SEASONAL VARIATIONS IN HOURS OF DAYLIGHT ASSOCIATED WITH FERTILITY LEVEL OF CATTLE UNDER NATURAL BREEDING CONDITIONS

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Losses due to sterility or low fertility amongst livestock in North America amount to millions of dollars annually. Though this fact is recognized by most workers in the field, controlled investigations have not yielded evidence to suggest that eliminating these losses is an easy matter soon to be achieved (2).

Sterile animals are identified readily in most dairy herds, but inefficient reproducers may be more difficult to expose and, in the aggregate, may contribute fully as much to monetary loss. The rapid growth of artificial breeding has served to emphasize the importance of the differences in relative fertility among dairy cattle and to focus attention on this problem.

From the records accumulating on thousands of cattle in the New York artificial breeding program it was believed that it might be possible to obtain evidence on the causes of the varying levels of fertility observed. The records are obtained from herds operated under a variety of conditions in all agricultural counties of the State. The data first were studied with the objective of determining the effect of various factors on fertility results. Certain inseminating practices and regional problems were studied. However, it was evident immediately that certain major factors influenced fertility level. These factors, unless thoroughly understood, might obscure other influences, or bias data used for other studies.

The first factor of major importance was the age of the cattle concerned. Data on that problem were published by Tanabe and Salisbury (31). Later Mercier and Salisbury (20) studied what then appeared to be the second major influence, that of season on fertility level of dairy bulls; highly significant differences between months in fertility level were found. Earlier Salisbury (27) had found seasonal variations in semen quality which were not reflected in variations in fertility level. Others (8, 12, 15, 21, 23, 24, 30) had noted a seasonal trend in fertility level of cattle, which they attributed largely to variations in temperature. The results of these studies were so diverse that no general conclusions could be drawn.

Recently, Mercier (19) reviewed the published data concerning the monthly fluctuations in fertility level of cattle. From his review and his

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own data he suggested that the seasonal fluctuations observed were not random variations, but followed definite patterns associated with climatic factors, of which variations in length of daylight played an important part. Previously, as mentioned above, the seasonal fluctuations in fertility level of cattle had been attributed largely to variations in temperature. However, it has been shown that light is the primary agent regulating the breeding behavior of many species of birds and lower mammals. This subject has been reviewed at length by other investigators (3, 4, 6, 18, 26). Evidence is yet to be produced to show that light does not influence fertility level in cattle.

The authors recognized that the definite experimental demonstration of the influence of light variations on fertility level of cattle would involve an enormous outlay of time and effort. In an experiment of this kind, more animals would be required to produce valid conclusions than usually are considered necessary. For direct proof of the theory it would be necessary to show that fertility level was modified by light manipulations. To demonstrate the reasons for such modifications of the fertility level by light manipulations, the morphological and physiological changes in the primary reproductive organs, as well as the hormone balance of the entire body, would have to be studied minutely.

As adequate facilities were not available for direct experiments on the question, it was felt that an indirect approach might reveal definite facts from which the importance of light variations on fertility level could be assayed. Thus, a detailed statistical study was made of Mercier's data (19), and additional evidence was obtained from the records of the New York Artificial Breeders' Cooperative, Inc.

The present report deals with a study of the conception rate of cattle under natural breeding conditions in Eastern Canada. It was undertaken because the authors felt that the possible detrimental effect of extreme temperatures on reproduction would be minimized because of the cool Canadian summers and the wintering of cattle in warm barns. On the other hand, they believed that the effect of light, if involved, would be emphasized because of the extreme length of the summer days and the shortness of the winter days.

MATERIALS AND METHODS

Three main points considered in the selection of herds to provide breeding records for this study were the latitude at which the farms were situated, the similarity in management practices, and the reliability of the available breeding records.

The purebred herds of the three following institutions, containing cows of the Ayrshire, Holstein, and beef and dual-purpose Shorthorn breeds, were selected: The College of Agriculture of MacDonald, Quebec, and the Experimental Stations of Ste-Anne-de-la-Pocatiere, Quebec, and Kapuskas-

ing, Ontario. Only a few females were brought into the herds during the period covered in this study, 1919–1944. In all herds there was a tendency to use sires of various ages, and no close-breeding systems were followed. Abortion waves occurred in two herds. Before 1935, reactors were eliminated; after that, the policy was to isolate females that aborted. In order to avoid bias due to these troubles, all records used were from cows which conceived prior to the fifth service.

