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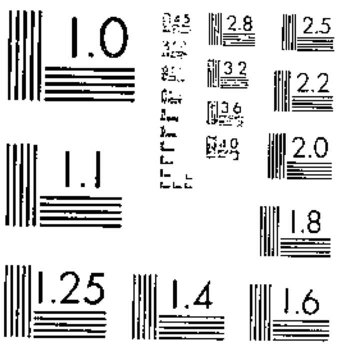
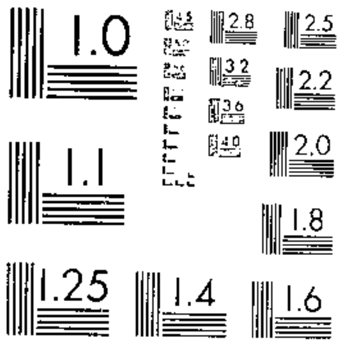


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A



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ANALYSIS OF THE ADVANCED REGISTRY RECORDS OF 611 DAUGHTERS OF 51 AYRSHIRE SIRES

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INTRODUCTION

This bulletin is the second publication of a series based on the studies made of the advanced-registry and register-of-merit records of the various breeds of dairy cattle, the first [1] being published in 1926. The factors that determine the quantity of milk production are inherited independently of those that determine the percentage of butterfat in the milk. It seemed logical, therefore, to study the milk production and the butterfat percentage in these records separately, rather than to study their combined results as represented by the butterfat-production records.

The animals in this study have proved to be so heterozygous in genetic make-up that the statistical analysis of their records has been very difficult from the standpoint of the study of heredity. Environment enters largely into the making of these official records,[2] and this also detracts from their usefulness in inheritance studies. Because records may be discontinued at any time, cows adversely

[1] GRAVES, R. R. TRANSMITTING ABILITY OF TWENTY-THREE HOLSTEIN-FRIESIAN SIRES. U. S. Dept. Agr. Bul. 1372, 32 p., illus. 1926.

[2] FOHRMAN, M. H. OFFICIAL RECORDS AS MATERIAL FOR STUDYING INHERITANCE OF MILK AND BUTTERFAT PRODUCTION. Jour. Dairy Sci. 9:286-292. 1926.

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affected by environment are usually withdrawn from test, which further distorts the effect of environment.

At the time these records were made, the rules for entry into the advanced registry required a minimum production of 6,000 pounds of milk and 214 pounds of butterfat for cows calving at or before 2 years of age, and 8,500 pounds of milk and 322 pounds of butterfat for those calving at 5 years of age or older, with graded requirements for intermediate ages.[3] This rule automatically excluded the cows that failed to reach the required production and introduces another disturbing factor. Gowen,[4] by a devious method, estimates that not more than 28.3 per cent of the cows are excluded from the advanced registry by the requirements for milk yield, but this figure seems rather high.

Although the records analyzed in this study were all completed years ago, they show the results of dairy-cattle breeding practices of that period, and any information which they yield can be incorporated in our present meager fund of knowledge regarding practical dairy-cattle breeding. This study of the practices followed by leading breeders of Ayrshire cattle during the period reviewed strengthens the theory that substantial improvement in dairy-cattle breeding can be made only by a better basis of selecting herd sires.

SOURCE OF DATA AND MATERIAL USED

This bulletin gives an analysis of the records of 611 advanced-registry daughters of 51 Ayrshire bulls, and the records of the dams of these daughters. The material was taken from the Ayrshire Record Advanced Registry [5] and includes only the tested daughters of bulls having at least six record daughters from dams with records. This was also the basis of sire selection used in the study reported in the first publication of this series; but since the work was begun, Davidson [6] has demonstrated that for the Jersey breed, on the average, 6 is the smallest number of first-tested daughters whose average production closely approximates the average production of the first 15 daughters of a sire, and that the average production and variability among the productions of the first 15 tested daughters are representative of the average production and variability among the productions of any larger number of the sire's daughters. While the method of selection used in this study did not always include the first six tested daughters, it is believed that each group of daughters used is fairly representative of the get of the sire.

ANALYSIS OF RECORDS OF MILK PRODUCTION

COMPARATIVE STATISTICS ON DAMS AND DAUGHTERS

These 611 daughters are the offspring of 452 dams, but for comparative study of dams and daughters the records of the dams are repeated as often as the dams are represented by daughters. The milk records have all been corrected to a uniform age basis by the

[3] Ayrshire Breeders' Association. The Ayrshire Record Advanced Registry. v. 1, p. 9. Brandon, Vt. 1917.
[4] Gowen, J. W. Milk secretion; the study of the physiology and inheritance of milk yield and butterfat percentage in dairy cattle. p. 137. Baltimore. 1924.
[5] Ayrshire Breeders' Association. Op. cit., also vols. 2–3.
[6] Davidson, F. A. Measuring the breeding value of dairy sires by the records of their first few advanced registry daughters. Ill. Agr. Expt. Sta. Bul. 270, pp. 545–596, illus. 1925.

use of factors developed from all initial records included in the Ayrshire Record Advanced Registry.[7]

Figure 1 shows the distribution of the dams (the actual number and weighted number), and their 611 daughters, according to milk production.

Table 1 lists the statistical constants for the generations studied.

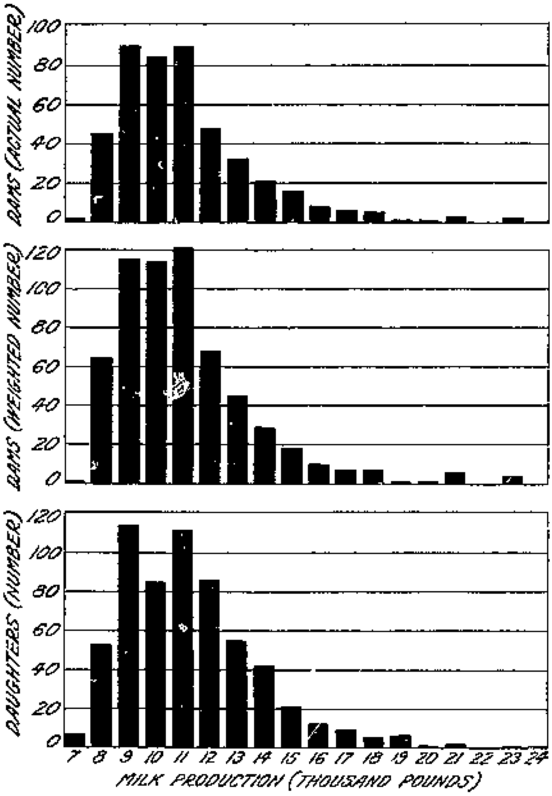

FIGURE 1.—Distribution of 452 dams (actual and weighted numbers) and their 611 daughters, according to milk production

TABLE 1.—*Statistical constants of milk production of the daughters and their dams*

Group	Average milk production	Animals above average	Animals below average	Standard deviation	Coefficient of variability
	Pounds	*Number*	*Number*	*Pounds*	*Per cent*
452 dams [1]	11,524±70	179	273	2,487±56	21.58±0.40
611 dams [2]	11,568±70	246	365	2,564±49	22.16± .43
611 daughters	11,732±69	263	348	2,510±48	21.39± .41

[1] Actual number. [2] Weighted number.

The 611 daughters have an average age-corrected record of 11,732 pounds of milk, whereas their dams average 11,568 pounds. The difference of 164 pounds of milk represents the increase in producing ability achieved in one generation of breeding. This increase amounts

[7] AYRSHIRE BREEDERS' ASSOCIATION. Op. cit., v. 1–3.

to 1.42 per cent, a rather slight rate of advance; and it is possible that at least part of this increase may be attributed to the ever-growing knowledge of methods of feeding and handling cows on test.

Table 2 shows the relationship of the milk-production records of dams and daughters. The correlation between the records of all dams and daughters is $+0.262 \pm 0.015$.

TABLE 2.—*Correlation surface for yearly milk-production records of the 611 daughters and their dams*

Yearly milk records of dams (pounds)	Number of daughters in milk-production class of—																	
	24,000 pounds	23,000 pounds	22,000 pounds	21,000 pounds	20,000 pounds	19,000 pounds	18,000 pounds	17,000 pounds	16,000 pounds	15,000 pounds	14,000 pounds	13,000 pounds	12,000 pounds	11,000 pounds	10,000 pounds	9,000 pounds	8,000 pounds	7,000 pounds	Total
24,000																			0
23,000											2		2						4
22,000																			0
21,000									2		1	1	2						6
20,000	1																		1
19,000						1													1
18,000							1			1		2	1		1	1			7
17,000				1								2	1	1	2				7
16,000								1	2		2	1	2		1	1			10
15,000		1									1	3	3	3	3	3		1	18
14,000					1	1	1	1	1	5	3	4	4	1	1	2	4		29
13,000						2		1	1		4	3	6	8	7	8	4	1	45
12,000				1		1	1			2	6	8	10	12	4	20	2	1	68
11,000								2	3	4	7	8	22	22	20	21	10	2	121
10,000						1	1			4	10	9	11	23	20	20	15		114
9,000							1	1	3	3	4	10	16	29	14	22	11	1	115
8,000								3		2	2	3	6	12	12	16	7	1	64
7,000												1							1
Total	1	1	0	2	1	6	5	9	12	21	42	55	86	111	85	114	53	7	611

EFFECT OF FEMALE SELECTION

In order to illustrate further the influence of the milk-producing capacity of the dams on the offspring when the sires are selected at random, the dams in this study have been divided into two groups on the basis of their yearly milk-production records. The 246 dams whose milk-production records are higher than the average for all the dams, 11,568 pounds, make up one group and will be referred to hereafter as the grade A dams. The 365 dams whose records are below the average make up the other group and will be referred to as the grade B dams. Similarly, the 611 daughters have been divided into two groups with the 11,732-pound average for all daughters as the dividing line. The 263 daughters whose records are above the average will be called grade A daughters, and the 348 daughters whose records are below the average will be called grade B daughters.

The grade A dams constitute only 40 per cent of all the dams, but they produced 51 per cent, or 134, of the 263 grade A daughters. Although these dams averaged 13,892 pounds of milk, their 246 daughters averaged only 12,361 pounds, and although the average for the grade A dams is 2,324 pounds above the average for all the dams, the average of their daughters is only 629 pounds above the average for all the daughters. Only 73 of the daughters of the grade A dams, or about 30 per cent, exceeded their dams in milk production, while 173 failed to do so.

The distribution of the grade A dams and their daughters in relation to their milk production is shown in Figure 2.

The grade B dams, which comprise 60 per cent of all the dams in the study, produced 129 of the 263 grade A daughters, or 49 per cent, and 236 grade B daughters. Although 253 of the daughters of grade B dams exceeded their dams in milk production, only 129, or 35 per cent, were above the average of the 611 daughters. The average milk production of the grade B dams was 10,002 pounds, which is 1,566 pounds below the average of all the dams; whereas the average of their 365 daughters was 11,309 pounds, which is only 423 pounds below the average for all daughters.

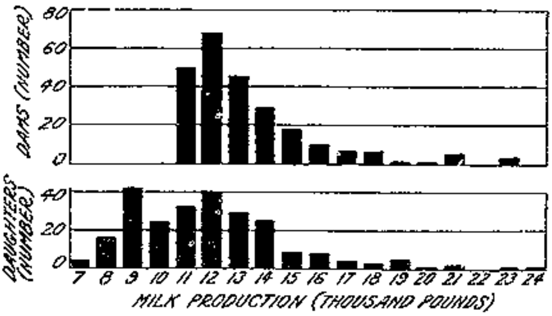

FIGURE 2.—Distribution of 246 grade A dams and their daughters according to milk production

The distribution of the grade B dams and their daughters, in relation to their milk production, is shown in Figure 3.

To summarize briefly, when the sires are selected at random, and the dams are arbitrarily divided at the line of average production, the records of the daughters in each group tend strongly to approach the average production of all the daughters.

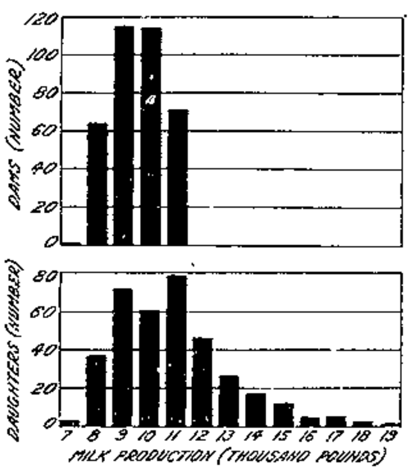

FIGURE 3.—Distribution of 365 grade B dams and their daughters according to milk production

This tendency is shown by the distributions in Table 2, and is emphasized strongly in the extremely high and low-producing groups. There are 54 dams with records above 15,000 pounds of milk, and only 5 have daughters with records above their own. Sixty-five dams produced less than 9,000 pounds of milk, and only 5 of their daughters failed to exceed the dams' records.

In the daughter group, 58 have records above 15,000 pounds of milk, and only 6 of these produced less than their dams; 60 of the daughters have records below 9,000 pounds of milk, and only 3 of them made more than their dams. These facts would have some bearing on the selection of females for breeding purposes.

The figures in Table 3 indicate a closer correlation between high-producing dams and their daughters than between low-producing dams and their daughters. The same is true of high-producing daughters and their dams as compared to low-producing daughters and their dams.

TABLE 3.—*Correlation between high-producing dams and their daughters, low-producing dams and their daughters, high-producing daughters and their dams, and low-producing daughters and their dams*

Group	Daughter-dam pairs	Production of dams: Average milk production	Production of dams: Standard deviation	Production of dams: Coefficient of variability
	Number	*Pounds*	*Pounds*	
Dams over 15,000 pounds milk	54	17,708±236	2,576±170	14.55±0.96
Dams under 9,000 pounds milk	65	8,647±17	213±12	2.46±0.15
Daughters over 15,000 pounds milk	58	12,893±290	3,273±205	25.39±1.59
Daughters under 9,000 pounds milk	60	10,970±157	1,800±120	16.40±1.01

Group	Production of daughters: Average milk production	Production of daughters: Standard deviation	Production of daughters: Coefficient of variability	Correlation coefficient
	Pounds	*Pounds*		
Dams over 15,000 pounds milk	13,459±309	3,363±222	24.99±1.65	+0.223±0.055
Dams under 9,000 pounds milk	11,123±190	2,267±134	20.38±1.21	+.161±.059
Daughters over 15,000 pounds milk	17,254±181	2,045±128	11.85±0.74	+.322±.041
Daughters under 9,000 pounds milk	8,513±29	333±21	3.91±0.24	−.140±.064

Selection from the female side alone holds small promise for permanent improvement in milk production. Even if drastic selection is practiced, the results are certain to be disappointing, as the high level established by the original culling can only be maintained by continued close culling, which would result in tremendous sacrifice of females. On the other hand, with no further selection of sires than was practiced in choosing the sires of the 611 daughters in this study, the daughters of the lower-producing dams tend almost uniformly to exceed their dams in production; but this method of selecting sires fails to greatly raise the average of the whole group because of the fact that the sires used were not sufficiently good to raise or even maintain the production of the higher-producing dams.

The average production of the various groups of dams, together with the averages of their respective daughters, is shown in Table 4.

TABLE 4.—*Average milk production of the dams and their daughters in the various production groups, number of daughters above and below their dams in each group, and number of daughters above and below the average of all daughters in the study*

Milk production group	Daughter-dam pairs	Average milk production of— Dams	Average milk production of— Daughters	Increase (+) or decrease (−) by daughters over dams	Daughters with records— Above their dams	Daughters with records— Above their dams	Daughters with records— Below their dams	Daughters with records— Above average of all daughters	Daughters with records— Below average of all daughters
	Number	*Pounds*	*Pounds*	*Pounds*	*Number*	*Per cent*	*Number*	*Number*	*Number*
23,000 pounds	4	23,821	13,631	−10,190	0	0	4	4	0
22,000 pounds									
21,000 pounds	6	21,428	14,217	−7,211	0	0	6	6	0
20,000 pounds	1	20,174	24,285	+4,111	1	100	0	1	0
19,000 pounds	1	19,387	19,809	+422	1	100	0	1	0
18,000 pounds	7	18,334	13,311	−5,023	0	0	7	5	2
17,000 pounds	7	17,349	13,353	−3,996	1	14	6	4	3
16,000 pounds	10	16,471	13,703	−2,768	1	10	9	8	2
15,000 pounds	18	15,463	12,175	−3,288	1	6	17	9	9
14,000 pounds	29	14,425	13,560	−865	12	41	17	22	7
13,000 pounds	45	13,432	11,695	−1,737	9	20	36	18	27
12,000 pounds	68	12,495	11,832	−663	23	34	45	32	36
11,000 pounds	121	11,477	11,530	+53	58	48	63	49	72
10,000 pounds	114	10,491	11,304	+813	66	58	48	38	76
9,000 pounds	115	9,503	11,315	+1,812	93	81	22	45	70
8,000 pounds	64	8,658	11,093	+2,435	59	92	5	20	44
7,000 pounds	1	7,974	13,004	+5,030	1	100	0	1	0
Total or average	611	11,568	11,732	+164	326	53	285	263	348

Heterosis, or hybrid vigor, may account for some of the higher-producing dams. It is probable, judging from these data, that most of the sires have a heterozygous genetic make-up, and the matings of these animals of mixed inheritance would result in offspring which tend to revert to the average of the parent stock in production. If it is assumed that the low-producing dams still carry some of the factors for high production, then from matings with the same heterozygous sires there should be some increase in the producing ability of the offspring, which is what occurred. Four of the dams whose production was above 15,000 pounds of milk dropped daughters which were considerably better producers, and in these instances there is evidence of an inheritance of the factors for high production from both of the heterozygous parents. Twenty of the dams with milk records below 9,000 pounds have daughters which failed to exceed their dams by 1,000 pounds of milk or more. Those producing much less than their dams would have been excluded from the advanced registry by the breed requirements and are not available for this study. The 121 daughters of the dams with a milk production of 11,000 pounds form an interesting group. Twenty-two are in the same class as their dams, 46 are in a higher class, and 53 in a lower class.

GROUPS OF SIRES WITH DAUGHTERS HAVING HIGHEST AVERAGE PRODUCTION AND HIGHEST AVERAGE INCREASE OVER DAMS

Because of the limited number of offspring of the individual sires it was deemed best to study them first in groups.

One group of 10 sires, having a total of 96 daughters, was selected on the basis of the high average production of the daughters of each sire. Taking the daughters of each sire as a unit, the average milk production ranged from 14,994 to 12,996 pounds. Mathematical constants for this group are listed in line 1, Table 5.

TABLE 5.—*Statistical data on the daughters of two groups of sires, one group selected on the basis of the high average production of their daughters, the other on the basis of the greatest average increase in production by the daughters over their dams*

Group	Daughter-dam pairs	Production of dams		
		Average milk production	Standard deviation	Coefficient of variability
	Number	*Pounds*	*Pounds*	*Per cent*
10 sires with highest average daughters	96	12,221±172	2,505±122	20.50±1.00
10 sires with greatest average increase by daughters over dams	84	10,831±163	2,217±115	20.47±1.07

Group	Production of daughters			
	Average milk production	Standard deviation	Coefficient of variability	Coefficient of correlation
	Pounds	*Pounds*	*Per cent*	
10 sires with highest average daughters	13,447±187	2,724±133	20.26±0.99	+0.383±0.026
10 sires with greatest average increase by daughters over dams	12,116±175	2,382±124	19.66±1.02	+ .440± .023

The interesting fact about the first 10 sires is that although the 96 dams to which they were mated averaged 653 pounds more milk than the average production of all dams in this study, their daughters exceeded the average of all the daughters by 1,715 pounds. The average increase by the daughters of these sires over their dams was 1,226 pounds, and 62 daughters were better producers than their dams.

