A STUDY OF REPRODUCTIVE PERFORMANCE OF THE OKLAHOMA STATE UNIVERSITY DAIRY HERD

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CHAPTER I

INTRODUCTION

The dairy cow, with her especially great proficiency in transforming feeds generally inedible by man into one of man's most nutritious foods, has led other classes of domestic animals in the economy of human food production. In order for a cow to maintain a long economically productive life, high milk production and reproductive efficiency are necessary. The use of genetically superior bulls presently available through artificial insemination appeared to be the most effective existing method for dairymen to increase milk production and income. In contrast to milk production, reproductive efficiency is much more complex in nature. Although there has been extensive research on breeding efficiency, there is only a limited amount of useful knowledge as to the most satisfactory way to improve reproductive performance. Feeding, management, season and disease are all factors which affect breeding efficiency. Low reproductive performance in terms of low conception rate and long calving interval is widely recognized to be of great economic significance. A 12-month calving interval is considered ideal for reproductive performance and productive potential of dairy herds. Shorter calving intervals will result in maximum income over feed cost as well as greater lifetime production.

The present trend toward large herds and the need for efficient feeding and milking management minimizes the contact between cow and dairyman. In addition, high labor cost or its unavailability, and time competition between several facets of dairy farming have led to lesser efficiency in dairy reproduction management. As a result of this, the calving interval has been gradually increasing.

A study based on breeding, calving and production records for the year 1968 through 1974 was conducted to determine the reproductive performance of the four dairy breeds of the Oklahoma State University dairy herd. The major objectives of the study were

(1) To determine the breeding efficiency as well as possible factors influencing its variation within a breed;

(2) to examine sources of variation affecting calving interval and their relative importance in each breed; and

(3) to relate the findings of the study to potential improvement in herd management.

CHAPTER II

LITERATURE REVIEW

Economic Losses Due to Low Reproductive Efficiency

Low reproductive efficiency due either to delayed first service, or great number of services per conception, has been a major problem in reproduction management.

Olds et al. (1954), Speicher et al. (1967), Louca et al. (1967), and Pelissier (1972) concluded that days open affected the gross income as a result of lower milk production, fewer calves, and reduced herd genetic improvement. It was estimated that a three-month delay in breeding would cost about $12 or $13 per year for an average cow, and $30 to $35 per year for a cow producing 10,000 pounds of milk per year (Olds, et al., 1954). A 12-month calving interval was found to be more desirable and economically justified by greater return over feed cost than longer intervals. A delay of conception beyond 86 and up to 116 days after freshening resulted in an average decrease in returns of $0.50 for each day. The decrease became $0.78 for each day when conception was delayed for 117 days longer (Pelissier, 1972). Cunba et al. (1969) calculated that by increasing the calf crop 5 percent, from 75 to 80 percent, the profit per calf would increase $5.00. Maijala (1964) reported that the average relative milk yield of cows with 15-month calving intervals was about 10 percent lower than that of other cows per year. The difference became 22 percent when only cows with 12-month calving intervals were taken as a basis of comparison. Pelissier (1972) showed an annual loss of $539,948,126 for the United States, resulting from low fertility and delayed conception. This amount would be equivalent to 7 percent of the gross national dairy income.

The importance of reproductive efficiency in terms of genetic progress has been often overlooked because of lack of data on which to base an estimate of the loss in herd improvement potential through culling and genetic improvement. Johanson _et al_. (1968) noted that 40 percent of cows leaving herds were culled for reproductive disorders and the figure was especially high in the age class 4-7 years, which is the time when cows reach their highest production capacity. A high calving rate is necessary to have sufficient replacement females to be able to cull cows in the selection process and at the same time maintain the herd size.

Fertility and Its Heritability

The above discussion gave us, in economic and genetic terms, the magnitude of low fertility in dairy cows.

Winters (1954) classified the causes of low fertility into 10 groups: anatomical defects, mechanical injury of the genital organs, infectious diseases, prenatal death of the fetus, physiological disturbances, especially improper hormone balance, gametic incompatibility, low viability of gametes, failure to breed at optimum time during estrus, psychic disturbances, and genetic causes. Asdell (1968) indicated that there were any number of trades between complete fertility and sterility of the cow and the bull.

In general, heritability of fertility in several studies has not been significantly different from zero. Maijala (1954), analyzing the data of 200,000 service periods of nearly 80,000 cows, concluded that heritability of reproductive efficiency varies according to the measure used, the age of cows, the A.I. units, the year of calving or insemination, and the source of information. The heritability of services per conception increased slightly with the number of calvings and ranged from 4 to 6 percent. The heritability of calving interval was about 4 percent. Everett et al. (1966) found similar results of five measures of breeding efficiency of Holstein and Guernseys: days open (respectively 0.07 and 0.07), calving interval (0.08 and 0.10), days from parturition to first breeding (0.04 and 0.02), days from first breeding to conception (0.08 and 0.07), and services per conception (0.03 and 0.05). These results did not confirm the high correlation of 0.546 ± 0.118 reported by Spielman et al. (1939) between the reproductive efficiencies of dams and daughters, suggesting a high degree of inheritance.

Although the heritability of some abnormalities (gonadal hypoplasia, lack of a segment of the epididymis, cryptorchidism, white heifer disease, and adrenal virilism) has historically been responsible for reduced fertility, the reproductive disturbances were often due to a chain of interacting causes. Therefore, it was not possible to separate the relative importance of genetic effect from environmental influences. Consequently, investigations were conducted to elucidate which source of information was the more reliable and practical for collecting data needed for assessing the fertility of individual cows.

Measures of Reproductive Performance

The low heritability, and consequently the lack of information on the degree of genetic influence on many components of reproductive performance, made selection for breeding efficiency hazardous and of little benefit for dairymen. However, for practical evaluation of the reproductive status of the dairy herds, it is of interest to emphasize the calving interval. The advantage of this interval from a practical standpoint was the fact that almost all causes of breeding problems had an influence on it. Calving interval might be considered the sum of one constant (gestation length) and two variables (parturition to first breeding and first breeding to conception).

Everett et al. (1966) reported high phenotypic and genetic correlations between days open and first breeding to conception (respectively 0.87 ± 0.003 and 0.94 ± 0.02), and between first breeding to conception and services per conception (respectively 0.83 ± 0.003 and 1.14 ± 0.07). This indicated that cow differences in first breeding to conception were largely responsible for the variation in days open. Poston et al. (1962) reported a correlation of 0.81 between days open and services per conception. They noted that 65 percent of the variation in days open were attributable to the variation of services per conception. Also correlation as high as 0.93 ± 0.01 between calving interval and days open suggested that calving interval would serve the same purpose as days open for evaluation of the reproductive performance of dairy herds.

Factors Affecting Calving Interval

Age of Cows

Everett et al. (1966) reported that breeding efficiency increases slightly as cows get older. The correlation coefficients between age in months and respectively calving interval, days open, parturition to first service, first service to conception and services per conception were low and negative except for services per conception. Maijala (1964) and Muller (1974) indicated that the occurrence of retained placentae increased slightly with age (1.80 percent in 2.3 year old cows versus 2.48 percent in 6.7 year olds). The frequency of distinct heat symptoms was also slightly higher in older cows than in three year old cows. On the contrary, the age significantly influenced the occurrence of ovarian cysts. The frequency of ovarian cysts was significantly higher in four year old cows than two year old cows and its annual occurrence was highly significant in the age class of five to nine year old cows. Pelissier (1972) reported a highly significant ($P < 0.001$) relationship of retained placentae to subsequent lowered breeding efficiency. However, Muller (1974) did not find a significant effect of retained placentae on days to first breeding, days to conception, and services per conception. Both agreed that the incidence of genital infection (vaginitis, metritis, dystocia, and other abnormal conditions) was greater for cows with retained placentae than normal cows, and was the intermediate cause of delayed breeding and reduced reproductive efficiency.

