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AGRICULTURAL EXPERIMENT STATION

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MOGENS PLUM AND MYRON G. A. RUMERY[1]

INTRODUCTION

IN 1913 THE NEBRASKA LEGISLATURE appropriated $17,500 to establish a Dairy Department at the North Platte Experiment Station. The department's herd was to be used in demonstrating management and breeding practices and as a source of breeding stock.

The original purchase consisted of 12 purebred Holstein-Friesian heifers. A few years later one more cow was added and in 1936 five cows were transferred to the North Platte Station from the Experiment Station at Valentine, Nebraska. None of these six additions stayed very long in the North Platte herd and none of them left any descendants in the present herd. They are, therefore, not included in this study which deals entirely with the 12 original foundation females and their progeny in the succeeding 40 years of dairy cattle breeding at the North Platte Experiment Station.

During most of its existence the herd has had a reputation for high production. During the first 35 years practically all the bull calves born were sold to dairy farmers for breeding purposes.

Since the North Platte herd was started, research in the field of animal breeding has developed new concepts in many phases of dairy cattle breeding and selection. In 1948 a regional project was started to study the improvement of dairy cattle through breeding and the herd of Holstein cattle at the North Platte Experiment Station became a part of this project.

The purpose of the present study is to analyze the progress made under a system of dairy cattle breeding and selection carried out according to the principles that dominated 40 years ago. The results of this study should form a basis upon which the application of more recent findings in the field of dairy cattle breeding can be evaluated.

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[1] Associate Dairy Husbandman and Assistant Dairy Husbandman, respectively. Data for the present study were collected while the herd was under the successive supervision of W. P. Snyder, M. L. Baker and Myron G. A. Rumery. During most of the time, the herd was under the care of A. R. Sharrah.

This study is a contrbiution from the Nebraska Agricultural Experiment Station as a cooperator under the North Central Regional Cooperative Research Project entitled "Improvement of Dairy Cattle Through Breeding—NC-2."

REVIEW OF LITERATURE

From 1926 to 1954 the average production of cows in Nebraska Dairy Herd Improvement Associations increased from 272 pounds of butterfat per year to 355 pounds (*11*). These averages are based on changing numbers of herds and cows, and different herds are represented in 1926 and 1954. The figures, therefore, show only that the production trend has been upward during this period. It is not possible to determine how much of the increase in production has been due to breeding and how much to improved methods of caring for dairy cows.

In studies of individual herds or groups of herds the same difficulty in appraising genetic improvement arises because it is very difficult to separate the effects of management and breeding.

Davis *et al.* (*1*) found an annual increase of 75 pounds of milk and 4.9 pounds of butterfat in the Holstein herd at Winterthur, Delaware, over a period of 34 years. Most of this increase took place during the first 15 years. During the last 19 years when all cows were milked two times daily, there was no material change in the average production of the herd. It is probably safe to assume that some of the early increase in butterfat production was due to a steadily improving technique in handling high producing dairy cattle.

Laben and Herman (*10*) studied the production in the University of Missouri Holstein herd from 1902 to 1950. All records were converted to 2x, 305 day, ME basis. No exact figures are given for the production averages for the herd for each year, but figure 4 in their publication indicates a slight increase in milk production and a considerable increase in butterfat production from 330 pounds to 400 pounds. The length of a generation is given as six years, so the improvement amounts to about 9 pounds of butterfat per generation. Production dropped markedly during the first years. If only the rising segment of the production curve is considered, there was an increase of 259 pounds of milk and 17 pounds of butterfat per generation. In this study no attempt was made to differentiate between the effects of heredity and management. Actually a computation of the production of the 260 daughter-dam pairs listed shows a mean decrease of 126 pounds of milk and a mean increase of 2.25 pounds of butterfat from dams to daughters.

In a study of a herd of Red Danish milk cattle in Denmark, Plum (*20*) found an increase in average production of 175 pounds of butterfat over a 33-year period from 1900 to 1933. He estimated that about 22 pounds of this increase was due to selection among cows.

Nelson and Lush (*19*) found an increase of 40 pounds of butterfat

over a 12-year period in the Iowa State College Holstein herd. In this net change is included an estimated 4.5 pounds decrease in butterfat for each per cent increase in inbreeding. Thus it is assumed that without inbreeding the increase in production would have been larger. Owing to elimination of disease during the period studied, little selection among the females for production could take place and the increase in production is attributed to the selection of bulls.

In a study of the Idaho University Holstein and Jersey herds, Harvey (*5*) made an attempt to separate the environmental and genetic changes from year to year and estimated an annual increase in genetic merit of 8.0 pounds and 5.3 pounds of butterfat for the Holstein and Jersey herds respectively.

In a study of the University of Illinois Holstein herd, Dillon *et al.* (*3*) found that the regression of average producing ability on years was 0.68 ± 14.00 pounds of 4 per cent fat corrected milk while the regression of environmental changes on year was 53.54 ± 14.4 pounds of F.C.M. This indicates that practically all the improvement which took place during the 54 years covered by the study was due to improvement in the environment which includes feeding, management, housing and milking procedure.

Rendel and Robertson (*21*) estimated that selection of cows contributed a genetic increase of 3.3 gallons of milk (or approximately 1 pound of butterfat) per year in a herd of British Friesian cattle. Most of the increase was attributed to the selection of cows whose sons were used in the herd.

In a study of 12 herds of Ayrshire cattle, Mahadevan (*18*) found a total improvement per generation of 25.4 gallons of milk (2.5 per cent of the herd average). Selection of dams of cows accounted for a genetic improvement of only .3 per cent per year.

Rendel *et al,* (22) concluded that the superiority of dams of heifers over their contemporaries was on the order of 1.6 per cent. This was approximately 100 pounds of milk and 3.6 pounds of butterfat. The probable annual gain from the selection of dams of cows and of dams of bulls was of the order of .3 to .4 per cent per year. Mahadevan (*17*) found that the genetic superiority of dams was 35 to 40 gallons as compared with a theoretical possible rate of 103 gallons.

Except for the Holstein herds studied by Davis *et al.* and by Harvey, these studies dealt with herds with production ranging from 300 to 400 pounds of butterfat (2x, 305 day ME).

NP Katherine Kilt 2060184 and five of her eight daughters.

MANAGEMENT

The herd at the North Platte Experiment Station has been managed in a rather consistent manner since its establishment. The cattle have been kept in loose housing all of the time and the cows have been milked in a stanchion barn. The rations have generally consisted of corn silage, alfalfa hay, and rather simple concentrate mixtures of ground corn, beet pulp, wheat bran and a high protein feed. During the summer months the cows have been on pastures of bromegrass and alfalfa.

Institutional records of milk and butterfat production have been kept since the herd was established. Seven-day official tests were first made on some of the foundation heifers in 1916 and eventually eight of the twelve foundation heifers entered the Holstein-Friesian Advanced Registry with seven-day tests. Since 1921 the entire herd has been on semiofficial advanced registry test. Until 1937 most of the records were made on four times daily milking. After 1937 all of the cows have been milked twice daily.