The other group of 10 sires was selected on the basis of average increase in milk production which the daughters of each sire had shown over the records of their dams. The sires selected were those whose daughters showed the greatest average increase. The 84 daughters of these sires averaged an increase of 1,285 pounds over the average of the dams. Mathematical constants for this group are listed in line 2, Table 5.

A comparison of the results obtained with both groups of good sires and with the entire class of 51 sires is shown in Table 6.

TABLE 6.—*Results of mating the 51 sires with the grade A and B dams, compared with the results of mating two selected groups of sires with grade A and B dams*

Number of sires and number and grade of dams with which each group of sires was mated	Average milk production of—		Increase (+) or decrease (−) by daughters over dams
	Dams	Daughters	
	Pounds	*Pounds*	*Pounds*
51 sires:			
611 grade A and B dams	11,568	11,723	+164
248 grade A dams	13,892	12,361	−1,531
365 grade B dams	10,002	11,309	+1,307
10 best sires, selected on the basis of high average production of their daughters:			
96 grade A and B dams	12,221	13,447	+1,226
48 grade A dams	14,184	14,130	−54
48 grade B dams	10,257	12,764	+2,507
10 best sires selected on the basis of greatest average increase in production by daughters over dams:			
84 grade A and B dams	10,831	12,116	+1,285
20 grade A dams	13,841	13,736	−105
64 grade B dams	9,890	11,609	+1,719

When the 51 sires were mated to grade A dams, 30 per cent of the daughters were better than the dams, and when mated to grade B dams, 70 per cent of the daughters were better than the dams.

When the 10 best sires by the first method of selection (high-average daughters) were mated to grade A dams, 50 per cent of the daughters were better producers than the dams, and when mated to grade B dams 80 per cent of the daughters were better than the dams.

The other 10 best sires, because of the basis of selection (high average increases), were able to get higher percentages of daughters better than the dams, but it is also true that both the grade A and grade B dams in these matings averaged below those mated with the preceding 10 sires.

INDIVIDUAL SIRES IN RELATION TO MILK RECORDS OF THEIR DAUGHTERS

With reference to the individual sires, there is a paucity of convincing data, partly because of the limited number of daughters sired by each of the bulls, and also because of the additional evidence of the heterozygous genetic make-up of the animals in the study. It is difficult to prove the existence of a pronounced upward trend in milk production in the get of any single sire or that any sire was homozygous for high milk production. Considering the sires individually, the the most striking tendency noted is the ability of the bulls to sire daughters inferior to the high-producing dams and superior to the low-producing dams to which they are mated. This emphasizes the heterozygous genetic make-up of both males and females.

For comparative purposes the sires were ranked according to the method used in the study of Holstein-Friesian sires.[8] This method was based on consideration of the average yields of milk and butterfat of the daughters, the average increase or decrease in milk and butterfat production of the daughters compared to their dams, and the proportion of daughters which exceeded their dams in milk and butterfat yield. The Ayrshire sires were first ranked according to each of these considerations, and the sum of the individual rankings determined the final rank of each sire. This method of ranking sires was used because no better system has yet been offered, and furthermore, the ranking of sires is merely incidental to this study and not its fundamental object.

Table 7 shows the ranking of the 51 sires and the distribution of their daughters according to the level of milk production. The table also shows the average production of the daughters, the average production of their dams, the difference in average production, and the rank of each group of dams and daughters.

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[8] GRAVES, R. R. Op. cit.

TABLE 7.—*Number of daughters by individual sires in each milk-production class, and average milk production and rank of daughters and dam*

Rank of sire [1]	Number of daughters in milk-production class of—																		Total daughters	Average milk production of daughters	Rank of daughters according to milk production	Average milk production of dams	Rank of dams according to milk production	Increase (+) or decrease (−) by daughters over dams	Rank of daughters by increase or decrease	Daughters with—	
	24,000 pounds	23,000 pounds	22,000 pounds	21,000 pounds	20,000 pounds	19,000 pounds	18,000 pounds	17,000 pounds	16,000 pounds	15,000 pounds	14,000 pounds	13,000 pounds	12,000 pounds	11,000 pounds	10,000 pounds	9,000 pounds	8,000 pounds	7,000 pounds								Increased production	Decreased production
																			Number	*Pounds*		*Pounds*		*Pounds*		*Number*	*Number*
1								1			2	1	1				1		6	13,482	4	11,977	19	+1,505	6	5	1
2				1							3	2	2	3		1			12	13,268	5	11,404	27	+1,864	2	8	4
3							1			3	3	2	3	3	1			1	17	13,240	7	11,464	25	+1,776	3	12	5
4		1				1						2	2	3	3		1		13	12,952	11	11,793	23	+1,159	11	9	4
5											3		1	1	1				6	13,108	9	11,180	33	+1,928	1	5	1
6									2			2	5	1	2		2		14	12,216	17	10,960	38	+1,256	9	12	2
7										1	2		1	2	1				7	12,996	10	11,958	21	+1,038	16	5	2
8	1							2		2		1	1	1	3	1	1		13	13,495	3	12,082	15	+1,413	8	8	5
9							1						1		2	3			7	11,472	27	9,705	49	+1,767	4	5	2
10						1			2	1			3						7	14,994	1	13,518	4	+1,476	7	5	2
11								1	2	2	5	8	8	7	5	7	3		48	12,251	16	11,192	32	+1,059	15	33	15
12						2		1	1	2	4	3	5	7	6	5	2		38	12,404	14	11,329	30	+1,075	14	26	12
13							1		1	2	2	1	1	1	1		1		11	13,685	2	12,851	6	+834	17	6	5
14													1	3	2		1		7	11,096	30	9,964	48	+1,132	13	5	2
15												1	3	3	2	1			10	11,489	26	10,664	42	+825	18	6	4
16							1						1	5	1	2			10	11,774	24	10,256	45	+1,518	5	8	2
17												1		4	1	2	1		9	10,621	41	9,439	51	+1,182	10	7	2
18						1					3	3	1	1		5			14	12,516	13	12,303	14	+213	24	9	5
19										1	1	6	2		1				11	13,238	8	13,550	3	−312	34	6	5
20									1		2	1	1	1	1	1	1	1	10	11,981	21	11,392	28	+589	19	5	5
21													2	4	2	2	1		11	10,902	36	10,367	44	+535	20	8	3
22								1		3		2	2	2	2		4		16	12,196	18	11,040	35	+1,156	12	9	7
23				1							1	4	2	6	4	2			20	12,177	19	12,352	13	−175	32	11	9
24												1	3	1		1			6	11,989	20	11,970	20	+19	27	3	3
25											1	1	3	3	2	2	1		13	11,258	28	11,382	29	−124	31	7	6
26								1	1		1			1		2			6	13,257	6	12,780	8	+477	21	2	4
27									1	1	1	2	2	4	4	12	3	1	31	10,767	39	11,011	37	−244	33	17	14
28					1					1	1	2	1	3	2	1	1		13	12,382	15	12,406	11	−24	29	5	8
29													1	2	2	1			6	10,933	34	10,916	39	+17	28	3	3
30						1				1		1			1	1	1		6	12,849	12	12,814	7	+35	26	2	4
31													1	1	1	4	2		9	9,946	46	10,049	47	−103	30	6	3
32													2	1		3	4	1	11	9,688	49	9,643	50	+45	25	4	7
33												1	3	4	2	4			14	11,205	29	12,366	12	−1,161	43	7	7
34											1		2	1	2	2	1		9	11,028	32	10,696	41	+332	23	5	4

35								1					3	3	1	7			15	11,080	31	11,768	22	−679	36	8	7
36							1		1		3	2	3	10	3	4	3		30	11,806	23	12,622	9	−816	38	12	18
37								1						2	2	4			9	10,916	35	11,273	31	−357	35	2	7
38														3		3			6	10,504	43	10,103	46	+401	22	3	3
39														2	4	1	2		9	10,176	44	11,012	36	−836	39	4	5
40												1		1	3	4	1	1	11	9,965	45	11,058	34	−1,093	42	4	7
41													1	2	3	2	1		9	10,507	42	11,418	26	−911	40	3	6
42											1	1	3	2	1	2			10	11,868	22	13,047	5	−1,179	44	3	7
43											1	1	1	1	1	1	1		7	11,530	25	15,279	1	−3,749	51		7
44											1		1	1	1	3			7	10,933	33	14,118	2	−3,185	50		7
45													3		1	3			7	10,721	40	12,064	16	−1,343	46	2	5
46												1	2	1		1	1	1	7	10,851	37	12,049	17	−1,198	45	3	4
47												1			2	5	3	1	12	9,612	50	10,408	43	−796	37	2	10
48										1			1	1	4		3		10	10,786	38	12,442	10	−1,656	47	3	7
49													1	1		4	2		8	9,736	48	10,731	40	−995	41	2	6
50														1	1	3	1		6	9,748	47	11,984	18	−2,236	49		6
51														1	1	2	3		7	9,531	51	11,635	24	−2,104	48	1	6

[1] This rank is arrived at by combining the relative standings of these sires on milk production, butterfat production, increase in milk and butterfat production by daughters over dams, and proportion of daughters better than dams in milk and butterfat production.

TABLE 8.—*Rank of sire and of sire's sire, milk production of sire's dam, and statistical constants on milk production of the daughters of the individual sires and of the dams of the daughters*

Rank of sire [1]	Daughters	Milk production of sire's dam	Rank of sire's sire [1]	Daughters: Average milk production	Daughters: Standard deviation	Daughters: Coefficient of variability	Dams: Average milk production	Dams: Standard deviation	Dams: Coefficient of variability	Coefficient of correlation
	Number	*Pounds*		*Pounds*	*Pounds*		*Pounds*	*Pounds*		
1	6	17,793	36	13,482± 760	2,758±537	20.46±3.98	11,977± 568	2,062±401	17.22±3.35	+0.750±0.120
2	12	12,969		13,268± 556	2,855±393	21.52±2.96	11,404± 357	1,833±252	16.07±2.21	+.023± .194
3	17			13,240± 383	2,344±271	17.70±2.05	11,464± 360	2,202±255	19.21±2.22	−.040± .163
4	13	18,110		12,952± 736	3,939±521	30.41±4.02	11,793± 610	3,262±431	27.66±3.66	+.443± .150
5	6	9,569	4	13,108± 416	1,511±294	11.53±2.25	11,180± 164	596±116	5.33±1.04	+.301± .250
6	14			12,216± 402	2,228±284	18.24±2.33	10,960± 560	3,105±396	28.33±3.61	+.235± .170
7	7			12,996± 446	1,749±315	13.46±2.43	11,958± 355	1,394±251	11.66±2.10	+.213± .243
8	13			13,495± 785	4,198±555	31.11±4.12	12,082± 511	2,733±361	22.62±2.99	+.690± .098
9	7	12,570		11,472± 749	2,936±529	25.59±4.61	9,705± 240	940±240	9.69±1.75	+.432± .207
10	7	21,331	20	14,994± 582	2,283±411	15.23±2.75	13,518± 871	3,417±616	25.28±4.56	+.729± .119
11	48	11,781		12,251± 224	2,296±158	18.74±1.29	11,192± 225	2,312±159	20.66±1.42	+.439± .078
12	38			12,404± 294	2,691±208	21.69±1.68	11,329± 268	2,454±190	21.66±1.67	+.311± .098
13	11	12,349		13,685± 545	2,680±385	19.58±2.82	12,851± 670	3,295±474	25.64±3.69	+.429± .165
14	7	8,853	39	11,096± 309	1,211±218	10.91±1.97	9,964± 266	1,043±188	10.47±1.89	−.575± .170
15	10	21,324	11	11,489± 254	1,189±179	10.35±1.56	10,664± 328	1,539±232	14.43±2.18	+.498± .160
16	10			11,774± 489	2,294±489	19.48±2.94	10,256± 237	1,112±168	10.84±1.63	−.080± .211
17	9			10,621± 311	1,382±220	13.01±2.07	9,439± 212	942±222	9.98±1.59	−.303± .204
18	14	14,412	4	12,516± 484	2,674±341	21.36±2.72	12,303± 701	3,888±496	31.60±4.03	−.073± .179
19	11	21,733	2	13,238± 224	1,099±158	8.30±1.19	13,550± 777	3,820±549	28.19±4.05	+.370± .175
20	10	21,023		11,981± 610	2,858±431	23.85±3.60	11,392± 775	3,633±548	31.89±4.81	+.419± .176
21	11	11,212	8	10,902± 246	1,211±174	11.11±1.60	10,367± 281	1,382±199	13.33±1.92	−.408± .169
22	16			12,196± 483	2,863±341	23.47±2.80	11,040± 386	2,288±273	20.72±2.47	−.192± .162
23	20	14,227	11	12,177± 391	2,591±276	21.28±2.27	12,352± 377	2,498±366	20.22±2.16	+.476± .116
24	6	12,571	4	11,989± 417	1,516±295	12.64±2.46	11,970± 692	2,512±489	20.99±4.09	+.257± .257
25	13	21,733		11,258± 301	1,612±213	14.32±1.89	11,382± 271	1,451±192	12.75±1.69	−.230+ .177
26	6	15,382	12	13,257± 850	3,086±601	23.28±4.53	12,780± 767	2,788±543	21.82±4.25	+.572± .185
27	31			10,767± 249	2,057±176	19.10±1.64	11,011± 203	1,674±143	15.20±1.30	+.159± .118
28	13			12,382± 550	2,940±389	23.74±3.14	12,406± 387	2,066±273	16.57±2.19	+.264± .174
29	6	11,505	4	10,933± 257	933±182	8.53±1.66	10,916± 230	836±163	7.66±1.49	−.727± .129
30	6	13,750	4	12,849±1,083	3,936±766	30.63±5.96	12,814± 752	2,731±532	21.31±4.15	−.011± .275
31	9	9,719		9,946± 264	1,173±186	11.79±1.87	10,049± 216	959±152	9.54±1.52	+.581± .148
32	11			9,688± 311	1,528±220	15.77±2.27	9,643± 143	705±101	7.31±1.05	+.480± .156
33	14	13,506	11	11,205± 205	1,134±214	10.12±1.29	12,366± 750	2,805±358	22.68±2.89	−.611+ .112
34	9			11,028± 395	1,756±279	15.92±2.53	10,696± 323	1,437±228	13.43±2.14	+.207± .215
35	15			11,089± 364	2,092±258	18.87±2.32	11,768± 706	4,063±500	34.53±4.26	+.321± .080
36	30			11,806± 273	2,219±193	18.80±1.64	12,622± 342	2,774±242	21.98±1.91	+.455± .097
37	9	9,874	40	10,916± 582	2,589±412	23.72±3.77	11,273± 366	1,630±259	14.46±2.30	−.400± .188

38	6	----------	22	10,505± 278	1,011±197	9.62±1.87	10,103± 395	1,436±280	14.21±2.77	−.715± .224
39	9	----------	----------	10,176± 192	852±135	8.37±1.33	11,012± 331	1,474±234	13.39±2.13	−.346± .107
40	11	----------	----------	9,965± 274	1,345±193	13.50±1.94	11,058± 348	1,710±246	15.46±2.22	−.537± .144
41	9	10,681	11	10,507± 282	1,253±199	11.93±1.90	11,418± 103	456± 72	3.09±0.63	−.322± .201
42	10	15,626	----------	11,868± 339	1,588±240	13.38±2.02	13,047± 235	1,102±166	8.45±1.27	−.135± .209
43	7	12,583	3	11,530± 468	1,835±331	15.92±2.87	15,279± 853	3,347±603	21.28±3.84	+.831± .078
44	7	13,896	35	10,933± 487	1,912±345	17.49±3.15	14,118±1,113	4,364±787	30.91±5.57	+.937+ .031
45	7	----------	----------	10,721± 309	1,212±218	11.30±2.04	12,064± 590	2,313±417	19.17±3.46	+.199± .244
46	7	8,865	16	10,851± 513	2,012±363	18.54±3.34	12,040± 443	1,737±313	14.42±2.60	−.356± .222
47	12	----------	----------	9,612± 277	1,425±196	14.83±2.04	10,408± 231	1,184±163	11.38±1.57	+.206± .186
48	10	----------	----------	10,786± 362	2,015±304	18.68±2.82	12,442± 441	2,069±312	16.63±2.51	+.103± .190
49	8	11,920	7	9,736± 307	1,287±217	13.22±2.23	10,731± 295	1,235±208	11.51±1.94	−.232± .225
50	6	10,389	----------	9,748± 253	918±179	9.42±1.83	11,984± 552	2,006±391	16.74±3.26	+.373± .236
51	7	----------	----------	9,531± 201	1,142±206	11.98±2.16	11,635± 534	2,095±378	18.01±3.25	+.214± .243

[1] The individual sires are referred to by the same number as the number of their rank given in Table 7.

Comparative studies of the various sires are rendered less valuable because of the differences in the number of daughters representing each sire and also because of the variation in the quality of the dams to which they were mated. Sire 11 [9] has 48 daughters, or eight times the minimum number which admitted 8 other bulls to the study. Sire 43 was mated with dams that averaged 15,279 pounds of milk, while sire 17 was mated to dams that averaged 9,439 pounds of milk. Any results of comparison of these sires would of necessity have to be modified by consideration of the transmitting tendencies of various grades of dams already discussed.

Table 8 shows the average milk production of the daughters of each sire and of the dams of the daughters, the standard deviation and coefficient of variability of each group, and the coefficient of correlation of the daughters of each sire with their dams. The table also shows the milk production of the sire's dam and the rank of his sire.

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[9] The individual sires are referred to by the same number as the number of their rank given in Table 7.

Figures 4 and 5 show the milk-production records of the daughters of several sires and of their dams.

Sire 12 is fairly representative of the better bulls in this study, and he clearly shows the tendency, mentioned on page 5, to sire daughters inferior to the high-producing dams, and superior to the low-producing dams with which he was mated.

