either high or low.

Among dairy cattle, fertility is of prime importance, as continued milk production is dependent upon the regular functioning of the reproductive system. In general, a dairy cow that is a persistent producer of milk and progeny until she is ten years of age is about three times as profitable as one of equal production that lives until she is only six years of age. The first two years of a cow's life is a period of growth. On the average, it takes the second two years to pay for the investment in feed and care required during the period of growth. Thus the cow remaining in the herd until she is six years of age has only two years of profitable production as compared to six years for the cow living until she is ten years of age.

The pounds of milk per unit of feed eaten by a cow during her whole lifetime increase rapidly with the increasing length of her productive life. The cow that is a consistent milker until she is ten years of age produces approximately one-fourth more milk per feed unit than the cow that milks until she is six years of age.

If the average reproductive lifetime of a herd is six years, approximately 50 per cent of the heifer calves must be raised to maintain the herd. However, only 25 per cent of the heifers need be raised if the average reproductive lifetime of a herd is ten years.

In principle, the fertility of any individual is the net resultant of the interplay between its own innate biological make-up and the forces acting upon it. Nutrition, disease, management, and environment are, in general, the main factors which affect the expression of any degree of fertility, whether it be high or low.

HISTORICAL

Since a majority of the investigators of heredity in livestock have been concerned with the transmission of the more apparent economic factors such as milk, butterfat, wool and egg production, there is no great amount of literature available dealing with the inheritance of fertility. The bulk of this work has been done with animals other than dairy cattle, due partially to the ease of measurement and to the ease of experimentation.

Drosophila

Considerable evidence accumulated from breeding experiments indicates the residual effects of some Mendelian factors upon the fertility of the common fruit fly, *Drosophila*. Morgan (40) and co-workers have shown that the sex-linked factors for the rudimentary and fused-wing condition are practically always associated with sterility or low fertility. Males having the rudimentary wing are usually fertile, whereas the females showing this type of wing are complete sterile. In flies with the fused-wing condition, there is absolute sterility in the female sex, but fertility in the male sex. Examination of the ovaries of flies thus afflicted revealed that ovogenesis did not proceed normally.

Moenkhaus (38) bred wild strains of Drosophila ampelophila for seventy-five generations. He drew the conclusion that there is a wide divergence in the fertility and productiveness among the different pairs taken from nature, but by the proper selection and closest inbreeding these may readily be brought to either a high or low with respect to these characters.

Breeding experiments conducted by Castle and associates (2) with Drosophila demonstrate the inheritance of fertility. They concluded that low fertility in Drosophila is inherited after the manner of a Mendelian recessive character in certain crosses made, skipping a generation and then reappearing. Hence low fertility of the female may be transmitted directly through the egg from the mother to a daughter, but only indirectly through the sperm, the character skipping a generation.

Wentworth (53) obtained three lines of Drosophila which produced distinctly different average progenies per pair. By crossing the extreme lines he obtained an F_2 generation, which indicated that three pairs of genetic factors were responsible for the difference in fertility.

Rodents

The inheritance of fertility and sterility in mammals was the primary object of an intensive study made by Feldman (12) of the Bussey Institution, Harvard University. The Norway rat, *Mus norvegicus*, was employed in the investigations because of its adaptation to laboratory use. The criteria of reproductive power used were size of litter, promptness of matings, percentage of young born alive, and percentage of fertile matings. The results obtained indicated that the characters of growth and reproduction were extremely variable. There is no doubt that part of the differences between individuals were genetic in nature; however, it is obvious that they were influenced by factors which were not hereditary.

A type of low fertility or sterility in guinea pigs was the object of an investigation made by Van Lone (52) working at the Wisconsin Station. The females failed to come in heat. The sex organs of the males remained infantile and produced no sperm. When two normal animals carrying the trait were mated, all of the offspring appeared normal at birth, but about one-fourth of them later proved unable to breed. Van Lone concluded that a single recessive Mendelian factor was responsible.

The inheritance of sterility in guinea pigs, as reported in the Indiana Agricultural Experiment Station Report (22), was found due to a simple recessive Mendelian character which manifests itself through a hormone secreted by the anterior pituitary.

At the Sixth International Congress of Genetics, Hammond (18) reported on a study of the inheritance of fertility in the rabbit. He used strains of rabbits possessing different levels of fertility, fixed by ten generations of inbreeding. Fertility in the rabbit may depend on three conditions, the number of eggs shed, the number of eggs fertilized, and the number of foetuses which survive to birth. The number of eggs shed appeared to behave as a multiple factor character, as shown by obtaining a blend of the two parents, with the calculated average agreeing closely with the observed average in the cross and back-cross. Foetal atrophy, which behaves as a recessive, is probably the main cause of reduced fertility that often occurs on inbreeding rabbits.

Domestic Fowl

Before the scientist can tackle any problem, he must be able to weigh or measure that with which he is dealing. Thus genetical experiment in respect to fecundity is much easier when dealing with the number of eggs produced by the domestic fowl.

Pearl (44) has presented a detailed analysis and interpretation of his extensive study of the inheritance of fecundity in the domestic fowl. The basic data were derived from the trap-nest records of something over a thousand adult females. This included records from pure Barred Plymouth Rocks, Cornish Indian Games, the F_1 individuals obtained by reciprocally crossing these to breeds, and the F_2 individuals obtained by mating the F_1's inter se and back upon the parent forms in all possible combinations.

Pearl classified these birds into three well-defined groups in respect to winter egg production, birds with high winter records, birds with low winter records, and birds which did not lay at all in the winter period. He concluded that there was a definite segregation in the Mendelian sense of the female offspring in respect to those three fecundity divisions. He further concluded that two pairs of genetic factors accounted for the differences, and that one of them appeared to be sex-linked.

In a more recent investigation, Foreman (14) of Michigan advanced the hypothesis that a Mendelian interpretation cannot be applied to the inheritance of higher fecundity in the domestic fowl because this character is neither dominant nor recessive. Also, he concluded that high fecundity is not a sex-linked character, but may be transmitted directly to the offspring from either sire or dam.

Swine

Because fertility in swine varies by discrete units, it provides a very favorable field for the investigation of hereditary transmission. From a study of data taken from the American Poland China Record, Rommel (48) concluded that fertility is slightly but definitely inherited. He found correlation values between the size of litters in which the dam was farrowed and the size of litters produced by daughters, ranging from +.1088 to +.0032. These values decreased with moderate regularity as the daughters became older.

Upon crossing breeds of swine having different litter size, Simpson (51) obtained very definite evidence of a segregation of fecundity factors. He crossed a wild German Schwarzwald boar to a young Tamworth sow. The Schwarzwald breed normally averages four and the Tamworth about eleven pigs per litter. The particular sow used was farrowed in a litter of twelve pigs. Nine pigs were farrowed as a result of the cross indicated. In the F_1 generation, three females were bred, one to a litter mate and the other two to sires unnamed. The first sow produced four pigs, the others four and six pigs, respectively, in their first litter. The sow producing the six-pig litter was later served by a Schwarzwald boar and farrowed seven pigs, being apparently constant for that degree of fertility. One of the sows from the brood of six gave birth to twelve pigs when mated to a Tamworth male. The evidence for a segregation of fecundity factors seems fairly clear, although the numbers are small.

Rommel and Phillip (49), in studying data taken from the Poland China herd book correlated the size of litters in which dams and daughters were farrowed. They found a correlation coefficient of +.0601 ±.0086. They recognized the smallness of the coefficient, but believed that the indications of inheritance of fertility are large enough to provide a basis for selection.

Wentworth and Aubel (54) studied the frequency curves of 3,540 litters taken from herdbooks. The modes for the frequency curves of the parental F_1 and F_2 generations were as follows: four, eight, and twelve pigs per litter. These investigators concluded that the three centers of deviation in swine fertility possibly correspond to genetic factors involved in the inheritance of fecundity.

Funquist (17) has reported on a case of low fertility in swine due to hereditary impotence (failure to breed) in the boar. He did not find the defect to be widespread, although several cases occurred in males from two female families. He deduced that the factor for impotence, p (allelomorph P), must be in the X chromosome, otherwise the character would be more prevalent. Thus it can be transmitted only through the females. A male, (Xp)y, is impotent and a male, (XP)Y, produces sows carrying the defect only when mated with females heterozygous for the impotence factor. Of the males thus born, the ratio of defectives to normals would be 1:1. By natural means, it would be impossible to obtain females homozygous for the factor p, but Funquist proposes to inseminate artificially known heterozygous sows with sperm from impotent boars and thus obtain sows homozygous for the defect, so that an experimental analysis of the factor may be made.

Lush (31) calls attention to the fact that the amount of evidence on which to base an estimate of how much of the permanent differences between the fertility of sows is really hereditary in the simple sense, and therefore subject to selection, is quite limited. He estimates that something like one-half to two-thirds of the permanent differences are hereditary.

Lush also estimates that in an entire breed where considerable attention is being paid to fertility, it will require something like ten to twenty years to increase the average litter one pig. Certain studies based on herdbook data indicate that litter size is actually increasing at rates not very different from these.

With only a small amount of data available, Henke (20) found no correlation between the number of pigs in the litters from which the sires and dams came and the number of pigs in the litters which they produced. This is in opposition to the theory that pigs from large litters consistently produce large litters.

Horse

One of the earliest statistical investigations of the inheritance of fertility was done by Karl Pearson and his collaborators (45), who worked with horses and man. Fertility among thoroughbred race horses was ascertained by the ratio of foals surviving to be yearlings, to the total number of foals possible under the given conditions. The following conclusions were reached:

(1) Fertility is inherited between dam and daughter.