The farms were located almost exactly 2° of latitude apart, one at 45°, one at 47°, and the other at 49°. These differences had little effect on monthly mean daylight hours, the northernmost station having approximately one-half hour less of daylight during January and the same amount more during June. As a consequence the monthly average number of daylight hours and hours of sunshine varied somewhat from station to station, but this variation was unimportant in comparison with the extreme change throughout the year. The monthly mean number of daylight hours varied from 8.2 hours in December to 16.0 hours in June. At no time during the year did the mean monthly outside temperature at any station reach 70°·F., which is well below the point of hyperthermal rise in body temperature.

The breeding records for each herd were sorted by month of service, and the number of successful services determined for each month. The data were tabulated as the per cent of successful services and were so used in this investigation. However, in order to make the results comparable with others published, they are expressed as services per conception.

The monthly per cent of successful services for each herd was considered as a single observation. Months were grouped into seasons: winter months being December, January, and February; spring months, March, April, and May; summer months, June, July, and August; and fall months, September, October, and November. Analyses of variance and covariance techniques, as described by Love (17), were used to colligate the evidence. In the first case the per cent of successful services was used, while in the second, the independent variable was the number of services and the dependent variable the number of conceptions. In the use of each statistical technique no significant herd × season interaction was observed. Thus, in each analysis the entire remainder including the primary interaction variance was used for testing the statistical significance of "herds" and "seasons".

RESULTS

The data grouped by season and herd are presented in figure 1. No significant differences in fertility level between herds were found by either method of analysis, but both methods showed a significant difference in fertility level between the seasons at the 5 per cent level of probability. These data show that fertility level as measured by the per cent of successful services was highest in summer and lowest in the winter and spring in these

Canadian herds. A study of the monthly per cent of successful services for the three herds suggested a definite trend. The poorest conception rate was obtained during the month of February and the best during the month of July, some time after the shortest and the longest day of the year, respectively.

For comparative purposes a survey of the number of services per conception in cattle obtained at various locations in the Northern Hemisphere is presented in table 1. The information published by Clapp (9) for the Cornell University dairy herd shows the same trends as do the data reported here and by Mercier (19). Except for the data of Dawson (10), Liang

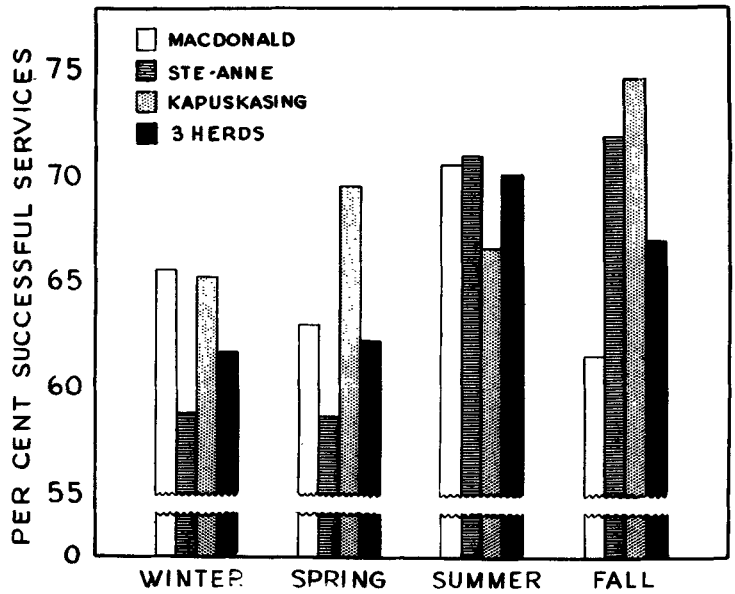

FIG. 1. Seasonal variations in fertility level of three herds in Eastern Canada.

[Phillips *et al.* (23)], and Seath *et al.* (30), which are largely from the southern portion of the Hemisphere, there is a tendency for the number of services per conception to decrease from February on through the spring until the days begin to shorten and the hot weather of summer supervenes.

The observed trend suggested that increased length of day or increased temperature, up to an optimum temperature, might beneficially influence reproduction in cattle. In Mercier's data (19) no decrease in fertility level during the summer was observed. In fact, the variations in fertility level seemed to vary directly with the length of daylight, the hours of sunshine, and the outside temperature, there being a lag of some time before the maximum effect was reached.