Sire 23 is of interest because of the variability in milk production shown by his 9 daughters from dams in the 11,000-pound class; and conversely, sire 36 is of interest because he produced 10 daughters with an average milk production of 11,000 pounds from dams with a wide range of production. In the case of sire 37, one of his lowest-

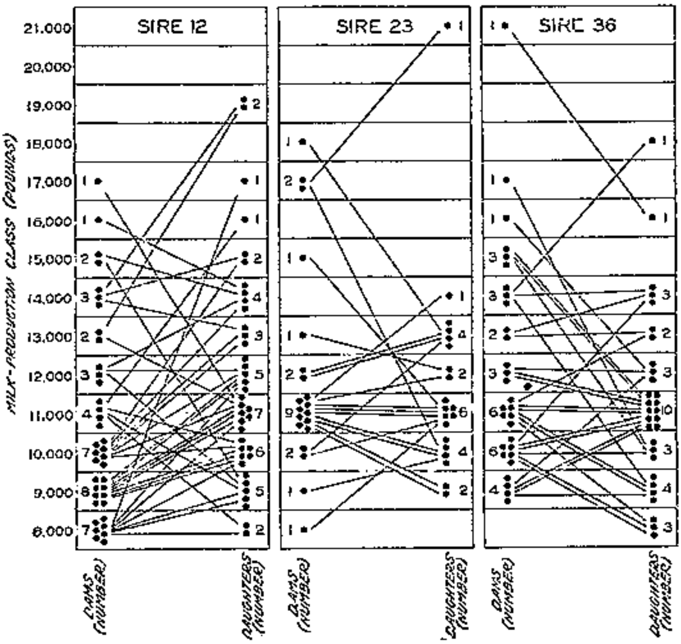

FIGURE 4.—Trend of milk production by daughters of three sires, as shown by the number of daughters, from dams in various milk-production classes

producing daughters is out of the highest-record dam to which he was mated, and his best daughter is out of one of the poorest dams. Sire 41 got daughters with a wide range of production from 8 dams in the 11,000-pound class. Sires 43 and 44 consistently lowered the milk production of the offspring of good dams, and the influence of these good dams is reflected in the high correlation between the daughters and the dams. (Table 8.) These two sires were without doubt decidedly lacking in ability to transmit the factors for high milk production to their daughters. The group of dams to which these sires were mated ranked first and second in average milk production (Table 7), and their offspring show the greatest average decrease. Even though these high-producing dams may be heterozygous, as has been suggested before, that fact alone is not enough to account for the uniform and large decline in producing ability shown by their offspring, and it must be conceded that these two sires are also at fault.

SIRES WITH GREATEST PROPORTION OF DAUGHTERS BETTER THAN THEIR DAMS

Individually these 51 sires showed ability to transmit a wide variation in producing capacity, but none was able to get daughters all of which exceeded their dams in milk production. The best showing in this particular was made by sire 6, 12 of his 14 daughters being better producers than their dams. This sire was mated to a mixed class of dams, one dam produced more than 21,000 pounds of milk, another more than 13,000 pounds, while the other 12 averaged 9,890 pounds,

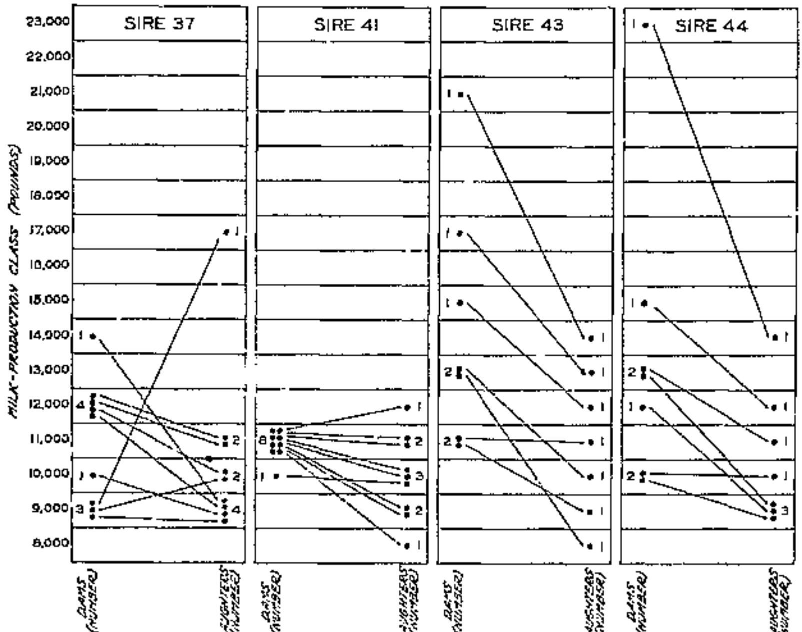

FIGURE 5.—Trend of milk production by daughters of four sires, as shown by the number of daughters, from dams in various milk-production classes

which would rank them low as a group. The offspring of sire 6 from the two high-producing dams were above the average in milk production, but their true value is best understood by comparing them with the get of other sires from these same dams. Each of this sire's daughters is the lowest producer of three maternal half sisters from these dams. His showing on the other 12 dams was very good and he evidenced ability to get better daughters from dams producing 9,000 pounds of milk, but in this class the normal expectation for improvement is high.

The showing of sire 6 when mated to cows having tested daughters sired by other bulls is interesting, and the results appear in Table 9.

TABLE 9.—*Comparison of the daughters of sire 6 with daughters of other sires from the same dams*

Sire No.	Milk production of—		Sire No.	Milk production of—		Sire No.	Milk production of—	
	Dam	Daughters		Dam	Daughters		Dam	Daughters
	Pounds	*Pounds*		*Pounds*	*Pounds*		*Pounds*	*Pounds*
6	21,331	12,153	6	10,784	11,334	6	8,903	10,443
20		16,618	12		13,346	4		11,961
4		13,049	6	10,428	12,797	6	8,420	8,588
6	13,437	16,701	4		13,199	12		10,678
4		19,357	6	9,509	13,033	4		10,351
12		19,108	12		10,641			
6	10,797	13,230	6	9,225	12,537			
12		11,074	12		11,691			

On the basis of his showing when in direct comparison with other sires, it would appear that sire 6 was rated too high by this system of ranking.

Two other sires had 5 of their 6 daughters better than the dams, but the small number of pairs in each case offers inadequate material for study. Sire 5 is one of these, and his 6 daughters show the greatest average increase over their dams. Among his daughters are 2 sets of full sisters—one of 3 and the other of 2. The variability even in these full-sister groups is great enough to make the high rank of this bull questionable. Sire 1 is the other bull with 5 of his 6 daughters better than their dams. He was mated to better average dams than sire 5, and his ability to improve production failed in only one instance, but that was when he was mated to a dam in the 10,000-pound class (where the whole population of sires raised 58 per cent of their daughters above their dams), and in this case the daughter produced 163 pounds less than her dam.

Eight of ten daughters by sire 16 exceeded their dams in milk production. He was mated to nine dams that were below the average in milk production, and his daughter from the best dam was inferior to her dam and was the poorest of her three maternal half sisters. This bull's progeny performed in close approximation to the average for the population, and his apparent ability to sire daughters better than their dams may be accounted for by the fact that he was bred to the class of dams that on the average produce a high percentage of daughters with ability exceeding their own.

It would appear from these cases that while the ability of a sire, when used in herds representative of this population, to get a high percentage of daughters which exceed their dams in milk production, is worthy of notice, it is not a definite assurance that this sire is much above the average in his transmitting ability for milk production.

If a sire were mated only with low-producing dams, where the normal expectation is for a high percentage of daughters better than their dams, he would have to show an increase in this percentage in order to show better than average ability. It would be easier to judge of the relative ability of sires that were mated to dams of different levels of production.

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SIRES WITH GREATEST PROPORTION OF DAUGHTERS POORER THAN THEIR DAMS

Three of the fifty-one sires had daughters all of which were below the dams in milk production. The daughters of sire 43 show the greatest average decline of the 51 groups. The number of daughters is only seven, but the results are so uniform as to warrant discussing them. The dams of these daughters constitute the highest-producing group of dams in this study. The general expectation is for daughters of high-producing dams to fall below their dams in production, but apparently this sire was an exceedingly poor transmitter of production or he would have maintained a higher level of milk yield in daughters from this grade of dams than he did. There is also a correlation between the records of these dams and their daughters of $+0.831 \pm 0.079$.

Sire 44 affords a similar example, as the group of dams with which he was mated ranked second in average milk production. His daughters were all inferior to their dams, and the correlation between dams and daughters is $+0.937 \pm 0.031$. This sire even failed to get improved daughters from two dams in the 10,000-pound class, a class in which the normal expectation for an increase is better than even.

The third bull whose daughters all produced less milk than their dams was sire 50. The average production of the dams to which he was mated was lower than that of the dams to which either sire 43 or 44 was mated.

Judging by the performance of the offspring of these three sires, it is evident that when a bull consistently sires daughters that are poorer producers than their dams, he carries few if any of the factors for high milk production, and that the producing ability of the offspring of such a sire will depend largely on what they inherit from the dams. This study also showed that sires 43, 44, and 50 sired daughters with the greatest decrease in milk production.

SIRES WITH DAUGHTERS SHOWING THE GREATEST AVERAGE INCREASE OVER THEIR DAMS

The three sires whose daughters show the highest average increase in milk yield over their dams, are Nos. 5, 2, and 3. Sire 5 has already been discussed. Sire 2 has 12 daughters that averaged 1,864 pounds of milk more than their dams, but this includes 1 that produced 8,952 pounds more than her dam. With this one exception sire 2 failed to accomplish much when mated to dams above the 12,000-pound class but showed unusual ability to increase the production from dams below that class. Considering only his 7 daughters from these lower-producing dams, the average increase in production by daughters over dams is more than 3,000 pounds, which is well above the general average increase from dams of this quality.

Sire 3 evidenced the same weakness as sire 2 on high-producing dams and the average increase in production by his daughters over their dams is due to the performance of his daughters from the lower-grade dams. Two sets of three full sisters contribute a large part toward establishing this high average increase.

The evidence offered by these three groups of daughters indicates that high increases in production by daughters over dams occur mostly where the dams rank in the lower levels of production. Bulls selected on this basis alone would be those that have been mated with lower-producing cows.

The opposite is clearly indicated in the case of sires 43 and 44. Bulls that fail to sire improved daughters from low-record dams may safely be classed as the poorest sires for transmitting milk production.

A further illustration of this apparent effect of the average production of the dams on that of the daughters is shown by Table 10, which lists the 6 sires whose daughters showed the greatest average increase in production over that of their dams, and the 6 sires whose daughters showed the greatest average decrease in production. The 6 high-ranking sires were mated to groups of dams with an average rank of 33, and 39 of them were grade B dams and 19 grade A dams. The 6 low-ranking sires were bred to groups of dams whose average rank was 12, and 14 of them were grade B dams and 30 were grade A dams.

TABLE 10.—*The six best and six poorest sires, ranked according to the greatest average increase and decrease, respectively, in production of their daughters over the dams of the daughters*

Group and sire No.	Average increase (+) or decrease (—) (pounds) in milk production by daughters over dams	Rank of dams, on basis of milk production	Number of dams in—	
			Grade A	Grade B
Six best:				
5	+1,928	33	3	3
2	+1,864	27	6	6
3	+1,776	25	5	12
9	+1,767	49	0	7
16	+1,518	45	1	9
1	+1,505	19	4	2
Six poorest:				
43	−3,749	1	7	0
[illegible]	−3,185	2	5	2
50	−2,236	18	4	2
51	−2,104	24	4	3
48	−1,656	10	5	5
45	−1,343	10	5	2

SIRES WITH DAUGHTERS HAVING THE HIGHEST AVERAGE MILK PRODUCTION

The five sires (Nos. 10, 13, 8, 1, and 2), whose daughters are highest in average milk production include only one sire that was considered under the discussion of sires having daughters with a high average increase over dams. As already stated, only 5 of the 54 dams that produced over 15,000 pounds of milk dropped daughters that excelled them as producers, and 3 of these 5 daughters were by sires 1, 8, and 10.

Sire 10 has the distinction of siring the most uniformly good daughters, so far as milk production is concerned, of any of the 51 sires. The coefficient of variability for his 7 daughters is 15.23 ± 2.75. They averaged 14,994 pounds of milk; and each one produced more than 12,000 pounds, which is well above the average of all daughters. Five of the dams were also in the class above 12,000 pounds, and the other two were in the 9,000-pound class. His daughters from the last two were far ahead of their dams in milk production.

Sire 13 has 11 daughters that averaged 13,685 pounds of milk from dams that averaged 12,851 pounds. Only 6 exceeded their dams in milk production, and there was wide variation in their records. His daughters from grade A dams are better than the average, but his best showing is in the daughters he sired from the lower-record dams. His record on this small group of daughters is not consistent.

Sire 8 has 13 daughters. They rank third in average milk production, but they show the greatest variability of any group of daughters. The dams also vary widely in their producing ability, but there is a correlation of -0.690 ± 0.098 between daughters and dams. The transmitting ability of this sire as shown by the performance of his daughters is rather unusual. The 4 best dams to which he was mated all had records above 12,000 pounds of milk, and the daughter of each of these cows was better than her dam. In the whole population only 1 daughter in 4 exceeded her dam when the dams produced 12,000 pounds or more of milk. The next 4 dams to which sire 8 was mated were all in the 11,000-pound class where the chances were even that a daughter would be a better or poorer producer than her dam, but all of the daughters fell below their dams and 3 of them by more than 1,000 pounds of milk. While such inconsistent performance is confusing, it is one of the things to be expected in analyzing material which is as heterozygous as this appears to be.

Sire 1 has 6 daughters with an average milk production of 13,482 pounds despite one with a production of only 8,652 pounds. Omitting this one, his showing is unusually good, both with respect to the high average increase in production by his daughters over their dams and the uniformity of the increase.

The daughters of sire 2 follow closely the general population. Three dams in the class above 13,000 pounds had daughters poorer than themselves. One dam in the 12,000-pound class dropped his highest-record daughter as well as one daughter in the 12,000-pound class. Mated to dams in the class below 12,000 pounds he got 7 daughters that were all decidedly better producers than their dams, but his breeding performance approaches the average in spite of the high production of his daughters and their high average increase over their dams.

SIRES WITH DAUGHTERS HAVING THE LOWEST AVERAGE MILK PRODUCTION

Daughters of sires 51, 47, and 32 have the lowest average milk production of all the daughter groups. Of seven daughters by sire 51 only one was above the average in production, and she came from a dam with a record of 14,657 pounds of milk. Only one daughter exceeded her dam, and she was from the poorest of the dams.

Sire 47 has only 1 daughter above the average in milk production and only 1 other that exceeds her dam. Of 12 daughters only 3 have records above 10,000 pounds of milk. Eight of the daughters were from dams in the 9,000 or 10,000 pound class, where the chances are 7 in 10 that the daughter will excel the dam, but only 2 out of these 8 daughters were better than their dams.

Sire 32 has 2 daughters with records above 12,000 pounds of milk, but the other 9 daughters were poor enough to pull the average of his daughters down to 9,688 pounds. The dams were all below average; and in the whole population the chances would be about 8 in 10 that daughters would excell these dams, but only 4 of his 11 daughters were better than their dams.

SIRES WITH LARGE GROUPS OF DAUGHTERS

Sires with large numbers of daughters usually afford more conclusive data for studies of this kind than sires with only a small number of daughters. Sire 11, with 48 daughters, has a larger number than any other. Table 11 shows the relative ability of the dams to which sire 11 was mated and of his daughters from those dams.

TABLE 11.—*Correlation surface of milk production of the 48 daughters of sire 11 and their dams; also average production of various groups of dams and daughters*

Milk-production class of dams [1]	Number of daughters in milk-production class [2] of—										Total daughters	Average milk production of—		Average increase (+) or decrease (−) by daughters over dams
	17,000 pounds	16,000 pounds	15,000 pounds	14,000 pounds	13,000 pounds	12,000 pounds	11,000 pounds	10,000 pounds	9,000 pounds	8,000 pounds		Dams	Daughters	
											Number	*Pounds*	*Pounds*	*Pounds*
21,000 pounds						1					1	21,324	12,554	−8,770
14,000 pounds	1	1	1	1	1						5	14,228	15,681	+1,453
13,000 pounds						1					1	13,507	12,004	−1,503
12,000 pounds			1	1	1	2	1	2			8	12,778	12,876	+98
11,000 pounds		1		1	1	1	1		1		6	11,661	13,027	+1,366
10,000 pounds				1	1	1			3	1	7	10,346	10,989	+643
9,000 pounds				1	3	2	4	1	1	2	14	9,660	11,575	+1,915
8,000 pounds					1		1	2	2		6	8,565	10,821	+2,256
Total	1	2	2	5	8	8	7	5	7	3	48	11,192	12,251	+1,059

[1] None of the dams, except the one in the 21,000-pound class, exceeded 14,000 pounds.
[2] None of the daughters was in a class above 17,000 pounds.

The daughters of sire 11 include a group of five full sisters from a cow with a 14,228-pound milk record. The unusually strong showing of this full-sister group plays a prominent part in bringing his rating as high as it is, and it may safely be said that their inheritance for milk production from the dam was better than from their sire. If these full sisters were omitted, it would reduce the average milk production of this sire's daughters by 400 pounds. When sire 11 was mated to other grades of dams the results were generally better than average, but not markedly so, particularly in the case of the dams in the 8,000 and 9,000 pound classes.

Sire 12 had the next largest number of daughters, a total of 38. His offspring from four dams with milk records over 15,000 pounds were all disappointing, but five of eight daughters were better than their dams that had records of 12,000 to 15,000 pounds, which is above the normal expectation. Twenty-two of the dams to which he was mated were in the class below 11,000 pounds, and his daughters from these dams averaged higher in production than the daughters of all the bulls, but there is nothing of distinguishing importance in his breeding record as a whole.

Two other sires, 27 and 36, had 30 or more daughters from tested dams. Sire 27 was mated to a group of dams that averaged about 11,000 pounds of milk, although more than half of them had records above that figure. His get from the better dams was disappointing; and while 12 of his 15 daughters from the poorer dams were better than their dams, the increase in production was below the normal expectation. The dams of the daughters of sire 36 averaged 12,622 pounds of milk and varied widely in their individual production. Only 12 of the 30 daughters exceeded their dams in milk production, and 8 of these were from dams with records below 11,000 pounds. If sires 27 and 36 had been mated only with dams in the 8,000, 9,000, and 10,000 pound classes, each would have ranked high on a basis of percentage of daughters better than dams, and yet on mixed groups of dams they failed to maintain the average production.

These four sires follow more or less the trends of the whole sire population, which is to be expected, since their daughters constitute almost one-fourth of the total number of daughters. They offer some interesting contrasts, however, in average production of their daughters and in the percentage of superior daughters. The daughters of sire 36 averaged over 1,000 pounds of milk more than those of sire 27; yet the daughters of sire 36 averaged 816 pounds less than their dams.

Interpretation of these results requires some knowledge of what relationship exists between the producing ability and the transmitting ability of high-record and low-record cows.

Sire 40 affords another good example of a sire that showed ability to get better-producing daughters from low-record cows, but from dams in the class above 11,000 pounds the daughters were all inferior.

The analysis of the individual breeding records of the remaining bulls did not bring out any information of value from the standpoint of heredity except to emphasize that the bulls are mediocre in their ability to sire daughters with any degree of uniformity in their milk production.

FULL-SISTER GROUPS OF DAUGHTERS

Interesting groups of animals in studies of this kind are the full sisters. Because of the additional relationship on the maternal side, this group has a higher coefficient of correlation between dams and daughters than is true of the population as a whole. The actual figure is $+0.314 \pm 0.024$ as compared to $+0.262 \pm 0.015$ for the 611 pairs.

The data include 1 set of 5, 2 sets of 4, 17 sets of 3, and 58 pairs of full sisters, making a total of 180 daughters. The 78 dams involved have a weighted average of 11,392 pounds of milk, or 176 pounds below the average of all dams; and the 180 daughters averaged 11,757 pounds which is 25 pounds more than the average of all daughters. The 58 dams of pairs of sisters averaged 11,405 pounds of milk, and the 116 daughters averaged 11,719 pounds. The average difference between members of the pairs is 2,328 pounds of milk.

Of the 58 pairs of full sisters there are 22 in which both daughters exceeded the dam in milk production, 19 in which both produced less than the dam, and 17 in which one daughter produced more and one less than the dam. As would be expected, 16 of the 22 dams with both daughters better are grade B dams, and 13 of the 19 dams with both daughters inferior are grade A dams.