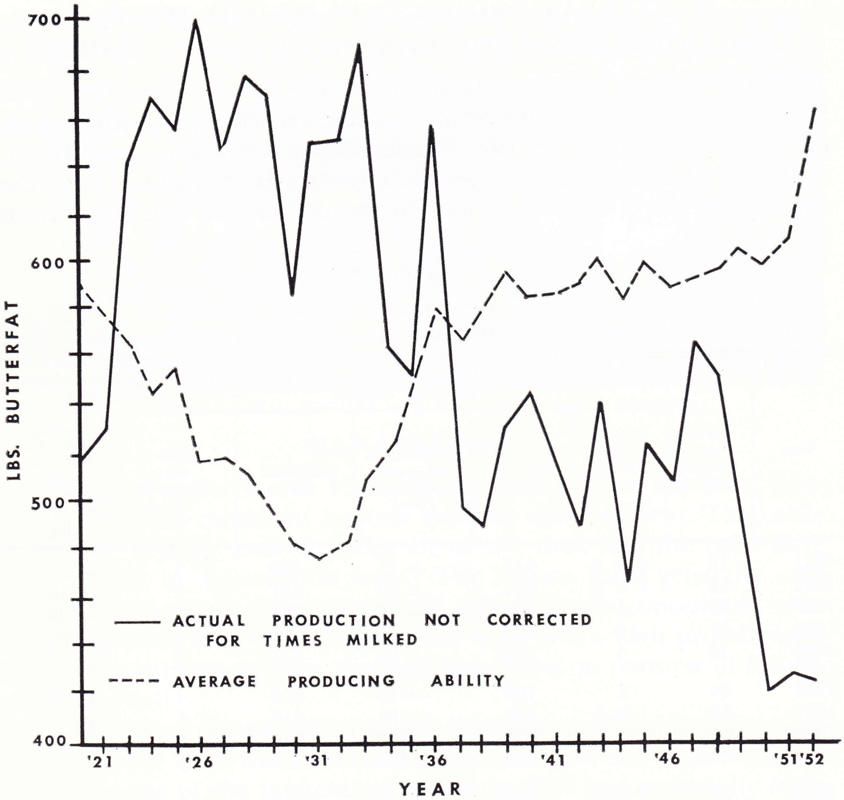
Four of the cows in the herd with records of more than 100,000 pounds of milk.

BUTTERFAT PRODUCTION OF THE HERD AND ADJUSTMENT FOR CHANGES IN MANAGEMENT

Table 1 gives the yearly lactation averages for the years 1921-1952. Records are entered for the year when the record was started and all figures are for 305-day records corrected to maturity using the D.H.I.A. conversion factors (*9*). The production records in column 4 are the 305-day ME records without any correction for times milked. Lush

TABLE 1.—Mean yearly butterfat production of cows in the North Platte Dairy Herd.

Year	Cows with records (No.)	Milked daily (times)	305 days ME butterfat records			Cows with descendants in herd 1954	
			Actual (lbs.)	Adjustment for yearly changes (lbs.)	Adjusted (lbs.)	Cows with records (No.)	Average butterfat production above contemporary herd average (lbs.)
1921	12	4 & 3	515	+ 75	590	2	— 22
1922	13	4 & 3	527	+ 54	581	3	— 15
1923	15	4	640	— 72	568	2	— 36
1924	15	4	668	—126	542	3	+ 66
1925	16	4	653	— 99	554	7	+ 4
1926	20	4	700	—185	515	4	+ 49
1927	19	4 & 3	646	—130	516	5	+ 80
1928	18	4	678	—168	510	5	+ 34
1929	19	4	669	—174	495	5	+ 65
1930	27	4 & 3	583	—104	479	4	+ 68
1931	17	4	650	—177	473	4	+ 36
1932	17	4 & 3	650	—173	477	6	+ 54
1933	13	4	691	—185	506	5	+ 55
1934	15	4	562	— 44	518	7	+ 35
1935	26	4 & 3	551	0	551	9	+ 40
1936	8	4	660	— 81	579	5	+ 77
1937	26	4 & 2	496	+ 70	566	7	+ 38
1938	21	2	487	+ 94	581	7	+ 44
1939	26	2	529	+ 67	596	13	+ 5
1940	26	2	544	+ 39	583	12	+ 10
1941	27	2	517	+ 66	583	13	+ 27
1942	27	2	484	+104	588	14	+ 23
1943	31	2	542	+ 57	599	17	+ 23
1944	27	2	465	+116	581	19	+ 5
1945	27	2	523	+ 75	598	18	— 7
1946	25	2	505	+ 82	587	16	+ 18
1947	30	2	568	+ 22	590	23	+ 13
1948	29	2	551	+ 42	593	19	+ 10
1949	37	2	473	+131	604	27	+ 9
1950	39	2	417	+180	597		
1951	37	2	423	+204	627		
1952	35	2	420	+236	656		



Average production of butterfat in the North Platte Herd from 1921 to 1952.

and Shrode (*16*) have suggested that the use of these age correction factors for records made on 4-time as well as on 2-time milking may tend to overcorrect the 4-time records made at two and perhaps three years of age.

The same data are presented in the figure above. The first thing one notices in the graphic presentation is the very sharp drop in production which took place when the herd was changed from 4-time to 2-time milking in 1937. The next point of note is that in spite of attempts to have a constant management, there are wide fluctuations in production from one year to another. Such fluctuations are very often caused by uncontrolled factors associated with the general health of the herd, changes in weather conditions, and quality of roughage from one year to another and also with changes in the level at which concentrates are fed and the quality of the actual milking operations.

Since the changes from 4-time to 2-time milking took place for the whole herd at one time, there is no way of checking how accurately the standard correction factors for correcting 4-time records to a 2-time milking basis apply to this herd. Fohrman (*4*) found that when the Dairy Husbandry Research Branch herd at Beltsville was changed from 3-time to 2-time milking the production did not drop in conformity with the conventional conversion factors. Laben and Herman (*10*) on the other hand found that in the Missouri Holstein herd the combined effects of changing from 3-time Advanced Registry testing to 2-time Herd Improvement Registry testing lowered the production by 32 per cent. There is no reliable way of estimating the effect of the feeding and management changes which took place when the milking policy was changed from 4 times to 2 times a day. Therefore, it was thought better not to attempt to correct the production records for number of daily milkings but to include the effect of milking practice in the over-all management effect. The corrections for yearly changes in management were made by the use of the maximum likelihood method outlined by Henderson (*6*).[2] By this method a set of adjustment figures for yearly changes in management were computed. The yearly adjustments are given in column 5 of table 1 and the adjusted butterfat production figures are given in column 6. On the graph these last figures are plotted and connected by a broken line.

According to the production figures which are corrected for changes in management, the genetic merit of the herd dropped during the period 1921 to 1931, then rose again until 1939. Thereafter the production showed only minor fluctuations until 1951. The last two years included in this study show a marked increase in genetic merit.

The curve naturally suggests this question: How was this change in genetic merit brought about? This study will discuss the question under the following headings:

The foundation cows and family selection.

Selection of individual cows.

Selection of sires.

[2] The authors are indebted to Dr. Lon D. McGilliard, Dairy Husbandry Department, Michigan State University, for advice regarding the execution of these computations.

THE FOUNDATION COWS AND FAMILY SELECTION

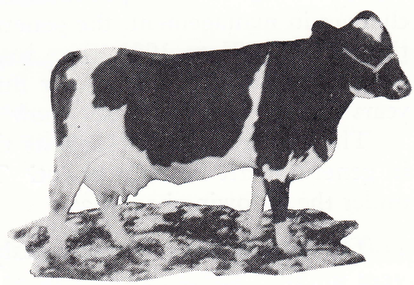
In table 2 are listed the 12 original foundation females. These cows were obtained from four different breeders in Nebraska, Iowa, and Michigan. Only the first four cows listed had descendants left in the herd in December 1954. All four of the foundation females came from E. P. Gregory, Howell, Michigan. No. 75 was the daughter and No. 77 the granddaughter of the cow Re-Becky 68641 while No. 83 was the daughter and No. 82 the granddaughter of the cow Gwendoline Pledge Rose 84645. Thus these four foundation cows actually are from only two cows. Of the 86 females now in the herd, 74 per cent belong to families 1A and 1B while 26 per cent belong to families 2A and 2B (table 3).

How did it happen that only four of the original 12 cows had descendants left after 40 years of breeding, and why does the relative frequency of the present-day descendants in the four families vary so much?

Nine of the 12 foundation females made their first lactation records in the North Platte herd during 1914 and 1915. A tenth cow made

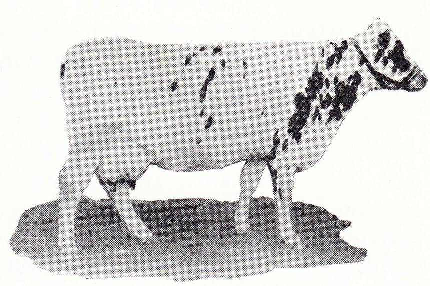
Four of the foundation cows whose progeny remained in the herd.