Milk Production

Gaines (1927), Boyd *et al*. (1954), Frank (1950), Touchberry (1959), Smith *et al*. (1962), and Everett *et al*. (1966) concluded that high producing cows were no less fertile than low producing cows. There was no significant effect of level of butterfat and milk production on days open and services per conception. Marion *et al*. (1968), Whitmore *et al*. (1974) reported a significantly longer interval from parturition to first ovulation estrus in high producing cows. Retained placentae, metritis, and follicular cysts were found to increase significantly with the level of milk production, suggesting that those structures were directly responsible for delayed estrus. The cysts persisted an average of 35 days. Robert (1955), Marion *et al*. (1966), and Morrow *et al*. (1966) reported that the occurrence of cystic follicles was significantly higher during winter than in spring. This suggested that seasonal stresses compounded the effects of production stress as a cause of follicular cysts. Muller *et al*. (1974) and Pelissier (1972) suggested an association between milk fever, retained placentae and high milk production. They found higher milk ($P < 0.1$) and fat ($P < 0.05$) production from cows with retained placentae and high relationship ($P < 0.01$) between milk fever and retained placentae.

Nutrition

Extensive research has been done on the influence of dietary energy on heifer reproductive performance. It was reported that sexual maturity was hastened by high intake energy and deferred by low intake energy. The effects of overfeeding were also thought to be fatty degeneration of the reproductive organs or clogging of the entrance to the oviduct (Asdell, 1968).

Reid (1960) did not find a significant difference in number of services per conception among cows raised on high, medium, and low planes of nutrition. Whitmore et al. (1974) reported from a study of 393 calving intervals of 168 Holstein cows that the intervals from parturition to first ovulation and to first estrus were significantly longer in cows on high level of nutrition than on average level of nutrition (32 versus 28 days, and 42 versus 35 days). There was more retained placentae in cows on high level of nutrition than on average level of nutrition (17 percent versus 7 percent, $P < 0.05$). A significant interaction ($P < 0.05$) between level of nutrition and genetic level of milk production was found for days open (high production-high nutrition: 83 days, high production-average nutrition: 87, low production-high nutrition: 85 days, low production-average nutrition: 75 days).

The adequacy of a ration may depend on how well the nutrients, vitamins, and minerals are balanced and made available for body metabolism. Bentley et al. (1951), Rojas et al. (1965), Wilson (1966), and Thomas (1970) reported the possibility of a conditioned manganese deficiency which would lead to failure of heat, subnormal ovarian activity, and an increase in number of services per conception. Most of the research reports, Wilson (1966), Ward et al. (1970), Hignett (1959), Alderman (1963), and Steevens et al. (1970) suggested that phosphorus or vitamin D supplement favorably influence the exhibition of estrus, decrease the number of services per conception, and therefore might shorten the calving interval. Although there was no evidence of the effect of calcium on the reproductive performance, the ratio calcium phosphorus was of importance for milk production.

The interrelationship of minerals and vitamins, and the lack of a complete understanding of their metabolism, has made it difficult to understand their individual effect on the reproductive performance of dairy cows. The effects of vitamin A deficiency are thought to be keratinization of the vagina epithelium and delayed conception (Asdell, 1968). Ronning *et al*. (1953) suggested that the lack of dietary carotene might be responsible for the seasonal trend of retained placentae in winter. Trinder *et al*. (1969) reported that a lack of vitamin E which is normally lower in stored feedstuffs might be a contributing factor to higher incidence of retained placentae. He found that the injection of 680 IU of d-α tocopherol aceta and 15 mg of selenium one month before calving resulted in no retained placentae in 20 treated cows compared to 42 percent retained placentae in 42 untreated cows.

Management

Heat Detection and Veterinary Aid in Fertility Management. It is generally accepted that the duration of the estrus cycle is normally 18 to 24 days except early in the postpartum period when it is 15 to 18 days. Anestrus after calving, frequently occurs in dairy cows and is caused by pyometra, inadequate nutrition, cystic follicles and persistent corpora lutea. Retained placentae and metritis resulting from dystocia, poor hygiene at parturition, and infection by certain organisms (*Trichomonas fetus*, *Vibrio fetus*, *Brucella abortus*, and others), might also cause delayed exhibition of estrus and conception. Thus, efficient management of reproduction will at times need to include veterinary expertise.

Pelissier (1972), Asdel (1968), Bozworth et al. (1972), Johnson et al. (1966), and Hall et al. (1959) attributed the great variation from one herd to another in days open, calving to first heat, and calving to first service to differences in heat detection practices. Herscher et al. (1964) reported that three years of fertility management reduced calving interval from 433 days to 386 days at the end of the third year. Morrow (1970) noted a reduction of number of services per conception from 2.3 to 1.6, and a reduction of forced culling of cows for disease purposes from 55 to 19 percent during four years of a reproductive health program. Examination of cows 25 to 40 days after parturition and prior to breeding to make sure that the reproductive tract were free of gross infection and undergoing involution at normal rate, and examination 30 to 45 days after breeding to confirm pregnancy, were essential for good management of reproductive performance.

Time of Breeding in Relation to Onset of Estrus and Parturition. The duration of standing heat is usually 12 to 18 hours in cows and somewhat shorter in heifers. Ovulation typically occurs 12 to 14 hours after the end of estrus. It is common practice that cows be bred near the end of standing heat. However, a standard interval from calving to first service is difficult to set up under all conditions. Various intervals have been given in the literature in relation to the fertility of the studied herds. It is logical that a certain minimum postpartum interval is required for involution of the uterus so as to avoid infection consequent to service. Without postpartum examination to confirm that cows were ready to breed, it was felt that higher fertility might be expected by waiting 60 days after calving.

Hofstad (1941) found that cows bred at 40 to 50 days postpartum required more services per conception (2.11 versus 1.58) and had higher percentage of abortion, cases of metritis, dystocia and retained placentae (33) than those bred at 60 to 70 days. VanDemark et al. (1950) reported a significant correlation (r = -0.116) between time of breeding within 80 days after calving and services per conception. Marion et al. (1968) indicated that the endometrium was again capable of being involved in normal activity by 30 days postpartum. Whitmore et al. (1974) noted that cows bred at non-standing estrus had lower fertility than those bred at standing estrus (27 percent versus 55.3 percent, $P < 0.01$). They found a significant ($P < 0.005$) relationship between conception rate at first service and the order number of estrus period before 74 days postpartum (35, 50, 73, 72 and 100 percent conception rate at first service on, respectively, 17, 28, 67, 61 and 7 cows within the same order 1, 2, 3, 4, and 5 postpartum estruses before 74 days). Thatcher et al. (1973) reported a significant ($P < 0.05$) decline in services required per conception with increased number of heat between zero and 60 days postpartum (0 heat, 2.60; 1, 2.58; 2, 2.32; 3, 2.21; 4, 1.75). He suggested that early estrus activity, especially between zero and 30 days postpartum might be indicative of greater likelihood of earlier re-breeding. All reports strongly indicated that a good record keeping system of the estrus periods of cows was highly useful in determining when a cow should be bred following parturition.

Hormone Use in Fertility Management. Since failure to detect estrus is a major cause of long calving intervals, especially in large herds where it is difficult and expensive to give attention to individual cows, many attempts have been made to synchronize heat.

A practical trial on 2,074 cows conducted by Frank (1950) suggested that pregnant mares' serum (PMS) treated cows did not differ from control and mechanically (enucleation of the corpus lutca, rupturing of a cyst, or massage of the ovaries and uterus per rectum) treated cows in reproductive performance. Current research reports on melengestral acetate (MGA) and prostaglandin ($PGF_2\alpha$) give some hope for the future. Britt et al. (1974), conducting an experiment on 27 normal Holsteins, reported that cows fed 1 mg of MGA for 14 days beginning 21 days after calving had better reproductive performance than control cows. Treated and untreated cows had almost the same average for calving to first service (73 ± 6 versus 75 ± 6 days). Treated cows compared to control cows had significantly ($P < 0.05$) shorter interval from calving to first estrus (37 ± 9 versus 63 ± 11) fewer days open (83 ± 6 versus 153 ± 15) and fewer services per conception (1.7 ± 3 versus 3.3 ± 8). Huertas et al. (1972) reported similar results when MGA was fed at an early postpartum date.