While the preceding analysis may indicate that full sisters tend to show a similar trend in their milk production, a closer analysis of the figures reveals wide discrepancies in the producing ability of sisters. Of the 22 pairs of sisters in which both are better than the dam, 11 show a difference of more than 1,000 pounds of milk between members of the pair. These differences range from 1,067 to 6,872 pounds. In only 4 of the other 11 pairs are the members less than 500 pounds apart. The members of 14 of the 19 pairs in which both are poorer than the dam differ by more than 1,000 pounds, and the differences are as high as 4,360 pounds. Four of the remaining pairs differ by less than 500 pounds. The 17 pairs of sisters in which one is better and one poorer than the dam show even less similarity in production. None of them differ by less than 500 pounds, 15 differ by more than 1,000 pounds, and 5 by more than 6,000 pounds of milk.

To summarize briefly, in only 8 of the 58 pairs of full sisters are the members sufficiently alike to have milk-production records differing by less than 500 pounds; 10 differ by 500 to 1,000 pounds; 16 differ by 1,000 to 2,000 pounds; 8 by 2,000 to 3,000 pounds; 7 by 3,000 to 4,000 pounds; 3 by 4,000 to 5,000 pounds; and 6 by more than 6,000 pounds of milk. It would appear, therefore, that for animals of this relationship there is but 1 chance in 7 that sisters will differ from each other by less than 500 pounds of milk, and 1 chance in 10 that they will differ by more than 6,000 pounds in the year's production. The chances are somewhat better than even that the difference between sisters will be less than 2,000 pounds on the average.

The preceding statements are general, but specific instances of large and small differences between full sisters are given in Table 12.

TABLE 12.—*Extremes of likeness and variation in milk production of pairs of full sisters*

Sire No.	Milk production of—		Difference between daughters' records	Sire No.	Milk production of—		Difference between daughters' records
	Dam	Daughters			Dam	Daughters	
	Pounds	*Pounds*	*Pounds*		*Pounds*	*Pounds*	*Pounds*
33	15,188	10,340 9,957	383	9	10,859	18,188 9,892	8,296
36	14,456	14,314 9,954	4,360	35	10,135	9,204 9,064	140
12	14,412	19,448 13,444	6,004	39	10,100	10,382 10,116	266
2	12,344	21,296 12,187	9,109	16	9,348	18,233 11,361	6,872
12	11,681	16,115 9,270	6,845	9	8,938	9,755 9,503	252
30	11,160	9,662 9,658	4				

These few cases fail to exhaust the possibilities for analysis and study of this group of full sisters, as they afford many contrasts and contradictions. Here again is found evidence of heterozygosis or mixed inheritance in the animals studied. This appears to be applicable to both male and female. Sires 9 and 12 manifest this quality, and notable inconsistency is evident in the progeny of other sires studied.

In Table 13 some interesting combinations of sisters by the various sires are shown.

Table 13.—*Milk-production records of pairs of full sisters by various sires, and the records of the dams*

Sire No.	Milk production of— Dam	Milk production of— Daughters	Increase (+) or decrease (−) by daughters over dam	Sire No.	Milk production of— Dam	Milk production of— Daughters	Increase (+) or decrease (−) by daughters over dam
	Pounds	*Pounds*	*Pounds*		*Pounds*	*Pounds*	*Pounds*
11	11,673	16,435	+4,762	32	9,725	12,058	+2,333
		13,311	+1,638			8,929	−796
	11,581	14,921	+3,340		9,250	9,170	−80
		12,316	+735			7,745	−1,505
	10,287	9,612	−675		8,838	9,290	+452
		8,541	−1,746			8,753	−85
13	18,751	18,265	−486	36	14,456	14,314	−142
		15,414	−3,337			9,954	−4,502
	13,260	14,127	+867		12,690	12,115	−575
		13,338	+78			11,605	−1,085
	13,058	12,644	−414		11,160	9,662	−1,405
		10,897	−2,161			9,658	−1,502
	9,557	16,645	+7,088		10,084	10,562	+478
		14,277	+4,720			8,641	−1,443
14	10,862	11,501	+639		9,164	12,072	+2,908
		8,840	−2,022			9,502	+338
	10,823	11,914	+1,091	41	11,850	11,239	−611
		10,365	−458			8,075	−3,775
21	10,002	11,189	+1,187		11,393	12,304	+917
		10,311	+309			11,724	+331
	9,797	12,185	+2,388	46	12,531	12,833	+302
		8,210	−1,587			12,044	−487
27	11,215	11,025	−190		11,885	13,333	+1,448
		9,903	−1,312			8,385	−3,500
	9,036	13,538	+4,502				
		9,537	+501				
	8,957	9,561	+604				
		9,188	+231				

COMPARISON OF FULL SISTERS WITH THEIR DAMS

In 14 of the 58 full-sister pairs, one daughter's milk record is within less than 50 pounds of the dam's while that of the other daughter differs from that of the dam by more than 1,000 pounds.

The data show that the production of both members of 21 pairs of sisters differed from the dams by more than 1,000 pounds. In 9 of these 21 pairs both daughters were better than the dam, in 7 pairs both were inferior, and in the remaining 5 pairs, the record of 1 daughter was above, and that of the other was below her dam's record by more than 1,000 pounds.

There are 10 pairs of sisters of which both daughters have records that differ from the dam by less than 1,000 pounds. In 7 of the pairs, both daughters exceed the dam in production, and in 3 pairs 1 daughter is better, and the other poorer than the dam.

Seventeen dams gave birth to sets of three sisters. Table 14, showing the extremes of likeness and variability in milk production of these 17 sets, includes the set in which the daughters are the most alike in milk production and also the set in which they differ the most.

TABLE 14.—*Two sets of three full sisters, showing the extremes of likeness and difference in milk production of the 17 sets*

Sire No.	Milk production of—		Increase (+) or decrease (—) by daughters over dam
	Dam	Daughters	
	Pounds	*Pounds*	*Pounds*
3	11,452	15,919	+4,467
		10,559	−893
		7,858	−3,594
33	11,089	11,999	+910
		11,690	+601
		11,279	+190

The extreme differences in these sets of three full sisters range from 720 to 8,061 pounds of milk, with an average difference of 3,156 pounds, which is about 27 per cent of the 11,570-pound average milk production of the 51 daughters in the 17 sets.

In 5 of the sets all 3 daughters exceeded the dams, and in 2 sets all 3 were poorer producers than the dams. In each of 4 sets, 2 daughters were better than the dam, and 1 was poorer; while in each of the other 6 sets 1 daughter was better than the dam and 2 were poorer.

There are five sets in which one daughter differs from the dam by less than 500 pounds in milk production, while the record of her sisters both differ by more than 1,000 pounds from the dam's record.

The breeding inconsistency of some of the bulls is further emphasized by the results of these multiple matings.

The sets of 4 sisters are only 2 in number, and afford meager data for study. Both dams are in the 12,000-pound class, and in each set of daughters only 1 produced more than the dam while 3 produced less. This is 1 in 4 as compared with the ratio of 1 in 3 for all dams in the 12,000 pound-class.

One set of five sisters is interesting because of the uniform distribution of the daughters. Records of this group are shown in Table 15.

TABLE 15.—*Milk-production records of five full sisters by sire 11*

Milk production of—		Increase (+) or decrease (—) by daughters over dam	Difference in milk production between nearest daughters
Dam	Daughters		
Pounds	*Pounds*	*Pounds*	*Pounds*
14,228	17,793	+3,565	
			1,131
	16,662	+2,434	
			975
	15,687	+1,459	
			1,025
	14,662	+434	
			1,053
	13,609	−619	

MATERNAL HALF SISTERS

The groups of maternal half sisters form a class most frequently found among the higher-record dams. There is evidence here of the purpose of the breeders to mate the outstanding cows to different bulls, and also of their wish to test the daughters of great cows. Table 16 gives the results of mating three cows, having milk records above 20,000 pounds, to eight different bulls.

TABLE 16.—*Results of mating three cows in the 20,000-pound milk-production class to eight different bulls*

Milk production of—		Increase (+) or decrease (−) by daughters over dams	Sire No.	Milk production of—		Increase (+) or decrease (−) by daughters over dams	Sire No.	Milk production of—		Increase (+) or decrease (−) by daughters over dams	Sire No.
Dam	Daughters			Dam	Daughters			Dam	Daughters		
Pounds	*Pounds*	*Pounds*		*Pounds*	*Pounds*	*Pounds*		*Pounds*	*Pounds*	*Pounds*	
	14,949	−8,962	44		16,018	−4,713	20	21,324	16,655	−4,669	36
23,011	12,980	−10,931	19	21,331	13,049	−8,282	4		12,554	−8,770	11
	12,562	−11,349	35		12,183	−9,148	6				

On an average these eight daughters produced 8,353 pounds less milk than their dams, and it would seem that the breeders' quest for a nick failed utterly in these instances. Judged by the ranking of these eight sires, five were only of average ability and could hardly be classed as suitable mates for these good cows.

Table 17 shows two maternal half-sister combinations that are unusual.

TABLE 17.—*Unusual milk-producing ability in two sets of maternal half sisters*

Milk production of—		Increase (+) or decrease (−) by daughters over dams	Sire No.
Dam	Daughters		
Pounds	*Pounds*	*Pounds*	
17,010	21,928	+4,918	23
	12,014	−4,996	3
	19,387	+5,950	4
13,437	19,108	+5,671	12
	16,701	+3,264	6

In the first case, a dam with a record of 17,010 pounds of milk had daughters by sires 3 and 23. The production records of these daughters are contrary to what would be expected, as sire 3 has 17 daughters that averaged 13,240 pounds of milk, with 12 better than their dams, and sire 23 has 20 daughters that averaged 12,177 pounds, with 11 better than their dams.

In the second case, the ability of the dam to transmit production to all her daughters is shown by three half sisters sired by different bulls. This is a very unusual case, as it is rare indeed in this study that dams with records above the average have offspring that are uniformly better than themselves. This would appear to be a case of the female approaching homozygosity for a high level of milk production, for, while the sires of these daughters would be classed as good bulls, none of them showed the ability to get daughters which were uniformly better than their dams, and only 9 of 45 daughters from dams in the 13,000-pound class were better than their dams.

There are 34 pairs of maternal half sisters, and in 17 pairs both daughters were better than the dam, in 8 pairs both daughters produced less than the dam, and in 9 pairs one daughter was better and the other poorer than the dam. In a general way this would seem to indicate that the sires of these daughters were genetically superior to the dams, so far as milk production is concerned.

Five dams each produced a pair of sisters and a third daughter by a different bull. Their records are shown in Table 18.

TABLE 18.—*Comparison of two full sisters with a maternal half sister*

Milk production of—		Increase (+) or decrease (−) by daughters over dams	Sire No.	Milk production of—		Increase (+) or decrease (−) by daughters over dams	Sire No.
Dam	Daughters			Dam	Daughters		
Pounds	*Pounds*	*Pounds*		*Pounds*	*Pounds*	*Pounds*	
	16,426	−192	26		11,289	+1,154	25
16,618	14,782	−1,836	25	10,135	9,204	−931	35
	14,011	−2,607	12		9,064	−1,071	35
	12,115	−575	36		14,597	+4,513	1
12,690	11,605	−1,085	36	10,084	10,562	+478	36
	11,347	−1,343	15		8,041	−1,443	36
	13,567	+909	23				
12,658	13,302	+644	23				
	11,483	−1,175	16				

In each of the first three cases the full sisters were sired by a bull of lower rank than the other, but the half sister proved to be a poorer producer than either of the full sisters. In the other two cases there is a marked difference between the pairs of full sisters and the other daughter of each dam, but there is evidence of the influence of the sires, and the results are more according to expectations.

The data include six pairs of maternal half sisters in which the daughter of the higher-ranking sire is a markedly poorer producer than the other half sister.

Such evidence throws no light on the method of transmission of milk production other than to indicate the extremely heterozygous make-up for the hereditary factors determining level of production in the animals.

The cow's record is a fair measure of her own producing ability, but there is still much uncertainty as to what value this may have as an index of her transmitting ability. In general, there is a relationship between the record of the dam and the ability of the daughter, as it has already been demonstrated that a positive correlation exists between records of dams and daughters. However, individual exceptions are all too numerous, and in some cases this evidence is strengthened by results shown by the matings of different cows with the same bulls. The two dams listed in Table 19 have records which are approximately equal.

TABLE 19.—*Relation of dam's milk record to her transmitting ability*

Milk production—		Increase (+) or decrease (−) by daughters over dam	Sire No.
Dam	Daughters		
Pounds	*Pounds*	*Pounds*	
8,830	8,591	−239	12
	8,287	−543	20
8,696	17,685	+8,989	12
	14,900	+6,204	20

Both dams have daughters by the same two bulls of quite different rank, and the pairs of half sisters are strikingly different in their producing ability. Although in the entire population of daughters the chances were only 5 in 64 that the daughter of a cow in the 8,000-pound class would fall below her dam, yet here two daughters of an 8,000-pound dam, sired by different bulls, both failed to equal the dam's record. The same two bulls sired daughters from another cow in this class both of which far exceeded their dam in production of milk. While these two cows showed equal ability to produce milk, there is incontrovertible evidence that they varied greatly in transmitting production to their daughters.

SIGNIFICANCE OF CORRELATION COEFFICIENTS OF MILK PRODUCTION OF DAMS AND DAUGHTERS

Statistical constants for groups of daughters of different sires are shown in Table 8. Because of the small numbers involved, the majority of the correlation coefficients are not significant, but even where the correlations are high and the errors small there is no evidence that the correlation coefficient throws any light on the relative value of the various bulls. This may be due to the fact that it is derived from production records which may or may not be an indication of transmitting ability. Positive correlations are more numerous than are negative correlations, but this is to be expected where the entire population of dams and daughters are positively correlated. The correlations range from +0.937 ±0.031 for daughters of sire 44, to −0.727 ±0.129 for daughters of sire 29, showing almost the limits of spread. There is no evidence that this constant has any bearing on the rank of the bull as herein determined. This is indicated in Table 20, for the 11 sires with the largest coefficients of correlation. This table also shows the relationship to the average production of the dams. There is better correlation between the dams of high-average production and their daughters than between dams of low-average production and their daughters.

TABLE 20.—*Relation of correlation coefficients of milk production of dams and daughters to rank of sire and to rank of dams in average production*

Rank of sire	Daughter-dam pairs	Correlation coefficients of milk production of dams and daughters	Average milk production of dams per year	Rank of dams
	Number		*Pounds*	
44	7	+0.937±0.031	14,118	2
43	7	+ .831± .078	15,279	1
1	6	+ .750± .120	11,977	19
10	7	+ .729± .119	13,518	4
8	13	+ .690± .098	12,082	15
31	9	+ .581± .148	10,049	47
26	6	+ .572± .185	12,780	8
29	6	− .727± .120	10,916	39
39	6	− .715± .224	10,103	46
33	14	− .611± .112	12,366	12
14	7	− .575± .170	9,964	48

Variability has no significance in these small groups of dams and daughters. In 29 of 51 cases the daughters had a higher coefficient of variability than their dams. Since average milk production by daughters is one basis on which the bulls were ranked, it is natural that the daughters of the higher-ranking bulls with their greater average production should show more variability.

INFLUENCE OF MILK RECORD OF SIRE'S DAM

It has long been a practice of breeders in selecting herd sires to emphasize the milk and butterfat records of the dam, and many of the bulls used in the better herds are the sons of high-record cows.

The official milk records of the dams of 30 of the bulls in this analysis are shown in Table 8. The importance which is attached to the dam's record is shown by the fact that 5 of the 30 bulls had dams with milk records above 20,000 pounds.

The 30 tested dams ranged from 21,733 to 8,853 pounds in milk production and averaged 14,042 pounds, 19 of them producing more than 12,000 pounds. There is such a wide difference between the better and poorer dams that an analysis of the 30 sires as a class would be of doubtful significance. These sires, mated to cows that averaged 11,797 pounds of milk, sired 316 daughters that averaged 11,948 pounds; while the 21 bulls from untested dams, mated to cows that averaged 11,324 pounds, got 295 daughters that averaged 11,500 pounds of milk (increases of 151 and 176 pounds, respectively). Although these sons of tested dams were mated with better cows they failed to get as large an average increase in production as did the other 21 bulls. In each group 53 per cent of the daughters excelled their dams. There is not such a close parallel in the case of daughters that averaged over 12,000 pounds of milk, as the 30 sires (sons of record dams) sired 141, or 58.5 per cent, of the 241 daughters with a milk production above that figure. Table 21 shows the number of daughters of each milk-production class sired by the two groups of bulls.

TABLE 21.—*Number of daughters in various milk-production classes sired by two groups of bulls*

Milk-production class	Daughters sired by 30 sons of tested dams	Daughters sired by 21 sons of untested dams	Milk-production class	Daughters sired by 30 sons of tested dams	Daughters sired by 21 sons of untested dams	Milk-production class	Daughters sired by 30 sons of tested dams	Daughters sired by 21 sons of untested dams
Pounds	*Number*	*Number*	*Pounds*	*Number*	*Number*	*Pounds*	*Number*	*Number*
24,000	----------	1	17,000	4	5	10,000	41	44
23,000	1	----------	16,000	7	5	9,000	57	57
22,000	----------	----------	15,000	7	14	8,000	19	34
21,000	2	----------	14,000	27	15	7,000	2	5
20,000	----------	1	13,000	36	19			
19,000	4	2	12,000	51	35	Total	316	295
18,000	2	3	11,000	56	55			

For a further study of the sons of tested cows the 30 bulls were divided into two lots, 19 from dams with records above 12,000 pounds of milk being in one lot, and 11 from dams with records below that figure in the other lot. If the record of the dam of the sire is significant, it might be of interest to know how many daughters of these sires equaled or excelled the milk record of their paternal granddams. The first five sires from dams with records over 20,000 pounds of milk failed to get a single daughter whose record was equal to that of her paternal granddam. Considering the sires in the first lot, it is found that only 32 of their 190 daughters produced more than the paternal granddam. If all 30 sires are considered, then 99 of the 316 daughters excelled the dams of their sires, but a number of these dams were only fair producers.

Perhaps a more severe test for the sire would be the performance record of his daughters that are from dams equal to, or better than his own dam. The 19 sires from the higher-record dams were mated to 36 cows that were as good or better producers than the dams of these sires, and only 3 of the 36 daughters are better producers than their dams and paternal granddams. By including the sons of the lower-record cows there are 27 of 74 daughters ahead of both dam and sire's dam. Two-thirds of the daughters of these sires, from dams with records below the sires' dams, are better producers than their dams. It would seem that a bull's reputation as a sire able to increase production could best be enhanced by mating him to cows inferior to his own dam as producers. Of course, this is more or less indicated in the material previously studied.

The sires whose dams had records of over 12,000 pounds of milk sired 190 daughters that averaged 12,374 pounds of milk from dams that averaged 12,303 pounds, and only 99 exceeded their dams. This increase of 71 pounds in milk is 201 pounds less than the increase shown by the 126 daughters of the other sires from tested dams. The 126 daughters averaged 11,306 pounds of milk and their dams 11,034 pounds. The sons of the higher-record cows were mated to dams that were far better than the dams to which the sons of lower-record cows were mated, and the average increase of the daughters of the latter bulls was greater than the normal expectation from dams of this class. Had the dams to which both lots of bulls were mated been of equal producing ability, no doubt the 19 sires would have shown the greater increases.

