UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1372

Washington, D. C. ▼ March, 1926

TRANSMITTING ABILITY OF TWENTY-THREE HOLSTEIN-FRIESIAN SIRES

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CONTENTS

BREEDING STUDIES ON DAIRY CATTLE

Dairy-cattle breeding experiments were initiated by the Bureau of Dairy Industry in 1918 with the object of determining what method of mating would give the most uniformly good results in the transmission of large milk and butterfat producing ability. These experiments included the comparison of line breeding with outbreeding, also of close inbreeding with outbreeding. Another project was the use, for generation after generation, of sires which have shown by the producing ability of their daughters that they are prepotent in transmitting the capacity for uniformly high milk and butterfat production. In addition to these experiments, studies are being made of the inheritance, for milk and butterfat production, of the animals in the advanced registry and register of merit of the dairy breeds.

The last-mentioned research has included a genealogical study to determine what families are most likely to transmit large milk and butterfat production (*1*).[1] Such studies, however, give very little information on the laws governing the transmission of milk and butterfat producing ability. In the following pages a study is made of the comparative milk and butterfat producing ability of the daughters, compared with their dams, of each Holstein-Friesian sire having six or more daughters with yearly records, all out of dams also having yearly records. This includes all sires on record up to and including volume 29 of the Advanced Register Yearbook.[2]

[1] Figures in italics in parentheses refer to "Literature Cited," p. 32.
[2] The writer desires to give credit to T. W. Gullickson, formerly with this bureau, for compilations in connection with the studies presented in this bulletin.

SCOPE OF THE STUDY

The following questions are discussed in this bulletin in connection with the comparative records of daughters and their dams, which are given in Tables 2 to 25, inclusive.

1. What is the method of inheritance of production of milk and butterfat in dairy cattle? Is it through the factors determining production, contributed by each parent? Is it a blending inheritance—are the records of the daughters of a sire an average between his inherent transmitting ability and that of the dam of the daughter?
2. Can a sire be prepotent or dominant in impressing his characteristics, or his standard of production, on his daughters regardless of the standard of production of the dams of those daughters?
3. Can a sire be prepotent in influencing both the milk yield and the percentage of butterfat?
4. What influence has the dam's producing ability and the method of breeding on the prepotency of the sire?
5. Which parent has the greater influence on the yield of milk? Which has the greater influence on the percentage of butterfat in the milk? Is this percentage of butterfat correlated with or independent of the milk yield?
6. Which is the greater sire—one that sires daughters capable of making much larger records than their medium-producing dams, or one that sires daughters capable of slightly larger, or, at least, as large records as their high-record dams?

HOW THE SIRES WERE SELECTED

In the list of 126 Holstein-Friesian sires given in another study (*1*) just 20 sires had 6 or more yearly record daughters whose dams also had yearly records. There were only three other sires in the breed, outside the above-mentioned list, up to Volume 29 of the Advanced Register Yearbook, that came within the category mentioned. The records of the daughters of these 23 sires, compared with their dams' records, provide the best material available in the Holstein-Friesian breed for the study of the transmitting ability of the sire. In choosing these sires for study the minimum number of six daughters was decided upon because it was felt that this number was the smallest which could be used in drawing conclusions relative to the correlation between the production of the daughters of any one sire and the production of their dams.

In checking over the records of the daughters of these 23 sires it was found that 1 of the 6 daughters of 1 sire had a record of 568.3 pounds of butterfat in 305 days, while her dam's record was 350.8 pounds of butterfat made in 207 days. These records did not offer a fair comparison and were not included. Consequently, one of the sires appearing in the records has only five daughters with yearly record dams. Three of the 23 yearly record daughters of another sire were taken out for the same reason.

To facilitate the study of the comparative records of the daughters and their dams, the milk as well as the butterfat was computed to maturity, when the records were made under 5 years of age. Table 1 gives the percentages and ages used in calculating records to maturity.

TABLE 1.—*Ages and per cent used in calculating production records to maturity*

Age, calculated to nearest whole month	Mature record equivalent	Age, calculated to nearest whole month	Mature record equivalent
	Per cent[1]		*Per cent*[1]
2 and under 2¼ years	70.0	3¾ and under 4 years	87.5
2¼ and under 2½ years	72.5	4 and under 4¼ years	90.0
2½ and under 2¾ years	75.0	4¼ and under 4½ years	92.5
2¾ and under 3 years	77.5	4½ and under 4¾ years	95.0
3 and under 3¼ years	80.0	4¾ and under 5 years	97.5
3¼ and under 3½ years	82.5	5 years and over	100.0
3½ and under 3¾ years	85.0		

[1] The percentages used for calculating records to maturity correspond very closely to the percentage differences of the average production in the various classes for the Holstein-Friesian breed. Aside from the corrrection for differences in age, other factors that might cause variation between the records of the daughters and their dams, such as number of times milked per day, were not considered, as the information is not available.

PRODUCTION RECORDS OF DAUGHTERS AND THEIR DAMS

Table 2 shows detailed production records of the daughters of these 23 sires, together with the production of their dams; the dam's record in every case is given on the same line as that of her daughter. Averages are stated also, to facilitate comparison. Other figures show the average quantity of milk, percentage of butterfat, and pounds of butterfat by which the daughters exceed their dams or are exceeded by their dams. Plus and minus signs indicate excess or deficiency of the average daughter's performance compared with the average dam's performance.

The object of the investigation was to study the hereditary transmission of production, not to point out the good or the poor sires of the breed; hence the sires in these lists have been designated by letter and not by name. The records are arranged in the order of the daughters' butterfat records, beginning with the highest record.

TABLE 2.—*Production records of daughters and their dams*

SIRE A

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	22,757.0	3.43	779.7	10,928.3	3.30	361.4
2	22,515.2	3.21	723.1	18,290.1	3.03	554.7
3	21,260.8	3.20	678.6	13,285.0	3.40	451.8
4	16,266.0	3.47	564.7	17,287.3	3.32	575.0
5	15,079.7	3.60	543.4	12,533.4	3.12	391.8
Average of 5	19,575.7	3.36	657.9	14,464.8	3.23	466.9
Increase (+) of daughters over dams	+5,110.9	+0.13	+191.0			
Per cent increase	+35.3	+4.02	+40.9			

Four daughters exceeded dams in milk.
Four daughters exceeded dams in butterfat.
Four daughters exceeded dams in percentage of butterfat.

TABLE 2.—*Production records of daughters and their dams*—Continued

SIRE B

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	28,575.5	3.39	970.5	14,562.4	3.44	501.6
2	23,924.4	3.81	912.1	20,202.9	3.33	674.6
3	22,674.8	3.74	848.8	17,080.8	3.57	610.1
4	22,235.3	3.69	821.2	14,454.0	3.19	462.1
5	23,840.9	3.37	804.5	16,508.6	3.39	560.8
6	22,817.1	3.43	784.2	17,046.4	3.08	526.3
7	21,539.7	3.45	745.0	20,105.1	3.36	676.1
8	23,265.9	3.17	738.6	14,245.7	3.14	448.5
9	20,622.8	3.52	727.5	20,202.9	3.33	674.6
10	18,530.6	3.71	688.3	18,125.0	3.66	663.7
11	18,724.7	3.33	623.7	15,655.1	3.35	525.9
12	13,959.4	3.71	517.9	17,597.7	3.73	658.0
13	15,857.8	3.19	506.1	17,027.3	3.39	577.4
Average of 13	21,273.8	3.50	745.3	17,138.5	3.39	581.5
Increase (+) of daughters over dams	+4,135.3	+0.11	+163.8			
Per cent increase	+24.1	+3.24	+28.2			

Eleven daughters exceeded dams in milk.
Eleven daughters exceeded dams in butterfat.
Eight daughters exceeded dams in percentage of butterfat.