Lauderdale (1974) indicated that cows treated with $PGH_2\alpha$ five days prior to the next expected estrus cycle, returned to estrus about 70 to 92 hours later. This would suggest that prostaglandins might have the potential for allowing artificial insemination without estrus detection.

Season Effects on Reproductive Performance

Stott et al. (1962) reported that high temperature and humidity were major factors for increased number of services per conception and prolonged estrus cycles associated with high rate of embryonic mortality. Heat stress might cause reduction of the intensity of estrus, and anestrus suggesting an alteration of the intricate balance between pituitary and ovarian hormones. Courot et al. (1961) and Stott et al. (1961) suggested that seasonal depression of fertility due to heat stress was attributable to the cows. Poston et al. (1962) found a linear correlation of 0.30 between the monthly variation in mean temperature (above 55°F) associated with the expected period of first service and mean subsequent calving intervals. Ingraham et al. (1974) reported that the conception rate response to the average temperature humidity index on the second day prior to breeding was linear ($r = -0.995$). Thatcher (1974) indicated that a deviation of 0.5°C above the mean of uterine temperature the day of insemination and the day after insemination decreased conception rate respectively 12.8 and 6.9 percent. A reduction of environmental thermal stress by cooling systems prevented the expected decrease in reproductive efficiency. Steinback et al. (1971) noted that the seasonal effect on dairy cattle might be obscured by the management (housing, feeding, and breeding season). In less intensive management, he found that the effect of the month upon monthly conception rate was highly significant ($P < 0.001$). The annual variation in rainfall was highly correlated ($r = -0.73$) to the conception rate suggesting an increase of the infestation or a reduction of the quality and quantity of forage supply. Müller (1974) and Wethrill (1965) found significantly higher incidence of retained placentae in winter than in summer.

Fertility of Bulls

The genetic fertility of bulls and the quality of their semen is of special interest for artificial insemination units. It is commonly considered that a 60 percent, 60-90 day non-return rate is the minimum level to retain a bull in artificial insemination usage.

Dickinson et al. (1968) pointed out a slight negative relationship between reproductive efficiency and genetic merit of bulls for milk production. However, there was no evidence that bulls with low predicted differences for milk production produced better semen or better breeding efficiency. Norman et al. (1970) reported significant differences among breeds in non-return rate. Jersey bulls were significantly ($P < 0.1$) higher than Holstein, Ayrshire, and Guernsey bulls (respectively, 72.7, 71.4, 70.1, 67.8 percent 60-90 day non-return rate to first service).

CHAPTER III

MATERIALS AND METHODS

Source of Description of Data

The data for this study were obtained from calving, breeding and production records of the Oklahoma State University dairy herd which included four breeds: Ayrshire, Guernsey, Holstein and Jersey. All cows which had completed a lactation and calves subsequently, between January 1, 1968, and March 3, 1974, were considered in the study. There were 701 calving interval records completed during the 75-month period. Two intervals were excluded for lack of information and three intervals were excluded because the number of inseminations was greater than seven, the maximum number of services allowed for inclusion in this study. The final data included 696 calving intervals on 370 cows (131 Ayrshires, 31 Guernseys, 161 Holsteins and 47 Jerseys with respectively 240, 57, 315 and 84 calving intervals).

Management of the Dairy Herd

An interview with Glenden Adams, manager of the herd, was used to determine possible relationship of managerial status to reproductive performance. He was in charge of the herd throughout almost the entire period of the study. All cows were in dry lot with limited pasture. A typical ration was sorghum silage, alfalfa hay or dry sudan grass, and concentrates. The amount of concentrate given each cow during her period of lactation ranged from 9 lbs. of a 12 percent crude protein mix for the average cows to 23 lbs. at a 18 percent crude protein mix for the high potential milk production group. When cows dried off, the concentrate was eliminated until 30 days before calving when a 12 percent crude protein mix was supplied at the rate of one percent of body weight. The ration was balanced for calcium and phosphorus requirement. All cows were milked twice daily. They were checked for heat twice daily, early in the morning and early in the afternoon and heat detection continued during the daily routine activity. Cows in heat in the morning were inseminated in late afternoon (at only about 7 hours after first detected) while those in heat in the afternoon were inseminated the next morning. Sometimes heat detection was suboptimum in very cold weather and heat patches were occassionally used to detect suspect cows with silent or short heats.

All cows were bred artificially by qualified technicians. Natural service was occassionally practiced after the second service. Frozen semen came from different artificial insemination units (ABS, CARNATION, NOBA, and CURTISS). The selection of bulls was based on type and production traits to improve the type characteristics and production potential of the herd. It was indicated that about 5 percent of the herd encountered breeding problems associated with uterine infection, retained placentae and cystic ovaries. Selection process for type and production traits was more intensive in Holsteins than in Ayrshires and no selection in Guernseys and Jerseys.

To maintain seasonal calving, all heifers were inseminated between 16 and 24-months of age starting on September 25, in order to start the calving season in July. A postpartum period of 60 days before first breeding was allowed for all cows which calved between July and November and 45 days for those which calved between December and March. If parturition occurred after March, re-breeding would be delayed until September. Therefore a portion of the variation in the length of calving intervals was due to a management decision and production goals.

Recording Statistics and Analysis Procedure

The data were processed on IBM cards. Two cards were made for each calving interval and included the following information: cow's identification, birthdate, breed, lactation number, date of calving, date of first and consecutive inseminations, identification of bull used for each insemination, date of subsequent calving, 305-day M.E. milk production and peak daily milk level during lactation.

The analysis was performed with a computer program (SAS) developed by Barr and Goodnight (1971). In the first phase, a frequency table of bull fertility was generated. The analysis on the breeding efficiency was based on this frequency table. The test criterion used was the chi-square technique as described by Steel and Torrie (1960). In the second phase, the analysis of sources of variation affecting calving interval and their relative importance, was based on the general regression model

$$(1) \quad Y_{ij} = \mu + C_i + L_j + B_1X_{1ij} + \ldots + B_9X_{9ij} + e_{ij}$$

where

Y_{ij} is the calving interval

μ is the population mean

C_i is the effect of the ith cow

L_j is the effect of the jth lactation

B is the partial regression coefficient of the independent variable X

The independent variables, X, were (1) the days from calving to first service (C-FS), (2) days from first service to conception (FS-Co), (3) services per conception (S/Co), (4) month of first service (MFS), (5) month of conception (MCo), (6) month of calving (MC), (7) year of calving (YC), (8) age of calving (AC) and (9) peak milk level (PML).

e_{ij} is the random element normally distributed with mean 0 and variance σ^2.

Since there were many cows and lactations for each breed, the matrix for handling the data became very large. A frequency table with two-way classifications (cow x lactation) was made available to avoid inadequate cells. The program was broken into the following steps:

the above equation could be written as

$$(2) \quad Y_{ij} = \mu + C_i + L_j + Z_{ij}$$

where

$$(3) \quad Z_{ij} = B_1X_{1ij} + \dots + B_9X_{9ij} + e_{ij}$$

Thus, the least square estimates for C_i and L_j were obtained from equation (2) and $Y_{ij} - \hat{Y}_{ij} = Z_{ij}$ was obtained. The new variable Z_{ij} obtained from this output was used to estimate the B values in equation (3). The Z_{ij} cards were punched so that the estimates for B in equation (3) could be obtained by stepwise regression procedure without necessity of converting the big matrix required by equation (1). The estimation of B values from equation (3) were interpreted as effects of X values on Y after removing cow and lactation effects. This could be done under the assumption that the linear effects due to X variables were the same for each cow and lactation observation. This would really tell us what effect did a change in one of X variables have on the change of $\hat{Y}$ variable holding all other variables fixed. The equation (3) was not to be used to estimate $\hat{Y}$.