Family 1A: G&B Becky Blesky Lyons



Family 1B: G&B ReBecky Segis

Family 2A: G&B Clothilde Topsy Lyons



Family 2B: G&B Segis Pledge Rose

her first record during 1917. These first records are given in table 2. The five cows from Michigan averaged 438.8 pounds of butterfat (305d-2x-ME) while the remaining five cows averaged only 293.6 pounds. This difference is highly significant and may have influenced selection of replacements in favor of the Michigan group during the years that followed.

The footnotes to table 2 show that members of some of the other families remained in the herd as late as 1948. The average production of the families is given in table 4. It is difficult to make a valid analysis of differences in the productive levels of the families. There were 32 sires used but 11 of these had only one offspring. Only four of the families (1A, 1B, 2A and 2B) were large enough to include daughters of a number of different sires. In order to analyze family differences, it was decided to confine the study to the four families mentioned above and to limit the cows to the daughters of bulls that had at least one daughter in each family. This left a total of 151 cows in four families and by 10 different sires.

The results of the analysis are given in table 5. Only 6 per cent of the variance in these first-year records is due to family differences while 34 per cent is due to the sires used and 60 per cent is not accounted for in this analysis. In a study of cow families in the Reymann Memorial herd of Ayrshires owned by the West Virginia Agricultural Experiment Station, Tabler *et al.* (*24*) found that sires accounted for 36 per cent of the variance in milk and fat production records. Cow families contributed nothing to the variance of butterfat records but accounted for 8 per cent of the differences in 4 per cent fat corrected milk and fat percentage. The results from the North Platte herd correspond closely to these results. "Family" differences, although significant, have not been as important as differences between sires. However, the small difference in production level which could be associated with differences between these four "families" has been

TABLE 5.—Analysis of variance of first-year butterfat records of 151 cows in four families and by 10 different sires. Records are 305d ME adjusted for management changes (including milking regime).

Source	D/F	Mean square	Estimated variance component	
			Actual	(%)
Sires	9	68,547**	4,091	34
Families	3	36,193**	697	6
Remainder	138	6,992	7,102	60

** Significant at 1% level

Differences between family averages, lbs. butterfat.

	1B	2A	2B
1A	6.6±16.3	15.7±16.8	58.8±16.1
1B		9.1±18.5	52.2±17.8
2A			43.1±18.3

TABLE 6.—Number of male and female offspring in four cow families that were represented in the North Platte Dairy Herd in 1954.

	Males	Females	Total	Females (%)
Descendants in 1954	146	218	364	59.9
No descendants in 1954	189	137	326	42.0
Total	335	355	690	
Per cent	48.6	51.4		

largely eliminated because less than 4 per cent of the present herd consists of members of family 2B which was the family with the lowest production average.

Some factor other than production seems to have caused the distribution of females in the herd to lean so heavily toward the 1A and 1B families. A necessary prerequisite for the development of a family in the sense of female descendants from a foundation female is that an adequate number of females are born, not only to maintain numbers but also to increase them. Table 6 shows the proportion of male and female offspring in the four families that had descendants left in the herd in 1954. The members of these four families are divided into two groups—those that had descendants in 1954 and those that did not have descendants left in the herd by that year. A total of 690 offspring were born in these four families, of which 335 were males and 355 were females. This gives an over-all percentage of female offspring of 51.4 per cent. In the group with descendants in 1954 the percentage of female offspring was 59.9 while the percentage of females in the group that had no descendants in 1954 was only 42.0. This difference in the sex ratios of the two groups is highly significant, χ^2 being 22.0.

This indicates that the development of the present families has been due mostly to chance and has depended upon the number of females that were born in the family.

SELECTION OF INDIVIDUAL COWS

The drop in average genetic merit of the North Platte herd from 1921 to 1931 should be viewed against the background of the expansion in numbers which took place during this period. From 1921 to 1930 the herd expanded from 12 to 34 cows (table 7). During this period the cows that were saved for another lactation averaged 1.8 pounds of butterfat above their contemporaries, ranging from 26.9 pounds above to 43 pounds below (table 8).

Although the average merit of the population does not necessarily decrease as the numbers increase, it must be remembered that the 12 cows present in the herd in 1921 were a selected group. Of the original 12 "families," only eight were represented by 1921 and of the 12 cows that had production records in 1921, 10 belonged to the four families

TABLE 7.—Number of cows in North Platte Dairy Herd by years—1921 to 1954.

Year	Addition from herd (No.)	Animals in herd (No.)	In herd following year (No.)	Culled (No.)	Expansion (No.)	
1921		12	8	4		
1922	5	13	10	3	+ 1	
1923	7	17	10	7	+ 4	+ 7
1924	8	18	13	5	+ 1	
1925	6	19	16	3	+ 1	
1926	9	25	22	3	+ 6	
1927	3	25	19	6	0	
1928	7	26	23	3	+ 1	+15
1929	6	29	25	4	+ 3	
1930	9	34	19	15	+ 5	
1931	3	22	15	7	—12	
1932	6	21	13	8	— 1	
1933	7	20	16	4	— 1	— 6
1934	5	21	12	9	+ 1	
1935	16	28	19	9	+ 7	
1936	1	20	20	0	— 8	
1937	12	32	22	10	+12	
1938	3	25	18	7	— 7	+ 1
1939	11	29	15	14	+ 4	
1940	14	29	20	9	0	
1941	13	33	23	10	+ 4	
1942	5	28	21	7	— 5	
1943	11	32	23	9	+ 4	+ 3
1944	9	32	24	8	0	
1945	8	32	27	5	0	
1946	6	33	24	9	+ 1	
1947	10	34	26	8	+ 1	
1948	7	33	25	8	— 1	+10
1949	15	40	29	11	+ 7	
1950	13	42	27	15	+ 2	
1951	15	42	28	14	0	
1952	19	47	25	22	+ 5	+10
1953	21	46	31	15	— 1	
1954	21	52			+ 6	

which persisted in 1954. The production of the herd had increased sharply during the years following 1914, and it was apparently felt that a nucleus had been established which was good enough to build on. Under circumstances like this it seems inevitable that a regression should take place. The drop during the years 1921-31, therefore, seems less surprising than the rise during the following five to eight years where the herd increased somewhat in size. During the 10-year period 1931 to 1940 the cows that were saved for another lactation averaged 7.8 pounds of butterfat above their contemporaries. Finally during the period 1941 to 1949 the cows that were saved for another lactation averaged 11.6 pounds of butterfat above their contemporaries.

As the herd reached a more stable size and smaller numbers were needed for replacement the selection differential became larger. In studies of Kansas and Iowa Dairy Herd Improvement Association production figures, Seath (*23*) found that 9.4 per cent of all cows were culled for low production and that the selection differential was 14 to 15 pounds of butterfat. This is slightly higher than that found during the latter period of this study when the herd was fairly stable in numbers. The average selection differential for the period 1921 to 1949 was 7.8 pounds of butterfat (table 8).

However, if the cows in the North Platte herd are divided by years into two groups, namely those that had descendants left in the present herd and those that had no descendants left, it is found that only a

TABLE 8.—Cows in the North Platte Dairy Herd that had a following record and the mean butterfat production above their contemporaries.