(2) Fertility is also inherited through the male line, i.e., the fertility of a daughter is inherited through the male line with the same intensity as through the female line.

Fertility, which is a latent character in the male, was measured for a stallion and for his sire and was found to be strongly inherited.

Wriedt (59) has stated that twinning is not an inherited character in the horse. He did find, however, that sterility is inherited and brings forth evidence which shows that in the Fredericksborg Stud (Denmark), white coat color is associated with a lethal factor which relates to sterility.

Sheep

The aim of every shepherd is to increase the per cent of twins born in their flocks. As early as 1837, Youatt (63) stated that the disposition to twinning is undoubtedly hereditary. He quotes an ancient and time-honored rhyme of the shepherds:

"Ewes yearly by lambing rich masters do make,
The lambs of such twinners for breeders go take."

Heape (19) collected statistics of over 120,000 sheep in Great Britain, representing a large number of breeds. He found significant differences between the various breeds as regards the percentage of lambs produced and the incidence of barrenness and abortion. He concluded "that the fertility of certain pure breeds is sufficiently marked to constitute a racial characteristic".

According to Crew (6), the Dorset Horn sheep and the Hampshire sheep are relatively highly fertile breeds, while others such as the Blackface are relatively infertile. In the latter, it has been found possible to increase the fertility of a flock by selecting ewes for breeding which possess a higher degree of fertility than the rest.

After analyzing questionnaires sent to sheep breeders in England, in which the several breeds were represented, Nichols (42) concluded that the causes of variation in fertility are environmental conditions acting on hereditary differences. The most important of these hereditary differences were those which produced a high proportion of multiple births and a low proportion of barrenness and abortion.

Wentworth and Sweet (55) selected the first twelve volumes of the American Southdown Record for a study of the inheritance of fertility. They found that in general, sheep of a high birth rank, that is high percentage of twins, tend to produce offspring of a high birth rank. No evidence for a sex-linkage of fecundity factors occurred in the pedigrees tabulated. They recognized that physiological factors may exert a marked influence on heredity.

Dairy Cattle

A study of the factors of age at first breeding, number of calves already dropped, and length of time from calving until bred again as relating to breeding efficiency in a herd consisting of purebred Jersey, Guernsey, and Holstein cattle, was made by Reaves (46). Out of 149 heifers, 13 were sterile and of these 11 were bred for the first time between the ages of 15 and 19 months. The age at the time of first breeding for the 136 fertile heifers ranged from less than 14 months to 28 months. Although the average number of services was quite variable for these heifers, more services per conception were required for all groups under 18 months of age when first bred than for those over that age. The average number of services for all fertile heifers was 2.089. A further study of the effect of age on breeding efficiency revealed that heifers may be slower to conceive than cows that have already calved. There was little variation in the number of services required per conception from the second to the seventh pregnancy.

Reaves (46) made a study of 275 records of conception to see what effect delaying breeding from one to eight months after calving would have on breeding efficiency. His results show that the largest number of services were required for conception with animals bred from two to three months after calving. However, this is far from being conclusive evidence.

The breeding records of the University of Minnesota for the twenty-nine years from 1900 through 1928 were studied by Eckles (10). Thirty-nine and seven tenths per cent of the total 2,900 services to fertile females resulted in conceptions. The average abortion rate was 14.6 per cent. The milk production of the herd increased about

50 per cent during the 29 years without an increase in breeding trouble, which is contrary to popular belief. Forty-seven cows that had an average of 342 pounds of butterfat compared to an average of 350 pounds for the entire herd, were sold as non-breeders. There was only a slight increase in the proportion of non-breeders in cows from the ages of two to ten years. However, after ten years of age, the proportion of non-breeders increased very rapidly. The percentage of services resulting in conceptions did not appear related to the season of the year at the time of service. Pregnancy resulted in 42.7 per cent of the first service periods. The percentage of service resulting in conceptions decreased as more service periods were required. After five service periods have passed without results, the chances appear to be about one to five that the sixth will result in conception, and only about one in thirteen when the tenth period is reached. Twenty-one per cent of all the aborting animals were sterile following abortion, indicating that abortion is an important factor in difficult breeding.

Eckles (10) also studied the breeding records of five private purebred herds and two branch experiment stations. The per cent of services resulting in a total of 1,199 conceptions ranged from 44.5 to 66 per cent in the seven herds studied.

Miller and Graves (37) tabulated the reproduction and health records of the Beltsville herd of the Bureau of Dairy Industry from May 1922 to May 1930. The percentage of heifers that conceived was as large as the percentage of cows that conceived, but more services were required for conception in heifers that were required in cows. A study of the distribution of services shows that a little more than 40 per cent of the conceptions resulted from the first service, and a little more than 70 per cent of the conceptions resulted from the first three services. More services were required for a conception in July, August and September than in other months of the year.

Dohler (9), in his contributions to the problem of obtaining healthy cattle by selection, warns that breeders do not pay sufficient attention to the possibility of bulls transmitting their dam's non-prolificacy to their female progeny.

Fernandez (13) of the Phillipine Bureau of Animal Industry states that the average breeding efficiency of cattle is about 78 per cent. However, it varies considerably according to conditions, cattle in small pastures producing about ten per cent more calves than do range cattle. He reports that the average breeding efficiency of a herd of 33 grade Ayrshires was 67 per cent.

Chapman and Casida (4) studied the length of the service period (interval from parturition to conception) in relation to productive and reproductive efficiency in dairy cows. The length of the service period is determined by the management policy and the reproductive physiology of the cow and bull. The average length of the service period in eight herds studied varied from 120 to 180 days. In one of the herds on the average, the length of service period was 150 days, 70 days from parturition to first subsequent oestrus, 50 days from first oestrus to first service, and 30 days from first service to conception. The average number of services per conception was one and two-thirds. Fifty per cent of these periods are less than 61 days, 40 per cent between 61 and 120 days, and ten per cent over 120 days in length. Part of this variation in length of service period is due to differences between cows; that is, service period lengths tend to agree, within certain limits, from one calving to another of the same cow more closely than they do with the service period lengths of other cows. Part of these differences between cows in those factors which determine the length of the service period are undoubtedly hereditary in nature. A greater part of these differences is modifiable by selection and by changing the breeding policy. There was a negative correlation between the average daily milk production and the length of the interval from parturition to conception.

In another herd of dairy cattle, Chapman and Casida (3) found that the average length of the period from parturition to the first oestrus following was 69 days, with a standard deviation of 39 days in cows clinically normal. If the cows showed no cystic follicles or retained corpora lutea, they were termed clinically normal. This study seemed to show that within a fairly wide range of variation, a cow tends to repeat a similar length of parturition to first oestrus in different calving intervals.

Clapp (5) took data from the Pabst Farms purebred Holstein herds collected over a period of years, and studied the length of the interval from calving to the first heat. The mean difference of 23 days between the length of the interval from calving to the first head for test cows and those not on test was not statistically significant. The frequency of suckling or handling of the teats in milking was thought to be the main cause of the difference in the length of the interval to first heat between the cows milked twice and three times daily. Age had no effect on the interval to first heat. There was a significant difference in persistency of milk production. Animals conceiving to the first service, and thus carrying the calf longer during the lactation year, were more persistent.

Fourt (15) analyzed the dairy cattle herd records of 45 dairy herd improvement association members in Idaho to learn the breeding efficiency of representative dairy herd improvement association cows in Idaho, to determine the relation of breeding efficiency to production feed cost and income of dairy cows, and to assemble facts indicating what should be expected under good management.

Breeding efficiency was calculated by taking an inventory of pregnancy at the beginning and end of the year. One calf for each cow every twelve months was considered as 100 per cent breeding efficiency. Of the 712 cows, 11.4 per cent had a breeding efficiency of less than 60 per cent, 16.6 per cent less than 70 per cent, 23.2 per cent less than 80, and one-third less than 90 per cent. The average breeding efficiency of this group of dairy herd improvement association cows was 85.3 per cent. However, heifers that were sterile and cows that aborted or were sold were not included.

The breeding efficiency of the Jersey and Holstein herds of the University of Idaho Experiment Station was summarized for an eleven-year period to secure data indicating what should be expected under good management. The Jersey herd varied from 61.8 per cent to 82.5 per cent, with an eleven-year average of 74.3 per cent. The Holstein herd varied from 60.4 per cent to 89.0 per cent, with an eleven-year average of 79.2 per cent. Fourt concludes that dairy farmers cannot expect to secure 100 per cent breeding efficiency in their herds unless they breed the cows soon after calving to offset delayed conception. It would appear from this study that high breeding efficiency is associated with fewer days in milk and more days dry than medium or low breeding efficiency.

Williams (56) recognized the economic and scientific importance of the application of some intelligible standard of breeding efficiency. He adopted two years as the ideal age at which a heifer should calve, which necessitates conception at fifteen months. Every calendar month after the fifteenth was designated as a "breeding month." Twelve months was considered as an ideal calving interval. He determined the average number of breeding months required to produce a calf by dividing the total breeding months by the number of calves born. The percentage reproductive efficiency was obtained by dividing the ideal number of twelve breeding months for the production of a calf, by the determined average number of breeding months per calf. Williams reported on a Guernsey herd which produced a calf for each 28.7 breeding months, or 41.8 per cent of ideal efficiency.