In such a program of stepwise multiple regression, the computer selects the most promising possible independent variable -- the one that provides the greatest reduction in the unexplained variation in $\hat{Y}$ -- at each stage. In doing this, the computer performs simple regression separately for each independent variable in equation (3), printing the results for the best one. The next step of the program performs separate multiple regressions, each combining one of the remaining independent variables with those selected in the previous stages. Again the one that reduces unexplained variation the most is chosen to be permanently included in all future stages. The process continues in successively higher dimensions until no further reduction in the unexplained variation is possible at the 0.1 significance level.

The partial correlation coefficients adjusted for cow and lactation were studied to express the relationships among variables included in equation (3).

CHAPTER IV

RESULTS AND DISCUSSION

Breeding Efficiency

In this study of 696 conceptions, as confirmed by subsequent calving, it was found that 2.10 services were required per conception over the entire period of 75 months. The chi-square test indicated that conception rate was significantly ($P < 0.1$) among breeds. Ayrshire and Guernsey breeds had lower breeding efficiency than Holsteins and Jerseys (respectively 2.27 and 2.27 versus 1.95 and 1.96 services per conception, Table I). Holsteins had a higher conception rate than Ayrshires ($P < 0.05$).

Conception rate at each service summarized for all breeds (Table II) shows that 46.84, 23.28, 15,37 percent of the services resulted in conception on the first, second and third services respectively. The remaining 14.51 percent of the conceptions took four or more services. The reproductive performance was better in Holsteins and Jerseys with only about 10 percent of the conceptions required more than three services compared to nearly 20 percent in Ayrshires and Guernseys. The efficiency of conception for Holsteins and Jerseys at each of the services after the third was consistently 65 percent or better. In Guernseys and Ayrshires, the efficiency of these services was quite variable.

TABLE I

SERVICES REQUIRED PER CONCEPTION AND PERCENT SERVICES RESULTING IN CONCEPTION DURING THE PERIOD 1968-1974

Breed	Number of Bulls	Number of Cows	Number of Conceptions	Number of Services	Services per Conception	Percent Services Resulting in Conception
Ayrshire	13	131	240	545	2.27	44.0
Guernsey	9	31	57	129	2.26	44.1
Holstein	33	161	315	613	1.95	51.3
Jersey	11	47	84	165	1.96	50.9
Overall Breed	66	370	696	1452	2.10	47.9

The decrease in conception rate at the second and third services was more evident in Ayrshires and Guernseys than in Holsteins and Jerseys (Table II). It was found that the conception rate at any one service depended significantly ($P < 0.05$) on the breed.

The distribution of bulls according to their level of fertility achieved is shown in Table III. The percentage of total services to bulls with conception rates greater than 60 percent, which was considered to be the average necessary to retain a bull in regular service, was 4.8, 15.5, 22.0 and 13.9, for Ayrshire, Guernsey, Holstein and Jersey bulls respectively. The number of services to bulls at the different levels of fertility differed significantly ($P < 0.005$) among breeds. Therefore it can be concluded that the conception rates among breeds were highly influenced by the differences in the number of

TABLE II

NUMBER AND PERCENT OF COWS CONCEIVING AT EACH
OF A SERIES OF CONSECUTIVE SERVICES

Breed	Item	Services Required Per Conception						
		1	2	3	4	5	6	7
Aryshire	Total Services	240	134	81	50	27	10	3
	Total Conceptions	106	53	31	23	17	7	3
	% Conception	44.1	39.5	38.2	46.0	62.9	70.0	100.0
	% of Total Conceptions	44.1	22.0	12.9	9.5	7.0	2.9	1.2
Guernsey	Total Services	57	30	16	11	9	5	1
	Total Conceptions	27	14	5	2	4	4	1
	% Conception	47.3	46.6	31.2	18.1	44.4	80.0	100.0
	% of Total Conceptions	47.3	24.5	8.7	3.51	7.0	7.0	1.7
Holstein	Total Services	315	164	88	31	11	4	
	Total Conceptions	151	76	57	20	7	4	
	% Conception	47.9	46.3	64.7	64.5	63.6	100.0	
	% of Total Conceptions	47.9	24.1	18.1	6.3	2.2	1.2	
Jersey	Total Services	84	42	23	9	3	3	1
	Total Conceptions	42	19	14	6	0	2	1
	% Conception	50.0	45.2	60.8	66.6	0.0	66.6	100.0
	% of Total Conceptions	50.0	22.6	16.6	7.1	0.0	2.3	1.1
Overall Breed	Total Services	696	370	208	101	50	22	5
	Total Conceptions	326	162	107	51	28	17	5
	% Conception	46.8	43.7	51.4	50.5	56.0	77.2	100.0
	$ of Total Conception	46.8	23.2	15.3	7.3	4.0	2.4	0.7

TABLE III

DISTRIBUTION OF BULLS USED ACCORDING TO THEIR CONCEPTION RATE

Breed	Percent Conception Rate								
	Greater than 60			50 to 60			Less than 50		
	No. Bulls	No. of Services	% of Services in Breed	No. Bulls	No. of Services	% of Services in Breed	No. Bulls	No. of Services	% of Services in Breed
Ayrshire	2	26	4.7	6	218	40.0	5	301	55.2
Guernsey	3	20	15.5	2	36	27.9	4	73	56.5
Holstein	14	135	22.0	7	256	41.7	12	222	36.1
Jersey	4	23	13.9	4	50	30.3	3	92	55.7

services to bulls of different fertility levels. However, the identification of causes of the low level of fertility were difficult to identify because of the complexity of management and environmental effects. Technician ability and the intervals from the observation of heat to service in some cases might contribute to the low conception rate. The trend for Holstein to have the best fertility could be due to better management being given to high producing cows.

Source of Variation in Calving Interval and Their Relative Importance

Table IV presents the unadjusted means for calving interval, the interval from calving to first service and from first service to conception, services per conception, gestation length, peak milk level and 2 x ME 305 day milk production for each breed. The calving interval ranged from 396 days for Holsteins to 414 days for Guernseys, or, a range of 13.0 to 13.5 months. The interval from calving to first service was relatively long and ranged from 83 days in Ayrshires to 90 days in Guernseys. These intervals were greatly influenced by some cows having to be held open for longer than necessary for optimum reproductive performance, to control calving dates to meet milk supply demand. The interval from first service to conception ranged from 33 days in Holsteins to 40 days in Ayrshires. The standard deviation was extremely large for all those intervals. Holsteins had the highest peak milk level with 64.8 lbs. compared to 54.3, 47.7 and 41.2, respectively, in Ayrshires, Guernseys and Jerseys.

Separate analyses were performed on the calving interval data in each of the four breeds in the study. The mean squares and coefficients

TABLE IV

OVERALL MEAN FOR CALVING INTERVAL, CALVING TO FIRST SERVICE FIRST SERVICE TO CONCEPTION, SERVICES PER CONCEPTION, GESTATION LENGTH, PEAK MILK LEVEL AND 305-DAY MILK PRODUCTION

Item	Breed							
	Ayrshire		Guernsey		Holstein		Jersey	
	Overall Mean	S.D[1]	Overall Mean	S.D	Overall Mean	S.D	Overall Mean	S.D
Calving interval (days)	400.6	57.3	414.1	54.2	396.1	51.1	401.8	65.5
Calving to first service (days)	83.1	29.0	90.7	37.5	84.8	33.1	84.2	31.1
First service to conception (days)	40.1	54.2	38.9	55.7	33.0	42.4	36.6	53.5
Services per conception	2.24	1.52	2.29	1.71	1.95	1.15	1.95	1.29
Gestation length (days)	277.5	-	285.1	-	278.2	-	280.9	-
Peak milk level (lbs.)	54.3	11.0	47.7	9.2	64.8	14.4	41.2	9.4
305-day milk production (lbs.)	13013.5	-	10610.3	-	15872.2	-	9138.3	-

[1]S.D = Standard deviation.

of determination (R^2) from the analysis of variance for calving interval are presented by breed in Tables V, VI, VII, and VIII. In such analyses, R^2 is the proportion of the total sum of squares that is attributable to the independent variable considered as a source of variation.