Year	Cows (No.)	Mean butterfat production above contemporaries (lbs.)
1921	8	+ 3.3
1922	10	+10.0
1923	8	+ 2.1
1924	10	+13.5
1925	13	+26.9
1926	17	+ 1.7
1927	13	+11.3
1928	15	+ 5.3
1929	14	— 7.3
1930	13	—43.0
1931	10	+ 2.0
1932	9	— 4.0
1933	9	—15.5
1934	6	— 6.3
1935	18	+ 4.3
1936	7	+ 3.2
1937	16	+13.3
1938	14	+14.1
1939	12	+43.9
1940	17	+ 4.5
1941	16	+12.5
1942	21	— 1.5
1943	23	+20.3
1944	20	+12.8
1945	23	+ 3.4
1946	16	+29.0
1947	22	+21.9
1948	21	+ 8.9
1949	28	+ 3.3
Weighted mean production above contemporaries		+ 7.77

few cows from the early years had descendants left in 1954. A comparison of the two groups shows that the group with descendants in 1954 averaged 21.3 pounds of butterfat above the contemporary herd averages in which these cows were included (see table 1).

During the first five-year period the cows with descendants in 1954 averaged 3.8 pounds of butterfat above their contemporaries. During the next five-year period they averaged 59.3 pounds above their contemporaries and after this they were better than their contemporaries during every one of the succeeding five-year periods. From 1921 until 1940 inclusive the weighted average of the cows that had descendants in 1954 was 34.1 pounds of butterfat above their contemporaries in the herd. This corresponds to approximately 85 per cent of the best producers being kept for replacements during this period.

Mr. A. R. Sharrah, who managed the herd from 1914 to 1947, explains that selection was based on production records but that animals were removed if they were of very undesirable type, especially in respect to udder. However, if a cow had a good dam she was kept in the herd even though her record was not as high as might be desired. Thus some emphasis has been placed on type and on the records of the relatives of the cows. Therefore, there may have been a time lag before a cow and her close relatives were finally eliminated and the results of the selection process would not be apparent until one or two generations of undesirable animals had been production-tested.

Since the standard deviation (including year and cow variation) was about 126 pounds of butterfat, a selection differential of 21.3 pounds corresponds to .17 times the standard deviation. A selection differential of this magnitude corresponds to a culling of 10 per cent of the lowest producing cows (*13*). The effective rate of culling for production has, therefore, been very close to the 9.4 per cent given by Seath (*23*).

Length of Productive Life and Average Production of Cows and Their Offspring

Table 9 gives a summary of the reproductive performance of the females in the North Platte herd. There were 202 dams that had a total of 241 daughters which entered the herd as milking cows. Some of these dams and daughters had no production records, but they were included in the table if they had daughters that entered the herd and in turn had female offspring. Of the 202 dams, 30.7 per cent did not have female offspring entering the herd. The 38.6 per cent of the dams that had only one daughter each entering the herd contributed 32.4 per cent of the females. The 19.8 per cent of the dams that had two daughters each entering the herd furnished another 33.2 per cent of the replacements while the 10.9 per cent of the dams that had three or more daughters entering the herd furnished 34.4 per cent of the replacements.

TABLE 9.—Reproductive performance of 202 dams in the North Platte Dairy Herd. Butterfat records corrected for yearly changes in management. This table includes only dams born before the oldest living female in the herd at the time of study.

Female offspring of dams (No.)	Dams				Daughters			
	(No.)	(%)	Butterfat production 1st records (lbs.)	Butterfat production Av. all records (lbs.)	(No.)	(%)	Butterfat production 1st records (lbs.)	Butterfat production Av. all records (lbs.)
0	62 (62)[1]	30.7	518.8	520.5	0	0	....	....
1	78 (74)	38.6	544.8	543.3	78 (77)	32.4	545.8	542.4
2	40 (37)	19.8	558.2	563.2	80 (75)	33.2	569.7	570.7
3-8	22 (22)	10.9	592.0	594.4	83 (78)	34.4	570.4	567.0
Mean	202 (195)	100	544.3	545.6	241 (230)	100	562.9	560.6
Weighted mean[2]			565.5	567.5			562.9	560.6
Daughters below dams							—2.6	—6.9

[1] Numbers in parentheses are numbers of cows with records.
[2] Mean weighted in proportion to number of daughters in each group.

The figures in table 9 show that the higher producing dams had relatively more daughters entering the herd than the lower producing ones. This is further evidence of the positive selection for production in this herd.

The daughters averaged 18.6 pounds butterfat above the dams during their first lactation and 15.0 pounds above the dams when the mean of all lactations was used for comparison. This apparent increase in production of daughters over dams should not be regarded as a measure of the genetic improvement from dams to daughters. It is mainly due to the fact that the dams that left no daughters in the herd had a mean butterfat production that was 25.1 pounds below the general mean.

When the dams' records are weighted according to the number of daughters they had in the herd, the daughters' production averaged 2.6 pounds of butterfat below their dams' on the basis of the first lactation records and 6.9 pounds below their dams' production on the basis of all available records for daughters and dams.

Average production of the cows in the North Platte herd has been estimated to be 546 pounds of butterfat. This is the mean of the average lifetime production of all cows born before the oldest living cow in the herd as of December 1, 1954.

The weighted records of the dams, presented in table 9, were 567.5 pounds of butterfat. Therefore, the dams averaged 21.5 pounds above the herd mean.

In table 1 it was shown that the effective selection differential was about 34 pounds of butterfat during the period 1921 to 1940 and

21.3 pounds for the entire period studied. No dams born after May 1945 are included in the figures presented in table 9. It can therefore be assumed that the dams that had offspring in the herd had a phenotypic superiority over their contemporaries of 21 to 22 pounds of butterfat. If heritability is assumed to be .25, this would give the dams a genetic superiority of 5 to 6 pounds above their contemporaries.

Average Production of the Cows in the North Platte Herd by Generations

Breeding progress is often measured in terms of improvement per generation. In a dairy herd the generations soon begin to overlap, making it difficult to obtain a clear picture of the actual change in productive merit per generation since animals representing the same generation have been under different management. Because all the records made in the North Platte herd were corrected for yearly changes in management, production averages could be tabulated by generations. The results are given in table 10. One set of figures gives the averages for all cows born before the oldest living female in the herd as of December 1, 1954. The other set of figures gives the averages for all females that had completed a record. By comparing the number of cows in each generation in the two groups, it will be seen that the cows present in the herd in 1954 represented females from the fourth through the tenth generations. The average cow-generation interval from 1921 to 1952 was 5.2 years.

A comparison of average production per generation for the two groups shows higher averages for the group including all the cows

TABLE 10.—Mean butterfat production of cows in the North Platte Dairy Herd by generations. Records adjusted for management changes and on a 305-day ME basis.

Generation	Cows older than oldest living cow				All cows that have a record			
	Cows (No.)	Av. no. lactations	Av. record 1st lact.	Av. record All lact.	Cows (No.)	Av. no. lactations	Av. record 1st lact.	Av. record All lact.
1	15	3.20	547.7	552.3	15	3.20	547.7	552.3
2	37	2.86	492.6	500.4	37	2.86	492.6	500.4
3	38	2.97	508.4	514.1	38	2.97	508.4	514.1
4	30	3.17	560.2	559.9	32	3.06	566.3	564.7
5	29	2.55	580.3	577.4	36	2.47	586.4	582.1
6	27	3.33	586.6	583.8	30	3.13	600.3	596.4
7	17	3.18	600.9	579.8	43	2.49	604.4	588.9
8	3	3.67	597.7	609.0	23	2.09	642.8	635.0
9	....	......	....	....	6		669.2	657.5
10	....	......	....	....	1		794	794

The foundation females are designated generation O. No very reliable figures are available for their production records because of the rapidly increasing production during the first years. Most of this increase must be due to improved management techniques during the first 10 years of the herd's existence. (See figure on page 8.)

than for the cows that were born before May 1945. This again seems to indicate that the estimate of the environmental decline during the last few years may have been somewhat exaggerated by the computational method used and consequently the genetic merit of the cows that have made records during the last few years may have been biased upward. Another possibility is that the bulls used during the last ten years have had exceptionally high genetic merit. For the time being it is probably safest to confine the study to an evaluation of the first seven generations of breeding and leave an evaluation of the apparent rise during the following two generations to a later date when an analysis of the present breeding project can be made.