Kab (27) studied the breeding records of 1,475 cows, 136 bulls, and 7,104 calves of the Yellow Franconian breed of dairy cattle. "An analysis of the fertility of the daughters of 22 bulls revealed considerable variation between the various families which indicated a genetic basis. Through several generations 35 families showed high fertility and 11 families low fertility."

Morgan and Davis (41) studied the records of the dairy herd of the University of Nebraska for the period 1896 to 1934. Holsteins, Jerseys, Guernseys, Ayrshires, and milking Shorthorns were included. The effects of the age of the bull, the age of the cow, and the season of the year on the number of services required per conception, were the main objects of the study.

They found that young bulls under two years of age showed the smallest number of services per conception. Above two years of age, the number of services required varied very little. Virgin heifers under two years of age required more services for conception than any age group of cows up to ten years of age; 2,090 cows required 3,041 services for 1,375 conceptions, or an average of 2.21. Between the ages of two and eight, little influence of age on the number of services required was noted. There appeared no significant difference in the number of services for conception during the various seasons of the year.

<u>Humans</u>

Pearson and his collaborators (45), applied biometrical treatment to 4,418 cases of mother and daughter fertility taken from "Foster's Peerage and Baronetage", and "Burke's Landed Gentry". A correlation of r = +.0204 for 1,000 cases of mother-daughter fertility taken from the Peerage was obtained. For 1,000 similar cases taken from the Landed Gentry, the value r = +.1045 ± .0211 was found. The correlation between the mean fertilities of all the mothers and all the daughters was r = ±.0101. Although this value is small, it is four times its probable error, so these investigators concluded that fertility is inherited in the female line. Data for father and son comparisons were obtained from the same source. The correlation r = ±.0514 ± .0087 was six times its probable error, so they concluded that male fertility is inherited. "Although we are not able to measure the potential fertility of the male, we are able to determine whether he transfers fertility from his mother to his daughter. This may be done by correlating the fertility of a woman with that of her paternal grandmother." This treatment applied to 1,000 cases from the Peerage revealed a correlation of r = ± .1123 ± .0211 from which the following conclusion was drawn. "The fertility of women is inherited through the male line with the same intensity as through the female.

In South Africa (23), Boer children are subjected to severe natural selection, thus the survival of the fittest results in a superior stock. The fertility of one, Thelia M. de Beer, who gave birth to fifty children, is cited; 270 grandchildren have descended from this highly fertile individual.

Pearl (43) has given the various factors which affect human fertility, that may be statistically evaluated. These various biological factors are rate of sexual intercourse per unit of time, occurrence of pregnancy in proportion to the exposure to risk of its occurrence, size of litter, reproductive wastage rate, and live birth rate.

The differences in fertility between different social groups is due to differences in hereditary fertility, according to Dr. Wagner Manclaus (39). He attributed the lowering of the fertility of the German nobility to the infiltration of the factors of partial sterility introduced by middle-class heiresses. He considered this an earlier stage of the sociologic chain of causation to which Galton ascribed the extinction of peerages in the English nobility.

Crew and Miller (7) attempted to explain the similarities and dissimilarities in reproductive rates of different generations. A four-generation pedigree of humans showing poor fertility was studied. As the females were not sterile, it appeared that the ovum was readily fertilized, but the spermatozoon was deficient in fertilizing ability. The sons of such females exhibited a fertility that was relatively poor. This deficiency was complete in the second generation males, but somewhat repaired in the third generation. It was thus assumed that the males of the third generation received from their mother, factors which improved the fertilizing power of their gametes.

Inbreeding

Castle and his collaborators (2) inbred the pumice-fly, Drosophila ampelophila, for more than fifty generations. After extended observations, they reached the conclusion that inbreeding is not necessarily attended by decreased fertility, but that particular degrees of fertility are transmitted in certain families.

Moenkhaus (38) mated brothers and sisters of a wild strain og Drosophila ampelophila for 75 generations. His results indicate that inbreeding in itself is not deleterious to the fertility of the species. He maintains that by judicious selection of the brothers and sisters to be mated from a brood that shows a high degree of infertility can be eliminated by selection although continuing the inbreeding in the closest possible way.

King (28) took four slightly undersized but otherwise normal albino fancy rats, two males and two females, as a foundation stock of two lines of inbred individuals. These rats were from stock already closely inbred and therefore approximately homozygous. Brother and sister matings were practiced for 25 generations. It was clearly demonstrated that by selection within an inbred population, vigorous, uniform strains could be built up, larger, longer-lived, and more fertile than many strains of the control stock.

Evans (11) reported on a strain of inbred rats in which the animals were not seriously disturbed in their capacity to conceive, but a striking indisposition to mating was manifested. This type of sterility or infertility was thought to be due to the hormonal impariment of sex behavior. There was no defect in the germ cells.

Wright (61) inbred brother with sister guinea pigs over a period of thirteen years. The net result was an average decline in vigor of all characteristics. The decline was most marked in the frequency and size of litter. Comparing the control stock raised under identical environmental conditions without being inbred, indicated that the inbreds suffered a genetic decline in vigor in all characteristics, and especially fertility.

Inbreeding with careful selection was practiced for over twenty generations in several families without any obvious degeneration. After studying the inbred families, Wright observed that the various elements of vigor, i.e., mortality at birth and between birth and weaning, the regularity in producing litters, the size of the litter, and resistance to tuberculosis, were inherited independently.

Wright concludes that one of the most important results of inbreeding is the bringing to light and fixing of characters in a family.

By crossing inbred families from unrelated foundation stock, Wright (62) produced a marked improvement over the parental stock in practically all elements of vigor. The offspring of the first cross showed the greatest improvement. He concluded that such crossing results in improvement because each family in general supplies some dominant factors lacking in the others.

Jull (26) reviewed the papers presented at the Fourth World's Poultry Congress in London, 1930. Dumon, of Belgium, crossed inbred strains of chickens and eliminated the disastrous effects of continuous inbreeding and maintained the desirable characteristics. Dunkerly of England pointed out that the production and maintenance of highly fecund stock is more likely to result from outbreeding than from inbreeding.

Hatchability was studied in relation to coefficients of inbreeding of the breeding stock by Jull (25). Hatchability decreased as the coefficients of inbreeding increased. The greatest relative decrease in hatchability appeared to occur between a coefficient of inbreeding of 0 and 12.5. The same coefficient of inbreeding, regardless of the year in which they were produced, did not give significant differences in hatchability results. Continuous full brother and sister matings were more detrimental to hatchability than full brother and sister matings alternated with half brother and sister matings.

Jull (24) again observed the effect of intercrossing inbred strains of chickens. It was shown, in general, that the hatchability percentage increased in the intercrossed inbred strains above that observed in the inbred matings.

An attempt to establish an inbred strain of Poland China swine by brother-sister matings was reported by McPhee and co-workers (36). They were unable to progress further than the second generation, due to a decrease in fertility and high mortality. Litter size and vigor was greatly reduced.

It would appear that their foundation stock was extremely heterozygous, and contained many undesirable characteristics which were brought to light by inbreeding.

Marshall (34) points out that thoroughbred horses in

England are notoriously inbred, and 40 per cent or more of the mares fail to foal each year.

Brockelbank and Winters (1) studied the breeding methods used by Shorthorn breeders. Their results indicate that show-winning cattle tend to produce show winners. Shorthorn breeders have been producing show winners by selection in the broad sense, considering individuality, breeding, performance and pedigree. The per cent of inbreeding for the breed as a whole is increasing.

The classic example of genetic sterility, bringing about the ultimate disappearance of the strain, is offered by the Duchess family of Shorthorn cattle as bred by Thomas Bates between the years 1810 and 1849. This family has been studied by Wright (60) in considerable statistical detail. Bates' original cow, upon which he developed his Duchess family, came from the Colling herd, which was about 40 per cent more inbred than the general run of Shorthorn cattle at the time. Bates outcrossed with new stock, but his degree of inbreeding remained about 40 per cent. The family was never prolific, and this character appears typical of the strain, for after Bates' death it was found impossible to maintain a pure Duchess strain. It is thought that the failure was due to breeders exceeding the level of inbreeding observed by Bates, and thus so far increasing the number of actually sterile animals beyond the possibilities of maintenance of the strain.

The Ayrshire breed of dairy cattle was the subject of a genetic study made by Fowler (16). The coefficient of inbreeding for the whole breed was calculated by Wright's "Approximate Method". A progressive increase from nil in 1877 to a mean value of 5.3 in 1927 was found. A large portion of the inbreeding was traced to two foundation sires, Burnhouses and Hover-A-Blink of Drumjoan. Using Wright's "Long Method", it was found that high milk-yielding cows showed a lower coefficient of inbreeding than the breed average. On the other hand, it appeared that inbreeding itself had no detrimental effect on the average milk yield of the breed.

McAlister (35) states that the average Holstein cow will have more than twice the number of descendants of the average Jersey in an equal period of years. He apparently bases his statement on the fact that a much greater number of purebred Holstein cattle are registered each year in the United States than are Jersey or Guernsey cattle, in spite of the larger importation of the Channel Island breeds. He concludes that this variation in fertility is the result of inbreeding of the Jerseys and Guernseys, whereas the Holstein breed was developed largely from the mating of unrelated animals.