A fair way to make an estimate of the significance of the record of the sire's dam would be to determine what each group of sires accomplished when mated with dams of various levels of production. In Table 22 are shown the results of mating three groups of sires to dams with milk records of 9,000, 10,000, 11,000 and 12,000 pounds respectively.

TABLE 22.—*Comparative results of mating sires in three different groups with cows in four milk-production classes*

Sire group	Daughter-dam pairs	Milk production of—		Increase (+) or decrease (—) in milk yield by daughters over dams	Daughters with records —	
		Dams	Daughters		Above dams	Below dams
	Number	*Pounds*	*Pounds*	*Pounds*	*Number*	*Number*
COWS IN 9,000-POUND MILK-PRODUCTION CLASS						
19 sires from dams above 12,000 pounds	23	9,447	12,653	+3,206	21	2
11 sires from dams below 12,000 pounds	29	9,620	11,514	+1,894	25	4
21 sires from untested dams	63	9,470	10,884	+1,414	46	17
All sires	115	9,503	11,315	+1,812	92	23
COWS IN 10,000-POUND MILK-PRODUCTION CLASS						
19 sires from dams above 12,000 pounds	33	10,536	11,823	+1,287	20	13
11 sires from dams below 12,000 pounds	27	10,485	10,605	+120	13	14
21 sires from untested dams	54	10,466	11,336	+870	33	21
All sires	114	10,491	11,304	+813	66	48

TABLE 22.—*Comparative results of mating sires in three different groups with cows in four milk-production classes*—Continued

COWS IN 11,000-POUND MILK-PRODUCTION CLASS

Sire group	Daughter-dam pairs	Milk production of— Dams	Milk production of— Daughters	Increase (+) or decrease (−) in milk yield by daughters over dams	Daughters with records — Above dams	Daughters with records — Below dams
	Number	*Pounds*	*Pounds*	*Pounds*	*Number*	*Number*
19 sires from dams above 12,000 pounds	38	11,424	11,830	+406	24	14
11 sires from dams below 12,000 pounds	27	11,595	11,524	−71	13	14
21 sires from untested dams	56	11,455	11,328	−127	22	34
All sires	121	11,477	11,530	+53	45	62

COWS IN 13,000-POUND MILK-PRODUCTION CLASS

Sire group	Daughter-dam pairs	Dams	Daughters	Increase (+) or decrease (−)	Above dams	Below dams
19 sires from dams above 12,000 pounds	20	12,521	12,883	+362	10	10
11 sires from dams below 12,000 pounds	18	12,526	11,539	−987	4	14
21 sires from untested dams	30	12,456	11,308	−1,148	9	21
All sires	68	12,495	11,832	−663	23	45

ALL COWS

Sire group	Daughter-dam pairs	Dams	Daughters	Increase (+) or decrease (−)	Above dams	Below dams
19 sires from dams above 12,000 pounds	190	12,303	11,797	−506	99	91
11 sires from dams below 12,000 pounds	126	11,034	11,306	+272	70	56
21 sires from untested dams	295	11,324	11,600	+276	157	138
All sires	611	11,568	11,732	+164	326	285

The sires from dams with milk records over 12,000 pounds have daughters in every class that are of higher average production than their dams. The increase was invariably larger than that shown by the other two groups of sires. Without exception they also had a larger percentage of daughters that exceeded their dams.

While the untested dams of the 21 sires in the group under discussion may only have lacked the opportunity to make an official record, it is conceivable that these sires might have entered either of the other classes if their dams had been tested. And yet the results as shown in Table 22 lead to the conclusion that the milk record of the dam of a sire affords some indication of his transmitting ability. This is best borne out where the record of the dam is above 12,000 pounds, and the cows to which the bull is mated are neither extremely low nor high producers.

HALF SISTERS OF THE SIRES

Twenty-one of the bulls in this analysis are sons of other sires in this study. A comparison of the daughters of a bull with his own paternal half-sisters is given in Table 23 for these sires.

TABLE 23.—*Average yearly milk production of the daughters and half sisters of 21 sires*

Rank of sires's sire	Rank of sire	Average milk production of—			Rank of sire's sire	Rank of sire	Average milk production of—		
		Sire's daughters	Sire's half sisters	Dams of sire's half sisters			Sire's daughters	Sire's half sisters	Dams of sire's half sisters
		Pounds	*Pounds*	*Pounds*			*Pounds*	*Pounds*	*Pounds*
2	19	13,238	13,268	11,404	12	26	13,257	12,404	11,320
3	43	11,530	13,240	11,464	16	46	10,851	11,774	10,256
	5	13,106			20	10	14,994	11,981	11,392
	18	12,516			22	38	10,505	12,196	11,040
4	24	11,980	12,952	11,703	35	44	10,933	11,080	11,768
	29	10,933			36	1	13,482	11,806	12,622
	30	12,849			39	14	11,098	10,176	11,012
7	49	9,736	12,090	11,958	40	37	10,916	9,965	11,058
8	21	10,902	13,495	12,082					
	15	11,489							
11	23	12,177	12,251	11,192					
	33	11,205							
	41	10,507							

On the basis used for ranking sires there are only 4 in 21 cases where the son ranks higher than his sire. Seventeen of the bulls are sons of sires that rank in the upper half, which indicates some appreciation of the worth of the sires in the choice of their sons for herd bulls. Sire 4 had five sons and sire 11 had four sons, but all fell below their sires' rank. Here is further evidence of the heterozygous genetic make-up of these animals as shown by a tendency to revert to the breed average as has already been found true on the female side.

The best-bred sire undoubtedly is sire 19. He is by sire 2, whose 12 daughters averaged 13,268 pounds of milk, or 1,864 pounds more than their dams, and 8 of the 12 exceeded their dams in milk production. The dam of sire 19 has a record of 21,733 pounds of milk for a year. His own 11 daughters averaged 13,238 pounds, with a range only from 10,485 to 15,317 pounds, but their dams averaged 13,550 pounds and only 6 of the 11 daughters exceeded their dams. The interesting point in this bull's record is that his daughters from dams with records below 13,000 pounds were all better than the dams, while his daughters from dams with records above 13,000 pounds were inferior. From the five high-record dams that averaged 18,503 pounds he got daughters that averaged 13,288 pounds, and from the 6 other dams that averaged 11,089 pounds, he got daughters that averaged 13,197 pounds. Had he been used only on dams of the latter class, he would have reached a high rank as a sire of daughters of high milk production.

Another sire with indications of good breeding was No. 43, a son of sire 3, from a dam with a record of 12,583 pounds. His sire had 17 daughters that averaged 13,240 pounds of milk, or 1,776 pounds more than their dams, 12 being better. Sire 43 has already been discussed, as he was mated to 7 dams that averaged 15,279 pounds, and all of his daughters fell below their dams in milk production, the average decrease being 3,749 pounds. This performance record of his daughters indicates that he did not inherit the factors for the high level of milk production possessed by his sire and his dam.

Sire 5 was the highest ranking son of sire 4, but his dam produced only 9,569 pounds of milk, which was the lowest record of any of the dams of the sons of sire 4. The 13 daughters of sire 4 averaged 12,952 pounds of milk or 1,159 pounds more than their dams, while the 6 daughters of sire 5 averaged 13,108 pounds and exceeded their dams by 1,928 pounds. The dam of sire 5 evidently transmitted better producing ability than her own as indicated by her 9,569-pound record, which is what may be expected in a heterozygous population.

Sire 18, another son of sire 4, was from a dam that produced 14,412 pounds of milk. His 14 daughters averaged 12,516 pounds of milk. or 213 pounds more than their dams, and 9 were better than their dams. The two best dams to which sire 18 was mated produced over 23,000 and 16,000 pounds of milk, respectively, and their daughters made records 9,000 and 6,000 pounds lower. When these two dam-and-daughter pairs are dropped from consideration, the remaining dams average 11,051 pounds of milk, and their daughters 12,665 pounds. This is an increase of 1,614 pounds by the daughters over their dams, which would have raised his ranking materially.

Sire 24, the next ranking son of sire 4, was from a dam that produced 12,571 pounds of milk. His tested daughters number only six, and in this small group he shows ability to transmit only a fair level of production, just about maintaining the dams' average of 11,970 pounds.

Sire 29, also a son of sire 4, was from a cow with a record of 11,505 pounds of milk. The six dams to which he was mated averaged 10,916 pounds of milk, and he raised this average through his daughters by only 17 pounds. The breeding record of this sire is far below that of his own sire, as his paternal half sisters average more than 2,000 pounds of milk more than his daughters.

Sire 30 is the lowest ranking son of sire 4, although his dam produced 13,750 pounds of milk. He was a bull with a very good pedigree, and when mated to six cows that averaged 12,814 pounds of milk, he produced only two daughters that excelled their dams. His dam was a daughter of sire 22, and while her own record is 13,750 pounds, her dam produced 18,110 pounds, or 4,360 pounds more.

None of these five sons of sire 4 ranked as high as he, and the only one whose daughters averaged higher than his half sisters was from the poorest dam of the lot.

Sire 49, one of the poorest in this study, is a son of sire 7. His dam produced 11,920 pounds of milk, but when he was mated to eight cows that averaged 10,731 pounds, he got eight daughters that averaged 9,736 pounds of milk. His seven half sisters averaged close to 13,000 pounds.

Sire 21 was a son of sire 8, whose 13 daughters averaged 13,495 pounds of milk. His dam had a yearly record of 11,212 pounds, but his 11 daughters averaged only 10,902 pounds, or less than his own dam and his half sisters.

Sire 11 had four sons, all of which ranked lower than their sire. The highest of the four was sire 15, whose dam had a yearly record of 12,324 pounds. Since he was the son of a bull whose 48 daughters averaged 12,251 pounds of milk, and from a dam with more than 21,000 pounds, his breeding would indicate that he had possibilities to sire increased production, yet his 10 daughters averaged only only 11,489 pounds of milk from dams that averaged 10,664 pounds.

They averaged about 10,000 pounds less in milk production than their paternal granddam, and midway between their own dams and the half sisters of their sire.

The next ranking son of sire 11 was sire 23, whose dam produced 14,227 pounds of milk. This bull was mated to 20 cows that averaged 12,352 pounds of milk, or considerably more than those bred to sire 15. His 20 daughters averaged slightly less than their dams in milk production, but 11 of the 20 excelled their dams. Although only one of his daughters was better than his dam in milk production, his 20 daughters averaged close to his 48 half sisters.

The third ranking son of sire 11 was sire 33, whose dam yielded 13,506 pounds of milk. He was mated to 14 cows that averaged 12,366 pounds of milk and got 14 daughters that averaged only 11,205 pounds; none of the daughters equaled the record of his dam.

The fourth ranking son of sire 11 ranked forty-first in this study. His dam produced 10,681 pounds of milk in a year, and his nine daughters averaged 10,507 pounds from dams that averaged 11,418 pounds.

A point of interest about these four sons of sire 11 is that they rank in the same order as the milk records of their dams.

Sire 10 offers the best illustration of improved transmitting ability. His sire was No. 20, whose dam had a yearly record of 21,023 pounds. The daughters of sire 20 averaged 11,981 pounds of milk and were from dams that averaged 11,392 pounds. Sire 10 was from a dam with a production of 21,331 pounds, and his seven daughters averaged 14,994 pounds from dams that averaged 13,518 pounds. These daughters have the highest average milk production of all the 51 daughter groups in this study, and the bull shows exceptional ability in raising the production of daughters from dams of this grade. There may be evidence here that he inherited and transmitted the producing ability of his own dam and the dam of his sire. Although neither bull sired daughters as good as his own dam the level of production was raised by both sires.

Sire 44 was the son of a poor sire, and of a dam that produced 13,896 pounds of milk in a year. His sire, No. 35, had 15 daughters that averaged 11,089 pounds of milk from dams that averaged 11,763 pounds. Even with this good dam sire 44 mated to cows that averaged 14,118 pounds of milk had seven daughters that averaged 10 933 pounds, a decrease of 3,185 pounds of milk.

By way of contrast, sire 1 was a son of sire 36 and out of a dam with a record of 17,793 pounds. The 30 daughters of sire 36 averaged 11,806 pounds of milk from dams with an average production of 12,622 pounds. Although sire 1 had a low-ranking sire, his dam was a good daughter of sire 11 and exceeded her dam in milk production by by 3,565 pounds. The six daughters of sire 1 averaged 13,482 pounds of milk, and it would appear that his ability to sire daughters that were better producers than their dams was the result of a combination of good factors inherited from his low-ranking sire and from his better-bred dam.

Sire 14 was a son of sire 39 and out of a dam with a milk record of 8,853 pounds. Although poorly bred he sired daughters that averaged 11,096 pounds of milk when mated to seven dams that averaged less than 10,000 pounds.

From the evidence offered by these cases it would appear that a sire's transmitting ability may be inherited from either or both his sire and his dam, but that the inheritance for milk production, so far as the observations on this population indicate, is still so mixed that results are uncertain even where careful selection based on performance of the parents is practiced.

The daughters of only 6 of the 21 bulls exceeded their sire's half sisters in average milk production, 3 others were close, but 12 groups of daughters were decidedly below their sires' half sisters.

METHODS OF MATING

Only 3 of the 51 bulls in this analysis show more than remote common ancestry, and there is not sufficient material to make comparisons on a basis of inbreeding, linebreeding, or outbreeding. This may be due to lack of popularity of systems of close mating or the practice of using imported bulls on home-bred cows.

Fifteen sires with a total of 306 daughters have only 6 linebred and 3 inbred daughters.

COMBINATIONS OF SIRES IN RELATION TO THEIR INFLUENCE ON MILK PRODUCTION

There are some interesting combinations in the get of several sires which are presented for whatever they may be worth.

Sire 23 had a total of 20 daughters, 11 of which excelled their dams in milk production. The daughters averaged 12,177 pounds of milk yearly, and their dams 12,352 pounds. Four of these dams were by sire 8, and nine were by sire 16. The dams by sire 8 averaged 14,285 pounds of milk, and their daughters by sire 23 averaged 14,825 pounds. The dams by sire 16 averaged 11,819 pounds of milk, and their daughters by sire 23 averaged 11,424 pounds. The daughters from the better grandsire easily excelled those descended from the lower-ranking grandsire.

Another similar example showing the influence of a good bull carrying through to the second generation is found in the record of sire 36. He had 30 daughters, and the dams of half of them were by sire 11, the dams of the other half being by various bulls. The dams by sire 11 averaged 12,479 pounds of milk and their 15 daughters by sire 36 averaged 12,493 pounds, an increase of 14 pounds, with 8 daughters exceeding their dams in production. The other dams, by various sires, averaged 12,766 pounds of milk, and their 15 daughters by sire 36 averaged 11,120 pounds, a decrease of 1,646 pounds, with 11 daughters producing less than their dams. Although sire 36 ranked low as a sire of daughters of higher milk production, only 12 of his daughters being better than their dams, 8 of these were from dams by sire 11, which is a good indication that they carried more factors for high production than did the other dams with which sire 36 was mated.

Sire 27 holds a medium rank, and three of his five highest ranking daughters and his poorest daughter are from dams which are half sisters. Five of these half-sister dams averaged 9,913 pounds of milk, and their daughters by sire 27 averaged 12,269 pounds. On the other hand, three daughters of sire 50 that averaged 10,768 pounds of milk had daughters by sire 27 that averaged only 9,994 pounds of milk.

The record of sire 12 is good on all groups of dams and may be summarized as follows:

Four dams by sire 4 averaged 10,677 pounds of milk and their daughters averaged 11,014 pounds.

Six dams by sire 6 averaged 10,996 pounds of milk and their daughters averaged 12,011 pounds.

Eight dams by sire 22 averaged 12,404 pounds of milk and their daughters averaged 11,538 pounds.

Three dams by sire 40 averaged 9,810 pounds of milk and their daughters averaged 11,819 pounds.

Four dams by one bull averaged 11,095 pounds of milk and their daughters averaged 13,888 pounds.

Thirteen dams by various bulls averaged 11,445 pounds of milk and their daughters averaged 13,223 pounds.

This bull failed to maintain production when mated to the better daughters of sire 22, but his get from the poorer daughters of sires

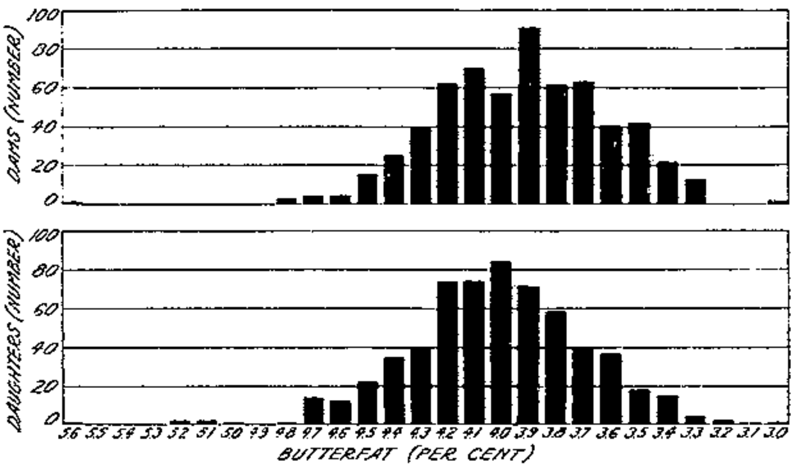

FIGURE 6.—Distribution of dams and daughters, according to their butterfat test

4, 6, 22, and 40, in most cases, excelled their dams in milk production.

Five daughters of one sire not listed in this study were the dams of 18 daughters by sire 11. The weighted average of the dams was 12,453 pounds of milk, and the daughters averaged 13,810 pounds, 13 exceeding their dams. Sire 47 was a half brother to these dams and 6 of his daughters when bred to sire 11 had daughters that averaged 10,636 pounds of milk, or 306 pounds more than their dams. Aside from the 5 daughters of one cow, this sire also showed unusual ability to increase production from the lower-record daughters of other sires.

In studying this 2-generation relationship the point previously brought out is again emphasized, that bulls in this study make their best showing as sires of daughters of increased production when mated to the lower-record daughters of other good sires and usually their poorest showing when bred to the higher-record daughters.

ANALYSIS OF RECORDS OF BUTTERFAT TEST

Because percentage of butterfat is inherited independently, this characteristic will be discussed without consideration of the quantity of milk produced. Although there is a slight decline in the average percentage of butterfat with advancing age, the change is not sufficiently great to warrant the use of correction factors, and the actual figures are used without regard to the age at which the cow was tested.

The dams average 3.97 per cent butterfat in their milk while their 611 daughters average 4.07 per cent, an increase by the daughters of 0.10 per cent; 372, or 60.9 per cent, of the daughters had a higher average butterfat test than their dams. The coefficient of correlation was found to be $+0.257 \pm 0.026$, indicating a positive relationship between daughters and dams about the same as for milk yield.

The distribution of these daughters and dams, according to their butterfat test, is given in Table 24 and illustrated by Figure 6.