During the six generations from the first to the seventh, the increase has been about 40 pounds of butterfat or approximately seven pounds per generation. This net increase includes a considerable drop during the second generation. If one starts at the low point there has actually been an increase of 80 to 90 pounds of butterfat during a period of only five generations or 16 to 18 pounds per generation. This, however, would be too optimistic a way to look at the possibilities for breed improvement over a long period. There are always ups and downs and it is usually easier to improve when there has been a temporary lowering of production.

Dillon *et al.* (*3*) have computed the linear regression of production on years in the University of Illinois Holstein herd. Since the estimated genetic merit of the North Platte herd has a definite nonlinear course up to 1936, it does not seem logical to try to fit a straight line regression to the data for the entire period 1921 to 1952. During the years 1936 to 1952 inclusive, the estimated genetic merit of the herd might reasonably be fitted to a straight line regression. During this 15-year period the regression of estimated genetic ability for butterfat production on years was found to be 1.6 pounds of butterfat per year, corresponding to approximately 8 pounds of butterfat per generation.

This result corresponds quite closely to the estimated improvement of 7 pounds per generation mentioned above.

SELECTION OF SIRES

In the North Platte Dairy Herd 21 sires had three or more daughters with production records that could be compared with the production records of their dams. There were 233 daughter-dam comparisons from these 21 sires. A summary of the daughter-dam comparisons is given in table 11. The table gives the mean pounds of milk, butterfat and fat percentage of the mature equivalent 305-day production of daughters and dams corrected for times milked according to the conventional conversion factors (*9*). The table also gives the means of the first records and of all records for daughters and dams on a 305-day mature-equivalent basis not corrected for times milked

TABLE 11.—Daughter-dam comparisons for 21 sires having at least three daughter-dam pairs in the North Platte Dairy Herd.

Sire	Pairs (No.)	2x–10 mon. ME records			Records corrected for yearly changes in management (Butterfat)	
		Milk (lbs.)	Butterfat (%)	Butterfat (lbs.)	1st year (lbs.)	Av. all records (lbs.)
100	3 daus	13,636	3.54	483	614	565
	3 dams	17,385	3.15	548	753	728
		— 3,749	+ .39	— 65	—139	—163
17	3 daus	12,347	3.46	427	543	513
	3 dams	12,585	3.38	425	580	566
		— 238	+ .08	+ 2	— 37	— 53
101	7 daus	13,198	3.67	484	518	497
	7 dams	13,633	3.41	465	588	563
		— 435	+ .26	+ 19	— 70	— 66
25	21 daus	14,091	3.43	483	488	501
	21 dams	13,217	3.50	462	586	574
		+ 874	— .07	+ 21	— 98	— 73
26	11 daus	11,909	3.96	472	475	465
	11 dams	11,966	3.71	444	496	485
		— 57	+ .25	+ 28	— 21	— 20
102	12 daus	13,186	3.67	484	433	503
	12 dams	13,475	3.61	487	529	530
		— 289	+ .06	— 3	— 96	— 27
104	26 daus	12,770	3.47	443	522	530
	26 dams	14,151	3.57	505	482	530
		— 1,381	— .10	— 62	+ 40	0
37	12 daus	12,495	3.35	418	563	575
	12 dams	12,702	3.53	448	460	516
		— 207	— .18	— 30	+103	+ 59
NP760	6 daus	15,342	3.70	568	632	636
	6 dams	15,519	3.41	529	552	621
		— 177	+ .29	+ 39	+ 80	+ 15
45	6 daus	15,664	3.59	562	650	629
	6 dams	12,776	3.51	448	548	562
		+ 2,888	+ .08	+114	+102	+ 67
107	14 daus	13,556	3.44	466	546	531
	14 dams	13,035	3.43	447	577	574
		+ 521	+ .01	+ 19	— 31	— 43
109	3 daus	14,658	3.45	505	551	564
	3 dams	13,275	3.72	494	536	555
		+ 1,383	— .27	+ 11	+ 15	+ 9
39	3 daus	15,532	3.53	549	613	613
	3 dams	15,363	3.54	544	477	603
		+ 169	— .01	+ 5	+136	+ 10

TABLE 11.—*Continued.*

Sire	Pairs (No.)	2x—10 mon. ME records			Records corrected for yearly changes in management (Butterfat)	
		Milk (lbs.)	Butterfat (%)	Butterfat (lbs.)	1st year (lbs.)	Av. all records (lbs.)
42	10 daus	14,670	3.49	512	585	592
	10 dams	14,445	3.63	525	577	596
		+ 225	— .14	— 13	+ 12	— 4
111	11 daus	14,062	4.00	562	671	627
	11 dams	14,567	3.52	513	578	583
		— 505	+ .48	+ 49	+ 93	+ 44
113	11 daus	13,558	3.39	459	566	552
	11 dams	14,712	3.45	508	578	578
		— 1,154	— .06	— 49	— 12	— 26
112	15 daus	13,277	3.77	500	618	606
	15 dams	14,210	3.46	491	597	579
		— 933	+ .31	+ 9	+ 21	+ 27
115	24 daus	11,258	3.68	414	586	588
	24 dams	14,132	3.69	521	623	612
		— 2,874	— .01	—107	— 37	— 24
116	5 daus	12,325	3.63	448	630	575
	5 dams	14,462	3.59	519	632	600
		— 2,137	+ .04	— 71	— 2	— 25
117	19 daus	12,402	3.58	444	662	647
	19 dams	12,659	3.72	471	565	581
		— 257	— .14	— 27	+ 97	+ 66
118	11 daus	12,139	3.63	441	675	669
	11 dams	13,250	3.78	501	636	619
		— 1,111	— .15	— 60	+ 39	+ 50
Mean daus		13,109		470.3	570.7	567.5
Mean dams		13,700		488.2	563.2	571.3
Daus—dams		— 591		— 17.9	+ 7.5	— 3.8

but corrected for yearly fluctuations in management as described previously. Using these latter figures, twelve sires lowered production, one maintained production and eight increased production. A weighted average of all 233 daughter-dam pairs shows that on the basis of the first available record the daughters averaged 7.5 pounds of butterfat above their dams while on the basis of all available records the daughters averaged 3.8 pounds of butterfat below their dams.

The discrepancies between the daughter-dam comparisons in tables 9 and 11 are due to the fact that table 11 includes all data where there were at least three dam-daughter pairs while table 9 includes only dams born before the oldest living female in the herd (May 1945).

Eight of the 21 sires with daughter-dam comparisons were bred at the North Platte Experiment Station. If these eight sires were evaluated for transmitting ability according to the suggestion by Henderson (7), four of them would have been evaluated as transmitters of above-average production. Of these four, three increased production and one neither increased nor decreased production. One sire was estimated to lower production by 30 pounds and actually lowered it 46 pounds. Three other bulls could be predicted to change production from +1 to −5 pounds. One of these lowered production while the two others increased it.

CORRELATION BETWEEN PRODUCTION OF DAUGHTERS AND DAMS

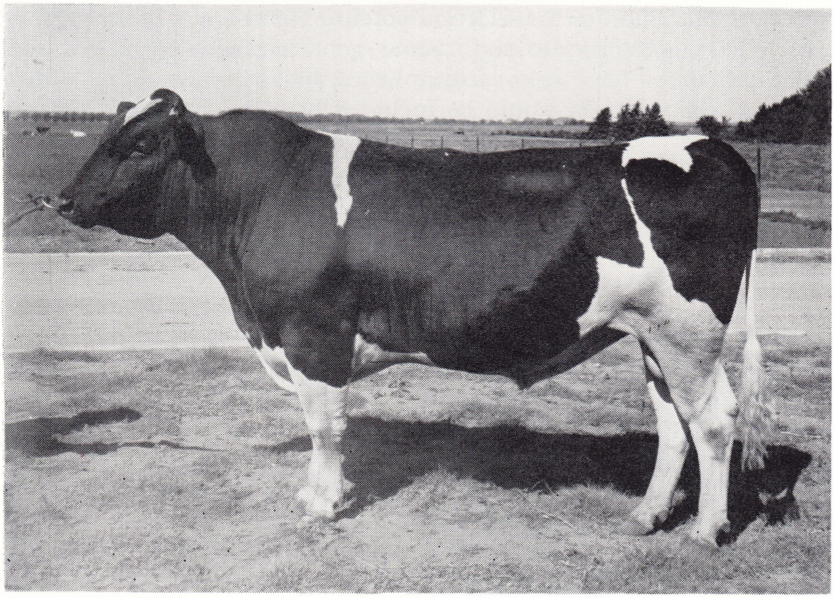
The degree to which selection may improve or change the genetic merit of a population depends in part upon the heritability of the trait under consideration. Although selection may have been directed toward other traits than production, this is the only trait considered in this study. The reason for this is that no adequate information was available regarding other traits.