Lush and co-workers (32) studied the genetic history of Holstein-Friesian cattle in the United States. Four hundred pedigrees per year for each of the years 1889, 1899, 1909, 1919, 1928, and 1931 were analyzed to determine the amount of inbreeding and the inter se relationship. The coefficient of inbreeding of the breed has risen from 2.4 in 1889 to 4.7 in 1928, in approximately ten generations. This slow drift toward homozygosity in the breed is very mild when calculated in terms of what might happen during one human lifetime. This inbreeding rate is about the same as if there were only about thirty bulls per generation in the whole breed, actively and equally taking part in reproducing the breed, but mating at random with a much larger number of cows.

The inter se relationship of the Holstein breed was the subject of the second paper by Lush (33). Average inter se relationship is measured by matching a random line from one pedigree against a random line traced from another pedigree, to see how often common ancestors are found in a pair of such lines. The more closely related the animals of the breed are to each other, the more likely it is that the same ancestor will be found in two such lines chosen at random. The inter se relationship has risen from .7 in 1899 to 3.4 in 1931. There is a faint tendency for the breed to form into separate families. This family separation is not carried far, presumably because the more popular families are soon used for outcrossing on others, and the less popular ones are discarded entirely or are outcrossed with sires from other families. The cow, De Kol 2nd, was found to have exerted more influence on the breed than any other individual. She furnished about one-tenth of the genes of the breed today.

In the Holstein breed there was no appreciable difference between the average amount of inbreeding and relationship, and that of the outstanding show winners and the high producers. However, these special groups do show a higher relationship to a few recent ancestors. This may be due to the limited number of herds competing in the show ring.

Woodward and Graves (58) inbred a small number of grade Guernsey and grade Holstein cattle. Although the number of animals was small and the generations few, the grade Holsteins did not decline in fertility, as judged by the services required per conception.

Dr. Shapiro (50) made an interesting study of the inhabitants of Pitcairn Island. In 1789 ten white men, ten native women, and six native men landed on Pitcairn Island. During the seventy years, 1864 to 1934, the population multiplied itself by at least five times. Fertility decreased from 11.4 children per female in 1815 to 4.2 children per female in 1889. Possible explanations are a loss of vigor as a result of prolonged inbreeding after initial heterosis and venereal diseases. Dr. Shapiro employed Pearl's index of inbreeding in his analysis of the carefully preserved records. He concluded that inbreeding has not been followed by degeneration among his subjects, showing that it is the presence of latent defects that makes inbreeding a dangerous thing, and not any mysterious punishment consequent to the process itself.

Lethal Factors

"The term 'lethal factor', used in the genetical sense, refers to the inheritance by an individual, from both parents, of a character which prevents the full and normal development of that individual, and results in the organism's death during the early stages of embryonic development or at birth."

The characters which lethal genes impose upon their exhibitors are various. They have been reported in all species of domesticated stock, and it is probable that they are far more common than is generally suspected. The presence of eleven such lethals in cattle has been definitely established (21). These are as follows: achrondroplasia (bulldog calf) of the Dexter breed, recessive achrondroplasia in the Telemark breed, epitheliogenesis imperfecta (denuded epithelium) in Holsteins, hypotrichosis congenita (hairlessness) in Swedish Holsteins, acroteriasis congenita (malformations of head and limbs) in Swedish Holsteins, short spine in the Oplandske breed in Norway, mummified foetuses in Red Danish cattle, lameness in hind limbs of Red Danish cattle, muscle contractures in Holsteins, Ljutikow's lethal (short legs) in Brown Swiss, ankylosis of lower jaw (short, calcified) in Norwegian Lyndal cattle.

For all practical purposes, lethal genes are recessive in their lethal effect, i.e., only the individual inheriting the factor in the homozygous condition dies. Therefore, it would seem that unless close inbreeding is practiced, a relatively small amount of infertility or sterility can be attributed to lethal factors.

Longevity

The duration of the life of the dairy cow is an important part of fertility. The percentage of young which must be saved for herd replacements is directly affected by the longevity of the parents. As the average productive life of the dairy cow is about four years, approximately 60 per cent of the heifer calves born must be saved for replacements. Because such a large per cent of the young are needed to maintain the herd size, the possibility of practicing very careful selection is limited.

It is a well known fact that as a dairy cow continues to be an economical producing animal over a long period of years, her margin of profit increases greatly.

Koppe (29) recognized the value of longevity and performance, and advocated the establishment of a new register for East Friesian cattle in Germany. He would register only cows that have produced a minimum total yield of 1,000 kilograms of butterfat at the completion of their ninth year, and have at least five surviving daughters.

He also cites the record of a cow nineteen years old which produced 2,601 kilograms of butterfat and has 18 surviving calves. Koppe concludes that the breeding aim of every dairyman should be a long-living animal combining high fertility and a good life performance.

Williams (57) reported on observations made during a period of fourteen years on a pure-bred Holstein-Friesian herd maintained in intimate contact with a large herd of healthy beef cattle under range conditions in a subtropical area in the United States. He noted that the fertility of heifer calves when they reached breeding age rose and fell in accordance with the rainfall which conditioned the quality and quantity of the food of their dams and themselves during intra-uterine and early postnatal life. He concluded that heifers which were efficient during their first breeding period continued to do well over a number of years, whereas those which showed poor reproductive ability during their first breeding period were inefficient and short lived.

PROPOSED STUDY

The following study was proposed to determine if genetic factors for fertility have been operating in the dairy herd owned by the Oregon State Agricultural College.

Part One: To determine if there is a difference in fertility in the dairy cattle breeds and in the cow groups.

Part Two: To determine if these differences are transmissible by inheritance.

DATA

The data available for this study consist of individual breeding records of 368 cows in the dairy herd owned by the Oregon State Agricultural College. The four major breeds of dairy cattle, Jersey, Ayrshire, Holstein-Friesian and Guernsey, are represented. These records cover the period beginning with the purchase of the foundation cows in 1913, and up to 1938.

The management policies have been substantially uniform for all groups of cows. All the dairy cattle were housed and fed in the same barn, with no attempt to segregate the various breeds or groups.

Undoubtedly the most important disease factor which could affect a problem of this kind is Bang's disease. The Veterinary Department of the College began testing the College dairy herd for contagious abortion in 1919, and has continued to test at regular intervals since that time. In the fall of 1922, all of the animals which reacted to the agglutination test for Bang's disease were removed from the College dairy herd. Since that time there has been an occasional removal of suspect or reactor animals. It is unlikely that any one group or breed of dairy cows intermingling freely in a herd would be more susceptible than others to an infectious disease affecting reproductive efficiency.

PART ONE

Measures of Breeding Ability

Various measures have been employed when measuring the breeding ability of dairy cattle. The number of services per pregnancy is the most widely used. Strictly speaking, it is an accurate measure of breeding ability and not reproductive efficiency, as it does not take into consideration the fact that many cows fail to show oestrus regularly, thereby lowering their reproductive efficiency but not necessarily affecting the services per pregnancy. In such a calculation, heifers that never calve are naturally omitted from the records. A mediocre individual might be disposed of as sterile after three or four services, whereas a more valuable animal might be given more consideration and conceive to a later service. Thus the individual value of a cow in other respects such as milk and butterfat production or type has a great influence on the number of services allowed before being considered sterile.

The percentage of females bred that actually conceive is a practical measure when applied to a herd. However, it is of no great value when individuals are considered.

Measures of Fertility

Fertility obviously depends on three factors, the number at birth, the frequency of reproduction, and the total number of successful gestations an animal may undergo. The occurrence of multiple births in dairy cattle is too infrequent to exert any appreciable effect upon fertility. The number of successful gestations is not a practical selective index for breeding purposes, since the breeder cannot afford to withhold progeny from breeding until their dams have completed their breeding cycles. Frequency of reproduction is presented as a more practical trait for purposes of selection.

The term "reproductive efficiency" is proposed as a measure of the frequency of reproduction. It represents the net biological accomplishment of all reproductive activity, which includes the integrated effect of all the factors concerned, i.e., oestrus, ovulation, fertilization, implantation, gestation, and parturition.

The derivation of the numerical value of reproductive efficiency is based on the assumption that to be one hundred per cent efficient, a heifer should be bred at a certain age, depending upon the breed, and that she should drop a calf every twelve months thereafter. The total reproductive months represent the months that an animal remained in the breeding herd.

As twelve months is assumed to be the desired calving interval, it follows that each cow should be credited with twelve one hundred per cent months per pregnancy. Thus, for convenience in obtaining a numerical expression of reproductive efficiency and for want of a better term, each month of the calving interval in excess of twelve months is considered as possessing zero per cent reproductive efficiency. Any cow known to be pregnant, which was removed from the herd before calving, was allowed one hundred per cent month for each month of pregnancy. The number of one hundred pe r cent months divided by the total number of reproductive months given the per cent reproductive efficiency. In the measure of reproductive efficiency proposed by Williams (56), incomplete reproductive cycles were not evaluated, and heifers that never calved were not considered.

The dairy cow which continues to maintain a high level of reproductive efficiency over a long period of years possesses a higher degree of fertility than the cow which ceases to reproduce early in life. The longevity of fertility rating is proposed as an expression of the number of successful gestations which an animal undergoes. Obviously this measure, because of its nature, is limited to cows that were disposed of as sterile or non-breeders, and to cows that have demonstrated their longevity of fertility by equaling the standard. One hundred twenty 100-per-cent months (ten calves) was selected as a standard longevity of fertility rating of 100.

Application

For the purpose of this study, each individual foundation cow and her female descendants retained in the College herd composed a cow group. Each breed was divided into its component cow groups. These groups included on the average from four to eleven generations, and contained from 11 to 62 cows with breeding records. Heifers sold for reasons other than sterility or difficult breeding before the completion of at least one pregnancy, were not included in the study.