SIRE C

	Daughters milk	Daughters butterfat		Dams milk	Dams butterfat	
1	26,497.6	3.46	917.4	21,309.5	3.42	730.7
2	22,498.2	3.97	893.4	17,577.1	3.26	574.5
3	26,059.6	3.42	891.6	23,714.2	3.76	892.7
4	20,147.3	4.28	862.7	10,755.1	3.76	404.5
5	24,055.5	3.43	825.8	18,068.2	3.51	635.6
6	23,626.1	3.32	784.5	19,410.7	3.26	633.1
7	23,238.1	3.35	779.9	17,958.6	3.37	605.5
8	21,928.2	3.54	777.6	20,255.9	3.62	735.2
9	21,650.7	3.58	775.7	20,255.9	3.62	735.2
10	20,404.6	3.60	738.0	17,367.8	3.39	588.9
11	17,225.0	3.50	604.1	17,958.6	3.37	605.5
12	17,504.9	3.36	588.6	19,410.7	3.26	633.1
Average of 12	22,074.6	3.56	786.6	18,670.2	3.47	647.9
Increase (+) of daughters over dams	+3,404.4	+0.09	+138.7			
Per cent increase	+18.2	+2.59	+21.4			

Ten daughters exceeded dams in milk.
Nine daughters exceeded dams in butterfat.
Seven daughters exceeded dams in percentage of butterfat

SIRE D

	Daughters milk	Daughters butterfat		Dams milk	Dams butterfat	
1	28,753.6	2.93	844.0	18,882.7	3.03	572.4
2	24,450.0	3.13	767.0	17,703.8	3.62	642.1
3	21,647.5	3.43	744.1	24,397.1	3.46	846.3
4	19,988.9	3.56	712.8	14,022.4	3.45	485.0
5	21,379.2	3.32	711.9	23,027.2	2.76	637.5
6	21,308.1	3.16	675.0	16,577.1	3.14	520.9
7	21,564.5	3.10	670.4	18,138.2	3.00	544.4
8	17,529.1	3.22	565.2	14,053.5	3.02	425.1
9	15,540.4	3.26	507.7	11,425.9	3.39	388.2
Average of 9	21,351.3	3.23	688.7	17,580.9	3.20	562.4
Increase (+) of daughters over dams	+3,770.4	+0.03	+126.3			
Per cent increase	+21.4	+0.94	+22.4			

Seven daughters exceeded dams in milk.
Eight daughters exceeded dams in butterfat.
Four daughters exceeded dams in percentage of butterfat.

TABLE 2.—*Production records of daughters and their dams*—Continued

SIRE E

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	24,941.0	3.73	930.3	19,539.4	3.24	634.4
2	26,949.8	3.33	899.5	22,377.0	3.05	684.6
3	24,872.1	3.19	794.3	22,377.0	3.05	684.6
4	25,301.6	2.92	739.2	22,377.0	3.05	684.6
5	17,684.0	3.91	691.6	17,173.9	3.90	670.5
6	21,056.1	3.07	648.4	16,422.0	3.79	622.4
Average of 6	23,467.4	3.34	783.9	20,044.4	3.31	663.5
Increase (+) of daughters over dams	+3,423.0	+0.03	+120.4			
Per cent increase	+17.1	+0.91	+18.1			

All daughters exceeded dams in milk.
All daughters exceeded dams in butterfat.
Four daughters exceeded dams in percentage of butterfat.

SIRE F

	Daughters milk	Daughters butterfat		Dams milk	Dams butterfat	
1	26,692.2	4.04	1,079.8	20,847.6	3.98	830.2
2	28,316.8	3.07	871.6	19,043.5	3.34	636.9
3	23,061.2	3.58	826.0	18,177.8	3.73	678.3
4	21,029.1	3.60	758.4	16,366.3	3.55	581.2
5	21,617.7	3.45	745.7	25,455.7	3.04	772.7
6	19,781.7	3.65	722.3	15,036.6	3.79	569.3
7	20,364.0	3.24	660.4	20,646.0	3.24	670.0
8	18,102.0	3.30	598.1	17,629.5	3.35	592.1
9	16,833.9	3.45	580.9	16,483.8	3.22	531.4
Average of 9	21,755.4	3.49	760.3	18,854.1	3.45	651.3
Increase (+) of daughters over dams	+2,901.3	+0.04	+109.0			
Per cent increase	+15.4	+1.16	+16.7			

Seven daughters exceeded dams in milk.
Seven daughters exceeded dams in butterfat.
Four daughters exceeded dams in percentage of butterfat.

SIRE G

	Daughters milk	Daughters butterfat		Dams milk	Dams butterfat	
1	24,690.0	4.31	1,065.4	15,032.6	4.30	647.1
2	23,044.6	4.21	972.2	28,090.0	3.25	913.9
3	18,831.0	4.25	801.1	17,591.5	3.61	636.1
4	22,097.8	3.43	760.0	22,287.0	3.60	802.6
5	22,695.8	3.32	753.8	19,753.7	3.52	696.3
6	15,657.2	4.39	687.4	15,735.4	3.83	602.8
7	13,945.5	3.81	531.8	14,971.7	3.88	581.8
Average of 7	20,137.4	3.95	795.9	19,066.0	3.66	697.2
Increase (+) of daughters over dams	+1,071.4	+0.29	+98.7			
Per cent increase	+5.6	+7.92	+14.2			

Three daughters exceeded dams in milk.
Five daughters exceeded dams in butterfat.
Four daughters exceeded dams in percentage of butterfat.

SIRE H

	Daughters milk	Daughters butterfat		Dams milk	Dams butterfat	
1	20,516.2	3.66	752.1	18,235.9	3.74	683.1
2	21,246.0	3.37	716.7	17,027.3	3.39	577.4
3	23,056.6	3.04	701.6	17,046.4	3.08	526.3
4	16,566.8	3.75	622.3	17,290.0	3.72	643.3
5	19,422.1	3.13	609.1	14,245.7	3.14	448.6
6	18,430.2	3.01	554.6	17,898.1	2.92	523.3
Average of 6	19,872.9	3.32	659.4	16,957.2	3.34	567.0
Increase (+) or decrease (−) of daughters over dams	+2,915.7	−.02	+92.4			
Per cent increase or decrease	+17.2	−.60	+16.3			

Five daughters exceeded dams in milk.
Five daughters exceeded dams in butterfat.
Two daughters exceeded dams in percentage of butterfat.

TABLE 2.—*Production records of daughters and their dams*—Continued

SIRE I

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	22, 308. 8	3. 54	791. 3	17, 514. 6	3. 59	629. 6
2	23, 477. 1	3. 33	782. 4	13, 700. 7	3. 49	479. 3
3	23, 229. 5	3. 22	748. 3	17, 514. 6	3. 59	629. 6
4	22, 149. 5	3. 04	675. 2	14, 178. 1	3. 53	500. 9
5	11, 553. 6	3. 77	436. 6	14, 178. 1	3. 53	500. 9
6	12, 051. 7	3. 01	362. 8	15, 720. 1	3. 24	510. 7
Average of 6	19, 128. 4	3. 31	632. 8	15, 467. 7	3. 50	541. 8
Increase (+) or decrease (−) of daughters over dams	+3, 660. 7	−0. 19	+91. 0			
Per cent increase or decrease	+23. 7	−5. 43	+16. 8			

Four daughters exceeded dams in milk.
Four daughters exceeded dams in butterfat.
One daughter exceeded dam in percentage of butterfat.