Cow effect was highly significant ($P < 0.005$) in all breeds. Fifty-two to 65 percent of the variability of calving interval can be explained by the model using only cow and lactation number as independent variables. The amount of variation accounted for by cow was 65.7, 60.5, 52.5 and 62.3 percent of the total sum of squares respectively in Guernseys, Jerseys, Holsteins and Ayrshires. This revealed the importance of variability among cows within breed in the reproductive performance. Although lactation effects, adjusted for cow, were significant in Holstein, and Ayrshire, the coefficient of determination was low.

From equation (3), the estimation of partial regression coefficients B were interpreted as effects of the independent variables, X, on calving interval after removing cow and lactation effects. In essence this was determining what effect did a change in one of the variables have on the change of calving interval ($\hat{Y}$), adjusted for cow and lactation, holding all other variables fixed. In Guernseys, the services per conception (S/Co) and calving to first service (C-FS) appeared to affect $\hat{Y}$ significantly (respectively $P < 0.025$ and $P < 0.1$, table V). Equation (3) indicated that the change in $\hat{Y}$ could be predicted to be 9.81 days for each service change regardless of the length of the interval for C-FS, and 0.29 days for each day change in C-FS holding S/Co fixed at constant value. The amount of variation in calving interval explained by S/Co and C-FS were respectively 6.4 and 2.8 percent of the total sum of squares.

TABLE V

MEAN SQUARES AND COEFFICIENTS OF DETERMINATION (R^2) FROM THE ANALYSIS OF VARIANCE FOR CALVING INTERVAL[1]

Source of Variation	DF	Mean Squares	F	P	R^2
Cow Unadj.	28	5292.6	2.3	P < 0.025	0.657
Lact. No. Adj.	3	3350.6	1.5		0.045
Svc/co Adj.	1	14339.3	6.4	P < 0.025	0.064
Clv - 1st Svc Adj.	1	6226.4	2.7	P < 0.1	0.028
Error	21	2233.5		Total	0.794

[1]Breed: Guernsey

Similarly, first service to conception (FS-Co) and C-FS had significant effects (P < 0.001 and P < 0.1 respectively, Table VI) on $\hat{Y}$ in Jerseys. The partial regression coefficients adjusted for cow and lactation were 0.55 and 0.24, respectively for FS-Co and C-FS. The magnitude of the coefficient of determination for FS-Co was relatively important (R^2 = 0.20), whereas that for C-FS was low (R^2 = 0.013).

In the two breeds with greater numbers of cows, Holstein and Ayrshire, more variables appeared to affect $\hat{Y}$. In Holsteins, C-FS (P < 0.01)

FS-Co (P < 0.01) and S/Co (P < 0.1) significantly influenced $\hat{Y}$ (Table VII). In Ayrshires the S/Co, C-FS and month of first service (MFS) influenced $\hat{Y}$ significantly (respectively P < 0.001, P < 0.001 and P < 0.05, Table VIII). The partial regression coefficients adjusted for cow and lactation were 0.53, 0.23, 7.34, -1.80 and -0.17, respectively for C-FS, FS-Co, S/Co, YC and PML in Holsteins and 14.25, 0.40, 2.02, 0.125 and 2.72, respectively for S/Co, C-FS, MFS, MCo and YC in Ayrshires. The negative partial regression for PML suggested that high producing cows had better management. The difference in response of the change of $\hat{Y}$ on the change of YC might be explained by the selection pressure practiced on Holsteins which resulted in better reproductive performance of this breed from one year to subsequent years for the studied period.

TABLE VI

MEAN SQUARES AND COEFFICIENTS OF DETERMINATION (R^2) FROM THE ANALYSIS OF VARIANCE FOR CALVING INTERVAL[1]

Source of Variation	DF	Mean Squares	F	P	R^2
Cow Unadj.	44	4677.1	2.1	P < 0.01	0.605
Lact. No. Adj.	6	249.9	0.1		0.004
1st Svc - Co. adj.	1	66483.6	30.9	P < 0.001	0.200
Clv - 1st svc. adj.	1	4329.1	2.0	P < 0.1	0.013
Error	29	2146.6		Total	0.822

[1]Breed: Jersey

TABLE VII

MEAN SQUARES AND COEFFICIENTS OF DETERMINATION (R^2) FROM THE ANALYSIS OF VARIANCE FOR CALVING INTERVAL[1]

Source of Variation	DF	Mean Squares	F	P	R^2
Cow unadj.	160	2836.9	1.9	$P < 0.001$	0.525
Lact. No. Adj.	6	4600.3	3.1	$P < 0.005$	0.032
Clv - FS adj.	1	85689.1	59.4	$P < 0.001$	0.10
1st svc - co. adj.	1	85244.7	59.1	$P < 0.001$	0.10
Svc/conc. adj.	1	4020.4	2.7	$P < 0.1$	0.005
Yr clv. adj.	1	1815.2	1.2		0.002
Peak Milk Level adj.	1	1815.5	1.2		0.002
Error	142	1442.3		Total	0.766

[1]Breed: Holstein

In Guernseys and Ayrshires which had lower breeding efficiency, the major factors affecting $\hat{Y}$ were S/Co and C-FS, whereas in Holsteins and Jerseys which required lesser S/Co, those of FS-Co and C-FS were more influential. However, the high partial correlation adjusted for cow and lactation between S/Co and FS-Co (respectively 0.817, 0.815, 0.859 and 0.908 in Jerseys, Holsteins, Guernseys and Ayrshires, $P < 0.01$, Tables IX, X, XI and XII) indicated that those two variables were both good measures of the time factor from first service to conception (Everett _et al._, 1966 and Poston _et al._, 1962). There were no substantial differences in the total coefficients of determination (R^2) when all significant factors were pooled within breed (respectively 0.794, 0.822, 0.766 and 0.793 in Guernseys, Jerseys, Holsteins and Ayrshires).

TABLE VIII

MEAN SQUARES AND COEFFICIENTS OF DETERMINATION (R^2) FROM THE ANALYSIS OF VARIANCE FOR CALVING INTERVAL[1]

Source of Variation	DF	Mean Squares	F	P	R^2
Cow unadj.	128	4487.2	2.2	P < 0.001	0.623
Lact. No. Adj.	6	3820.4	1.8	P < 0.1	0.025
Svc/con. adj.	1	94487.7	46.6	P < 0.001	0.106
Clv - FS adj.	1	23852.0	11.7	P < 0.001	0.026
Mo. 1st scv. adj.	1	8842.3	4.3	P < 0.05	0.01
Mo. con. adj.	1	3726.8	1.8		0.004
Yr. clv. adj.	1	3216.4	1.5		0.003
Error	94	2033.9			Total 0.793

[1]Breed: Ayrshire

In all breeds, there were low and negative correlations between MC and MCo (significant in Ayrshires, -0.148, $P < 0.05$, Jerseys, -0.261, $P < 0.05$ and Guernseys, -0.339, $P < 0.05$). This likely a reflection of the fact that the majority of calving in the herd was forced to occur from July to January. The net effect of this would be to penalize cows that did not calve at the optimum time for rebreeding efficiently.