The per cent reproductive efficiency was determined for each cow. The mean per cent reproductive efficiency with its probable error was determined for each cow group having eleven or more individuals, and for each breed. The mean longevity of fertility was not determined for each cow family due to the small number of cows, but was determined for each breed. Bessel's (30) formula for the application of probability to small samples was used. To determine if the differences between the various cow groups and breeds were significant, the odds against such a difference occurring due to chance were calculated. Odds of 30:1 or greater were considered significant.

The longevity of fertility rating was determined for each cow whenever possible. The mean longevity of fertility rating was not calculated for each cow group due to the small number of cows to which this measure could be applied. The mean longevity of fertility rating was determined for each breed.

RESULTS OF STUDY

Individual Cows

In the following tables, I, II, III, and IV, the reproductive efficiency and the longevity of fertility rating of the individual cows of each breed are given.

TABLE I--BREED NO. 1
Reproductive Efficiency of Individual Cows

Cow No.	Reason for or Method of Disposal	Reproductive Months No.	100% Months No.	Reproductive Efficiency %	Longevity of Fertility Rating
1	non-breeder	121?	48?	39.7?	40.0?
2	poor producer	141	96	68.1	
3	aged cow	131	96	73.2	80.0
4	non-breeder	121	96	79.3	
5	poor producer	106	96	90.56	
6	non-breeder	112	60	53.58	50.0
7	septicemia	91	48	52.74	
8	poor condition	118	108	91.52	
9	non-breeder	108	60	55.55	50.0
10	non-breeder	135	48	35.55	50.0
11	non-breeder	75	24	32.00	20.0
12	mastitis	127	96	75.59	
15	metritis	76	60	78.94	
16	poor condition	89	84	94.38	
17	pneumonia	55	48	87.27	
18	non-breeder	93	48	51.61	50.0
19	abortion reactor	68	48	70.58	
20	poor producer	100	98	98.00	
21	non-breeder	66	24	36.36	20.0
22	non-breeder	120	96	80.00	80.0
23	abortion reactor	63	48	76.19	
24	non-breeder	155	96	61.29	80.0
26	milk fever	127	120	94.48	100.0
28	poor producer	42	36	85.71	
29	mastitis	41	36	87.8	
30	abortion reactor	47	36	76.59	
31	aged cow	79	60	75.94	
32	non-breeder	116	96	82.84	80.0
33	poor producer	35	24	68.56	
36	abortion reactor	33	12	36.36	
38	poor producer	29	24	82.75	
39	poor producer	21	12	57.14	
40	abortion reactor	22	12	54.54	
41	non-breeder	57	48	84.21	40.0
42	non-breeder	127	108	85.04	90.0
43	mastitis	104	84	80.76	
44	non-breeder	32	12	37.50	10.0
45	milk cow	45	36	80.0	
46	sterile	14	0	0	0
47	sterile	12	0	0	0
48	sterile	21	0	0	0

TABLE I (Continued)

Cow	Reason for or Method of Disposal	Reproductive Months	100% Months	Reproductive Efficiency	Longevity of Fertility Rating
No.		No.	No.	%	
51	sterile	20	0	0	0
52	non-breeder	92	60	65.21	
54	milk cow	81	60	74.07	
55	injured	54	48	88.88	
56	non-breeder	86	60	69.76	50.0
57	poor producer	46	39	84.78	
59	milk cow	42	36	85.71	
60	milk cow	86	84	97.67	
61	poor producer	15	12	80.0	
62	poor type	15	12	80.0	
64	milk cow	58	48	82.75	
66	non-breeder	41	24	58.53	20.0
67	sterile	19	0	0	0.0
68	non-breeder	27	12	44.44	10.0
70	poor producer	53	48	90.56	
71	milk cow	44	36	81.81	
72	abortion reactor	12	12	100.0	
73	sterile	17	0	0	0.0
74	non-breeder	68	48	70.58	40.0
77	foreign body	14	12	85.71	
79	abortion reactor	63	60	95.23	
80	milk cow	41	36	87.81	
83	abortion suspect	110	95	87.27	
84	non-breeder	52	48	92.3	40.0
85	poor producer	21	12	57.1	
86	milk cow	25	12	48.0	
87	non-breeder	74	48	64.86	40.0
88	milk cow	32	24	75.0	
89	non-breeder	89	72	80.9	60.0
91	sterile	29	0	0	0.0
93	sterile	19	0	0	0.0
94	bloat	67	36	53.73	
97	non-breeder	42	12	28.57	10.0
98	non-breeder	84	48	57.14	40.0
101	abortion reactor	88	72	81.81	
102	abortion reactor	77	48	62.33	
105	sterile	24	0	0	0
106	milk cow	12	12	100.00	
107	milk cow	12	12	100.00	
108	poor producer	60	60	100.00	
109	non-breeder	19	12	63.21	10.0
111	non-breeder	59	24	40.67	20.0

TABLE I (Continued)

Cow	Reason for or Method of Disposal	Reproductive Months	100% Months	Reproductive Efficiency	Longevity of Fertility Rating
No.		No.	No.	%	
112	milk cow	46	36	78.26	
115	non-breeder	39	24	61.54	20.0
116	poor type	30	8	26.6	
117	sterile	21	0	0	0.0
118	mastitis	32	24	92.3	
119	injured	26	24	92.3	
121	poor condition	48	36	75.0	
127	abortion suspect	27	24	88.88	
132	non-breeder	31	24	77.42	20.0
140	poor producer	13	12	92.3	
142	poor type	22	12	54.5	
Animals still in herd:					
96		91	60	65.93	
113		64	48	75.0	
120		62	60	96.77	
122		45	36	80.0	
126		51	48	94.19	
128		48	36	75.0	
129		50	48	96.0	
130		49	48	97.9	
131		41	36	97.3	
134		37	36	97.3	
135		34	24	70.58	
137		36	36	100.0	

TABLE II--BREED NO. 2
Reproductive Efficiency of Individual Cows

Cow No.	Reason for or Method of Disposal	Reproductive Months No.	100% Months No.	Reproductive Efficiency %	Longevity of Fertility Rating
201	foreign body	145	108	74.48	
202	injured	99	60	60.6	
204	injured	64	48	75.0	
205	lead poisoning	116	72	62.07	
212	aged cow	176	120	68.20	100.0
213	non-breeder	85	60	70.56	50.0
215	abortion reactor	103	84	81.55	
216	metritis	108	84	77.77	
217	mastitis	75	60	80.0	
218	non-breeder	142	108	76.5	90.0
219	tuberculosis	90	60	66.66	
221	non-breeder	117	84	71.81	70.0
222	mastitis	126	96	76.19	
223	non-breeder	56	36	64.29	30.0
224	abortion reactor	31	24	77.41	
225	foreign body	45	36	80.0	
226	non-breeder	64	36	56.25	30.0
227	abortion reactor	26	16	61.53	
228	non-breeder	131	108	82.44	90.0
229	non-breeder	120	60	50.0	50.0
230	non-breeder	21	12	57.14	10.0
231	mastitis	33	24	72.72	
232	abortion reactor	52	43	82.7	
233	mastitis	119	108	90.75	
234	poor producer	25	12	48.0	
236	non-breeder	138	48	34.06	
237	poor producer	18	12	66.66	
239	sterile	12	0	0.0	0.0
240	septicemia	87	72	82.75	
241	sterile	14	0	0.0	0.0
242	tuberculosis	21	12	59.04	
244	non-breeder	65	36	46.06	30.0
245	non-breeder	39	24	61.53	20.0
246	mastitis	49	36	73.46	
247	aborted triplets	77	60	77.91	
248	abortion suspect	70	60	45.71	
251	aborted triplets	34	24	70.59	
254	mastitis	61	60	99.9	
255	died bloat	47	36	76.59	
258	poor producer	26	24	92.3	
259	nurse cow	58	48	82.75	

TABLE II (Continued)

Cow No.	Reason for or Method of Disposal	Repro-ductive Months No.	100% Months No.	Repro-ductive Efficiency %	Longevity of Fertil-ity Rating
260	non-breeder	29	12	41.37	10.0
261	mastitis	93	84	90.32	
262	milk cow	18	12	66.66	
263	sterile	14	0	0.0	0.0
264	poor producer	67	60	89.55	
265	died bloat	14	12	85.71	
266	milk cow	29	24	82.75	
267	milk cow	30	24	80.0	
268	poor producer	22	12	54.54	
269	milk cow	30	24	80.0	
271	milk cow	36	24	75.0	
272	milk cow	19	12	63.15	
273	aged cow	104	84	80.76	
274	milk cow	43	24	55.81	
275	milk cow	15	12	80.00	
278	milk cow	36	36	100.00	
279	poor type	15	12	80.0	
280	milk cow	14	12	85.71	
281	mastitis	81	60	74.07	
284	mastitis	84	48	57.14	
285	poor producer	34	24	70.59	
288	mastitis	72	60	83.33	
290	non-breeder	57	48	86.96	40.0
293	nurse cow	54	48	88.88	
294	milk cow	17	12	70.5	
295	nurse cow	53	48	90.56	
296	mastitis	63	60	95.23	
297	milk cow	28	24	85.71	
299	nurse cow	60	48	80.0	
301	mastitis	69	60	86.95	
307	abortion suspect	60	36	60.0	
309	mastitis	58	36	62.06	
313	abortion suspect	46	36	78.26	
314	poor producer	14	12	85.71	
324	sterile	7	0	0.0	0.0
330	killed (?)	14	12	85.71	
344	failed to lactate	13	12	92.3	