SIRE J

1	29, 053. 2	3. 40	988. 2	25, 227. 1	3. 46	875. 3
2	25, 345. 3	3. 80	965. 1	13, 447. 5	3. 61	485. 9
3	23, 359. 5	4. 04	945. 0	25, 227. 1	3. 46	875. 3
4	21, 837. 5	4. 29	937. 6	11, 006. 9	3. 42	377. 2
5	24, 741. 6	3. 77	933. 1	20, 877. 2	3. 28	684. 9
6	26, 331. 0	3. 39	895. 2	26, 134. 2	3. 27	856. 6
7	22, 424. 6	3. 70	830. 9	23, 340. 1	3. 58	835. 9
8	23, 853. 6	3. 24	774. 0	27, 762. 5	3. 60	1, 000. 3
9	19, 045. 8	3. 78	720. 1	19, 602. 3	3. 59	704. 3
10	18, 569. 0	3. 79	703. 8	23, 485. 6	3. 45	811. 2
11	18, 759. 8	3. 66	688. 3	27, 762. 5	3. 60	1, 000. 3
12	18, 804. 3	3. 59	676. 0	15, 788. 4	3. 29	519. 5
13	18, 826. 5	3. 59	677. 4	15, 788. 4	3. 29	519. 5
14	19, 080. 8	3. 48	665. 2	25, 227. 1	3. 46	875. 3
15	17, 585. 5	3. 61	635. 7	11, 337. 3	3. 70	419. 7
16	15, 401. 7	3. 70	570. 1	8, 891. 4	4. 01	357. 1
17	16, 264. 4	3. 44	561. 0	11, 006. 9	3. 42	377. 2
18	15, 104. 5	3. 55	536. 7	21, 796. 6	3. 33	725. 9
19	14, 894. 0	3. 55	530. 2	12, 266. 6	3. 55	436. 2
20	11, 412. 9	4. 14	473. 3	12, 266. 6	3. 55	436. 2
Average of 20	20, 034. 8	3. 67	735. 3	18, 912. 1	3. 48	658. 7
Increase (+) of daughters over dams	+1, 122. 7	+0. 19	+76. 6			
Per cent increase	+5. 9	+5. 46	+11. 6			

Eleven daughters exceeded dams in milk.
Fourteen daughters exceeded dams in butterfat.
Fifteen daughters exceeded dams in percentage of butterfat.

SIRE K

1	21, 689. 0	3. 59	777. 8	20, 690. 2	3. 55	734. 6
2	19, 132. 7	3. 71	709. 3	14, 562. 4	3. 44	501. 6
3	20, 558. 8	3. 19	655. 1	17, 046. 4	3. 09	526. 3
4	14, 146. 2	4. 34	614. 8	17, 027. 3	3. 39	577. 4
5	16, 570. 7	3. 26	539. 4	14, 245. 7	3. 15	448. 6
6	12, 413. 2	3. 51	436. 8	14, 562. 4	3. 44	501. 6
Average of 6	17, 418. 4	3. 57	622. 2	16, 355. 7	3. 35	548. 3
Increase (+) of daughters over dams	+1, 062. 7	+0. 22	+73. 9			
Per cent increase	+6. 5	+6. 57	+13. 5			

Four daughters exceeded dams in milk.
Five daughters exceeded dams in butterfat.
All daughters exceeded dams in percentage of butterfat.

TABLE 2.—*Production records of daughters and their dams*—Continued

SIRE L

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	23, 451. 5	3. 35	786. 5	22, 449. 5	3. 50	785. 8
2	21, 183. 7	3. 39	718. 4	15, 967. 8	3. 66	584. 2
3	21, 892. 1	3. 13	684. 4	18, 716. 3	3. 53	660. 7
4	19, 693. 0	3. 47	683. 1	14, 096. 2	3. 77	531. 9
5	18, 355. 0	3. 51	644. 0	14, 946. 5	3. 61	539. 9
6	18, 214. 5	3. 45	627. 9	16, 133. 9	3. 36	541. 3
7	15, 972. 4	3. 74	597. 5	14, 096. 2	3. 77	531. 9
8	18, 236. 5	3. 25	593. 5	18, 716. 3	3. 53	660. 7
9	17, 350. 5	3. 38	586. 7	14, 096. 2	3. 77	531. 9
10	14, 815. 3	3. 75	555. 7	14, 946. 3	3. 61	539. 9
11	12, 196. 6	3. 13	382. 0	11, 593. 3	3. 96	459. 0
Average of 11	18, 305. 6	3. 41	623. 6	15, 978. 0	3. 62	578. 8
Increase (+) or decrease (−) of daughters over dams	+2, 327. 6	−0. 21	+44. 8			
Per cent increase or decrease	+14. 6	−5. 80	+7. 7			

Nine daughters exceeded dams in milk.
Nine daughters exceeded dams in fat.
Two daughters exceeded dams in percentage of butterfat.

SIRE M

1	16, 465. 6	3. 69	608. 4	12, 480. 8	3. 88	483. 9
2	15, 429. 6	3. 44	531. 0	12, 445. 7	3. 40	423. 1
3	14, 918. 3	3. 56	530. 8	12, 470. 8	3. 68	458. 7
4	14, 925. 1	3. 49	521. 2	12, 470. 8	3. 68	458. 7
5	14, 972. 0	3. 33	499. 8	21, 746. 2	2. 98	649. 0
6	12, 240. 9	3. 68	450. 1	12, 480. 8	3. 88	483. 9
Average of 6	14, 825. 2	3. 53	523. 5	14, 015. 8	3. 52	492. 9
Increase (+) of daughters over dams	+809. 4	+0. 01	+30. 6			
Per cent increase	+5. 8	+0. 28	+6. 2			

Four daughters exceeded dams in milk.
Four daughters exceeded dams in butterfat.
Two daughters exceeded dams in percentage of butterfat.

SIRE N

1	18, 218. 0	3. 87	705. 6	11, 311. 8	3. 81	431. 4
2	18, 456. 8	3. 77	695. 0	12, 529. 7	3. 55	445. 2
3	19, 973. 4	3. 40	678. 4	15, 357. 5	3. 54	543. 1
4	17, 300. 3	3. 75	648. 7	19, 258. 8	4. 41	849. 2
5	16, 756. 9	3. 78	632. 9	14, 913. 7	3. 54	527. 9
6	15, 826. 2	3. 48	550. 3	11, 649. 3	3. 94	458. 4
7	16, 017. 2	3. 38	541. 6	17, 882. 3	4. 32	773. 2
8	13, 761. 6	3. 71	510. 4	14, 241. 8	3. 71	528. 5
9	15, 096. 2	3. 33	502. 3	17, 022. 3	4. 41	750. 0
Average of 9	16, 822. 9	3. 61	607. 2	14, 907. 5	3. 96	589. 7
Increase (+) or decrease (−) of daughters over dams	+1, 915. 4	−0. 35	+17. 5			
Per cent increase or decrease	+12. 8	−8. 84	+2. 9			

Five daughters exceeded dams in milk.
Five daughters exceeded dams in butterfat.
Three daughters exceeded dams in percentage of butterfat.

TABLE 2.—*Production records of daughters and their dams*—Continued

SIRE O

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	14, 173. 8	3. 02	428. 5	13, 615. 1	3. 42	466. 3
2	12, 336. 0	3. 81	469. 7	10, 546. 0	3. 47	366. 3
3	19, 162. 7	4. 21	806. 6	19, 316. 4	4. 17	805. 9
4	21, 578. 0	3. 13	674. 5	15, 708. 5	3. 27	513. 1
5	13, 329. 5	3. 52	469. 7	15, 901. 4	4. 03	640. 9
6	13, 479. 7	3. 63	489. 1	13, 615. 1	3. 42	466. 3
Average of 6	15, 676. 6	3. 55	556. 3	14, 783. 7	3. 67	543. 1
Increase (+) or decrease (−) of daughters over dams	+892. 9	−0. 12	+13. 2			
Per cent increase or decrease	+6. 0	−3. 27	+2. 4			

Three daughters exceeded dams in milk.
Four daughters exceeded dams in butterfat.
Three daughters exceeded dams in percentage of butterfat.

SIRE P

	Daughters Milk (Pounds)	Daughters Butterfat (Per cent)	Daughters Butterfat (Pounds)	Dams Milk (Pounds)	Dams Butterfat (Per cent)	Dams Butterfat (Pounds)
1	18, 355. 7	3. 70	678. 7	18, 670. 1	3. 23	603. 5
2	19, 861. 0	3. 03	602. 7	18, 762. 6	3. 08	577. 5
3	14, 776. 1	3. 71	547. 9	15, 223. 1	3. 65	556. 2
4	14, 634. 5	3. 64	533. 9	16, 510. 8	3. 06	505. 4
5	13, 167. 6	3. 31	435. 9	15, 754. 3	3. 28	516. 1
6	12, 713. 1	3. 10	393. 9	13, 051. 4	3. 04	396. 3
Average of 6	15, 584. 6	3. 41	532. 2	16, 328. 7	3. 22	525. 8
Increase (+) or decrease (−) of daughters over dams	−744. 1	+0. 19	+6. 4			
Per cent increase or decrease	−4. 6	+5. 90	+1. 2			

One daughter exceeded dam in milk.
Three daughters exceeded dams in butterfat.
Five daughters exceeded dams in percentage of butterfat.