The relationship between each of these climatic factors and the average fertility level of the three herds was determined. To get an idea of the

TABLE 1

Seasonal variation in conception rate of cattle under natural conditions
(services per conception)

Month	Dawson (10) 8 states	Morgan & Davis (21) Nebr. 1896–1934	Erb *et al.* (12) Ind. 1920–'40	Hilder *et al.* (15) Md. 1919–'42	Clapp (9) N. Y. 1929–'45	Mercier (19) E. Canada 1919–'44	Phillips *et al.* (24) Md. 1935–'42	Seath *et al.* (30) La. 1923–'40	Liang (23) S. China
Jan.	2.50	2.08	1.54	2.57	2.18	1.51	1.93	Winter	Dec.–Feb.
Feb.	2.34	2.25	1.69	2.81	2.29	1.67	1.89	2.5*	1.71
March	2.45	2.46	1.41	2.80	2.05	1.54	1.80	1.5†	March–May
April	2.26	2.16	1.53	2.65	2.03	1.56	1.68	Spring	1.96
May	2.54	2.20	1.35	2.64	1.99	1.66	1.71	2.8*	
June	2.63	2.10	1.47	2.36	1.96	1.43	1.82	1.9†	June–Aug.
July	2.31	2.07	1.66	2.94	1.90	1.41	2.40	Summer	2.37
Aug.	2.48	2.78	1.72	2.88	2.20	1.43	2.45	3.4*	
Sept.	2.56	2.85	1.60	2.82	2.11	1.46	2.38	2.4†	Sept.–Nov.
Oct.	2.42	1.99	1.60	2.52	2.13	1.49	1.98	Fall	1.66
Nov.	3.08	2.09	1.57	2.64	2.26	1.50	1.85	2.7*	
Dec.	2.50	1.94	1.64	2.52	2.26	1.52	1.82	1.4†	
Av.	‡$\frac{2982}{1197}$ = 2.49	$\frac{2979}{1375}$ = 2.16	$\frac{1440}{922}$ = 1.56	$\frac{9181}{3439}$ = 2.67	$\frac{4250}{2019}$ = 2.11	$\frac{3543}{2322}$ = 1.53	$\frac{1135}{584}$ = 1.94	.....	$\frac{795}{430}$ = 1.85

* = Expt. herd.
† = Univ. herd.
‡ = $\frac{\text{Services}}{\text{Conceptions}}$.

length of the apparent lag effect, the correlation coefficients between the per cent of successful services for one month and the average monthly values for temperature, length of day, and number of hours of sunshine for the month corresponding to and of the first, second, third, and fourth month prior to mating were calculated. The correlation coefficients are shown in table 2.

The relationship between fertility level and each of the three climatic factors was approximately of the same magnitude. The correlation coefficients for the second month prior to mating, in general, were the highest. As hours of sunlight are a function of the length of day, and as Olson (22) has reported that lack of direct sunshine had no measurable effect on reproduction in cattle, the authors have eliminated this item from further

TABLE 2

Correlations between the conception rate and the monthly averages for climatic factors for the month corresponding to and the months prior to mating

Correlations between fertility level and:	Months for climatic factors				
	Corresponding	Prior to mating			
		First	Second	Third	Fourth
Temperature	0.588*	0.732†	0.692†	0.441	0.220
Day-length	0.275	0.604*	0.731†	0.668†	0.460
Daily sunshine hours	0.346	0.573*	0.697†	0.603†	0.388

* Significant at the 5% level of probability.
† Significant at the 1% level of probability.

consideration. Partial correlations for the second month prior to mating, using the individual observations for each herd, indicated that length of daylight and not temperature change was the more important factor associated with the conception rate under Canadian conditions. The partial correlation coefficients were 0.352 and 0.017, respectively, the first being significant at the 5 per cent level of probability. The results suggest that longer daylight has a beneficial effect on the conception rate of cattle in Eastern Canada.