TABLE II (Continued)

Cow	Reason for or Method of Disposal	Repro- ductive Months	100% Months	Repro- ductive Efficiency	Longevity of Fertil- ity Rating
No.		No.	No.	%	
Animals still in herd:					
283		87	60	68.96	
286		86	72	83.72	
287		83	72	86.74	
292		80	72	90.0	
305		27	24	88.88	
306		65	60	92.3	
308		60	48	80.0	
316		48	48	100.0	
317		48	50	96.0	
318		50	36	72.0	
322		36	36	100.0	
323		27	24	88.88	
326		37	36	97.	
327		39	36	92.3	
331		27	24	88.88	
332		26	24	92.3	
338		26	24	92.3	
339		24	24	100.0	
340		24	24	100.0	
341		24	24	100.0	
342		24	24	100.0	
343		25	24	96.0	
347		12	12	100.0	
348		13	12	92.3	
350		12	12	100.0	
353		13	12	92.3	
354		12	12	100.0	
356		12	12	100.0	
357		12	12	100.0	

TABLE III--BREED NO. 3
Reproductive Efficiency of Individual Cows

Cow No.	Reason for or Method of Disposal	Reproductive Months No.	100% Months No.	Reproductive Efficiency %	Longevity of Fertility Rating
401	non-breeder	118	108	91.5	90.0
402	pneumonia	78	60	76.9	
403	broken femur	66	48	72.7	
404	milk cow	66	60	90.9	
405	poor producer	102	84	82.3	
406	?	69	60	86.9	
407	milk cow	92	72	78.2	
408	abortion reactor	167	144	86.2	120.0
409	non-breeder	121	95	79.3	80.0
412	poor producer	26	12	46.1	
413	milk cow	49	36	73.4	
414	milk cow	45	36	80.0	
415	poor producer	84	72	85.7	
416	abortion reactor	68	48	70.5	
417	non-breeder	46	24	52.1	20.0
418	abortion reactor	68	60	88.2	
419	milk cow	34	24	70.5	
420	abortion reactor	113	96	84.9	
421	abortion reactor	159	132	83.0	110.0
423	non-breeder	118	95	81.3	80.0
424	abortion reactor	107	84	78.5	
425	poor producer	53	48	90.5	
426	milk cow	47	41	87.2	
427	milk cow	78	57	73.0	
428	abortion reactor	170	108	63.5	
429	foreign body	29	25	86.2	
430	abortion reactor	71	48	67.6	
431	mastitis	59	48	81.3	
432	abortion reactor	164	120	73.2	100.0
433	sterile	20	0	0.0	0.0
435	milk cow	60	48	80.0	
436	abortion reactor	42	39	92.8	
437	abortion reactor	74	60	81.0	
438	abortion reactor	78	72	92.3	
439	milk fever	27	24	88.8	
440	abortion reactor	30	15	50.0	
441	abortion reactor	26	24	92.3	
442	abortion reactor	24	24	100.0	
443	mastitis	36	24	66.6	
445	died bloat	98	84	85.7	
446	abortion reactor	110	60	54.5	

TABLE III (Continued)

Cow No.	Reason for or Method of Disposal	Reproductive Months No.	100% Months No.	Reproductive Efficiency %	Longevity of Fertility Rating
447	milk cow	37	36	97.3	
449	milk cow	35	29	82.8	
450	milk cow	86	48	55.8	
451	inbred, poor type	35	24	68.5	
452	died, yellow body removed	50	48	96.0	
453	milk cow	31	30	96.9	
456	milk cow	99	99	100.0	
457	milk cow	85	84	98.8	
458	actinomycosis	12	12	100.0	
459	milk cow	55	48	87.2	
460	interitis	14	12	85.7	
462	milk cow	76	72	94.7	
463	milk cow	23	21	91.3	
466	poor producer	21	17	84.2	
467	T.B. reactor	24	24	100.0	
468	milk cow	87	60	68.9	
469	old age	154	144	93.5	120.0
470	milk cow	12	12	100.0	
473	milk cow	29	24	82.7	
477	milk cow	86	84	97.6	
479	milk cow	26	24	92.3	
482	milk cow	22	12	54.5	
491	actinomycosis	16	12	75.0	
497	aborted	55	48	87.2	
510	septicemia	12	12	100.0	
511	mastitis	113	84	74.3	
512	non-breeder	92	60	65.2	50.0
514	mastitis	33	24	69.2	
515	foreign body	52	36	69.2	
516	non-breeder	21	12	57.1	10.0
517	poor producer	62	48	77.4	
518	foreign body	78	60	76.9	
519	poor producer	55	48	87.2	
520	milk cow	60	48	80.0	
521	foreign body	24	12	50.0	
526	milk cow	64	48	75.0	
529	milk cow	32	24	75.0	
532	poor producer	82	84	102.4	
535	milk cow	25	24	96.0	
537	bloat	57	48	84.2	
540	poor producer	27	24	88.8	

TABLE III (Continued)

Cow No.	Reason for or Method of Disposal	Reproductive Months No.	100% Months No.	Reproductive Efficiency %	Longevity of Fertility Rating
552	mastitis	81	72	88.8	
543	bloat, died	46	36	78.2	
549	non-breeder	81	72	88.8	60.0
551	milk cow	36	36	100.0	
552	sterile	14	0	0.0	0.0
554	milk cow	12	12	100.0	
555	abortion suspect	84	72	85.7	
556	abortion suspect	75	60	80.0	
559	milk cow	12	12	100.0	
560	milk cow	24	24	100.0	
561	poor producer	60	60	100.0	
562	poor type	15	12	80.0	
563	poor type	15	12	80.0	
565	poor producer	40	36	90.0	
567	poor producer	54	48	88.8	
568	non-breeder	46	36	78.2	30.0
570	poor producer	46	24	52.1	
571	milk cow	16	12	75.0	
575	mastitis	55	48	87.2	
579	poor producer	33	24	72.7	
580	sterile	15	0	0.0	0.0
586	poor producer	29	12	41.6	
Animals in herd at present:					
483		156	138	88.0	110.0
503		143	128	88.7	100.0
536		104	101	97.1	
538		102	92	90.1	
539		99	96	96.9	
557		75	67	89.3	
564		65	57	87.6	
572		58	48	82.7	
573		56	53	94.6	
582		49	44	89.7	
589		38	36	94.8	
592		36	36	100.0	
700		27	24	88.8	
702		17	12	70.5	
703		24	24	100.0	
704		25	24	96.0	
705		16	12	75.0	

TABLE III (Continued)

Cow No.	Reason for or Method of Disposal	Reproductive Months No.	100% Months No.	Reproductive Efficiency %	Longevity of Fertility Rating
706		20	12	60.0	
707		14	12	85.7	
711		13	12	92.3	
712		12	12	100.0	
713		13	12	92.3	
714		12	13	100.0	

TABLE IV--BREED NO. 4
Reproductive Efficiency of Individual Cows

Cow No.	Reason for or Method of Disposal	Reproductive Months No.	100% Months No.	Reproductive Efficiency %	Longevity of Fertility Rating
602	non-breeder	105	60	57.1	50.0
603	non-breeder	72	60	83.3	50.0
604	non-breeder	121	84	69.4	70.0
606	foreign body	47	24	51.0	
607	abortion reactor	40	36	90.0	
608	non-breeder	36	12	33.3	10.0
609	died expelled uterus	139	96	69.0	
612	poor producer	73	48	66.0	
615	milk fever	48	36	75.0	
616	pyo-nephritis	92	57	61.9	
617	non-breeder	32	22	68.7	18.3
618	non-breeder	27	12	44.4	10.0
619	non-breeder	25	12	48.0	10.0
620	poor producer	62	60	96.7	
622	poor producer	23	12	52.1	
623	foreign body	117	108	92.3	
624	abortion reactor	30	24	80.0	
625	broken pelvis	102	84	82.3	
626	non-breeder	14	10	71.4	8.2
629	milk cow	85	60	70.5	
631	unprofitable and non-breeder	23	12	52.1	10.0
634	non-breeder	108	60	55.5	50.0
635	non-breeder	23	12	52.1	10.0
636	aged cow	143	108	75.5	
635	non-breeder	23	12	52.1	10.0
638	milk cow	71	60	85.4	
639	milk cow	48	36	75.0	
640	milk cow	59	36	61.0	
641	milk cow	96	24	87.5	
642	died, bloat	18	12	66.6	
644	poor producer	44	36	81.8	
645	milk cow	35	24	68.5	
646	milk cow	55	48	87.2	
647	milk cow	49	48	97.9	
648	pyometra	34	24	70.6	
649	milk cow	12	12	100.0	
650	milk cow	49	48	97.9	
656	died	13	12	92.3	

TABLE IV (Continued)

Cow No.	Reason for or Method of Disposal	Reproductive Months No.	100% Months No.	Reproductive Efficiency %	Longevity of Fertility Rating
658	sterile	?			
659	milk cow	23	12	52.1	
663	milk cow	14	12	85.7	
664	milk cow	14	12	85.7	
665	milk cow	14	12	85.7	
668	milk cow	11	9	81.8	

Cow Groups

The foundation cows and their respective female descendants that compose each breed are given in tables V, VI, VII, and VIII.