TABLE IX

PARTIAL CORRELATION COEFFICIENTS ADJUSTED FOR COW AND LACTATION[1]

Variables	2	3	4	5	6	7	8	9	10
Calving to first service	-0.104	0.113	0.117	-0.275	-0.074	-0.128	0.073	0.169	0.106
First service to conception		-0.087	-0.015	0.069	0.815**	-0.071	0.090	0.100	0.707**
Peak of milk level			0.078	-0.149	-0.043	0.187	0.419**	0.012	-0.087
Month of conception				-0.241*	-0.118	0.139	-0.121	0.490**	0.092
Month of calving					0.121	0.068	-0.092	-0.187	0.007
Services per conception						0.120	0.028	0.195	0.638**
Year of calving							-0.115	0.152	-0.047
Age at calving								-0.137	-0.037
Month of first service									0.137
Calving interval adjusted for cow and lactation									

[1]Breed: Jersey

**$P < 0.01$

*$P < 0.05$

TABLE X

PARTIAL CORRELATION COEFFICIENTS ADJUSTED FOR COW AND LACTATION[1]

Variables	2	3	4	5	6	7	8	9	10
Calving to first service	-0.054	-0.010	0.050	-0.160**	-0.061	-0.007	-0.050	0.052	0.473**
First service to conception		0.092	-0.257**	0.049	0.859**	0.081	0.116*	-0.051	0.445**
Peak of milk level			-0.096	-0.271**	0.138*	0.024	0.456**	-0.218**	-0.008
Month of conception				-0.041	-0.243**	0.006	-0.067	0.565**	-0.086
Month of calving					0.095	0.084	-0.116*	0.117*	-0.057
Services per conception						0.162**	0.168**	-0.090	0.428**
Year of calving							-0.058	0.127*	-0.014
Age at calving								-0.185**	-0.014
Month of first service									0.028
Calving interval adjusted for cow and lactation									

[1]Breed: Holstein

**P < 0.01

*P < 0.05

TABLE XI

PARTIAL CORRELATION COEFFICIENTS ADJUSTED FOR COW AND LACTATION[1]

Variables	2	3	4	5	6	7	8	9	10
Calving to first service	-0.072	-0.112	-0.034	-0.287*	-0.052	-0.094	0.043	0.008	0.280*
First service to conception		0.067	-0.052	-0.100	0.817**	-0.001	-0.027	0.194	0.434**
Peak of milk level			0.164	-0.327*	0.187	0.029	0.288*	0.068	0.004
Month of conception				-0.339*	-0.043	0.096	-0.011	0.553	-0.060
Month of calving					-0.263*	0.229	-0.100	-0.148	-0.212
Services per conception						0.191	0.061	0.144	0.461**
Year of calving							0.257	0.121	0.021
Age at calving								-0.165	-0.024
Month of first service									0.040
Calving interval adjusted for cow and lactation									

[1]Breed: Guernsey

**$P < 0.01$

*$P < 0.05$

TABLE XII

PARTIAL CORRELATION COEFFICIENTS ADJUSTED FOR COW AND LACTATION[1]

Variables	2	3	4	5	6	7	8	9	10
Calving to first service	-0.040	-0.037	0.116	-0.184**	-0.058	-0.239**	-0.044	0.005	0.239**
First service to conception		-0.058	-0.176**	-0.003	0.908**	-0.176**	0.081	-0.057	0.532**
Peak milk level			0.0003	-0.205**	0.078	0.055	0.561**	-0.146*	-0.054
Month of conception				-0.148*	-0.183**	0.091	-0.088	0.501**	-0.081
Month of calving					-0.011	0.140*	-0.208**	0.036	0.056
Services per conception						-0.166*	0.148*	-0.123	0.539**
Year of calving							-0.115	0.121	-0.051
Age at calving								-0.221**	-0.032
Month of first service									0.096
Calving interval adjusted for cow and lactation									

[1]Breed: Ayrshire

**$P < 0.01$

*$P < 0.05$

Table VI verifies that the average interval from calving to first service was longer in all breeds than is characteristically suggested before re-breeding should commence.

The same explanation is given for the finding in all four breeds that there was a significant ($P < 0.01$) negative correlation between the MC and the interval from C-FS. From the management point of view, to minimize the compounding effect of month of calving on calving interval, cows should calve in such a pattern that they would not be held open for excessively long periods prior to first service.

The high partial correlation coefficient adjusted for cow and lactation between MFS and MCo ($r = 0.553$, 0.490, 0.565 and 0.490), respectively in Guernseys, Jerseys, Holsteins and Ayrshires) occurs because the time a cow is first served will distate to a strong degree the time she will conceive.

The partial correlation coefficient adjusted for cow and lactation between PML and MFS was negatively significant ($P < 0.05$) in Holsteins and Ayrshires. This suggested that a high peak milk level may delay slightly the time when the animal would first be served. In all breeds, the PML was negatively correlated with MC ($r = -0.205$, $P < 0.01$; -0.271, $P < 0.01$; -0.327, $P < 0.05$ and -0.149 respectively in Ayrshire, Holstein, Guernsey and Jersey). There was strong suggestion that in Oklahoma, the breed average for milk and fat production is depressed during the season corresponding to May-September (Oklahoma DHIA Records, Summary, 1974). The high partial correlation coefficient adjusted for cow and lactation between PML and age at calving indicated that PML increased as cows got older (respectively 0.418, 0.456, 0.288 and 0.561 in Jerseys, Holsteins, Guernseys, and Ayrshires).

There were significant negative partial correlation coefficients adjusted for cow and lactation between YC and respectively C-FS (0.239), FS-Co (0.176) and S/Co (0.140) in Ayrshire, whereas the YC was positive significantly correlated with S/Co (0.162) in Holsteins. However these coefficients were low and could be of little concern in a breeding program. None of these partial correlation coefficients adjusted for cow and lactation was significant in Guernseys and Jerseys.

As could be expected, the C-FS, FS-Co and S-Co were highly and positively correlated with the calving interval adjusted for cow and lactation. The partial correlation coefficients adjusted for cow and lactation between C-FS and respectively FS-Co and S/Co were negative but not significant. On the average, more than 80 days postpartum interval was allowed to the cow before the first breeding. It has been suggested that long intervals prior to breeding have a slight effect on services per conception (Everett et al., 1966, VanDemark et al., 1950 and Hofstad et al., 1941).

Relation of the Findings of the Study to Potential Improvement in Herd Management

The results indicated that C-Fs, FS-Co and S/Co were the major factors affecting the calving interval adjusted for cow and lactation. However, in spite of their significance, their pooled coefficients were only 0.205, 0.213, 0.128 and 0.092, respectively in Holsteins, Jerseys, Ayrshires and Guernseys. Most of the variation in calving interval was brought about by the variability among cows in reproductive performance. The variation in cows accounted for approximately 60 percent of the variation in calving interval. This was mostly due to the management decisions where a postpartum interval of about 60, 45, or 90 to 180 days were imposed before first breeding for cows calving from July to November, from December to March and from April to June respectively. This management policy might tend to confound the magnitude of C-FS, FS-Co and S/Co effects with the magnitude of cow effect.

The effects of MC, MFS, MCo and YC were minor and were probably related to the managerial decisions and not the climatic effect. The age of cow, lactation number and peak milk level had little or not effect on calving interval.

In Holsteins, the peak milk level was significantly ($P < 0.05$) correlated with S/Co ($r = 0.138$) suggesting that cows with high peak milk level could be more difficult to settle. However, the net effect of peak milk level favored a better reproductive performance slightly. This was illustrated by the partial regression coefficient adjusted for cow and lactation for peak milk level (-0.17). The selection pressure placed on Holsteins had obviously led to a better management which decreased the calving interval and increased breeding efficiency.

Consequently the attainment of a minimum number of services per conception and minimum intervals from C-FS and from FS-Co would be major items to be considered in attaining an optimum calving interval. However, on the average, services per conception were not extremely variable among breeds. The overall mean of first service to conception revealed that the variation in this interval was much larger than could be attributed to the variation in services per conception. Services per conception ranged from 1.95 to 2.29 (Table IV) and could account for no more than 20 to 27 days of lost time in reproduction. Days lost from first service to conception appeared to be about 1.6 as many days as due to failures to conceive. This was due to missed heat periods including human error, anestrus and embryonic mortality. Barr (1975) found that days lost in first service to conception were twice the days due to failure to conceive. Expressed in another manner, Holstein and Jersey did not differ in service per conception and calving to first service, but differed in length of calving interval. Thus, the variation in calving intervals was not only due to the failure of cows to conceive, but due to missed heats. Larson (1974) indicated that there was no difference in services per conception between cows with long and short calving intervals.