TABLE 24.—*Correlation surface of 611 Ayrshire daughters and dams, according to their butterfat test*

Butterfat test of dams [1]	Number of daughters whose butterfat test is— [2]																								Total
	5.6	5.2	5.1	5.0	4.9	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.1	4.0	3.9	3.8	3.7	3.6	3.5	3.4	3.3	3.2	3.1	3.0	
5.6							1																		1
4.8	1									1															2
4.7						1		1		1			1												4
4.6			1							1	1	1													4
4.5							1			1	1	3	2	4	1	1				1					15
4.4							1		2	2	3	4	1	3	3	1		2	2	1					25
4.3			1				2	1	2	5	4	4	5	4	5	2	3	1	1						40
4.2							1	2	3	4	5	3	9	11	6	7	3	5	1	1	1				62
4.1				1			3	2	6	3	6	13	7	8	6	6	3	2	1	3					70
4.0								1	1	5	5	8	8	6	7	7	4	3	1	1					57
3.9							2	3	3	4	5	16	9	14	14	8	6	3	2	1				1	91
3.8								1	2	5	2	5	10	12	4	6	5	3	3	3			1		62
3.7		1							2	1	2	6	10	10	7	8	7	5		2	2				63
3.6		1					2			1	3	5	6	4	3	2	5	5	2		1				40
3.5							1	2	1		1	4	4	4	8	3	4	6		1		2			41
3.4									1	1	2	2	2	1	2	5		1	3	1					21
3.3														3	5	2		1	1						12
3.0																			1						1
Total	1	2	2	1		1	14	13	23	35	40	74	74	84	71	58	40	37	18	15	4	2	1	1	611

[1] None of the dams except the one with a butterfat test of 5.6 per cent exceeded 4.8 per cent.
[2] None of the daughters except the one with a butterfat test of 5.6 per cent exceeded 5.2 per cent.

The difference between dams and daughters, when measured in percentage of the dams' average, is greater in the average butterfat test than in milk yield, but a point of greater significance is that more than 60 per cent of the daughters had a higher test than their dams, thus showing a decided trend toward a better average test. With a significant majority of the daughters better than their dams in butterfat test there would seem to be evidence that the sires were exerting a favorable influence on this characteristic. This is further indicated by the fact that the average butterfat test of the daughters of 37 of the 51 sires is better than that of their dams.

A study of Table 25 reveals that the group of dams with a butterfat test of 4.14 per cent is the highest-testing group having a majority of daughters with a higher test than their own. Of 70 daughters in this group, 37 excelled their dams. In all lower-testing groups of dams a decided majority of the daughters are better than the dams, and in the largest single class (those testing 3.90 to 3.99) two-thirds of the daughters have a higher test than their dams. The table as a whole shows the tendency of daughters of extremely high and low testing dams to drift toward the breed average, somewhat the same as in the case of milk production, but in butterfat test the average in the second generation is appreciably higher than in the first generation.

TABLE 25.—*Average butterfat test of the 611 dams and daughters in the various grades*

Daughter-dam pairs (number)	Average butterfat test of—		Increase (+) or decrease (−) in test by daughters over dams	Daughters whose butterfat test is—		
	Dams	Daughters		Above dams		Below dams
	Per cent	*Per cent*	*Per cent*	*Number*	*Per cent*	*Number*
1	5.66	4.77	−0.80	0	0	1
2	4.81	5.04	+.23	1	50	1
4	4.74	4.53	−.21	1	25	3
4	4.05	4.56	−.09	1	25	3
15	4.54	4.12	−.42	1	7	14
25	4.43	4.10	−.33	5	20	20
40	4.34	4.20	−.14	13	33	27
62	4.24	4.07	−.17	17	27	45
70	4.14	4.14	0	37	53	33
57	4.04	4.07	+.03	32	56	25
01	3.95	4.10	+.15	61	67	30
62	3.84	4.01	+.17	43	09	19
03	3.75	3.99	+.24	54	86	9
40	3.63	4.03	+.40	35	88	5
41	3.55	3.96	+.41	38	93	3
21	3.44	3.97	+.53	20	95	1
12	3.35	3.89	+.54	12	100	0
1	3.00	3.52	+.52	1	100	0
Total or average	3.974	4.069	+.10	372	61	239

For convenience in discussion, the dams whose butterfat test is higher than the 3.974 per cent average will hereafter be referred to as the grade A dams, and those below the average will be called grade B dams. Similarly the daughters whose butterfat test is higher than the 4.069 per cent average will be referred to as the grade A daughters, and those below the average will be called the grade B daughters.

Accordingly, there are 318 grade A dams and 293 grade B dams, a more even division than in the case of milk production (p. 4.) The grade A dams dropped 168 of the 297 grade A daughters. In other words, while the grade A dams constitute only 52 per cent of the total number of dams, they bore 56 per cent of the grade A daughters. The grade A dams had an average butterfat test of 4.21 per cent, and their daughters averaged 4.13 per cent. The decrease of 0.08 per cent is slight, and 41.5 per cent of these daughters had a higher test than their dams.

The grade B dams had an average butterfat test of 3.72 per cent, while their daughters average 4.01 per cent, and 82 per cent of the daughters had a higher test than their dams. This difference of 0.29 per cent is about three times as great as the difference between the entire group of dams and daughters and shows the trend toward higher average tests.

In this random breeding, 6 of 10 daughters exceeded their dams in butterfat test, and if the dam tested above the average there were about 4 chances in 10 that her daughter would test higher; but if the dam tested below average, then more than 8 in 10 daughters were better.

It is apparent that breeding the higher-testing cows results in a somewhat higher average test in the daughters than does breeding the lower-testing dams, yet the difference between the two groups of daughters is 0.12 per cent while the dams differed by 0.49 per cent on the average. This is very similar to the results shown in the case of milk production and emphasizes the need for greater care in the selection of sires. While there is noticeable average improvement and a majority of the daughters are better, the possibilities for surer and more pronounced increases in the percentage of butterfat through the selection of sires of better transmitting ability offer an interesting field for study.

GROUPS OF SIRES WITH DAUGHTERS HAVING HIGHEST AVERAGE BUTTERFAT TEST AND HIGHEST AVERAGE INCREASE IN TEST OVER DAMS

TEN SIRES WITH DAUGHTERS HAVING HIGHEST AVERAGE BUTTERFAT TEST

By selecting the 10 sires whose daughters have the highest average butterfat test, it is found that these sires were mated with cows whose average butterfat test was 3.99 per cent. These cows produced 120 daughters with an average test of 4.28 per cent, an increase of 0.29 per cent. While the butterfat test of these dams was about the same as that of the whole group of dams the increase shown by their daughters was nearly three times as large as the increase by the entire 611 daughters. Ninety-eight of the 120 daughters had a higher test than their dams.

The average results of the matings of these 10 bulls with dams of various classes are shown in Table 26.

TABLE 26.—*Average butterfat test of the daughters of 10 sires mated to dams of various grades*

Daughter-dam pairs (number)	Average butterfat test of—		Increase (+) or decrease (−) in test by daughters over dams	Daughters whose butterfat test is—		
	Dams	Daughters		Above dams		Below dams
	Per cent	*Per cent*	*Per cent*	*Number*	*Per cent*	*Number*
1	5.66	4.77	−0.89	0	0	1
2	4.81	5.04	+.23	1	50	1
2	4.73	4.39	−.34	0	0	2
1	4.61	5.17	+.56	1	100	0
1	4.51	4.74	+.23	1	100	0
2	4.45	4.49	+.05	1	50	1
8	4.32	4.42	+.10	4	50	4
11	4.24	4.34	+.10	7	64	4
14	4.14	4.35	+.21	12	86	2
12	4.04	4.17	+.13	9	75	3
16	3.95	4.22	+.27	15	94	1
15	3.85	4.13	+.28	13	87	2
13	3.75	4.15	+.40	12	92	1
12	3.62	4.31	+.69	12	100	0
8	3.56	4.19	+.63	8	100	0
1	3.45	4.19	+.73	1	100	0
1	3.36	4.01	+.64	1	100	0
Total or average	3.99	4.28	+.29	98	82	22

In this herd of 120 dams there are 57 grade A and 63 grade B dams. The grade A dams have an average test of 4.25 per cent, and their daughters by the 10 selected sires have an average test of 4.38 per cent, an increase of 0.13 per cent; whereas the 51 sires mated to 318 grade A dams had daughters that tested 4.13 per cent. Of these 57 daughters, 39 had a higher test than their dams. This is 68.4 per cent as against 41.5 per cent for the entire above-average group.

These same 10 sires, mated to 63 grade B dams with an average test of 3.75 per cent, produced daughters with an average test of 4.18 per cent, an increase of 0.43 per cent, or a 0.14 per cent greater increase than that shown by the 293 daughters of all the sires. Fifty-nine of the 63 had a higher test than their dams.

The comparative influence of the two groups of sires on the butterfat test of their daughters from two classes of dams is shown in Table 27.

TABLE 27.—*Comparative results showing the influence of two groups of sires on the butterfat test of their daughters from two classes of dams*

Number and grade of dams with which each group of sires was mated	Average butterfat test of—		Increase (+) or decrease (−) by daughters over dams
	Dams	Daughters	
	Per cent	*Per cent*	*Per cent*
61 sires:			
611 grade A and B dams	3.97	4.07	+0.10
318 grade A dams	4.21	4.13	−.08
293 grade B dams	3.72	4.01	+.29
10 best sires, selected on the basis of the highest average butterfat test of their daughters:			
120 grade A and B dams	3.99	4.28	+.29
57 grade A dams	4.25	4.38	+.13
63 grade B dams	3.75	4.18	+.43

The point of interest in these data is the strong indication of what could be accomplished toward improvement of the butterfat percentage by the use of sires such as those in this group of 10. When mated to the group of 120 representative dams, they sired daughters which exceeded their dams by about three times the average increase, and when the dams are divided into classes above and below average, the daughters of each class are decidedly better than the general run of daughters from these two grades of dams.

TEN SIRES WITH DAUGHTERS HAVING HIGHEST AVERAGE INCREASE IN BUTTERFAT TEST

Ten sires whose daughters showed the highest average increase in butterfat percentage were studied as a group. While the 130 daughters of these sires averaged 0.37 per cent higher in butterfat percentage than did their dams, and 115 of them were better than their dams, the dams averaged only 3.82 per cent in butterfat percentage and are not so representative of the whole herd of dams as those mated to the 10 sires previously discussed. Only 33 dams had a test above the general average of 3.974 per cent, and their average test was 4.26 per cent as compared to an average of 4.41 per cent for their daughters. The other 97 dams, with an average test of 3.68 per cent, had daughters with an average test of 4.11 per cent.

Those sires whose daughters show the greatest average increases in butterfat percentage over dams are usually found to have been mated largely with cows testing below the average, and the data as a whole indicate that increases from lower-testing dams are more frequent than decreases even when no sire selection is made.

INDIVIDUAL SIRES IN RELATION TO BUTTERFAT TEST OF THEIR DAUGHTERS

Table 28 shows the distribution of the daughters of the individual sires according to their percentage of butterfat. It also gives the average of the daughter group of each sire, the group averages of the dams, average differences, rank of each group, and number of daughters better than their dams.

Table 29 shows the means, the standard deviations, the coefficients of variability, and the coefficients of correlation for the average percentage of butterfat for the daughters of each sire and their dams.

TABLE 28.—*Distribution and rank of the daughters of each sire, according to their butterfat test, and number of daughters that tested better than their dams*

Rank of sire[2]	Number of daughters whose butterfat test is—[1] 5.6	5.2	5.1	5.0	4.9	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.1	4.0	3.9	3.8	3.7	3.6	3.5	3.4	3.3	3.2	3.1	3.0	Total daughters	Average butterfat test of daughters	Rank of daughters according to butterfat test	Average butterfat test of dams	Rank of dams according to butterfat test	Increase (+) or decrease (−) by daughters over dams	Rank of daughters according to increase or decrease	Daughters making— Increase	Daughters making— Decrease
																									Number	*Per cent*		*Per cent*		*Per cent*		*Number*	*Number*
1								1				2			2	1									6	4.14	16½	4.09	13	+0.05	30½	4	2
2								1	1	2	1		1	1	3	1			1						12	4.16	13	4.08	16	+.08	24½	6	6
3							1			1		1	1	4	2	4	1	2							17	4.00	35	3.80	46	+.20	13	11	6
4		1					2		2		2		3	1		1	1								13	4.36	3	3.74	47	+.62	1	12	1
5																2	1	3							6	3.75	49	3.91	36	−.16	45	2	4
6											2	1	2	4	1	1	3								14	4.04	31	3.83	41	+.21	12	10	4
7												1		1	3	1			1						7	3.93	41	3.82	43	+.11	20½	5	2
8											1	1	1	1	2	2	1	2	2						13	3.88	42	3.85	39½	+.03	33½	7	6
9												4	1					2							7	4.04	31	3.96	32	+.08	24½	6	1
10												1				2	1	1	1	1					7	3.74	50	4.19	5	−.45	50	0	7
11		1					1	2	3	4	4	13	2	4	5	4	3			2					48	4.18	11½	3.99	28½	+.19	14	37	11
12				1			1	1	2	2	1	5	3	6	4	2	4	2	1	2		1			38	4.05	27½	3.98	30½	+.07	27	19	19
13											1	1	2			2	1	3			1				11	3.87	43	3.81	45	+.06	29	6	5
14											2	1	1	1					2						7	4.04	31	3.89	37	+.15	18	5	2
15								1	2		1		1	2	1	2									10	4.19	9½	4.02	25	+.17	16½	7	3
16												1		2	1	3					1		1	1	10	3.73	51	4.02	25	−.29	48	2	8
17												2	2	2		1	2								9	4.02	34	4.08	16	−.06	40	5	4
18								1	1	2		1	1		2	2	2	2							14	4.06	25	4.05	21	+.01	35½	7	7
19						1			1	1	1	2		3			1			1					11	4.18	11½	4.09	13	+.09	23	7	4
20									1	3	1		1	1	1				1	1					10	4.15	14½	4.12	9	+.03	33½	7	3
21											1		1	4	1	3		1							11	3.99	36½	3.82	43	+.17	16½	9	2
22								1				2	1		1	3	1	2	2	2	1				16	3.81	46	3.93	35	−.12	43	5	11
23							1	1	1	2	1	4	3	4	2		1								20	4.21	8	3.95	33½	+.26	10	19	1
24			1							1		1	3												6	4.37	2	4.26	3	+.11	20½	4	2
25								1	1	4	1	1	1	2	1		1								13	4.27	5	4.05	21	+.22	11	10	3
26												1	2	1	1	1									6	4.06	25	4.38	1	−.32	49	0	6
27	1						1	2	1	5	3	7	5	2	3					1					31	4.30	4	3.95	33½	+.35	5	26	5
28							1			1		1	4	2	3			1							13	4.12	19	4.08	16	+.04	32	7	6
29										1		1	1	1	2										6	4.11	20½	4.04	23	+.07	27	3	3
30												1	1	1	2	1									6	4.05	27½	4.16	6½	−.11	42	0	6
31											1	1	2	2	2					1					9	4.04	31	3.61	50	+.43	2	8	1
32									1	1		1	4	1		1	2								11	4.10	22	3.68	48	+.42	3	11	0
33											1	3		2	4	2		2							14	3.99	36½	3.65	49	+.34	6	13	1
34											1			1	3		1	2	1						9	3.86	44	4.11	10½	−.25	47	1	8
35									1	1	2		3	2		2	4								15	4.07	23	4.06	19	+.01	35½	9	6
36							1				2	2	3	6	7	1	1	4	1	2					30	3.96	39	4.11	10½	−.15	44	10	20

37	---	---	---	---	---	---	---	1	1	1	---	1	---	2	1	---	1	1	---	---	---	---	---	---	9	4.15	14½	3.85	39½	+.30	7½	7	2
38	---	---	---	---	---	---	---	---	---	1	---	---	---	1	2	1	---	---	1	---	---	---	---	---	6	3.95	40	3.98	30½	−.03	37½	3	3
39	---	---	---	---	---	---	---	---	---	---	---	1	3	1	---	---	---	1	1	1	---	1	---	---	9	3.84	45	3.57	51	+.27	9	7	2
40	---	---	---	---	---	---	---	---	1	---	2	1	2	2	2	---	1	---	---	---	---	---	---	---	11	4.13	18	4.01	27	+.12	19	7	4
41	---	---	---	---	---	---	---	---	2	---	2	1	1	---	---	1	---	1	1	---	---	---	---	---	9	4.14	16½	4.09	13	+.05	30½	6	3
42	---	---	---	---	---	---	---	---	---	---	---	---	---	2	1	2	2	1	---	1	1	---	---	---	10	3.77	48	4.23	4	−.46	51	0	10
43	---	---	1	---	---	---	2	---	---	---	---	2	1	---	1	---	---	---	---	---	---	---	---	---	7	4.45	1	4.15	8	+.30	7½	5	2
44	---	---	---	---	---	---	2	---	---	---	1	---	1	1	---	1	1	---	---	---	---	---	---	---	7	4.23	6½	3.87	38	+.36	4	7	0
45	---	---	---	---	---	---	---	---	---	1	3	1	1	---	---	1	---	---	---	---	---	---	---	---	7	4.23	6½	4.05	21	+.18	15	5	2
46	---	---	---	---	---	---	---	---	---	---	---	---	2	3	---	1	---	1	---	---	---	---	---	---	7	3.97	38	4.16	6½	−.19	46	2	5
47	---	---	---	---	---	---	---	---	1	1	1	1	1	3	2	2	---	---	---	---	---	---	---	---	12	4.11	20½	4.02	25	+.09	22	7	5
48	---	---	---	---	---	---	---	---	---	---	---	1	---	1	1	1	1	3	2	---	---	---	---	---	10	3.78	47	3.82	43	−.04	39	6	4
49	---	---	---	---	---	---	---	---	---	---	---	2	3	1	---	1	1	---	---	---	---	---	---	---	8	4.06	25	3.99	28½	+.07	27	5	3
50	---	---	---	---	---	---	1	---	---	---	---	1	2	---	1	1	---	---	---	---	---	---	---	---	6	4.19	9½	4.29	2	−.10	41	3	3
51	---	---	---	---	---	---	---	---	---	---	1	1	1	1	1	1	1	---	---	---	---	---	---	---	7	4.04	31	4.07	18	−.03	37½	2	5

[1] Except the 1 daughter whose butterfat test was 5.6 per cent, none exceeded 5.2 per cent.

[2] This rank is arrived at by combining the relative standings of these sires on milk production, butterfat production, increase in milk and butterfat production by daughters over dams, and proportion of daughters better than dams in milk and butterfat production.