TABLE V--COW GROUPS OF BREED NO. 1

Cow Group	Foundation Cow	Female Descendants
A	1	A_1-A_2-A_3-A_4
A_1	2	27-43-75-117
A_2	3	20-22-25-30-40-41-48-51-55-59-60-61-65-67-68-73-74-77-78-83-84-91-92-93-106-113-115-122-123-125-132-140-144-145-146-153-155-158
A_3	4	17-21-23-28-31-33-37-49-52-54-57-69-70-71-76-79-81-82-90-94-100-107-108-109-112-114-116-124-126-130-133-136-138-141-142-152-157
A_4	5	24-35-38-44-47-62-64-85-96-103-110-119-129-137-143-148-154
B	8	16-19-26-34-39-42-53-58-63-80-89-118-127-134-151
C	9	10-15-29-36-45-46-66-86-98-111-128-147-150
D	12	32-50-56-72-87-88-97-101-102-105-120-121-131-135-139-156

TABLE VI--COW GROUPS OF BREED NO. 2

Cow Group	Foundation Cow	Female Descendants
E	201	220-229-253-268-284-325
F	202	F_1-F_2
F_1	216	221-225-231-236-247-255-265-267-275-286-295-296-297-306-317-320-327-328-330-332-336-339-341-347-350-351-355-360-363-367-370-373-237-248-264-276-285-298-287-329-321-274-308-337-346-358-338-368
F_2	218	228-256-262-263-278-307-353
G	204	215-219-226-227-230-233-234-238-246-243-249-251-258-259-261-269-271-272-279-280-281-290-293-299-300-302-305-309-312-313-316-318-323-324-326-331-333-340-342-343-345-348-354-356-357-362-365-369-374
H	205	213-224
I	217	222-232-241-242-244-254-260-266-277-282-283-288-289-294-301-322-334-352-361
J	212	223-235-239-240-245-257-273-292-303-304-314-344-359-372

TABLE VII--COW GROUPS OF BREED NO. 3

Cow Group	Foundation Cow	Female Descendants
K	401	K_1-K_2-K_3-K_4-K_5-K_6
K_1	402	424-437-458-488-493-508-524
K_2	404	420-427-433-440-459-474-489-495-509-528
K_3	405	423-428-436-442-447-461-472-473-477-492-506-510-511-520-527-529-535-539-541-547-549-556-560-563-567-569-577-587-595-709-718
K_4	403	435-451-453-480-498
K_5	418	454-467-512-553-575-599-591
K_6	425	450-465-476-499-525
L	406	L_1-L_2
L_1	407	411-414-416-430-431-438-441-445-448-452-456-466-469-478-479-483-486-491-496-497-502-503-504-507-514-515-517-518-521-523-526-531-536-537-538-542-543-548-551-554-557-558-561-562-564-565-566-570-571-573-578-579-581-582-583-585-586-588-589-592-593-594-596-597-598-700-701-702-703-704-705-706-708-710-711-713-714-715-716-717-719-720-722-723-724-725-726-727-728-729-730-732.
L_2	413	--
M	408	M_1-M_2-M_3-M_4-M_5
M_1	421	475-484-501-532-555-559-568-576-580-590-707-712-732
M_2	426	443-449-463-464-482
M_3	432	471-485-500-513-522-550

TABLE VII (Continued)

Cow Group	Foundation Cow	Female Descendants
M_4	457	487-505
M_5	481	---
N	409	412-417-422-429-439-446-455-460-462-468-490-494-516-519-530-533-540-545-552

TABLE VIII--COW GROUPS OF BREED NO. 4

Cow Group	Foundation Cow	Female Descendants
	602	631
	603	
	604	606-607-608-630
	609	618-629-644-664-651
	610	
	611	
	612	627
	613	
	614	622-626-632-635
O	615	620-625-634-638-639-645-647-650-652-654-657-660-661-662-663-667-668-670-672-673
	616	624-628-633
	617	621
	618	
	623	636-640-643-648-649-653-655-665-669-671-674
	641	642-646-656-659-666

Reproductive Efficiency of Cow Groups

In breed No. 1 the foundation cow of groups A_2, A_3, and A_4 were daughters of foundation cow of group A. In breed No. 2, foundation cow of group F_1 was a daughter of F, and in breed No. 3 foundation cow K_3 was a daughter of K. However, since all these cows were purchased as foundation animals, the female descendants of each were considered as composing a cow group. This treatment results in duplication in the above indicated groups.

Breed No. 1. As shown in Table IX, breed No. 1 contains seven cow groups of 11 to 62 animals with breeding records. The mean per cent reproductive efficiency for the various cow groups ranged from 54.46 ± 4.83 to 85.48 ± 2.44, a difference of 31.02 ± 5.4. The odds against such a difference occurring due to change are 6249:1. The foundation cows of groups A_2, A_3, and A_4 were full sisters. The foundation cows of groups B, C, and D were not related.

Breed No. 2. Four cow groups in breed No. 2 contain from 14 to 39 animals with breeding records. Group F_1 has the highest mean reproductive efficiency with 81.86 ± 1.88. Group I has the lowest with 68.83 ± 5.28. The difference of 14.03 ± 5.6, with odds of 9:1, may not be significant.

Breed No. 3. The number of cows with breeding records in five of the cow groups of breed No. 3 ranged from 13 to

52. The difference in reproductive efficiency between the high group K_3 and the low group N is 18.81 ± 5.35. The odds against such a difference occurring due to chance are 54:1.

Breed No. 4. Breed No. 4 contains one cow group of 11 or more cows with breeding records. Group O with 11 cows has a mean reproductive efficiency of 81.97 ± 1.06 per cent.

TABLE IX--REPRODUCTIVE EFFICIENCY OF COW GROUPS

Cow Group	Females with Herd Number	Cows with Breeding Record	Reproductive Months	100 per cent Months	Mean reproductive Efficiency
	No.	No.	No.	No.	%
Breed No. 1					
A	97	62	3264	2463	67.24 ± 2.51
A_2	38	25	1241	926	63.74 ± 4.68
A_3	38	22	1138	889	71.33 ± 3.55
A_4	18	12	619	468	70.57 ± 5.6
B	15	11	776	672	85.48 ± 2.44
C	13	12	709	396	54.46 ± 4.83
D	16	14	863	624	70.02 ± 4.85
Breed No. 2					
F_1	49	31	2104	1519	81.86 ± 1.88
F	58	39	2032	1576	79.35 ± 1.29
G	50	37	1574	1252	79.24 ± 2.15
I	20	14	753	571	68.83 ± 5.28
Breed No. 3					
K_3	32	19	1098	999	87.22 ± 1.62
K	71	40	2419	2037	81.9 ± 1.92
L_1	94	52	2851	2428	84.38 ± 1.19
M	30	16	1003	835	79.72 ± 4.46
N	19	13	653	469	68.41 ± 5.10
Breed No. 4					
O	21	11	608	477	81.97 ± 1.06

The study of cow groups, disregarding breeds, shows a significant difference of 32.76 ± 5.09 per cent in mean reproductive efficiency between the high group in breed No. 3 and the low group in breed No. 1. The odds against such a difference occurring due to chance are 16,665:1.

The cow groups of breed No. 1 show the greatest variation, ranging from a low of 54.46 per cent for group C to a high of 85.48 per cent for group B. The difference of 31.02 ± 5.41 per cent is significant. As a contrast, there is only a small amount of variation among the cow groups of breed No. 2. There is no significant difference between the reproductive efficiency of the high and low group of this breed.

Composite Reproductive Efficiency

It willbe recalled that in studying the cow groups only those groups with eleven or more cows with breeding records were considered. However, in compiling the data presented in Tables X and XI, which deal with the reproductive efficiency of the entire herd, all cows with reproduction records were included. This difference in procedure explains what might appear to be a discrepancy in the number of animals considered in Table IX, as compared to the numbers in Tables X and XI. Duplications of cows are also eliminated in Table XII.

TABLE X--REPRODUCTIVE EFFICIENCY OF HERD

Breed	Females with Herd Number	Cows with Breeding Record	Reproductive Months	100 per cent Months	Mean reproductive Efficiency
	No.	No.	No.	No.	%
1	143	99	5612	4156	67.55 ± 1.88
2	153	106	5549	4215	76.44 ± 1.47
3	214	121	6926	5769	81.27 ± 1.67
4	71	42	2269	1648	72.77 ± 1.51

Table X gives a comparison of the reproductive efficiency of all animals in the four breeds. Breed No. 1, containing 99 cows with breeding record, has the lowest mean reproductive efficiency with 67.55 ± 1.88 per cent. Breed No. 3, with breeding records of 121 cows, has the highest mean reproductive efficiency with 81.27 ± 1.67 per cent. The difference of 13.72 ± 2.51 per cent seems significant, with odds of 3,570:1 against such a difference occurring due to chance. From a practical standpoint, this means a loss of about one calf or lactation every three years for breed No. 1, as compared to a similar loss every five years for breed No. 3.

More space is devoted to breed comparisons because it is felt that the breed differences may be more representative, due to the larger number of animals involved. No less striking or significant, however, are the differences existing between the various cow groups.

The frequency distributions of the reproductive efficiency of the individual cows of each breed is presented in Table XI.