It could be concluded that if a dairyman's ability to substantially influence conception rate is limited, he has his "management opportunity" in reducing the interval from calving to first service and to ultimate conception. An interval from calving to first estrus of 40 to 50 days could be obtained by either examination of cows 25 to 35 days after parturition to make sure that the reproductive tract is free of gross infection and undergoing involution at normal rate, or by recording early estrus between 0 and 30 days postpartum (Marion et al., 1968, Marrow, 1970 and Thatcher, 1973). The interval from first service to conception depends on the success of insemination and the ability of heat detection. Technician ability, timing of insemination and fertility of bull or semen are of major importance for the success of insemination when cows are considered to be normal, free of any infection. From previous discussion, it was indicated that heat detection was of major importance in achieving an optimum interval from first service to conception. A good records keeping system of the cow status and her estrus periods to predict next estrus, combined with careful detection of all signs of estrus is so far the most useful tool in determining when cows should be bred or removed from the herd for reproductive deficiency. Consistently short estrus intervals (less than 15 days) frequently indicates systic follicles or nymphomania. Consistently long estrus intervals of approximately 40 to 45 days or 25 to 35 suggest respectively possible missed estrus periods and early embryonic mortality. Variable length estrus intervals may reflect poor heat detection or recognition. It becomes obvious that a good record keeping system is of great help for the dairyman to reduce veterinary expenses and the length of calving interval, and therefore to increase his potential profit.

CHAPTER V

SUMMARY

The objectives of this study were (1) to determine the breeding efficiency as well as possible factors influencing its variation within a breed, (2) to examine sources of variation affecting calving intervals and their relative importance in each breed and (3) to relate the findings of the study to potential improvement in herd management.

The data were obtained from breeding, calving and production records of the Oklahoma State University dairy herd which included four breeds: Ayrshire, Guernsey, Holstein and Jersey. All cows which had completed a lactation and calved subsequently between January 1, 1968, and March 3, 1974, were considered in this study. A total of 696 calving intervals in 370 cows were used (240 calving intervals on 131 Ayrshire cows, 315 on 161 Holsteins, 84 on 47 Jerseys and 57 on 31 Guernseys). The same manager was in charge of the herd for almost all of the study period.

The herd was managed so that the majority of the cows calved from July to January, with very few calving outside of this period. This coincides with the greatest student demand for milk on the campus. Cows were checked for heat at least twice daily and artificially inseminated by dairy barn personnel. Cows in heat in the morning were inseminated in late afternoon while those in heat in the afternoon were inseminated the next morning.

The factors analyzed within each breed to evaluate their possible effect on length of the calving interval were: interval from calving to first service, interval from first service to conception, services per conception, peak milk level, year of calving, month of calving, month of first service, month of conception, and age at calving.

Overall, Ayreshires and Guernseys had lower breeding efficiency than did Holsteins and Jerseys (respectively 2.27 and 2.26 versus 1.95 and 1.96 services per conception). Approximately 90 percent of Holsteins and Jerseys had settled by three services while only about 80 percent of Guernseys and Ayrshires had settled to three services. There was a significant ($P < 0.05$) difference in the conception rate between Holsteins and Ayrshires in favor of Holsteins. The conception rate at any one service depended significantly ($P < 0.05$) on the breed. There was a significant ($P < 0.005$) difference in the fertility level of bulls used in the different breeds. Variations in fertility level of bulls used, insemination technique and timing of insemination in relation to first observation of heat undoubtedly contributed to lower conception rate and influenced the differences in breeding efficiency among breeds.

The calving interval ranged from 396 days for Holsteins to 414 days for Guernseys. In all breeds, the effects of cow, interval C-FS and either S/Co or FS-Co were significant. The interval from FS-Co and S/Co were highly correlated (respectively 0.817, 0.815, 0.859 and 0.908 in Guernseys, Jerseys, Holsteins and Ayrshires, $P < 0.01$).

The variation in cows accounted for approximately 60 percent of the variation in calving intervals. This high variability among cows within breed in the reproductive performance was mostly due to the fact that some cows had to be held open for longer than necessary period of time in order to get them to calve at the desired time. The significant effect of MFS found Ayrshires was related to the managerial status and, therefore, could be of little concern in a breeding program. Lactation number was also of little significance in Holsteins and Ayrshires. Year of calving, month of calving, month of conception, age at calving and peak milk level had no or little effect on calving interval. However, the significant ($P < 0.05$) partial correlation adjusted for cow and lactation between peak milk level and services per conception found in Holsteins suggested that cows with high peak milk level would be somewhat difficult to settle. However, the net effect of peak milk level favored a better reproductive performance slightly. The selection pressure placed on Holsteins had led to better management of high producing cows. Overall means of services per conception and interval from first service to conception suggested that total days lost from this interval were 1.6 times greater than the days accounted for by failure to conceive. Therefore, if a dairyman's ability to influence substantially conception rate is limited, he has his "management opportunity" to shorten calving interval and this should increase his potential profit.

LITERATURE CITED

Alderman, G. 1963. Mineral nutrition and reproduction in cattle. The Vet. Record. 75:1015.

Asdell, S. A. 1966. Cattle Fertility and Sterility. Little Brown, Boston.

Barr, H. L. 1975. Influence of estrus detection on days open in dairy herds. J. Dairy Sci. 2:247.

Barr, A. J., and J. H. Goodnight. 1972. Statistical Analysis System. North Carolina State University, Raleigh.

Barret, G. R., C. A. Lloyd and R. A. Carpenter. 1948. Order number of insemination and conception rate. J. Dairy Sci. 31:683.

Barret, E. R., L. E. Casida and C. A. Lloyd. 1948. Measuring breeding efficiency by pregnancy examinations and by nonreturns. J. Dairy Sci. 31:682.

Bentley, O. G. and P. H. Phillips. 1951. The effect of low manganese ration upon dairy cattle. J. Dairy Sci. 34:396.

Bond, J., J. N. Wiltbank and A. C. Cook. 1958. Cessation of estrus and ovarian activity in a group of beef heifer on extremely low levels of energy and protein. J. Anim. Sci. 17:1211.

Boyd, L. J., D. M. Seath and D. Olds. 1954. Relationship between level of milk production and breeding efficiency in dairy cattle. J. Anim. Sci. 13:89.

Bozworth, R. W., G. Ward, E. P. Call and E. R. Bonewitz. 1972. Analysis of factors affecting calving intervals of dairy cows. J. Dairy Sci. 55:334.

Britt, J. H. 1975. Early postpartum breeding in dairy cows. A review. J. Dairy Sci. 2:266.

Britt, J. H., D. A. Morrow, R. J. Kittok and B. E. Seguin. 1974. Uterine involution, ovarian activity, and fertility after melengestrol acetate and estradiol in early postpartum cows. J. Dairy Sci. 57:89.

Courot, M., M. Gourraux, and R. Ortavant. 1968. Analyse des variations saisonnières de la fertilité des bovins dans le Jura francais. Ann. Biol. Anim. Bioch. Biophy. 8:209.

Cumba, T. J., A. C. Warnick, and M. Koger. 1969. Factors Affecting Calf Crop. University of Florida Press, Gainesville.

Dickinson, F. N., and B. T. McDaniel. 1969. Status and potential of artificial insemination for increasing production and income over feed cost for dairymen. J. Dairy Sci. 52:1464.

Dickinson, F. N., and B. T. McDaniel. 1968. Current and potential value of dairy herd improvement association sire evaluations to dairymen using artificial insemination. Abstr. J. Dairy Sci. 51:986.

Everett, R. W., D. V. Armstrong and L. J. Boyd. 1966. Genetic relationship between production and breeding efficiency. J. Dairy Sci. 49:879.

Foote, R. H. 1975. Estrus detection and estrus detection aids. J. Dairy Sci. 2:249.

Frank, A. H. 1950. Imparied breeding in cattle. Field observations and results of treatment. Proceeding Book. Amer. Vet. Med. Ass. 87th Annual Meeting, Miami Beach. Aug. 21-24, pp. 191.

Gaines, W. L. 1927. Milk yield in relation to the recurrence of conception. J. Dairy Sci. 10:2.

Hall, J. G., C. Branton, and E. J. Stone. 1959. Estrus, estrus cycles, ovulation time, time of service, and fertility of dairy cattle in Louisiana. J. Dairy Sci. 42:1086.

Herschler, R. C., C. Miracle, B. Crowl, T. Dunlap and J. W. July. 1964. The economic impact of a fertility control and her management program on dairy farm. J. Amer. Vet. Med Ass. 145:672.