SIRE Q

	Daughters Milk (Pounds)	Daughters Butterfat (Per cent)	Daughters Butterfat (Pounds)	Dams Milk (Pounds)	Dams Butterfat (Per cent)	Dams Butterfat (Pounds)
1	22, 552. 5	3. 21	723. 8	17, 893. 0	3. 80	679. 5
2	20, 267. 7	3. 55	719. 0	14, 122. 2	3. 34	472. 3
3	20, 895. 6	3. 28	686. 4	14, 630. 0	3. 58	523. 2
4	19, 048. 2	3. 51	667. 9	19, 999. 8	3. 27	654. 4
5	18, 463. 0	3. 28	605. 0	17, 879. 1	3. 35	598. 2
6	18, 300. 4	3. 13	573. 4	16, 497. 4	3. 33	549. 0
7	16, 654. 4	3. 30	549. 6	16, 497. 4	3. 30	544. 4
8	13, 245. 5	3. 69	488. 7	18, 509. 7	3. 60	666. 4
9	15, 807. 8	3. 07	484. 9	14, 755. 6	3. 23	475. 9
10	14, 547. 4	3. 29	478. 0	21, 063. 0	3. 43	723. 0
11	13, 966. 8	3. 34	466. 1	17, 894. 8	3. 35	598. 9
Average of 11	17, 613. 6	3. 33	585. 7	17, 249. 3	3. 42	589. 6
Increase (+) or decrease (−) of daughters over dams	+364. 3	−0. 09	−3. 9			
Per cent increase or decrease	+2. 1	−2. 63	−0. 7			

Seven daughters exceeded dams in milk
Eight daughters exceeded dams in butterfat.
Three daughters exceeded dams in percentage of butterfat

TABLE 2.—*Production records of daughters and their dams*—Continued

SIRE R

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	15, 458. 3	3. 23	499. 8	17, 287. 3	3. 33	575. 0
2	17, 718. 1	2. 75	487. 7	15, 387. 8	2. 74	423. 1
3	13, 285. 0	3. 40	451. 8	12, 258. 9	3. 53	433. 0
4	15, 688. 1	2. 61	409. 7	15, 387. 8	2. 74	423. 1
5	11, 975. 8	3. 20	383. 2	12, 258. 9	3. 53	433. 0
6	10, 928. 3	3. 31	361. 4	11, 367. 8	3. 25	368. 9
Average of 6	14, 175. 6	3. 05	432. 3	13, 991. 4	3. 16	442. 7
Increase (+) or decrease (−) of daughters over dams	+184. 2	−0. 11	−10. 4			
Per cent increase or decrease	+1. 3	−3. 48	−2. 3			

Three daughters exceeded dams in milk.
Two daughters exceeded dams in butterfat.
Two daughters exceeded dams in percentage of butterfat

SIRE S

	Daughters Milk (Pounds)	Daughters Butterfat (Per cent)	Daughters Butterfat (Pounds)	Dams Milk (Pounds)	Dams Butterfat (Per cent)	Dams Butterfat (Pounds)
1	14, 064. 6	4. 30	604. 2	10, 300. 0	4. 44	457. 6
2	16, 728. 5	3. 27	546. 6	18, 329. 6	3. 34	611. 8
3	13, 594. 9	4. 00	541. 9	16, 355. 5	3. 88	634. 2
4	15, 168. 5	3. 28	496. 9	15, 068. 3	3. 63	546. 4
5	14, 897. 0	3. 18	473. 2	14, 069. 5	3. 24	456. 2
6	11, 831. 1	3. 88	458. 8	15, 669. 8	3. 22	505. 1
7	11, 779. 5	3. 44	405. 1	16, 032. 5	3. 37	540. 5
Average of 7	14, 009. 2	3. 60	503. 8	15, 117. 9	3. 55	536. 0
Increase (+) or decrease (−) of daughters over dams	−1, 108. 7	+0. 05	−32. 2			
Per cent increase or decrease	−7. 3	+1. 41	−6. 0			

Three daughters exceeded dams in milk.
Two daughters exceeded dams in butterfat.
Three daughters exceeded dams in percentage of butterfat.

SIRE T

	Daughters Milk (Pounds)	Daughters Butterfat (Per cent)	Daughters Butterfat (Pounds)	Dams Milk (Pounds)	Dams Butterfat (Per cent)	Dams Butterfat (Pounds)
1	23, 050. 3	3. 32	765. 9	18, 511. 7	3. 67	679. 9
2	19, 737. 4	3. 53	697. 6	19, 074. 8	3. 70	706. 1
3	18, 347. 6	3. 61	662. 3	16, 977. 6	3. 58	607. 1
4	18, 057. 7	3. 31	596. 8	17, 809. 8	3. 92	697. 4
5	16, 702. 7	3. 56	595. 4	19, 074. 9	3. 70	706. 1
6	17, 417. 4	3. 29	572. 3	21, 611. 7	3. 37	728. 0
7	16, 481. 0	3. 35	551. 6	18, 619. 5	3. 63	675. 7
Average of 7	18, 542. 0	3. 42	634. 5	18, 811. 4	3. 65	685. 8
Decrease (−) of daughters over dams	−269. 4	−0. 23	−51. 3			
Per cent decrease	−1. 4	−6. 30	−7. 5			

Four daughters exceeded dams in milk.
Two daughters exceeded dams in butterfat.
One daughter exceeded dam in percentage of butterfat.

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TABLE 2.—*Production records of daughters and their dams*—Continued

SIRE U

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	13, 994. 8	3. 35	468. 5	12, 691. 9	3. 88	492. 9
2	14, 990. 5	3. 07	459. 7	15, 071. 8	3. 78	569. 5
3	14. 239. 6	3. 41	485. 2	15, 559. 1	3. 27	508. 6
4	13, 580. 1	3. 16	429. 2	16, 335. 1	3. 46	565. 8
5	14. 913. 1	3. 23	481. 1	9, 555. 6	3. 68	351. 7
6	14, 727. 0	3. 06	451. 6	19, 002. 6	3. 20	608. 1
7	11. 881. 9	3. 29	390. 8	14, 446. 3	3. 30	477. 4
Average of 7	14, 046. 7	3. 22	452. 3	14, 666. 0	3. 48	510. 5
Decrease (−) of daughters over dams	−619. 3	−0. 26	−58. 2			
Per cent decrease	−4. 2	−7. 47	−11. 4			

Two daughters exceeded dams in milk.
One daughter exceeded dam in butterfat.
One daughter exceeded dam in percentage of butterfat.

SIRE V

1	16, 971. 7	3. 54	601. 2	17, 148. 8	3. 29	563. 7
2	16, 687. 4	3. 32	554. 1	18, 670. 1	3. 23	603. 5
3	14, 973. 1	3. 44	515. 5	15, 754. 3	3. 28	516. 1
4	14, 135. 2	3. 42	483. 7	20, 108. 2	3. 26	656. 2
5	18, 049. 3	2. 62	472. 1	13, 815. 9	3. 02	417. 4
6	15, 237. 6	3. 06	466. 2	17, 343. 6	3. 27	566. 6
7	12, 126. 5	3. 82	463. 1	20, 108. 2	3. 26	656. 2
Average of 7	15, 454. 4	3. 29	508. 0	17, 564. 2	3. 24	568. 5
Increase (+) or decrease (−) of daughters over dams	−2, 109. 8	+0. 05	−60. 5			
Per cent increase or decrease	−12. 0	+1. 54	−10. 6			

One daughter exceeded dam in milk.
Two daughters exceeded dams in butterfat.
Five daughters exceeded dams in percentage of butterfat.