That this observation may have wider application is indicated by other evidence. In England, Hammond (14) and Sanders (29) observed that cows calving in spring and bred in summer, especially in the northern districts of the country (14), required less time to get in calf than those calving in fall and bred in winter. Plum and Lush (25) found that heifers in Iowa bred in spring and summer calved at an earlier age than those bred in late fall and winter. In a similar study of the age of Ayrshire heifers in the United States calving for the first time during 1942–1945, Salisbury and Mercier (28) observed the same trend. Furthermore, in their data, comparison of the ages of the heifers calving in the states below the 40° of latitude, none of which are in the extreme South, and those calving in the states north of that parallel showed that the monthly average age at

first calving varied more for the group calving in states north of the 40° of latitude than for the group calving in states south of that latitude. Huntington (16) has observed a similar increase in the amplitude of seasonal conception curves in human beings in the United States and Canada as the population areas studied shifted from the Equator towards the North. It would appear that at high latitudes heifers as well as mature cows are somewhat less fertile during periods of the shortest length of day and, as a consequence, conception and calving are delayed.

DISCUSSION

Dawson (10), studying the fertility of aged bulls used at various locations in the United States, found that the relative fertility of sires used at southern stations was 36 per cent as compared to 49 per cent for sires used at northern and western locations. Seath *et al.* (30) in Louisiana and Liang [Phillips *et al.* (23)] in southern China attributed the poor results secured during summer and spring (see table 2) to high environmental temperature. Although this interpretation may explain satisfactorily the contrasting seasonal difference between their results and those of the authors, it does not explain adequately the rather uniformly low monthly conception rate of aged sires in the south of the United States (10).

It is known that the seasonal variation in day-length becomes less and less, the winter days being relatively longer and the summer days shorter, as one approaches the Equator. For instance, the day-length averages for the months of June and December are, respectively, 16.0 and 8.2 hours in Eastern Canada (1) and 14.1 and 10.3 hours in Louisiana (33). The lesser variation in length of daylight may account somewhat for the relatively good winter results reported at low latitudes (10, 23, 30).

That level of nutrition is probably not a controlling factor in the increased breeding efficiency observed as spring advances is indicated by the fact that in the north the gradual change is underway before pasture becomes available. Also, the evidence suggests that confining cows in stanchions is not responsible for the lower breeding efficiency observed in winter. Webster (35) from New Zealand reported that the majority of barren cows kept on pasture the year around bred successfully, most of the time at the first attempt, when carried over the winter to the following spring.

Though the action of light on reproductive activity of vertebrates is not entirely clear, it is known to act on the pituitary and possibly on other areas of the midbrain through the eye, retina, and the optic nerve (3, 4, 6, 18, 26). Fiske (13) has shown that light stimulates the pituitary of the female rat to produce and release follicle-stimulating hormone. Conversely, lack of light favors an increase in the production of luteinizing hormone.

Since the relationship of temperature to the reproductive processes is not thoroughly understood, the effect of high temperature on the semen

production of males may be only a secondary effect rather than a primary one. There is direct evidence that temperature affects the function of the thyroid gland in the rat (11) and in the ram (7) and also the gonadotropic potency of the anterior pituitary in the ground squirrel (36). Furthermore, it has been shown that in the rat (32) the pituitary controls the rate of formation and the release of thyroxin into the circulation, and that it acts on the gonads of certain species of fish (34) through the thyroid. Seasonal variations in the amount of thyrotropic hormone in the blood of cocks and ducks, associated with changes in the activity of the thyroid and the testis, were reported by Benoit and Aron (5).

While these reports strongly suggest that the seasonal variations in reproductive efficiency reflect primarily pituitary and, secondarily, thyroid activity, more evidence is needed before definite conclusions may be drawn.

The results of research published by others and the work reported here lead the authors to conclude that light plays an important role in controlling the breeding efficiency of cattle. Obviously, further studies should be made to determine any specific effect of light and temperature on reproductive activity of cattle of various ages and to modify, if possible, these two environmental factors or to change management practices in order to improve conception rate, especially of cows bred to calve in the fall.

SUMMARY

In a study of three herds of cattle located at different latitudes in Eastern Canada, the lowest per cent of successful services was obtained during winter and spring and the highest during summer and fall. The differences in fertility level between herds were not significant statistically but those between seasons were significant at the 5 per cent level of probability.

The average monthly conception rate of the three herds was significantly correlated with the monthly average length of daylight, there being a lag of approximately 1 to 2 months before the maximum effect was reached. Temperature changes had no measurable direct effect on fertility level under the existing conditions.

The authors believe that at high latitudes variations in length of daylight measurably influence the fertility level in cattle.

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