TABLE 29.—*Rank of sire and of sire's sire, butterfat test of sire's dam, and statistical constants on the butterfat test of the daughters of the individual sires and of the dams of the daughters*

Rank of sire [1]	Butterfat test of sire's dam	Rank of sire's sire [1]	Daughters	Butterfat test of daughters			Butterfat test of dams			Correlation coefficient
				Mean	Standard deviation	Coefficient of variability	Mean	Standard deviation	Coefficient of variability	
	Per cent		*Number*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	
1	3.79	36	6	4.14±0.07	0.24±0.05	5.91±1.15	4.09±0.05	0.17±0.03	4.05±0.79	+0.095±0.273
2	3.79	----	12	4.16± .06	.32± .04	7.72±1.06	4.08± .08	.39± .05	9.65±1.33	+.604± .124
3	----	----	17	4.00± .04	.27± .03	6.81± .79	3.80± .05	.28± .03	7.43± .86	+.194± .157
4	4.53	----	13	4.36± .07	.39± .05	8.86±1.17	3.74± .06	.30± .04	8.11±1.07	+.114± .185
5	3.65	4	6	3.75± .02	.07± .01	1.94± .38	3.91± .06	.22± .04	5.66±1.10	−.013± .275
6	----	----	14	4.04± .04	.20± .03	5.02± .64	3.83± .03	.19± .02	4.87± .62	−.243± .120
7	----	----	7	3.93± .06	.22± .04	5.54±1.00	3.82± .07	.27± .05	7.02±1.27	+.130± .251
8	----	----	13	3.88± .05	.24± .03	6.30± .83	3.85± .05	.25± .03	6.43± .85	+.103± .185
9	3.71	----	7	4.04± .07	.26± .05	6.45±1.16	3.96± .05	.22± .04	5.43± .98	+.343± .225
10	4.23	20	7	3.74± .06	.24± .04	6.32±1.14	4.19± .08	.31± .06	7.38±1.33	+.146± .250
11	4.15	----	48	4.18± .03	.32± .02	7.68± .53	3.99± .03	.23± .02	5.73± .39	+.231± .092
12	----	----	38	4.05± .04	.38± .03	9.34± .72	3.98± .04	.35± .03	8.79± .68	+.241± .103
13	3.91	----	11	3.87± .06	.28± .04	7.34±1.06	3.81± .06	.31± .04	8.10±1.16	+.240± .192
14	4.39	39	7	4.04± .09	.34± .06	8.33±1.50	3.89± .08	.33± .06	8.35±1.51	+.413± .211
15	3.61	11	10	4.19± .06	.30± .04	7.04±1.06	4.02± .04	.18± .03	4.36± .66	+.491± .162
16	----	----	10	3.73± .08	.38± .06	10.40±1.57	4.02± .06	.26± .04	6.47± .98	+.544± .150
17	----	----	9	4.02± .04	.19± .03	4.73± .75	4.08± .04	.18± .03	4.33± .69	+.648± .130
18	3.93	4	14	4.06± .06	.33± .04	8.06±1.03	4.05± .04	.23± .04	5.74± .73	−.525± .131
19	3.99	2	11	4.18± .08	.37± .05	8.93±1.28	4.09± .07	.37± .05	9.00±1.29	+.421± .167
20	3.83	----	10	4.15± .08	.37± .06	8.83±1.33	4.12± .04	.17± .03	4.21± .63	+.251± .200
21	4.04	8	11	3.99± .04	.18± .03	4.44± .064	3.82± .04	.26± .05	[illegible]± .98	+.131± .200
22	----	----	16	3.81± .06	.35± .04	9.13±1.09	3.93± .04	.22± .03	5.67± .68	+.473± .139
23	4.26	11	20	4.21± .04	.24± .03	5.75± .61	3.95± .03	.20± .02	5.08± .54	+.410± .126
24	3.45	4	6	4.37± .07	.37± .07	8.45±1.65	4.26± .06	.36± .10	8.36±1.63	+.621± .169
25	3.99	----	13	4.27± .05	.26± .03	6.02± .80	4.05± .04	.19± .03	4.74± .63	+.290± .170
26	4.64	12	6	4.06± .04	.14± .03	3.47± .68	4.38± .06	.23± .05	5.30±1.03	+.955± .024
27	----	----	31	4.30± .04	.35± .03	8.19± .70	3.95± .04	.34± .03	8.55± .73	+.472± .094
28	----	----	13	4.12± .05	.25± .03	6.09± .81	4.08± .05	.28± .04	6.96± .92	+.385± .159
29	3.54	4	6	4.11± .05	.17± .03	4.23± .82	4.04± .08	.28± .06	7.01±1.36	+.374± .237
30	4.20	4	6	4.05± .04	.15± .03	3.77± .73	4.16± .03	.13± .02	3.00± .58	+.708± .137
31	4.30	----	9	4.04± .06	.25± .04	6.28±1.00	3.61± .03	.14± .02	3.91± .62	+.194± .216
32	----	----	11	4.10± .05	.24± .03	5.79± .83	3.68± .04	.19± .03	5.03± .72	+.457± .161
33	4.50	11	14	3.99± .04	.21± .03	5.28± .67	3.65± .05	.20± .04	7.92±1.01	+.479± .139
34	----	----	9	3.86± .05	.23± .04	5.90± .94	4.11± .07	.30± .05	7.37±1.17	+.583± .148
35	----	----	15	4.07± .05	.26± .03	6.50± .80	4.06± .05	.27± .03	6.54± .81	+.458± .138
36	----	----	30	3.90± .03	.28± .02	7.05± .61	4.11± .04	.30± .03	7.22± .63	+.104± .122
37	3.87	40	9	4.15± .07	.32± .05	7.68±1.22	3.85± .07	.33± .05	8.45±1.34	−.340± .198
38	----	22	6	3.95± .07	.26± .05	6.67±1.30	3.98± .10	.36± .07	9.06±1.76	+.201± .264

39	----------	----------	9	3.84± .08	.36± .06	9.35±1.49	3.57± .04	.16± .02	4.37± .70	+.270± .208
40	----------	----------	11	4.13± .04	.22± .03	5.32± .77	4.01± .03	.13± .02	3.14± .45	+.403± .170
41	3.79	11	9	4.14± .08	.35± .05	8.35±1.33	4.09± .05	.21± .05	5.07± .81	+.709± .112
42	3.43	----------	10	3.77± .05	.23± .03	6.08± .92	4.23± .03	.12± .03	2.94± .44	−.487± .163
43	4.31	3	7	4.45± .10	.41± .07	9.15±1.65	4.15± .06	.25± .04	5.99±1.08	+.380± .217
44	4.33	35	7	4.23± .09	.37± .07	8.65±1.56	3.87± .08	.32± .06	8.21±1.48	+.747± .113
45	----------	----------	7	4.23± .05	.19± .03	4.47± .81	4.05± .03	.13± .02	3.19± .58	−.047± .254
46	393	16	7	3.97± .04	.15± .03	3.86± 70	4.16± .05	.18± .03	4.42± .80	−.613± .159
47	----------	----------	12	4.11± .04	.23± .03	5.45± .75	4.02± .07	.34± .05	8.52±1.17	+.315± .175
48	----------	----------	10	3.78± .05	.21± .03	5.65± .85	3.82± .06	.27± .04	7.08±1.07	+.349± .187
49	3.86	7	8	4.06± .04	.16± .03	3.98± .67	3.99± .04	.16± .03	4.02± .68	+.509± .177
50	4.19	----------	6	4.19± .08	.30± .06	7.09±1.38	4.29± .18	.06± .13	15.36±2.99	+.896± .054
51	----------	----------	7	4.04± .05	.19± .03	4.58± .83	4.07± .06	.22± .04	5.35± .96	+.453± .203

[1] The individual sires are referred to by the same number as the number of their rank as given in Table 7.

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The discussion of the individual sires is limited to those which appear to be of unusual or of special interest.

SIRES WITH DAUGHTERS HAVING HIGHEST AVERAGE BUTTERFAT TEST

The seven daughters of sire 43 have the highest average butterfat test (4.45) of the 51 groups but are quite variable and range from 5.15 to 3.93 per cent. Six are above the grand average, and five are better than their dams. While this bull sired daughters of high average butterfat test, the dams from which they came had an average test of 4.15 per cent and were well above the general average.

Sire 24 has six daughters that averaged 4.37 per cent, all of which are above the grand average, although two failed to test as high as their dams. This group of dams had an average test of 4.26 per cent, and ranked third in the 51 groups of dams.

Thirteen daughters of sire 4 have an average test of 4.36 per cent and vary from 5.22 to 3.77 per cent. Most of these are from low-testing dams, and all but one have a higher test than their dams. These daughters made the highest average increase in butterfat test over their dams, and only three of the dams are above the grand average. This sire shows marked ability to increase the average test, but whether or not he would do so well on higher-testing dams is open to question.

Sire 27 ranks well both in the high average test of his 31 daughters and in the increase in test by the daughters over their dams. The 31 dams are quite variable in butterfat test, ranging from 4.81 to 3.56 per cent, the average being 3.95 per cent, but 26 of the daughters have a higher test than their dams and the average is 0.35 per cent better than that of the dams. Four of the five daughters that had lower test than their dams were from dams with a test above 4.20 per cent, and without question the ability of this bull to increase the percentage of butterfat when mated to dams below this figure is remarkably uniform.

The daughters of sire 25 rank fifth among the daughter groups in average percentage of butterfat. Their average test was 4.27 per cent while that of their dams was 4.05 per cent. This was an unusually good group of dams as 11 of the 13 were better than the average and while this sire's daughters did not make so high an increase over their dams as did those in several other groups, a comparison of this bull's get with all the daughters from similar dams shows that he got higher increases in percentage of butterfat and improved a larger proportion of his daughters.

SIRES WITH DAUGHTERS HAVING GREATEST AVERAGE INCREASE IN BUTTERFAT TEST

Sires 4, 31, 32, 44, and 27 are the five ranking bulls on a basis of average increase in percentage of butterfat by daughters over dams. Sire 4 has already been discussed, and attention is called to the low-average test of 3.74 per cent for the dams to which he was mated. Even on these low-testing mates his performance was above the average for similar groups.

The outstanding features of the data on these five bulls are the low-average test of their mates and the high proportion of their daughters that excelled their dams. The data are given in Table 30.

TABLE 30.—*Analysis of the data of five sires whose daughters have greatest average increase in butterfat test over their dams*

Sire No.	Daughter-dam pairs	Average butterfat test of—		Average increase by daughters over dams	Daughters making—	
		Dams	Daughters		Increase	Decrease
	Number	*Per cent*	*Per cent*	*Per cent*	*Number*	*Number*
4	13	3.74	4.36	0.62	12	1
31	9	3.61	4.04	.43	8	1
32	11	3.68	4.10	.42	11	0
44	7	3.87	4.23	.36	7	0
27	31	3.95	4.30	.35	26	5
Total or average	71	3.82	4.24	.42	64	7

It would be unfair to compare the records of sires 31 and 32 with other bulls, because all the dams to which they were bred tested well below the average, and the increases shown by their daughters are about the same as those made by all daughters from similar dams. It would appear that the showing made by these bulls can be accounted for to a considerable extent by the grade of dams with which they were mated.

Sire 44 has only a small number of daughters, but the dams from which they come vary widely in butterfat test and the correlation between dams and daughters is $+0.747 \pm 0.113$, all the daughters having a higher test than do their dams. He shows by this small group of daughters that he transmits the ability to increase butterfat percentage when mated to dams of various grades.

SIRES WITH LARGEST PROPORTION OF DAUGHTERS HAVING A HIGHER BUTTERFAT TEST THAN THEIR DAMS

On a basis of the largest proportion of daughters having a higher butterfat test than their dams, the leading bulls are sires 32, 44, 23, 33, 4, 31, and 9. The first two bulls increased the butterfat test of all daughters, and the other five bulls increased the test of all but one. In every case the average test of the dams to which the bull was mated was below the grand average, and in most instances it would seem that the sire's high rank in this regard is the result of his being mated to low-testing cows, rather than to the presence of an unusual combination of factors that enable a sire to transmit to all daughters the ability to produce butterfat of higher test, irrespective of the test of their dams.

Sires 32 and 44 have already been discussed, and the record of sire 23 is worthy of comment. His mates had an average butterfat test of 3.95 per cent, ranging from 4.35 to 3.58. The butterfat test of the daughters varied from 4.71 to 3.78 per cent, the average being 4.21 per cent, and 19 of the 20 had a higher test than their dams. His daughters from all grades of dams equaled or excelled the general average of all daughters both in actual increase in the percentage of butterfat and in the proportion of daughters better than their dams.

A surer interpretation may be made of the inheritance of the butterfat test than of the inheritance of milk production because environment interferes less with the expression of the inherited butterfat test.

Sire 33, with 13 of his 14 daughters better than their dams, affords another example of a sire mated to low-testing cows. The dams averaged 3.65 per cent in butterfat with only two over 4 per cent, and the daughters averaged only 3.99 per cent as compared with the average of 4.07 per cent for the daughters of all sires. This sire's record, even on low-testing dams, only approximated the average record of sires studied.

SIRES MATED TO LOW-TESTING DAMS

In the group of sires whose daughters show the greatest average increase in butterfat test over that of their dams, and also in the group with the largest proportion of daughters better than dams, it has been shown that the mates of these bulls were among the lowest-testing group of dams. Of the five sires (Nos. 39, 31, 33, 32, and 4) that were bred to the lowest-testing dams, the performance of all but sire 39 has already been discussed. Sire 39, mated to the lowest-testing group of females, has seven daughters that are better and two that are poorer than their dams in butterfat percentage. These dams range from 3.85 to 3.38 per cent in butterfat test, and the data show that on a comparative basis the best showing made by this sire was through his daughters from the better dams. Seven of the dams had a butterfat test below 3.6 per cent, and in these matings he did not get as good results as did the 51 bulls as a whole. The daughters of sire 39 are extremely variable in butterfat test, ranging from 4.21 to 3.24 per cent, and the correlation between dams and daughters is not significant because of the high probable error. Theoretically, this sire, if he had transmitting ability equal to the average ability of the 51 sires, would have shown large increases in the test in his daughters; but although seven of the daughters exceeded their dams, it appears that he did not transmit a high enough average test to raise the test of his daughters as much as is expected from this grade of dams.

Most of the foregoing discussion has been of sires mated to dams of low-average production because the sires selected probably attained their distinction by virtue of the fact that they were mated to low-testing dams. Since this appears to be the case, it might be well to study some of the sires bred to high-average dams.

SIRES MATED TO HIGH-TESTING DAMS

Sires 26, 50, 24, 42, and 10 were bred to the five groups of dams that ranked highest in butterfat test. These bulls sired 35 daughters, and only 7 had a higher test than their dams. The dams had an average test of 4.26 per cent, or 0.29 per cent more than the average of the 611 dams in the study; whereas the 35 daughters had an average test of 3.99 per cent, or 0.08 per cent less than the average of the daughters of the 51 sires. If these high-testing dams were transmitting the factors for a high percentage of butterfat, the expectation would be that their daughters by five different sires would average better than the whole daughter population, yet only 14 daughters tested higher than 4.07 per cent, the average of the 611 daughters. On analyzing the records of these sires, it is found that they sired larger proportions of inferior daughters than did the average sire.

The five bulls whose daughters show the greatest average decrease in butterfat test below that of their dams are sires 42, 10, 26, 16, and

34. The first three are in the group of sires mated to high-testing dams.

Four of these sires (42, 10, 26, and 34) together with sire 30 make up the group of five having the highest proportion of daughters testing lower than their dams. All were mated with groups of high-testing dams, and the first four sired daughters that were all lower in butterfat test than the dams, while sire 34 had one daughter that tested 0.01 per cent higher than her dam and eight that tested lower than their dams.

This set of sires includes 3 that were among the 5 mated to the 5 highest testing groups of dams, but their daughters from dams of all grades did not equal the daughters of the 51 bulls in average test. From 38 dams with an average test of 4.21 per cent these sires had daughters with an average test of 3.87 per cent, a decrease of 0.34 per cent, and 37 daughters had a lower test than the dams.

SIRES WITH DAUGHTERS HAVING LOWEST AVERAGE BUTTERFAT TEST

It is interesting to know which bulls are responsible for the lower-testing daughters, and in Table 31 are listed the five sires whose daughters have the lowest average butterfat test.

TABLE 31.—*Analysis of data of five sires whose daughters have lowest average butterfat test of all daughter groups*

Sire No.	Daughter-dam pairs	Average butterfat test of—		Average decrease by daughters over dams	Daughters making—	
		Dams	Daughters		Increase	Decrease
	Number	*Per cent*	*Per cent*	*Per cent*	*Number*	*Number*
16	10	4.02	3.73	−0.29	2	8
10	7	4.19	3.74	−.45	0	7
5	6	3.91	3.75	−.16	2	4
42	10	4.23	3.77	−.46	0	10
48	10	3.82	3.78	−.04	6	4

While these sires are alike in that they have daughters with a low average butterfat test, they differ markedly in transmitting ability. Generally speaking, 2 were mated to dams with a high average test, 1 to dams with an intermediate test, and the other 2 to dams with a low average test. All the daughter groups averaged lower than the dams in butterfat test, but this difference diminished as the average of the dams declined. Only 10 of the 43 daughters had a higher test than their dams, and these were all by sires mated to the dams of lower average test. For purposes of interpretation, it would be desirable that there be some consistency in the breeding results, but apparently such is not the case, as the low-average daughters do not all come from either high or low average dams, and the results shown in Table 33 seem to indicate that both the sires and the dams are contributing to the hereditary make-up of the daughters for butterfat test.

BEST SIRES ON BASIS OF FIGURES RELATING TO PERCENTAGE OF BUTTERFAT ONLY

The method used for ranking sires considers milk and butterfat production, which places double emphasis on milk production. For this reason, two groups of sires are discussed that are ranked by using only the figures for percentage of butterfat as a basis for the three considerations, that is, average test of daughters, increase of daughters over dams, and proportion of daughters better than their dams. The five high-ranking bulls on this basis are sires 4, 44, 27, 23, and 43, and the five low-ranking bulls on the same basis are sires 10, 42, 16, 34, and 5. Both groups are shown in Table 32.

TABLE 32.—*Analysis of data of five high-ranking and five low-ranking sires on basis of figures relating to percentage of butterfat only*

Rank and Sire No.	Daughters	Average butterfat test of—		Increase (+) or decrease (−) in butterfat test of daughters over dams	Daughters making—	
		Dams	Daughters		Increase	Decrease
	Number	*Per cent*	*Per cent*		*Number*	*Number*
Five high-ranking sires:						
4	13	3.74	4.36	+0.62	12	1
44	7	3.87	4.23	+.36	7	0
27	31	3.95	4.30	+.35	26	5
23	20	3.95	4.21	+.26	19	1
43	7	4.15	4.45	+.30	5	2
Total or average	78	3.93	4.30	+.37	69	9
Five low-ranking sires:						
5	6	3.91	3.75	−.16	2	4
34	9	4.11	3.86	−.25	1	8
16	10	4.02	3.73	−.29	2	8
42	10	4.23	3.77	−.46	0	10
10	7	4.19	3.74	−.45	0	7
Total or average	42	4.10	3.77	−.33	5	37

The mates of the five high-ranking sires had an average butterfat test of 3.93 per cent as compared with 4.10 per cent for the mates of the low-ranking bulls, but the increases and decreases are greater than the average from these classes of dams.

Sire 11 has 48 daughters that averaged 4.18 per cent in butterfat test from dams that averaged 3.99 per cent, and 37 tested higher than the dams. This is a record above the average in all respects.

SIGNIFICANCE OF CORRELATION COEFFICIENTS AND COEFFICIENTS OF VARIABILITY OF BUTTERFAT TEST OF DAMS AND DAUGHTERS

Correlation coefficients have been calculated for the daughter group of each sire and the dams of the daughters, but on account of the small numbers in many of the groups these figures are not significant. In the cases of those bulls with 20 or more daughters the coefficients of correlation do not vary greatly from that of the whole population. It may be a coincidence but it so happens that the highest coefficient of correlation ($+0.955 \pm 0.024$) is between the daughters of sire 26 and their dams, which have the highest average test for all groups of dams mated to any one sire. The second ranking correlation coefficient ($+0.896 \pm 0.054$) is between the daughters of sire 50 and their dams, which rank second in high average percentage of butterfat. A somewhat similar result was found in regard to positive correlations on average milk production. The 10 sires whose daughters have the highest coefficients of correlation with their dams in percentage of butterfat are listed in Table 33.