SIRE W

1	21, 208. 6	3. 71	786. 4	15, 652. 5	3. 76	589. 1
2	23, 088. 1	3. 40	785. 8	20, 407. 7	3. 94	804. 3
3	19, 502. 2	3. 48	678. 8	20, 323. 0	3. 51	712. 4
4	19, 652. 2	3. 36	660. 2	18, 510. 7	3. 67	679. 9
5	18, 640. 6	3. 50	653. 8	17, 562. 0	3. 60	632. 7
6	18, 251. 3	3. 53	643. 8	20, 407. 6	3. 94	804. 3
7	17, 330. 0	3. 71	643. 0	17, 809. 8	3. 92	697. 4
8	17, 421. 4	3. 63	632. 0	17, 478. 9	3. 96	692. 5
9	19, 799. 0	3. 18	629. 6	16, 668. 2	3. 88	646. 5
10	16, 511. 8	3. 71	613. 2	17, 478. 9	3. 96	692. 5
11	17, 285. 7	3. 53	610. 4	20, 323. 0	3. 51	712. 4
12	18, 562. 4	3. 18	589. 6	24, 858. 1	3. 07	762. 7
13	16, 796. 1	3. 40	570. 4	18, 619. 5	3. 63	675. 7
14	15, 058. 2	3. 52	530. 3	18, 676. 8	3. 64	680. 1
15	13, 278. 0	3. 65	484. 6	15, 701. 7	3. 73	586. 2
16	13, 296. 8	3. 22	428. 2	21, 611. 7	3. 37	728. 0
Average of 16	17, 855. 1	3. 48	621. 2	18, 880. 6	3. 67	693. 5
Decrease (−) of daughters over dams	−1, 025. 5	−0. 19	−72. 3			
Per cent decrease	−5. 4	−5. 18	−10. 4			

Five daughters exceeded dams in milk.
Two daughters exceeded dams in butterfat.
Two daughters exceeded dams in percentage of butterfat.

Table 3 is a summary of Table 2 showing the increase or decrease in yield of milk, percentage of butterfat, and yield of butterfat of the daughters of each of the 23 sires as compared with the records of their dams. Comparisons are made in pounds of milk, pounds of butterfat, and fat tests, with the per cent of increase or decrease in each case.

TABLE 3.—*Summary of sires having six or more yearly-record daughters whose dams have yearly records, in order of relative increase in pounds of butterfat, by daughters over dams*

Sire	Increase (+) or decrease (−) of daughters over dams.					
	Milk		Butterfat test		Butterfat	
	Pounds	Per cent	Amount	Per cent	Pounds	Per cent
A	+5, 110. 9	+35. 3	+0. 13	+4. 02	+191. 0	+40. 9
B	+4, 135. 3	+24. 1	+0. 11	+3. 24	+163. 8	+28. 2
C	+3, 404. 4	+18. 2	+0. 09	+2. 59	+138. 7	+21. 4
D	+3, 770. 4	+21. 4	+0. 03	+0. 94	+126. 3	+22. 4
E	+3, 423. 0	+17. 1	+0. 03	+0. 91	+120. 4	+18. 1
F	+2, 901. 3	+15. 4	+0. 04	+1. 16	+109. 0	+16. 7
G	+1, 071. 4	+5. 6	+0. 29	+7. 92	+98. 7	+14. 2
H	+2, 915. 7	+17. 2	−0. 02	−0. 60	+92. 4	+16. 3
I	+3, 660. 7	+23. 7	−0. 19	−5. 43	+91. 0	+16. 8
J	+1, 122. 7	+5. 9	+0. 19	+5. 46	+76. 6	+11. 6
K	+1, 062. 7	+6. 5	+0. 22	+6. 57	+73. 9	+13. 5
L	+2, 327. 6	+14. 6	−0. 21	−5. 80	+44. 8	+7. 7
M	+809. 4	+5. 8	+0. 01	+0. 28	+30. 6	+6. 2
N	+1, 915. 4	+12. 8	−0. 35	−8. 84	+17. 5	+2. 9
O	+892. 9	+6. 0	−0. 12	−3. 27	+13. 2	+2. 4
P	−744. 1	−4. 6	+0. 19	+5. 90	+6. 4	+1. 2
Q	+364. 3	+2. 1	−0. 09	−2. 63	−3. 9	−0. 7
R	+184. 2	+1. 3	−0. 11	−3. 48	−10. 4	−2. 3
S	−1, 108. 7	−7. 3	+0. 05	+1. 41	−32. 2	−6. 0
T	−269. 4	−1. 4	−0. 23	−6. 30	−51. 3	−7. 5
U	−619. 3	−4. 2	−0. 26	−7. 47	−58. 2	−11. 4
V	−2, 109. 8	−12. 0	+0. 05	+1. 54	−60. 5	−10. 6
W	−1, 025. 5	−5. 4	−0. 19	−5. 18	−72. 3	−10. 4

METHOD OF INHERITANCE

A study of the records of the daughters and their dams in Table 2 shows a remarkable variation. Note the following instances:

The highest-record daughter of sire A is out of the dam that has the lowest record of the five. His lowest-record daughter is out of the dam with the next lowest record. The one daughter which failed to make a larger record than her dam was from the dam with the highest butterfat record, and yet this daughter's record is 6,491 pounds of milk and 215 pounds of butterfat lower than his highest-record daughter.

Sire B's highest-record daughter is out of a dam with the third from the lowest record, and his daughter with the next to lowest record is from the fourth highest dam. There are two full sisters in his list of daughters. One is second in the list of 13 daughters, the other is ninth, the latter with 3,301 pounds of milk and 184 pounds of butterfat less than her sister.

Sire C has 12 daughters whose dams have yearly records. The highest-record dam, which produced 892 pounds of butterfat, has a daughter with the third highest record, or 891 pounds of butterfat; whereas the lowest-record dam, with 404 pounds of butterfat, has a daughter with the fourth highest record, or 862 pounds of butterfat. His highest-record daughter produced 917 pounds of butterfat and her dam 730 pounds. The next highest daughter, which produced 893 pounds of butterfat, is from a dam with 574 pounds.

The lowest-record dam in the list of sire D produced 388 pounds of butterfat; her daughter, sire D's lowest-producing daughter, has a record of 507 pounds of butterfat, an increase of 119 pounds. Sire D's highest-producing daughter produced 844 pounds of butterfat and her dam produced 572 pounds, an increase by the daughter of

272 pounds over the dam. The highest-record dam produced 846 pounds of butterfat and her daughter 744 pounds, or a 102-pound decrease. This daughter of the highest-record dam has a record that is 100 pounds lower than that of the highest-record daughter, whose dam's record, 572 pounds of butterfat, is 274 pounds less than that of the highest-record dam.

The highest-record daughter of sire F was out of a dam with the highest record of any of the dams, 20,847 pounds of milk and 830 pounds of butterfat; yet this daughter's record is larger than the dam's by 5,845 pounds of milk and 249 pounds of butterfat. His lowest-record daughter was out of the lowest-record dam. This dam has a record of 16,483 pounds of milk and 531 pounds of butterfat. Her daughter's record is larger by 350 pounds of milk and 49 pounds of butterfat. Note the difference between this increase from a low-record dam and the increase from the highest-record dam. Two of his other daughter's records were lower than those of their dams.

The highest-record dam of the daughters of sire G has a record of 913 pounds of butterfat. The daughter of this dam exceeded this record by 59 pounds. This increase was due to a rise of almost 1 per cent of butterfat. The yield of milk of the daughter was less by 5,046 pounds. The lowest-record dam produced 581 pounds of butterfat and her daughter 531 pounds, a decrease of 50 pounds. This decrease was due to both a lower yield of milk and a lower percentage of butterfat in the milk. The one other daughter of this sire that had a lower butterfat record than her dam was out of a dam which produced 802 pounds of butterfat.