Heritability estimates may be made by doubling the intrasire regression of daughters on dams (*12*). The 21 sires that had three or more daughters with production records had 233 daughters whose dams also had production records. The statistics for the 233 daughter-dam pairs are given in table 12.

The daughter-dam regressions have been computed on the basis of three sets of values. First the 2x, 305-day ME values of daughters and dams. These are the butterfat records, corrected for times milked to a 2x basis and corrected to a mature basis. These figures would correspond closely to "official figures" published either by the breed organizations or the Dairy Husbandry Research Branch, U.S.D.A. in their sire proofs. The second set of figures are the first records for daughters and dams, corrected for age and corrected for yearly changes in management (including milking regime). The third set of figures

TABLE 12.—Correlations between butterfat production of daughters and dams and regression of daughters' production on dams' production of butterfat.

			2X—10 mo. ME butterfat (lbs.)	Records not corrected for times milked but corrected for management: 1st record ME butterfat (lbs.)	Records not corrected for times milked but corrected for management: Mean all records ME butterfat (lbs.)
Correlation	Total	(231 D/F)	.04	.22	.21
	Within Sire	(210 D/F)	.03	.13	.09
Regression	Total	(231 D/F)	.04	.23	.22
	Within sire	(210 D/F)	.03	.12	.085
Heritability estimate			.06	.24	.17



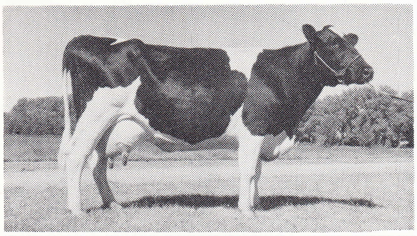
Carnation Sunnyslope Governor 764799 (sire 111 in the North Platte Herd).

are the means of all records of daughters and dams, corrected for age and adjusted for changes in management.

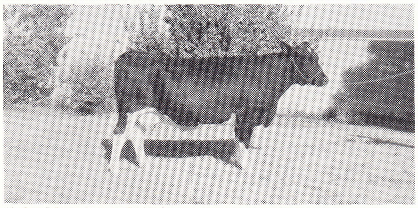
Using the 2x, 305-day ME records, the daughters averaged 591 pounds of milk and 17.9 pounds of butterfat below their dams. Using the first available records for daughters and dams, corrected for changes in management, the daughters averaged 7.5 pounds of butterfat above their dams. When the means of all available records were used, the daughters averaged 3.8 pounds below their dams. Using the 2x, 305-day ME records, the over-all regression of daughters on dams was found to be .04 and the corresponding within sire regression was .03. Using the records corrected for changes in management, the over-all regressions are .23 and .22 for first and all records respectively and the within sire regressions are .12 and .085 respectively. Calculating the heritability as twice the intrasire regression of daughters on dams gives figures of .06 for records uncorrected for management changes and .24 and .17 for records corrected for management changes.

In the North Platte herd, selection has been made on the basis of records that were not corrected for changes in management. This may in part explain why no greater genetic progress has been accomplished in the herd in spite of a rather vigorous selection program.

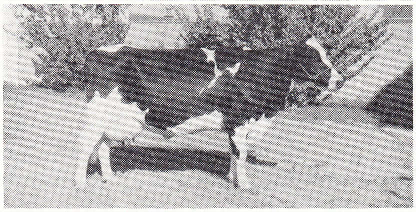
Apparently most of the selection potential has been spent on phenotypic selection in order to maintain a "good average" and only slight genetic changes have been accomplished by this procedure. Under "phenotypic" selection would be included breeding failure, abortions and anything else that might tend to lower the average production of the herd. This procedure which is a part of good dairy husbandry practice as advocated by D.H.I.A. extension goes a long way to explain why this breeding system brought about only relatively small changes in the genetic merit of the herd.



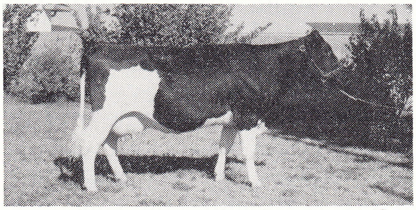
Daughter of Carnation Heilo Imperial 842465 (sire 115).



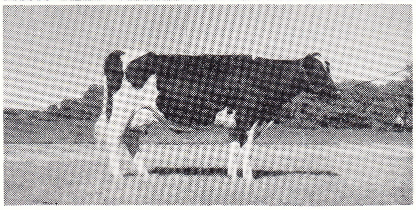
Daughter of NP Perfection Knight 1128839 (sire 124, records not completed).



Daughter of Ellenvale King Mooie Perfection 943134 (sire 117).



Daughter of NP Perfection Quinn 1058866 (sire 120, records not completed).



Daughter of NP Carnation Imperial 1017541 (sire 118).

INBREEDING OF FEMALES AND RELATIONSHIP BETWEEN INBREEDING AND PRODUCTION AND LENGTH OF LIFE IN THE HERD

A number of sires used in the North Platte herd were bred in the Station herd and consequently some inbreeding has taken place. In order to study the effect of inbreeding on production and length of life in the herd, only those animals that were born before the oldest living animal in the herd as of December 1, 1954, were included in this part of the study. A total of 201 offspring from 29 sires met this requirement.

Eleven of these sires had only one daughter each and are excluded from table 13. The mean values for the first records, coefficients of inbreeding and length of life in the herd in months for the daughters of the 18 remaining sires are listed. Fourteen of the 29 sires were bred at the North Platte Station but eight of these sires had only one daughter each. Altogether the North Platte herd bulls had only 70 of the 201 offspring. Only 12 sires had daughters of varying degrees of inbreeding and these 12 sires had 118 daughters (table 13).

The correlations between degree of inbreeding, production, and length of life are given in table 14. This table also gives the regression of production and length of life on degree of inbreeding and of length of life on production.

TABLE 13.—Sires used in the North Platte Dairy Herd and mean values of their daughters' first butterfat records, coefficient of inbreeding and length of life in the herd. Only females born before the oldest living female at the time of study are included in these figures.

Sire	Daughters (No.)	Av. 1st record butterfat (lbs.)	Av. coefficient of inbreeding	Av. length of life (months)
100	8	406.25	0	136.62
17	4	420.50	0	102.75
26	11	475.36	0	67.73
111	12	603.25	0	87.42
104[1]	26	436.50	.01	81.54
112[2]	11	543.91	.01	71.27
45	6	583.00	.014	97.50
25	21	472.29	.018	108.62
101	12	471.5	.026	94.00
102	13	455.38	.031	75.38
42	12	510.50	.037	81.00
27	2	464.00	.039	71.50
39	3	573.67	.050	59.33
37	12	390.92	.057	56.75
105	6	555.0	.073	78.33
107	15	486.27	.077	57.27
113	13	447.77	.102	54.77
109	3	512.00	.169	67.33

[1] Had one daughter with inbreeding coefficient .25.
[2] Had two daughters with inbreeding coefficient .05.