Hignett, S. L. 1959. Some nutritional and other inter-acting factors which may influence the fertility of cattle. Vet. Record. 71:247.

Hofstad, M. S. 1941. Study of breeding records of one large herd of dairy cattle. Cornell Vet. 31:379.

Huertas, Vega E., J. H. Britt and C. L. Ulberg. 1972. System for managing reproduction in dairy cattle. J. Dairy Sci. 55:401.

Ingraham, R. H., D. D. Gillette, and W. D. Wagner. 1974. Relationship of temperature and humidity to conception rate of Holstein cows in subtropical climate. J. Dairy Sci. 57:476.

Johansson, Ivor and J. Rendel. 1968. Genetics and Animal Breeding. W. H. Freeman, San Francisco. pp. 238-263.

Johansson, Ivor. 1961. Genetic Aspect of Dairy Cattle Breeding. University of Illinois Press, Urbana.

Johnson, A. D., J. E. Legates and L. C. Ulberg. 1966. Relationship between follicular cysts and milk production in dairy cattle. J. Dairy Sci. 49:731.

Kelley, J. W. and J. R. Holman. 1975. A modified herd reproductive status for South Carolina dairy herds. J. Dairy Sci. 2:265.

Lauderdale, J. W. 1974. Estrus detection and synchronization of dairy cattle in large herds. J. Dairy Sci. 57:348.

Louca, A., and J. E. Legates. 1967. Losses in yield due to excessive days open. Abstr. J. Dairy Sci. 50:975.

Maijala, K. 1964. Fertility as a breeding problem in artificially bred population of dairy cattle. I. Registration and heritability of female sterility. Ann. Agric. Fenniae Suppl. 1. 3:1-94.

Marion, G. B. and H. T. Gier. 1968. Factors affecting ovarian activity after parturition. J. Anim. Sci. 27:1621.

Morrow, D. A., S. J. Robert, K. McEntree and H. G. Gray. 1966. Postpartum ovarian activity and uterine involution in dairy cattle. J. Am. Vet. Med. Ass. 149:1596.

Muller, L. D., and M. J. Owens. 1974. Factors associated with the incidence of retained placentae. J. Dairy Sci. 57:725.

Norman, H. D., B. T. McDaniel and F. N. Dickinson. 1970. Nonreturn rates of artificial insemination sires by breeds in the United States for 1967 and 1968. National Cooperative Dairy Herd Improvement Program, pp. 1-20.

Norman, H. D., and H. W. Thoele. 1967. Effect of calving interval upon 305 days milk and fat production. Abstr. J. Dairy Sci. 50:975.

Olds, D., and T. Cooper. 1970. Effect of postpartum rest period in dairy cattle on the occurrence of breeding abnormalities and on calving intervals. J. Amer. Med. Ass. 157:92.

Olds, D. and D. M. Seath. 1954. Factors affecting reproductive efficiency in dairy cattle. Kentucky Agr. Exp. Sta. Bull. No. 605.

Olds, D. and D. M. Seath. 1953. Repeatability, heritability and the effect of milk production on the occurrence of first estrus after calving in dairy cattle. J. Anim. Sci. 12:10.

Olds, D. and D. M. Seath. 1950. Predictability of breeding efficiency in dairy cattle. J. Dairy Sci. 33:721.

Pellissier, C. L. 1972. Herd breeding problems and their consequences. J. Dairy Sci. 55:385.

Pellissier, C. L. 1971. Field problems affecting dairy breeding efficiency. Amer. Dairy Sci. Annual Meeting, Michigan State University, East Lansing, Michigan.

Pellissier, C. L. 1970. Factors contributing to low breeding efficiency in dairy herds. Abstr. J. Dairy Sci. 53:684.

Poston, H. A., C. L. Ulberg and J. E. Legates. 1972. Analysis of seasonal fluctuation of reproductive performance in dairy cows. J. Dairy Sci. 45:1376.

Rakha, A. M., and Ig boeli. 1971. Effect of nutrition, season and age on the estrus cycle of indogenous central African cattle. J. Anim. Sci. 32:943.

Reid, J. T. 1960. Effect of energy intake upon reproduction in farm animals. Suppl. J. Dairy Sci. 43:103.

Robert, S. J. 1955. Clinical observations on cystic ovaries in dairy cattle. Cornell Vet. 45:497.

Rojas, M. A., I. A. Dyer, and W. A. Cassatt. 1965. Manganese deficiency in the bovine. J. Anim. Sci. 24:664.

Ronning, M., E. R. Berousek, A. H. Kuhlman, and W. D. Gollup. 1953. The carotene requirement for reproduction in Guernsey cattle. J. Dairy Sci. 36:52.

Schaeffer, L. R., R. W. Everett, and C. R. Henderson. 1972. Lactation records adjusted for days open in sire evaluation. J. Dairy Sci. 56:602.

Smith, J. W., and J. E. Legates. 1962. Relation of days open and days dry to lactation and fat yields. J. Dairy Sci. 45:1192.

Speicher, J. A., and C. E. Meadows. 1967. Milk production and costs associated with length of calving interval of Holstein cows. Abstr. J. Dairy Sci. 50:975.

Spielman, A., and I. R. Jones. 1939. The reproductive efficiency of dairy cattle. J. Dairy Sci. 22:329.

Sorensen, A. M., W. Hansel, W. H. Hough, T. D. Armstrong, K. McEntree and R. W. Brotton. 1959. Influence of underfeeding and overfeeding on growth and development of Holstein heifers. Cornell University Agr. Exp. Sta. Bull. 936.

Steevens, B. J., L. J. Bush and J. D. Sout. 1970. Effect of varying amounts of calcium and phosphorus in rations for dairy cows. J. Dairy Sci. 54:655.

Steinbach, J. and A. A. Bologum. 1971. Seasonal variation in the conception rate of beef cattle in the seasonal equatorial climate of Southern Nigeria. Int. J. Biometior. 15:71.

Stott, G. H. and R. J. Williams. 1962. Causes of low breeding efficiency in dairy cattle associated with seasonal high temperature. J. Dairy Sci. 45:1369.

Stott, G. H. 1961. Female and breeding associated with seasonal fertility variation in dairy cattle. J. Dairy Sci. 44:1698.

Thatcher, W. W. 1974. Effect of season, climate, and temperature on reproduction and lactation. J. Dairy Sci. 57:360.

Thatcher, W. W. and C. J. Wilcox. 1973. Postpartum estrus as an indicator of reproductive status in the dairy cow. J. Dairy Sci. 56:608.

Thomas, J. W. 1970. Metabolism of iron and manganese. J. Dairy Sci. 53:1107.

Thrimberger, C. W. and H. P. Davis. 1943. Conception rate in dairy cattle by artificial insemination at various stages of estrus. Nebr. Agr. Exp. Sta. Res. Bull. 129.

Touchberry, R. W., K. Rottensen, and H. Anderson. 1959. Association between services interval, interval from first service to conception, number of services per conception and level of butterfar production. J. Dairy Sci. 42:1157.

Trinder, N., C. D. Woodhouse, and C. P. Renton. 1969. The effect of vitamin E and Selenium on the incidence of retained placentae in dairy cows. Vet. Record. 85:550.

VanDemark, N. L. and G. W. Salisbury. 1950. The relation of postpartun breeding interval to reproductive efficiency in dairy cows. J. Anim. Sci. 9:307.

Ward, George, G. B. Marion, C. W. Campbell and J. R. Dunham. 1970. Influences of calcium intake and vitamin D supplementation on reproductive performance of dairy cows. J. Dairy Sci. 54:204.

Wethrill, G. D. 1965. Retained placentae in the bovine. A brief review. Con. Vet. J. 6:290.

Whitmore, H. L., W. J. Tyler, and L. E. Casida. 1974. Effect of early postpartum breeding in dairy cattle. J. Anim. Sci 38:339.

Wilson, J. G. 1966. Bovine functional in Devon and Cornwall: response to manganese therapy. The Vet. Records. 79:562.

Winters, L. M. 1954. Animal Breeding. 5th ed. New York.

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