Included in the list of six daughters of sire I are two pairs of full sisters. The dam of one of these pairs had a record of 17,514 pounds of milk and 629 pounds of butterfat. Both daughters of this dam made more milk and more butterfat than the dam. One daughter exceeded her dam's production by 4,794 pounds of milk and 162 pounds of butterfat and had nearly the same test as the dam. The other daughter produced 5,715 pounds of milk more than the dam, but the percentage of butterfat in her milk was 0.37 less than that of her dam and her increase in total butterfat was only 119 pounds. The dam of the other pair of sisters has a record of 14,178 pounds of milk and 500 pounds of butterfat. One of these sisters increased the yield of milk 7,971 pounds, lowered the percentage of butterfat 0.49 (from 3.53 to 3.04) and increased the total butterfat 175 pounds. The other sister decreased the yield of milk 2,625 pounds, raised the percentage of fat 0.24 and decreased the total butterfat 64 pounds.

Such examples as those mentioned may be cited in the records of the daughters of every sire in the list. A careful study of the comparative records of each sire will show great variations in the records of the daughters of the same sire, and between the records of the daughters and their dams. Instances are found of the highest-record daughters coming from the lowest-record dams. There are other instances in which both the highest-record and the lowest-record dams have daughters which show increases, whereas other dams coming in between these extremes have daughters showing decreases.

It seems clear that the daughters' records are not a blend between the production ability of sire and dam, and it also seems clear that the increase or decrease of the records of a sire's daughters over or under

the records of their dams will not be uniform; nor is the size of the record of the dam a criterion of the size of the record of the daughter.

THE BLENDING-INHERITANCE THEORY

Many investigators and breeders believe that the inheritance of milk and butterfat production is of the blending type. It has been suggested, in accordance with this theory, that the true measure of a sire's inherent ability might be calculated by adding the average increase of the daughters over their dams to the average record of the daughters, the result being the true inherent transmitting ability of the sire for milk and butterfat production. The assumption is that the capacity of the daughter is halfway between that of her sire and that of her dam. Thus, if the sire's inherent transmitting ability is 800 pounds of butterfat and he is bred to a 600-pound-butterfat cow, the daughter should have the ability to make an average between the two, or 700 pounds of fat.

This theory was tried out by taking the average butterfat records of the daughters of sire B and their dams. The average of the daughters was 745 pounds of butterfat; the average of their dams was 581 pounds of butterfat. The difference between the average of the daughters and the average of the dams was 164 pounds. This added to the average of the daughters gives the sire an inherent transmitting ability of 909 pounds of butterfat. With the inherent transmitting ability of the sire a known quantity, as is also the record of the cow to which he is mated, it should be possible to predict the producing capacity of a particular daughter by halving the sum of the sire's standard and dam's record, the resulting average being the daughter's producing capacity. But when this system is applied to the individual daughters of sire B the results do not check well with the actual records in Table 2. The comparison is shown in Table 4.

TABLE 4.—*Butterfat records of daughters of sire B, showing butterfat production predicted by blending-inheritance computation, and that actually produced*

Daughter No.	Butterfat predicted	Butterfat produced	Difference of predicted from actual production	Daughter No.	Butterfat predicted	Butterfat produced	Difference of predicted from actual production
	Pounds	*Pounds*	*Pounds*		*Pounds*	*Pounds*	*Pounds*
1	705.3	970.5	−265.2	8	678.8	738.6	−59.8
2	791.8	912.1	−120.3	9	791.8	727.5	+64.3
3	759.6	848.8	−89.2	10	786.4	688.3	+98.1
4	685.6	821.2	−135.6	11	717.5	623.7	+93.8
5	734.9	804.5	−69.6	12	783.5	517.9	+265.6
6	717.7	784.2	−66.5	13	743.2	506.1	+237.1
7	792.6	745.0	+47.6				

It is true that where there have been crosses between two distinct breeds of dairy cattle that have a considerable difference between their milk flow and their range of butterfat percentage, such as the Holstein-Friesian cross on Guernsey or Jersey, it has been observed that the resulting progeny have a milk flow and a percentage fat that are intermediate between those of the two parents. In these crosses between distinct breeds there are probably so many independently inherited factors having a bearing on the milk flow and the percentage fat in each parent, that it is almost impossible to bring about, in any limited number of animals, a segregation of factors that will result in the exact reappearance of either of the parental characters. For crosses within a breed, however, there is not the same evidence of intermediate milk flow and percentage fat. The great variation in records between the daughters of a sire, and also the variation between records of the daughters and their dams, do not indicate a blended inheritance of the type shown by crosses between distinct breeds.

There are several explanations that may be given to account for this great variation in the production capacity of the daughters of a sire: (1) The factors that determine high-producing capacity may be dominant over those determining a low-producing capacity. (2) Each individual sire and dam may have a double nature in its hereditary make-up. The dam may be a good producer, because of dominant factors for high production received from one parent, but she may also possess recessive factors for low-producing capacity that she received from her other parent; and, consequently, she may transmit to a part of her offspring an inheritance for high-producing capacity and to the other part an inheritance for low-producing capacity. (3) The cumulative or multiple factor hypothesis is based on the theory that quantitative characters are produced by cumulative factors; that is, when a factor is added to another similar factor, the cumulation affects the degree of development of that character.

WHAT IS A GREAT SIRE OF PRODUCTION?

Which is the greatest sire of production? Is it (1) one that gets daughters that are as good as their high-producing dams; (2) one that gets daughters that make considerably larger records than good dams; (3) one that gets daughters that make much larger records than their low or medium-producing dams; (4) one that gets daughters with the greatest average increase of milk and butterfat over their dams; (5) one whose daughters have the highest average yield of butterfat and milk regardless of the dam's average; (6) one that has the greatest proportion of his daughters better than their dams regardless of the amount of the increase; or (7) one that has daughters showing the greatest uniformity of production?

If sires were judged solely by the average increase in yield of their daughters over their dams, some sires having only one-third of their daughters better than their dams would appear better than other sires with two-thirds of their daughters better than their dams. Nor can a sire be judged entirely by the number of his daughters that are better than their dams, for if the dams were low producers and the increase of the daughters was small, the sire would not have great merit.

It seems desirable to take into consideration all the following factors in judging the comparative merits of several sires: The average yield of their daughters; the average increase in the yield of the daughters over that of their dams; and the number of daughters that were better than their dams.

The 23 sires studied are given comparative rankings in Table 5 with respect to average milk yield of their daughters, average butterfat yield, average increase of milk, average increase of butterfat, and the percentage of daughters that were better than their dams in milk and in butterfat yield; in the last column is the sum of his rankings in the various classes.

TABLE 5.—*Ranking of the 23 sires in various classes based on the comparative production of their daughters*

Sire	Relative rank in this group	Number of daughters	Rank according to— Average milk yield of daughters	Average butterfat yield of daughters	Average increase of milk	Average increase of butterfat	Percentage of daughters making increase in milk	Percentage of daughters making increase in butterfat	Total of rankings
E	1	6	1	3	5	5	1	1	16
B	2	13	5	5	2	2	2	3	19
C	3	12	2	2	6	3	3	8	24
D	4	9	4	7	3	4	6	2	26
A	5	5	9	9	1	1	5	6	31
F	6	9	3	4	8	6	6	7	34
H	7	6	8	8	7	8	3	4	38
G	8	7	6	1	12	7	13	10	49
I	9	6	10	11	4	9	7	12	53
L	10	11	12	12	9	12	4	5	54
J	11	20	7	6	11	10	11	11	56
K	12	6	15	13	13	11	7	4	63
N	13	9	16	15	10	14	10	13	78
Q	14	11	14	16	16	17	8	9	80
T	15	7	11	10	18	20	9	16	84
M	16	6	20	19	15	13	7	12	86
O	17	6	17	17	14	15	12	12	87
P	18	6	18	18	20	16	16	14	102
W	19	16	13	14	21	23	14	18	103
R	20	6	21	23	17	18	12	15	106
S	21	7	23	21	22	19	13	16	114
U	22	7	22	22	19	21	15	17	116
V	23	7	19	20	23	22	17	16	117

No sire has the same rank in all classes. Several have the same rank in three classes. The smallest total of the rankings in the six classes indicates the sire having the best general rank.