TABLE XI--DISTRIBUTION OF REPRODUCTIVE EFFICIENCY OF ALL COWS STUDIED

Class Reproduction Efficiency	0%	1-20%	21-40%	41-60%	61-80%	81-100%
Breed		% of all animals of each breed				
1	9.6	0	8.6	12.4	34.6	34.5
2	3.6	0	.9	10.9	36.6	47.6
3	2.3	0	0	8.5	27.0	61.9
4	0	0	2.3	23.2	34.8	39.5
Herd	4.4	0	2.85	11.95	32.73	48.05

It is interesting to note in what class of reproductive efficiency the majority of cows of each breed fall; 34.6 per cent of all the cows of breed No. 1 showed a reproductive efficiency of 61-80 per cent, while 61.9 per cent of the cows in breed No. 3 possessed a reproductive efficiency of 81 per cent or better. The majority of cows in breed No. 2 ranged above the 71 per cent mark, with 70.5 per cent of the cows ranging in reproductive efficiency from 71-100 per cent; 81.2 per cent of all the cows of breed No. 3 were above 71 per cent in reproductive efficiency. Breed No. 1 had only 56.6 per cent of the cows with reproductive efficiency above 71 per cent. One may readily see the striking differences between the various breeds studied.

Discussion

It is realized that in a study of this type some assumptions are necessary, and it is impossible to eliminate all factors that may affect the results obtained. Apart from the procedure and numerical method of expressing reproductive efficiency, two questions arise which have important bearing on the validity of the conclusions arrived at.

One question is the number of animals necessary for such a study. In comparing cow groups within the breeds, only those with eleven or more cows with individual breeding records have been considered. Inasmuch as this study involves the reproductive performance of 368 animals, it is felt that the results should possess a fair degree of reliability.

One of the most difficult problems in a study of this sort is to assess the influence of the herd sire. It is not to be inferred that the impaired reproductive efficiency encountered in this analysis was not in part due to the sires. However, since this study extended over a period of 24 years and involved some 21 bulls for breed No. 1, 17 bulls for breed No. 2, 10 bulls for breed No. 3, and 16 bulls for breed No. 4, obtained from widely different sources and largely unrelated, it does not appear likely that the influence of any sires of low fertility was concentrated in any one breed or group. This is strengthened by the fact that widely different efficiencies were obtained with substantially the same sires. For example, in breed No. 1, cow group C shows a very low mean reproductive efficiency, while cow group B shows a very high mean reproductive efficiency.

Longevity of Fertility

The longevity-of-fertility rating for each breed, and the data upon which it is based, are given in Table XII. It will be recalled that 120 100-per-cent months was set up as a standard longevity of fertility rating of 100. As this measure is an attempt to evaluate the longevity of fertility, its applicability is limited to cows that were disposed of because of poor reproductive efficiency or to cows that have demonstrated their long-lived fertility by producing ten or more calves.

TABLE XII--LONGEVITY OF FERTILITY

Breed No.	Non-breeders No.	Sterile Females No.	Cows with 120 or More 100% Months No.	Longevity of Fertility Rating Mean
1	28	10	1	32.56 ± 3.19
2	12	4	1	36.47 ± 5.53
3	8	3	6	63.52 ± 7.35
4	12	0	0	25.54 ± 4.37

Due to the fact that many of the cows in breed No. 4 were sold when fairly young, the mean longevity-of-fertility rating for the 12 cows of this breed is the lowest of the group. It is interesting to note the number of non-breeders, sterile females, and cows with 120 or more 100 per cent months in each breed on which this measure was based. Breed No. 1 contained 28 non-breeders, 10 sterile females, and only one cow that produced 10 or more calves, as compared to eight non-breeders, three sterile females, and six cows with 120 or more calf months in breed No. 3. Assuming that the mean longevity-of-fertility rating is representative, then the average cow of breed No. 1 would drop about three calves in comparison to about six calves per cow of breed No. 3.

Reason for or Method of Disposal

The following table gives the reason for or method of disposal for all the cows included in this study. It is interesting to note that the largest number of abortion reactors, 16, were in breed No. 3 which also had the highest mean reproductive efficiency. This would seem to strengthen the contention that the disease factor, contagious abortion, is not responsible for the poor showing of breed No. 1.

TABLE XIII--REASON FOR OR METHOD OF DISPOSAL

Reason or Method	Breed No. 1	Breed No. 2	Breed No. 3	Breed No. 4	Total
Non-breeder	28	12	8	12	60
Sterile	10	4	3	0	17
Poor producer	12	7	14	4	37
Mastitis	4	13	6	0	23
Abortion reactor	9	4	16	2	31
Abortion suspect	2	3	2	0	7
Milk cow	12	12	31	15	70
Foreign body	1	2	4	2	9
Bloat	1	2	3	1	7
Aged cow	2	2	1	1	6
Poor condition	3	0	0	0	3
Nurse cow	0	4	0	0	4
Poor type	3	1	3	0	7
Pneumonia	1	0	1	0	2
Septicemia	1	1	1	0	3
Metritis, pyometra	1	1	0	1	3
Milk fever	1	0	0	0	1
Injured	2	1	1	1	5
Lead poisoning	0	2	0	0	2
Aborted triplets	0	2	0	0	2
Died, yellow body removed	0	0	1	0	1
Pyo-nephritis	0	0	0	1	1
Tuberculosis	0	2	1	0	3
Failed to lactate	0	1	0	0	1
Interitis	0	0	1	0	1
Actinomycosis	0	0	2	0	2

PART TWO

Animal breeders have long been of the opinion that families and breeds of livestock vary greatly in their inherent capacity for prolific reproduction. The belief that these differences are due to the presence and expression of genetic factors is well founded, as demonstrated by the studies on *Drosophila* and other species.

The results obtained in Part One revealed significant differences in fertility existing among the various dairy cow groups and breeds available for this study. It was thought that these differences might be due to hereditary factors transmitted by the foundation cows to their female descendants.

Foundation Cows and Female Descendants

Correlation Coefficient. In order to have some convenient mathematical expression of the relationship between the foundation cows and their female descendants regarding reproductive efficiency, the correlation coefficient was obtained from the data given in Table XIV.

TABLE XIV--FOUNDATION COWS AND FEMALE DESCENDANTS

Breed No.	Family	Foundation Cow No.	Reproductive Efficiency Foundation Cow %	Reproductive Efficiency Female Descendants Mean %
1	A_2	3	73.2	63.34
1	A_3	4	79.3	70.95
1	A_4	5	90.56	68.75
1	B	8	91.52	84.88
1	C	9	55.55	54.36
1	D	12	75.59	69.60
2	F_1	202	60.6	77.76
2	F	204	75.0	79.35
2	G	216	77.77	81.99
2	I	217	80.0	69.05
3	K_3	401	91.5	81.65
3	K	405	82.3	87.5
3	L	406	86.9	84.33
3	M	408	86.2	79.29
3	N	409	79.3	67.50
4	O	615	75.0	82.17

Only foundation cows with ten or more female descendants with breeding record are given in this table. The correlation coefficient of $r = + .546 \pm .118$ seems very significant. Although the number of cow groups considered in this correlation is not large, it does give a good indication of the influence of foundation cows on their female descendants. Judging from this significant correlation, it would seem that the selection of foundation cows with a high degree of reproductive efficiency would insure to a great extent female descendants with the inherent capacity for high reproductive efficiency.

Coefficient of Variability. This constant considers both the variability as expressed by the standard deviation, and the position of the distribution as expressed by the mean, and therefore gives a constant expressing relative variability. The coefficient of variability of the foundation cows is C = 12.44 ± .47 per cent; of the female descendants, C = 11.74 ± .448 per cent. The difference of .70 ± .205 per cent is not significant with odds of 22.23:1 against such a difference occurring due to chance. The mean per cent reproductive efficiency of the foundation cows is slightly higher, 78.76 ± 1.65 per cent, as compared to 75.53 ± 1.46 per cent for the female descendants. The foundation cowsrange from 55.55 per cent to 91.52 per cent, and the mean values of the female descendants range from 54.36 per cent to 87.5 per cent. It may be concluded that there is no appreciable difference between the variation in reproductive efficiency among the foundation cows and the variation in the reproductive efficiency among their female descendants as determined from Table XIV.

<u>Reproductive Efficiency and Longevity of Fertility</u>

Williams (60) has observed that heifers which were efficient during their first breeding period continued to be efficient and were long-lived.

In the present study there were 83 cows, regardless of breed, with longevity-of-fertility rating. Correlating the per cent reproductive efficiency with the longevity-of-fertility, a significant value of r = + .804 ± .026 was obtained. This close relationship suggests that the per cent reproductive efficiency of a cow may be a good indication of the probable number of successful gestations which that animal may undergo.

Reproductive Efficiency and Number of Cows with Breeding Records

It was thought there might be some relationship between the mean per cent reproductive efficiency and the number of cows with breeding records in each cow group, regardless of breed. A correlation of r = ± .140 indicates that a small amount of selection for high reproductive efficiency may have taken place. In view of the management policy of the herd in which no selection for fertility has been practiced, and the small correlation value, it may be assumed that this selection has been due to natural forces; that is, self-elimination of animals with poor reproductive efficiency.

SUMMARY

1. The per cent reproductive efficiency and the longevity-of-fertility rating have been proposed as measures of the fertility of dairy cattle.

2. The study of the breeding records of dairy cow breeds revealed a significant difference in mean per cent reproductive efficiency. A corresponding difference among the cow groups was noted.

3. A significant difference in the longevity-of-fertility among the four breeds studied was observed.

4. Evidence has been presented indicating that the fertility of the foundation cows of the Oregon State College dairy herd determined to a large degree the fertility of their female descendants.

5. Results indicate that cows with high reproductive efficiency may have a longer reproductive lifetime than cows with low reproductive efficiency.

6. Evidence that perhaps some natural selection for fertility in the herd studied may have taken place, has been presented.

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