TABLE 14.—Correlations between first-year butterfat production (P) coefficient of inbreeding (F) and length of life (L) for 118 daughters of 12 sires that had inbred daughters. Regressions of production and length of life on coefficient of inbreeding and of length of life on production are also given. When F = 1.00, inbreeding is 100%.

	F x P	F x L	P x L
Within-sire correlation	+ .162	+ .046	+ .268**
Within-sire regression	+267.7	+ 40.9	+ .146
Total correlation	— .034	— .276**	+ .275**
Total regression	— 52.1	—213.0	+ .137

** P less than .01.

Over-all effect. Per 1 per cent inbreeding —.5 pound butterfat.
Per 1 per cent inbreeding —2.13 months in the herd.
For each pound butterfat decrease in first year .14 month shorter stay in herd (4-5 days).

TABLE 15.—Mean coefficient of inbreeding of females born in the North Platte Dairy Herd.

Year	No. females born	No. females inbred	Mean coefficient of inbreeding of inbreds
1918	1	1	.004
1919	3	1	.125
1920	7	6	.033
1921	8	4	.032
1922	7	6	.022
1923	9	8	.020
1924	4	4	.040
1925	7	2	.016
1926	6	0	
1927	2	1	.031
1928	8	7	.035
1929	2	2	.059
1930	12	6	.022
1931	4	1	.028
1932	10	0	
1933	7	4	.037
1934	6	4	.044
1935	9	9	.108
1936	2	2	.034
1937	14	14	.077
1938	14	14	.061
1939	11	11	.048
1940	6	2	.040
1941	8	1	.080
1942	11	11	.100
1943	5	3	.118
1944	9	3	.034

This table includes only animals older than the oldest living female at the time of study.

The regressions show that for each per cent increase in inbreeding, production decreased by .5 pound of butterfat and the length of life in the herd was shortened by 2.13 months. For each pound of butterfat increase during the first year's production, length of life in the herd was increased by .14 month or four to five days. Thus 7 pounds of butterfat more during the first year of production testing would lengthen the stay in the herd by one month.

It should be mentioned that inbreeding has not been very intense in this herd. The number of inbred females born each year is given in table 15. Only 8.9 per cent of the total number of females were inbred 12.5 per cent or more and only one third of the inbred females had coefficients of inbreeding above 6.25 per cent.

DISCUSSION

For most of this study the production figures used have been the actual 305-day butterfat records corrected to maturity and adjusted for yearly changes in management according to the maximum likelihood method of Henderson (*6*). Unbiased results by this method depend upon the use of correct age correction factors and upon the use of the correct value for repeatability of records (*8*).

The age correction factors which have been used are those suggested by the Dairy Husbandry Research Branch of the United States Department of Agriculture. They are the result of a compromise between studies made of Dairy Herd Improvement Association records processed by the Dairy Husbandry Research Branch and of records processed in the office of the Holstein-Friesian Association of America. A majority of these records have been made under 2-times-a-day milking.

When age conversion factors based on 2-time milking are used for the age correction of records made under 4-time milking, Lush and Shrode (*16*) have pointed out that there may be a tendency to overcorrect the records of the younger cows that were actually milked four times daily. When records thus overcorrected are used to estimate changes in management, the environment will appear to become worse even though there is actually no environmental change. As a consequence, the estimated genetic change would be biased upward. In the present data this might have happened during the period before 1937 when the cows were milked four times daily. During the first half of this period the genetic merit went down as compared with the actual production. This in turn implies that the environmental conditions improved at a higher rate than the actual production increased. During the latter part of this period the reverse was true. The period from 1931 to 1936 is the only period where the increase in genetic merit was so rapid that one might suspect some bias due to overcorrection of records of young animals.

The other source of bias in the use of the maximum likelihood method for estimating environmental and genetic fluctuations is the use of an incorrect value for repeatability. If too large a value for repeatability is used and if the cows with the lower records are culled, the environmental trend is biased downward and consequently the estimate of the producing ability or genetic value of the herd is biased upward.

In the computations a repeatability value of .50 was used. This value was based on the value of .49 found in an analysis of variance of all the records made in the herd from 1921 to 1952 when the records were corrected to maturity and also corrected for times milked. It is not known what the repeatability would have been if the records had not been corrected for times milked, but since the repeatability figure of .49 is computed on a within-year basis and since practically all cows were milked four times before 1937 and two times thereafter, it is felt that the value would not have been much different if the within-year repeatability had been computed from records that were not corrected for times milked.

During a period of 32 years the management conditions might very well have fluctuated. Since the value for repeatability found in these data represents a pooled estimate of the within-year repeatability, it is almost certain that the value would not have stayed the same year after year. From 1931 to 1945 the relative rate of culling was the largest. From 1931 to 1935 there is not much evidence of the lower producing cows being culled and during the following 10 years the superiority of the cows that had a following lactation was slightly less than 12 pounds of butterfat. During the last few years where the actual production decreased considerably, one may suspect that repeatability has been lower than .49. During these years it was furthermore the established policy that all heifers had to be tested for one year, while there is no way of determining what the policy was on this point before 1949. There is therefore reason to show only cautious optimism about the marked increase in genetic merit during the last few years covered by this study.

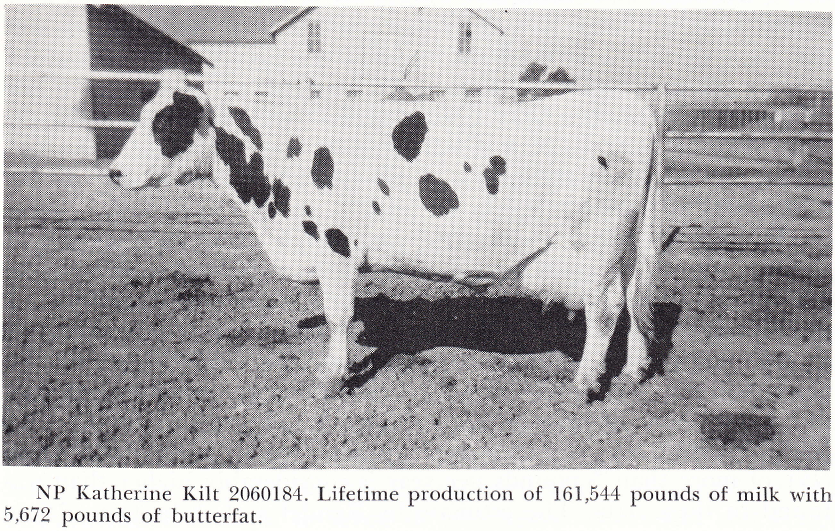
The drop in genetic merit from 1921 to about 1931 and the subsequent rise in genetic merit is most logically explained as a result of the expansion in numbers during the first ten years and a more rigorous culling process during the latter part of this period. This trend may have been somewhat augmented by the influence of the sires that were used in the herd.

The changes in genetic merit which have taken place are due partly to selection of dams and partly to the influence of the sires. The effective selection differential for dams has been close to 20-25 pounds of butterfat, as evidenced in tables 1 and 9. This tends to bias the estimate of the genotype of the dams (*15*). The data indicate a herita-

bility of around 25 per cent based on first records, and a selection differential of 20 to 25 pounds would therefore lead to an increase in genetic merit of 2.5 to 3 pounds of butterfat per generation, due to selection of dams. This is between one half and one third of the increase in production which took place during the first seven generations of breeding.

Normally one should expect a higher value for heritability when the estimate is made on the basis of averages of several records as compared with single records. Some explanation may be offered as to why the heritability estimates obtained from these data show the opposite results. Occasionally an exceptionally good producing cow may have been kept in the herd even after her production dropped off because of injuries to the mammary system. No records were excluded from the study unless there were special notices in the herd book about disease, abortion or lost quarters and such information was only scanty. The result may also be due to the effect of selection, which has been quite vigorous in the North Platte herd. Laben and Herman (*10*) have pointed out that selection could cause the lifetime average to be biased upward, and this bias would increase the longer a cow stays in the herd and is subject to selection after each new record has been completed. This bias would be quite pronounced if culling took place during the lactation or if the official test were discontinued if there were indications that the record would be lower than was hoped.