This method of comparing the merit of several sires for their ability to transmit milk and butterfat producing capacity to their daughters is not without its faults. Probably the most serious fault is in allowing average production of milk and of butterfat to have equal weight with the average increase of milk and butterfat yield and the percentage of daughters that were better than their dams. These last two qualifications would appear to measure fairly the influence of the sire; but the first qualification, the average yield of daughters, may be due to a very great extent to the influence of the dams.

An illustration of the influence that the high average production may have in the final rankings is shown in sires Q, T, M, O, and P, whose final relative rankings are near together. The average productions of milk and butterfat of the daughters of these sires are given in Table 6.

TABLE 6.—*Production of daughters (and their dams) from five sires with comparative rankings shown*

Sire	Rank	Daughters Milk	Daughters Fat	Dams Milk	Dams Fat
		Pounds	*Pounds*	*Pounds*	*Pounds*
Q	14	17,613.6	585.7	17,249.3	589.6
T	15	18,542.0	634.5	18,811.4	685.8
M	16	14,825.2	523.5	14,015.8	492.9
O	17	15,676.6	556.3	14,783.7	543.1
P	18	15,584.6	532.2	16,328.7	525.8

Thus sires Q and T, who decreased the average butterfat yield of their daughters, have a higher ranking than do sires M, O, and P, who increased the average butterfat yield of their daughters. This is brought about largely through the much higher average yield of milk and butterfat of the daughters of the sires Q and T, though the relative ranking among these five sires in the percentage of daughters better than their dams is high for sire Q in both milk and butterfat and for sire T in milk.

Such inconsistencies do not appear in the rankings of the other sires, though the final ranking is not always in the same order as the amount of the average increase or decrease of the daughters for any one class.

THE STANDARD DEVIATION AND COEFFICIENT OF VARIABILITY FOR BUTTERFAT YIELD OF THE DAUGHTERS OF THE 23 SIRES AND OF THEIR DAMS

Judging by the records of the daughters of the 23 sires in this study, it is not to be expected that any sire, at this stage of breed improvement, will get daughters all of which will have the capacity to make uniform records of any certain standard. This is true regardless of how uniform the production records may be of the dams to which a sire is mated. A study of the detailed records given in Table 2 readily shows the great variation in the producing capacity of each sire's daughters. It is not strange that there should be such a great variation when the double nature of the hereditary make-up of each individual is considered and when we realize how few matings are made where the animals are known to be homozygous or pure in their inheritance for the desired characters. If a sire's inheritance for a character, such as milk and butterfat producing capacity, is not homozygous, so that he can not transmit to each of his offspring the same capacity for production, and then if this sire is mated to a group of dams, each of whose 30 ancestors in 4 ancestral generations show varying degrees of producing capacity, it is not surprising that the offspring should show a wide variation in producing ability.

It would seem that a prepotent sire, mated to a group of cows having a considerable range in producing capacity, would get daughters showing greater uniformity of production. The standard deviation [3] and the coefficient of variability of the butterfat yields of daughters, and of their dams, as given in Table 7, does not show that the sires who decrease the coefficient of variability were any more prepotent in increasing production as measured in Table 5, than were the sires who increased the variability of the butterfat producing capacity of their daughters. The dams to which sire N was mated had a standard deviation of 148 pounds butterfat, whereas his daughters had a standard deviation of only 76 pounds butterfat—a decrease in the coefficient of variability from 25.22 per cent for the dams, to 12.57 per cent for the daughters. Yet sire N ranks thirteenth in prepotency for producing capacity as measured in Table 5.

On the other hand sire I's daughters show a standard deviation of 170 pounds butterfat as compared with a standard deviation of only 62 pounds butterfat in their dams. The coefficient of variability is increased from 11.56 per cent for the dams to 26.91 per cent for the daughters. Sire I ranks ninth in prepotency among the 23 sires as measured in Table 5. The daughters of sire E, who ranks first in prepotency for production capacity in Table 5, show a greater coefficient of variation than do their dams. This is also true of the daughters of sire B, who ranks second, but the daughters of sires C, D, and A who rank third, fourth, and fifth, respectively, in Table 5, all show a smaller coefficient of variation than do their dams. Thus it will be seen that greater or less uniformity of production of a sire's daughters as compared with that of their dams is no indication of the sire's prepotency for producing capacity.

The smallest variation of production in butterfat in any group of daughters is found in the daughters of sire U, that have a standard deviation of only 30 pounds butterfat and a coefficient of variation of 6.68 per cent. Sire U ranks twenty-second in the 23 sires for prepotency, according to Table 5. Sire I's daughters show the greatest variation—standard deviation 170 pounds butterfat—in any group of daughters, as well as the greatest increase in coefficient of variation as compared with that of their dams. The daughters of sire G show the second greatest standard deviation among the groups of daughters, with 161 pounds. Sire G ranks eighth among the 23 sires. Neither the greatest nor the least variations among the groups of daughters, nor the amount of variation among daughters as compared with that of their dams, is indicative of the prepotency of the sire in transmitting producing capacity. This will probably be true as long as the sires and dams that are mated are heterozygous in their hereditary factors controlling producing capacity.

TABLE 7.—*Standard deviation and coefficient of variation of butterfat records of the daughters of each of the 23 sires, and of the dams of the daughters; also the increase or decrease of coefficient of variation of the daughters of each sire as compared with that of their dams; and the rankings of the sires as in Table 5*

Sire	Daughters		Dams		Increase or decrease in coefficient of variation	Rank of sires
	Standard deviation	Coefficient of variation	Standard deviation	Coefficient of variation		
	Pounds	*Per cent*	*Pounds*	*Per cent*		
A	90.9	13.81	85.0	18.20	−4.39	**5**
B	131.9	17.69	80.6	13.85	+3.84	**2**
C	100.8	12.81	113.4	17.50	−4.69	**3**
D	95.6	13.88	128.9	22.94	−9.06	**4**
E	103.1	13.15	25.6	3.85	+9.30	**1**
F	144.7	19.03	92.6	14.22	+4.81	**6**
G	161.9	20.34	110.5	11.54	+8.80	**8**
H	68.7	10.42	78.5	13.84	−3.42	**7**
I	170.3	26.91	62.7	11.56	+15.35	**9**
J	158.0	21.48	217.7	33.05	−11.57	**11**
K	107.4	17.25	91.2	16.63	+0.62	**12**
L	99.0	15.88	86.1	14.87	+1.01	**10**
M	47.0	8.98	72.7	14.73	−5.75	**16**
N	76.3	12.57	148.7	25.22	−12.65	**13**
O	136.7	24.58	142.9	26.31	−1.73	**17**
P	95.7	17.98	66.9	12.70	+5.28	**18**
Q	95.8	16.35	80.3	13.61	+2.74	**14**
R	51.5	11.90	63.1	14.25	−2.35	**20**
S	61.0	12.09	64.3	12.00	+0.09	**21**
T	71.2	11.22	35.5	5.16	+6.06	**15**
U	30.2	6.68	78.0	15.28	−8.60	**22**
V	48.5	9.55	77.7	13.66	−4.11	**23**
W	89.4	14.39	61.6	8.59	+5.80	**19**

[3] "Standard deviation" is a term used in statistical calculations to denote a mathematical measure of the variability of the items in a group from the mean, or average, of the whole group. "Coefficient of variation" is an index of variability appearing in the form of rate per cent.

PREPOTENCY OF THE SIRE

The available records do not indicate whether a sire can be completely prepotent in raising the production of his daughters, for the reason that comparatively few of the tested daughters of the various sires have dams that have been tested. Then, too, the lowest-producing daughters of a sire may not be tested, for it is doubtful whether some breeders would test a low-producing daughter of their herd sires. When the dam of a tested daughter does have a record, information is not available to show whether the dam's record was made under as favorable conditions as was the daughter's record. Although the information relative to the conditions under which the dams and daughters were tested is not available, and it is not known whether the poorer-producing daughters of these sires were tested, the information contained in Table 8 should be of interest. It shows the number of each of the 23 sires' daughters that increased and the number that decreased the yield of milk and butterfat, and the percentage of butterfat in the milk as compared with the yields of their dams.