TABLE 33.—*The 10 sires whose daughters have highest coefficients of correlation with their dams on basis of butterfat test*

Sire No.	Coefficient of correlation	Average butterfat test of dams	Rank of dams	Average butterfat test of daughters	Rank of daughters
		Per cent		*Per cent*	
26	+0.955±0.024	4.38	1	4.06	25
50	+.896± .054	4.29	2	4.19	9½
44	+.747± .113	3.87	38	4.23	6½
41	+.709± .112	4.09	13	4.14	16½
30	+.708± .137	4.16	6½	4.05	27½
46	−.614± .159	4.16	6½	3.97	38
18	−.525± .131	4.05	21	4.06	25
42	−.487± .163	4.23	4	3.77	48
37	−.349± .198	3.85	39½	4.15	14½
6	−.243± .120	3.83	41	4.04	31

The daughters of sire 18 from his higher-testing mates dropped below those from his lower-testing mates, with the result that the averages for both the dams and the daughters are about the same.

The ability of a sire to transmit the factors for a definite percentage of butterfat to his daughters might possibly result in a decrease in the variability of those daughters. This would be true as homozygosity for a definite percentage of butterfat is approached and as the offspring become purer for this characteristic. Twenty-six of the sires have groups of daughters less variable than their dams. There is no significant difference in the variability of high or low testing groups of daughters and dams.

The five bulls whose daughters are least variable are sires 5, 26, 30, 46, and 49, and those whose daughters show the greatest variation are sires 12, 16, 22, 39, and 43. Data on both groups are presented in Table 34.

TABLE 34.—*Analysis of data of sires whose daughters show the least and the greatest variability in butterfat test*

Sire No.	Daughters	Coefficient of variability	Average butterfat test of—		Daughters making—	
			Dams	Daughters	Increase	Decrease
	Number		*Per cent*	*Per cent*	*Number*	*Number*
5	6	1.94±0.38	3.91	3.75	2	4
26	6	3.47± .68	4.38	4.06	0	6
30	6	3.77± .73	4.16	4.05	0	6
46	7	3.86± .70	4.16	3.97	2	5
49	8	3.95± .67	3.90	4.06	5	3
16	10	10.40±1.57	4.02	3.73	2	8
39	9	9.35±1.40	3.57	3.84	7	2
12	38	9.34± .72	3.98	4.05	19	19
43	7	9.15±1.05	4.15	4.45	5	2
22	16	9.13±1.09	3.93	3.81	5	11

According to the information shown in Table 34, the five sires with the most variable daughters are better as a class than the five with the least variable daughters, but this is not a safe generalization as the make-up of each set is quite heterogeneous. Apparently, the coefficient of variability of the daughters' percentage of butterfat is of no significance in determining the breeding value of a bull except to indicate those sires that may transmit the factors for the wider range of butterfat percentage.

FULL-SISTER GROUPS OF DAUGHTERS

The dams of 58 pairs of full sisters had an average butterfat test of 3.93 per cent and the 116 sisters an average of 4.04 per cent, an increase of 0.11 per cent. There were 29 pairs in which both daughters tested higher than the dam, 15 pairs in which both tested lower, and 14 pairs in which one daughter tested higher and the other lower than the dam. This proportion of daughters better than dams is approximately the same as for the whole dam and daughter population.

As to similarity of these full sisters it is found that four pairs varied by as little as 0.01 per cent in their butterfat test. The maximum variation was 1.11 per cent, the average variation was 0.33 per cent, and 33 pairs varied less than the average.

Seventeen sets of three full sisters are from dams with an average butterfat test of 3.81 per cent and the daughters averaged 4.10 per cent. The most uniform set were by sire 11, and they tested 4.21, 4.21 and 4.17 per cent respectively. Their dam's test was 3.97 per cent. The widest variation is found in the sisters by sire 4 from a dam testing 4.60 per cent. The daughters tested 5.22, 4.70, and 4.18 per cent respectively.

Table 35 gives the percentage of butterfat of two groups of four and one of five full sisters.

TABLE 35.—*Percentage of butterfat of three groups of full sisters*

Sire No.	Butterfat test of—		Sire No.	Butterfat test of—		Sire No.	Butterfat test of—	
	Dam	Daughters		Dam	Daughters		Dam	Daughters
	Per cent	*Per cent*		*Per cent*	*Per cent*		*Per cent*	*Per cent*
11	4.26	4.38 4.24 4.06 3.81 3.79	11	3.82	4.41 4.26 3.94 3.76	27	3.76	4.46 4.23 4.19 4.16

The coefficient of correlation between the percentage of butterfat of full sisters was found to be $+0.584 \pm 0.010$, with slightly less variability among the lower-testing sisters.

A noteworthy record of performance in siring full sisters that are better than their dams in butterfat test is that of sire 27 as shown in Table 36.

TABLE 36.—*Butterfat test of groups of full sisters by sire 27*

Butterfat test of—		Average butterfat test of daughters	Butterfat test of—		Average butterfat test of daughters
Dam	Daughters		Dam	Daughters	
Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
3.76	4.46 4.23 4.19 4.16	4.26	3.56	4.60 4.23 3.94	4.26
3.08	4.52 4.46 4.29	4.42	3.94	4.75 4.12	4.44
3.62	4.39 4.27 4.18	4.28	3.94	4.29 4.01	4.15

All 17 daughters of this sire have a higher test than their dams, and the average increase in test is greater than that shown by the whole daughter population.

INFLUENCE OF BUTTERFAT TEST OF SIRE'S DAM

The butterfat record of the dam has long been used as a basis for selecting a herd sire, and it is interesting to determine if there is any noticeable difference to be found in the offspring of sires whose dams have different percentages of butterfat in their milk.

The dams of 30 sires had official records, and the butterfat test of these dams ranged from 4.64 to 3.43 per cent, averaging just 4 per cent. These sires were mated to 316 cows that averaged 3.99 per cent butterfat, and their daughters averaged 4.11 per cent.

The other 21 sires from untested dams were bred to 295 cows that averaged 3.96 per cent butterfat, and their daughters averaged 4.02 per cent. The amount of increase is 0.06 per cent in favor of the sires from tested dams. It is possible, of course, that the untested dams of the 21 sires may be as good as, or better than, those of the other sires.

For further study, the sires from tested dams are divided according to the butterfat tests of their dams. Thirteen of these dams had a butterfat test above 4 per cent, and 17 below.

The major points of interest in studying the transmitting ability of these various classes of sires are the average butterfat test of their mates, the average test of their offspring, the increase or decrease in test by daughters over dams, and the percentage of daughters that test higher than their dams. These data are given in Table 37.

TABLE 37.—*Average butterfat test of daughters of different classes of sires and their dams*

Number and class of sires	Daughter-dam pairs	Average butterfat test of—		Increase in butterfat test by daughters	Daughters better than dam	Sires that—	
		Dams	Daughters			Raised average	Lowered average
	Number	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Number*	*Number*
21 sires from untested dams	295	3.96	4.02	0.06	50	13	8
13 sires from dams testing above 4 per cent	161	3.94	4.14	.20	73	9	4
17 sires from dams testing below 4 per cent	155	4.01	4.05	.04	65	14	3
Total or average	611	3.97	4.07	.10	61	36	15

Table 37 shows that the sons of the higher-testing dams got the greatest increase in the butterfat test of the daughters and also had the largest percentage of better daughters. This average increase is double that shown by the daughters of all sires and more than three times as great as that shown by the daughters of sires from untested dams.

A 2-generation study of inheritance of percentage of butterfat is possible in several cases, and the best of these is the group of sons of sire 4. This sire, whose dam had a butterfat test of 4.53 per cent, got 13 daughters with an average test of 4.36 per cent from dams that tested 3.74 per cent, and the increase of 0.62 per cent was the largest average increase in butterfat test shown by any sire's daughters. Apparently this son of a high-testing dam transmitted that characteristic to his female progeny. He had five sons from tested dams, and Table 38 gives the data on these sons.

TABLE 38.—*Comparative results on sire 4 and his five sons, relative to their transmitting ability for percentage of butterfat*

Sire No.	Average butterfat test of sire's—			Increase (+) or decrease (−) in butterfat test of daughters over their dams	Number of daughters making—	
	Dam	Mates	Daughters		Increase	Decrease
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Number*	*Number*
4	4.53	3.74	4.36	+0.62	12	1
30	4.20	4.16	4.05	−.11	0	6
18	3.93	4.05	4.06	+.01	7	7
5	3.65	3.91	3.75	−.16	2	4
29	3.54	4.04	4.11	+.07	3	3
24	3.45	4.26	4.37	+.11	4	2
Total or average		4.08	4.06	−.02	16	22

The sons of sire 4 do not approach their sire in ability to increase the butterfat test, for their 38 daughters average less than the dams and 22 have a lower test than their dams. The mates of these sons had a considerably higher average test than the mates of sire 4, but the fact remains that their daughters which did show increases were almost all from dams testing below 4.2 per cent.

This group of five sires affords an example of how pedigree selection of herd sires sometimes fails in its purpose. Assuming that a breeder is looking for a young sire that will raise the average butterfat test in his herd, by sound planning he would want a son of sire 4, since this sire has shown that he transmits an increased butterfat test to his daughters, and besides, his own dam had a butterfat test of 4.53 per cent. Having decided on the sire of his herd bull, the breeder finds there are five young sons available, sires 5, 18, 24, 29, and 30, as listed here. By the logic of pedigree selection, the breeder would choose sire 30 because he has the highest-testing dam of any of the available bulls. The dam of sire 30 tested 4.20 per cent, the half sisters averaged 4.36 per cent, and the paternal granddam 4.53 per cent, and yet when this bull was mated to cows whose average test was 4.16 per cent, he sired daughters that averaged 4.05 per cent, or 0.11 per cent less than their dams, and every daughter fell below her dam. On the other hand, sire 24 from the lowest-testing dam of any of the five sons, was mated to dams whose average test was 4.26 per cent and had six daughters which averaged 4.37 per cent, or 0.11 per cent higher than their dams, and four were better than their dams. The daughters of sire 18 just about equaled their dams in butterfat test; those of sire 5 fell below their dams; and although the daughters of sire 29 averaged 0.07 per cent higher than their dams, half of them tested lower. These results again point to the heterozygous condition of the animals in this study for percentage of butterfat as well as milk production.

Sire 11 had four sons from tested dams. The dam of sire 11 tested 4.15 per cent, and his 48 daughters from dams that tested 3.99 per cent averaged 4.18 per cent, 37 of the daughters exceeding their dams. The data on the four sons are presented in Table 39.

TABLE 39.—*Comparative results on sire 11 and his four sons, relative to their transmitting ability for percentage of butterfat*

Sire No.	Average butterfat test of sire's— Dam	Average butterfat test of sire's— Mates	Average butterfat test of sire's— Daughters	Increase in butterfat test of daughters over their dams	Number of daughters making— Increase	Number of daughters making— Decrease
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Number*	*Number*
11	4.15	3.99	4.18	0.19	37	11
33	4.50	3.65	3.99	.34	13	1
23	4.26	3.95	4.21	.26	19	1
40	3.70	4.09	4.14	.05	7	4
15	3.61	4.02	4.10	.17	7	3
Total or average		3.90	4.13	.23	46	9

Two of the sons of sire 11 (Nos. 33 and 23) had 34 daughters, 32 of which tested higher than their dams, but neither group of daughters averaged so high as the dam of their sire. The other two sons were out of lower-testing dams, and 14 of their 21 daughters tested higher than their dams and both daughter groups averaged higher than the dams of their sires. These sons collectively make an unusual showing in their ability to increase the average percentage of butterfat, and their daughters from all grades of dams are almost uniformly better than the average.

SIRES THAT INCREASED BOTH QUANTITY OF MILK AND PERCENTAGE OF BUTTERFAT

As the data on the 51 sires from the standpoint of their ability to transmit the factors for milk production and percentage of butterfat have already been discussed separately, there remains for consideration those sires that have the ability to increase both these characteristics in their offspring. Although many breeders may not feel deeply concerned about improving the percentage of butterfat and would rather concentrate their efforts toward raising the quantity of milk per cow, there is reason to believe that sires can be found which have the factors for increasing both the quantity of milk and the percentage of butterfat.

On a basis of averages, 19 sires raised both the quantity of milk and the percentage of butterfat, 9 raised the quantity of milk and lowered the percentage of butterfat, 17 decreased the quantity of milk and increased the percentage of butterfat, and the other 6 lowered both.

The sires that increased both the average milk production and the percentage of butterfat sired 261, or 42.7 per cent, of all the daughters in this study, but they had 117, or 61 per cent of the 192 daughters which exceeded their dams both in quantity of production and percentages of butterfat, and only 29, or 28 per cent, of the 104 daughters that were lower than their dams in both quantity and percentage.

The sires that lowered both the milk production and the percentage of butterfat had only 11 per cent of the total number of daughters and only 5, or less than 2 per cent, of the group that increased both milk production and butterfat percentage, and 30, or 29 per cent, of the 104 which dropped below dams in both milk production and butterfat percentage.

The averages of dams to which these four different classes of bulls were mated and the averages of their daughters are presented in Table 40.

TABLE 40.—*Average increase or decrease in milk and butterfat production, and in butterfat test by daughters of different groups of sires over the dams of the daughters*

Sire group	Milk production of—		Increase (+) or decrease (−) in milk production	Butterfat production of—		Increase (+) or decrease (−) in butterfat production	Butterfat[1] test of—		Increase (+) or decrease (−) in butterfat test
	Dams	Daughters		Dams	Daughters		Dams	Daughters	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Per cent*	*Per cent*	*Per cent*
19 sires, increased both milk yield and butterfat percentage	11,296	12,310	+1,014	448	502	+54	3.94	4.09	+0.15
9 sires, increased milk yield and decreased butterfat percentage	11,151	12,417	+1,266	454	469	+15	4.06	3.87	−.19
17 sires, decreased milk yield and increased butterfat percentage	11,769	10,993	−776	464	460	−4	3.95	4.16	+.21
6 sires, decreased both milk yield and butterfat percentage	12,446	11,167	−1,279	510	436	−74	4.10	3.94	−.16

[1] Average of the butterfat tests of all cows in each group.

When measured in terms of total butterfat yield, the difference between the end groups is striking, as an increase of 54 pounds was made by daughters of the 19 bulls as against a decrease of 74 pounds for the get of the 6, but there is only a difference of 66 pounds between the averages of the two groups of daughters, and a disparity almost equally as great between the averages of the dams to which these bulls were mated.

Analyses of individual bulls on a basis of the records in increasing or decreasing both the quantity of milk and the percentage of butterfat would result in much repetition of what had already been written, but one of the outstanding sires in this respect is sire 4. Mated to 13 dams that averaged 11,793 pounds of milk testing 3.74 per cent butterfat, he increased milk production by 1,159 pounds and the butterfat test by 0.62 per cent in his daughters. Eight were better in both milk yield and butterfat test, and all but one tested higher than their dams. This unusual showing stamps this bull as prepotent for both increased milk yield and butterfat percentage and gives him first rank on average increase in quantity of butterfat.

Another good bull on this combined basis is sire 6 with 10 of his 14 daughters higher in both milk yield and percentage of butterfat. One of his failures is the daughter of a cow with a yearly record of more than 21,000 pounds of milk.

A very good showing was made by sire 11, 27 of his 48 daughters being better in both respects than their dams.

Of the six poor bulls, sire 51 decreased the milk yield of 6 of his 7 daughters and lowered the average 2,104 pounds, and 5 of his daughters tested lower than their dams for an average decrease in butterfat of 86 pounds.

Most of the other individual sires show the contradictory up and down results which are characteristic of the heterozygous material in this study.

INDEPENDENT INHERITANCE OF QUANTITY OF MILK AND PERCENTAGE OF BUTTERFAT

Further evidence of the independent inheritance of the factors for milk production and those for percentage of butterfat in the milk is afforded by this study. In 25 of the 51 dam-and-daughter groups the quantity of milk and percentage of butterfat went together, either up or down, while in the remaining 26 groups the quantity of milk was increased and the percentage of butterfat lowered, or vice versa.

A study of the production records of the 611 pairs of dams and daughters gives a similar result as 192 daughters were better than their dams in both quantity of milk and percentage of butterfat, and 104 were poorer in both, making a total of 296 cases where quantity of milk and percentage of butterfat moved together. In 315 cases one factor was raised and the other lowered, 134 daughters exceeded their dams in milk production but fell below in percentage of butterfat, while the other 181 daughters produced less milk but raised the average butterfat percentage.

SUMMARY AND CONCLUSIONS

The 611 daughters produced 164 pounds more milk and had a 0.10 per cent higher butterfat test than their dams. This is a measure of the rate of progress made in a generation, through accepted breeding practices.

Permanent breed improvement in milk production can not be accomplished through female selection except by continued extensive culling which is costly and wasteful.

One of the most striking conclusions presented by this study is the extremely heterozygous genetic make-up of these animals in so far as the factors for milk production are concerned. Evidence of this condition crops up continuously as the data are reviewed.

Sires whose dams have milk records of more than 12,000 pounds appear to be better sires of milk production than are the sires from untested dams or from dams with records of less than 12,000 pounds, when mated to cows with records of 9,000 to 13,000 pounds of milk.

Sons of cows having a butterfat test of more than 4 per cent sired daughters testing somewhat higher than did the daughters by sons of untested dams or the sons of dams testing below 4 per cent.

With small numbers of pairs of dams and daughters as here studied there is no indication that coefficients of correlation or variability have any significance in determining the breeding value of males or females.

It is doubtful if very many sires will ever have a sufficient number of daughters to offer suitable statistical material.

The cow's record indicates her milk-producing ability but is not an infallible guide as to her transmitting ability.

It appears that very little information regarding the inheritance of milk and butterfat production in dairy cattle will be evolved from studies of advanced-registry records: (1) Because of the heterozygous condition of the animals dealt with, (2) because they come from a very small and unfairly selected portion of the total dairy-cattle population, and (3) because of the lack of control of environmental conditions which so strongly influence milk and butterfat production of dairy cows.

The Mendelian laws of inheritance are adequate to explain all breeding results surveyed here when due allowance is made for the effects of a fluctuating environment. There is no evidence in these data for the assumption of sex linkage in the inheritance of milk production.

The influence of good sires is best illustrated by the average increase in milk production made by the daughters of a selected group of 10 sires. This increase was more than eight times as much as for the entire group of sires.

This study of the results which have come from the practices followed by the leading breeders of Ayrshire cattle during the period reviewed strengthens the theory that substantial improvement in dairy-cattle breeding can be made only by a better choice of herd sires. In all cases where groups of bulls were selected on a basis of their performance the results show the soundness of the use of proved sires for herd improvement.

Evaluating the transmitting ability of a proved sire requires a complete analysis of the performance of all his daughters, due consideration being given to the environmental influences. This necessitates a study of the herd in which the sire was proved. Correction factors designed to equalize these environmental influences are of questionable value, as there are no descriptive terms that will adequately define the variable conditions under which cows are tested. The certainty of success in breeding for uniformly high production is a sufficient incentive to cause the foresighted breeder to train himself to study and analyze performance records in order properly to select a proved sire. A generation ago much effort was applied to pedigree analysis, and the same amount of effort devoted to mastering the intricacies of record analysis and proper interpretation will equip a breeder properly to select sires for his herd.

The authors are of the opinion that no so-called bull index in existence to-day is so formulated as to afford a guide to constructive breeding procedure. At best, the bull index gives only a relative assay of the value of an animal as a sire. In a group of poor sires the one with the best index would still fail as a sire of daughters of high-milk production.

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