From table 9 it is estimated that the general mean production for the cows born before May 1945 was 546 pounds of butterfat. It is



NP Katherine Kilt 2060184. Lifetime production of 161,544 pounds of milk with 5,672 pounds of butterfat.

probable that the average actually was somewhat lower than this because there undoubtedly was some culling of less promising heifers just before they calved and of low producing heifers before any production figures were recorded. At least the herd book shows that sales of heifers have taken place before they freshened or within 30 to 60 days after they freshened. If it is assumed that the "genetic" average of the herd was 546 pounds of butterfat, the selection of dams should have resulted in heifers producing 2.5 to 3 pounds more if the sires neither added to nor subtracted from the genetic merit. Actually the daughters averaged 567.5 pounds of butterfat which is 18 to 19 pounds above expectation. This would indicate an exceptionally high merit of the sires. If, however, 10 per cent of the lowest producing heifers were culled before any production figures were recorded, the average of the remaining heifers would be increased by .20 standard deviation or 20 to 25 pounds in the present data (*13*). Culling of 10 per cent would mean only one or two heifers per year and under the expert herdsmanship that has been practiced in the North Platte herd such a culling rate seems entirely possible. Therefore, there is good reason to assume that the daughters have been exposed to some culling and that the apparent rise in the daughters' production above the level expected of them is biased somewhat by culling according to the principles of good herdsmanship. Otherwise the genetic merit of the herd should have increased more than it did.

The data seem to indicate that genetic improvement has been of the order of slightly more than 1 pound of butterfat per year. The cow-generations were 5.2 years in length. The mean age of the bulls when their daughters were born was 4.2 years, making the length of a bull-generation four fifths the length of a cow-generation. It may therefore be estimated that the improvements due to selection of cows and of bulls have been about equal, each contributing 2.5 to 3.0 pounds per generation. Owing to the fact that the bull-generations were somewhat shorter than the cow-generations, the part of the improvement per year due to selection of dams of cows is slightly less than half and that due to selection of bulls slightly more than half of the improvement obtained.

The improvement of about 1 pound of butterfat per year is slightly less than was found by Laben and Herman (*10*) in the Missouri Holstein herd. If only the rising segments are considered, the North Platte herd and the Missouri herd show about the same increase of 17 to 18 pounds per generation. Plum's (*20*) estimate of a yearly increase in production of approximately ⅔ pound of butterfat due to selection of cows is slightly higher than was found in these North Platte data. The improvement reported by Nelson and Lush (*19*) of more than 3 pounds per year is considerably higher than was found in these data. The estimate by Rendel and Robertson (*21*) of

an annual gain of .3 to .4 per cent from selection of dams of cows and dams of bulls is about twice the value estimated from the North Platte herd. The results obtained are better than the ones reported by Dillon *et al.* (*3*) but fall far short of the impressive results of improvements of 5 and 8 pounds per year reported by Harvey in the University of Idaho herds of Jerseys and Holsteins (*5*).

Inbreeding had only a minor influence on the production of the cows in the North Platte herd, the regression being only –.5 pound of butterfat for each per cent increase in inbreeding. The influence of inbreeding on length of life was immaterial, but females with a higher first lactation record stayed on the average one month longer in the herd for each 7 pounds of increase in production during the first year.

The over-all picture of the development of the herd is probably quite typical of what is found in herds that are started from highly selected stock. Because selection is mainly made on the basis of the records (and type) of the individuals and because heritability for these traits is rather low, a regression is to be expected during the following generations when most of the offspring of the foundation stock are kept for replacement in order to increase numbers with a consequent decrease of the selection pressure.

Some selection has taken place between cow families since only four of the original twelve foundation cows had descendants in the herd by 1954. Only 6 per cent of the variance in first lactation records was due to family differences while 34 per cent was due to differences between the sires used.

The possible improvement due to selection of cows and of bulls is a function of the selection differential and the heritability of the trait for which selection is made. Since improvement takes place from one generation to the next, improvement per year is also a function of the generation length. The shorter the generations are, the faster the improvement can be made in terms of yearly improvement, provided the selection pressure can be maintained at the same level. Since heritability of butterfat is only 20 to 25 per cent, some improvement in accuracy of selection can be obtained by a combination of individual and family selection in the case of selection of females (*14*), and by the use of progeny tests in the case of selection of sires. The only disadvantage of using selection based partly on relatives and partly on progeny performance of sires (besides the selection of females for individual merit) is that it takes time to obtain this added information and consequently the generation intervals become longer. The greater accuracy in estimating genetic merit is therefore offset by the added time required.

The use of young bulls could lower the length of the sire-generations (average age of sire when his offspring are born) to between two and three years while the use of progeny tested bulls lengthens the sire-generation interval to seven to nine years. Dickerson and Hazel

(2) have shown that under these circumstances the use of progeny tests actually decreases the rate with which progress per year can be achieved. In addition, if any of the daughters of the sires are culled before they have completed a production record, the progeny test of the sire could be greatly misleading and the breeder would not only lose time but also the accuracy which the progeny test was intended to furnish.

The herd at the North Platte Experiment Station has been maintained at a rather high level of production during the 40 years following its foundation. This has apparently been accomplished by a vigorous culling program which has resulted in an effective selection differential of more than 20 pounds of butterfat. Since heritability has been estimated to be 20 to 25 per cent, the selection among dams of cows could account for approximately half of the improvement obtained during the first six generations (first through seventh) of breeding.

The genetic improvement obtained from the use of the sires is somewhat more difficult to assess. There is evidence that some culling of low producing heifers has taken place before figures of their production have been recorded. Otherwise the production average of the daughters from the selected dams could hardly be expected to be as high as it was found to be. It is estimated that slightly more than half of the genetic improvement is brought about by the sires. It should be emphasized that the herd at the North Platte Experiment Station was not established to carry out a breeding experiment, but to be a demonstration of what farmers in that area could accomplish with good dairy cattle. At the same time the herd was intended to furnish breeding stock for the area. In these two respects the herd has fulfilled its mission with great success. Rigorous culling was carried out according to the best principles of good herdsmanship and breeding, as this concept was understood at that time. Unfortunately it was not realized that a vigorous culling program would make any analysis of the actual genetic changes that took place in the herd very difficult if not impossible.

The best sires from the herd were not generally brought back into service after their progeny test became available. More progress might have been expected if the bull-generations had been shorter and if full use could have been made of the results obtained from the progeny tests. The over-all improvement of 7 pounds of butterfat per generation or a little more than 1 pound of butterfat per year is not spectacular, but it is not out of line with progress reported in other studies where attempts have been made to separate the effects of heredity and the ever changing environment.

SUMMARY

The dairy herd at the North Platte Experiment Station was established in 1913 by the purchase of 12 purebred Holstein-Friesian heifers. By 1954 the herd consisted of 86 females, all descending from four of the original heifers, representing females from the fourth to the tenth generation.

The average generation length has been 5.2 years for cows and 4.2 years for bulls and it is estimated that the genetic improvement has amounted to approximately 7 pounds of butterfat per generation. Slightly less than half of this improvement has been brought about by selection among females and slightly more than half has been due to the effect of the sires used.

A rather rigorous culling program has been carried out, resulting in an effective selection differential of about 20 pounds of butterfat. This culling program has maintained the herd at a rather high level throughout most of the period from 1913 to 1954.

All the females that were in the herd in 1954 were descendants of only four cows and almost half of the sires used in the herd were home-bred. In spite of this, inbreeding has been only slight. The depressing effect of inbreeding has been –.5 pound of butterfat for each per cent of inbreeding.

The study confirms that rigorous culling of low producing or otherwise undesirable animals before production records become available may help in maintaining a rather high herd average. This procedure, however, is not in the best interests of a sound breeding program and may actually have delayed genetic progress.

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