TABLE 8.—*Number of each sire's tested daughters that increased or decreased the milk and butterfat yield and the percentage of butterfat, as compared with their dams*

Sire	Number of daughters with tested dams	Milk yield		Percentage of butterfat		Total butterfat	
		In-creased	De-creased	In-creased	De-creased	In-creased	De-creased
A	5	4	1	4	1	4	1
B	13	11	2	8	5	11	2
C	12	10	2	7	5	9	3
D	9	7	2	4	5	8	1
E	6	6	0	4	2	6	0
F	9	7	2	[1] 4	[1] 4	7	2
G	7	3	4	4	3	5	2
H	6	5	1	2	4	5	1
I	6	4	2	1	5	4	2
J	20	11	9	[1] 15	[1] 4	14	6
K	6	4	2	6	0	5	1
L	11	9	2	2	9	9	2
M	6	4	2	2	4	4	2
N	9	5	4	[1] 3	[1] 5	5	4
O	6	3	3	3	3	4	2
P	6	1	5	5	1	3	3
Q	11	7	4	[1] 3	[1] 7	8	3
R	6	3	3	2	4	2	4
S	7	3	4	3	4	2	5
T	7	4	3	1	6	2	5
U	7	2	5	1	6	1	6
V	7	1	6	5	2	2	5
W	16	5	11	2	14	2	14

[1] One daughter had same test as dam.

In Table 8, the second column gives the number of daughters of each sire that have yearly records and have dams with yearly records. In the column headed "Milk yield" is shown, on the left side, the number of daughters that made larger milk yields than their dams, and on the right side the number of daughters that made smaller yields than their dams. Similar comparisons are given in the columns headed "Percentage of butterfat" and "Total butterfat." In the column headed "Percentage of butterfat," it will be noted that the number of daughters increasing and the number of daughters decreasing the percentage of fat does not always equal the number of tested daughters given in the first column. The difference represents the number of daughters that had same test as their dams.

No sire in this list is completely prepotent; that is, no sire has all his tested daughters better than their dams in yield of milk, percentage of butterfat, and yield of butterfat. Sire E is the only one that increased the milk and butterfat yield of all his tested daughters over the yields of their dams, but only four of his daughters had a higher percentage of butterfat than their dams. Several sires increased the milk yield of a great majority of their daughters. For example, one sire increased the milk yield of 4 out of 5 daughters; another sire increased the milk yield of 11 out of 13 daughters; another 10 out of 12 daughters; another 9 out of 11 daughters; and another 7 out of 9 daughters.

Some sires were also prepotent in decreasing the milk yield; for example, one sire decreased the milk yield of 5 out of 6 daughters; another, 6 out of 7 daughters; another, 11 out of 16; and another, 4 out of 7 daughters.

Four sires were prepotent in influencing the percentage of butterfat in the milk of their daughters. One sire's daughters had higher percentages of butterfat than their dams in every case. On the other hand, two sires had 6 out of 7 daughters with lower percentages of butterfat than their dams, and another sire had 14 out of 16 daughters with lower percentages.

Only nine sires had a majority of their daughters with higher percentages of butterfat than their dams. There were 15 sires that had over half their daughters with a larger yield of milk than their dams, and 16 sires had over half their daughters with a larger yield of butterfat than their dams.

This study indicates that some sires are capable of increasing in the great majority of their daughters both the yield of milk and the percentage of butterfat in the milk over that of the dams. Some sires may increase the yield of milk in the majority of their daughters and decrease the percentage of butterfat. Several sires decreased both yield of milk and percentage of butterfat in the milk. Fewer sires were prepotent in increasing the percentage of butterfat in the milk of their daughters than in increasing the milk yield of their daughters. No sire in the list increased both the milk yield and the percentage of butterfat in the milk of all his daughters, or decreased the milk yield and the butterfat percentage in the milk of all his daughters.

METHOD OF BREEDING AND RECORD OF DAM AS INDICATIONS OF A SIRE'S BREEDING ABILITY

Table 9 shows the 23 sires listed in the order in which they were ranked on the basis of comparative production of milk and butterfat of their daughters, as in Table 7. The record of the dam of each sire is given first. The next column shows whether the sire was inbred, line bred, or outbred; and the last two columns give this same information for his sire and his dam. The figures in the last three columns refer to the popular expression "common blood," meaning the percentage of common ancestry that appeared on the sire's and dam's side of the pedigree in five ancestral generations.

TABLE 9.—*Method of breeding of each of 23 sires and records of their dams*

Sire	Record of his dam			How this bull was bred	How his sire was bred	How his dam was bred
	Time	Milk	Butterfat			
		Pounds	*Pounds*			
E	No record			Line bred (28.1 [1])	Line bred (25 [1])	Line bred (31.2 [1]).
B	7 days	567.9	25.04	Outbred (18.75 [1])	Outbred	Outbred.
C	do	534.5	22.1	Line bred (34.37 [1])	Inbred (50 [1])	Line bred (25 [1]).
D	do	545.1	22.1	Line bred (34.37 [1])	Outbred	Outbred.
	1 year	20,174.6	724.7			
A	7 days	539.1	10.5	Outbred	Line bred (43.75 [1])	Do.
F	do	638.7	21.4	Inbred (56.24 [1])	Line bred (25 [1])	Inbred (50 [1]).
H	do	520.1	20.2	Outbred	Outbred	Outbred.
G	do	568.9	20.0	do	Line bred (26.31 [1])	Do.
I	do	707.6	24.6	do	Outbred	Do.
L	do	480.3	24.7	do	do	Do.
J	do	535.4	28.4	do	Outbred (18.75 [1])	Outbred (18.75 [1]).
	1 year	15,972.2	593.8			
K	No record			Outbred	Outbred	Outbred.
N	7 days	523.7	16.7	Line bred (28.12 [1])	do	Line bred (43.75 [1]).
Q	No record			Outbred	do	Outbred.
T	7 days	469.2	14.4	do	do	Do.
M	7 days	478.0	19.2	Line bred (31.25 [1])	do	Do.
	1 year	[2] 16,679.0	[2] 522.5			
O	7 days	437.6	15.87	Inbred (65 [1])	Line bred (21.87 [1])	Line bred (25 [1]).
P	do	533.6	21.0	Outbred	Outbred	Outbred.
W	do	581.7	22	Inbred (62.49 [1])	do	Inbred (75 [1]).
R	do	558.5	20.4	Outbred	do	Outbred.
S	do	514.1	20.3	Outbred (12.5 [1])	do	Do.
V	do	437.1	16.2	Outbred	do	Do.
U	do	423.7	19.42	Line bred (31 [1])	do	Do.

[1] Per cent common blood. [2] At 11 years 1 month

On the basis of the dam's records one would hardly be able to select the best breeding sire from the first group of 10. These records, however, average higher than the records of the dams of the 10 poorest sires. The records of the dams of the 10 poorest sires do not follow any more closely the ranking of the sire according to merit than is the case with the 10 best sires.

It is hardly to be expected that the mere fact of an individual, his sire, or his dam, being line bred or inbred would cause him to be more prepotent than if he were outbred; that is, without any concentration of blood lines. In order that the line breeding or inbreeding may have a favorable effect on prepotency it would seem necessary that the individual which appears more than once in the ancestry be an animal of superior breeding ability. It is a common belief, however, that the mere fact that a sire is outbred militates against the chances of his being prepotent. Three of the five sires heading the list in Tables 7 and 9 were line bred, the second and fifth each being outbred. Fourteen of the 23 sires are classed as outbred. Six of the first 10 sires are in this class and 6 of the last 10 sires are also classed as outbred.

The pedigree of any individual is only an indication of what the transmitting ability of that individual, for milk and butterfat production, may be. Until such time as we have pedigrees in which the sires have a sufficient number of tested daughters from tested dams, so that their breeding performance can be analyzed, as has been done with these 23 sires, predictions can not be made with much certainty as to the transmitting ability of any untried individual. When animals are produced with pedigrees in which all the sires for several generations have ability to transmit, such as sires E, B, and C displayed, then it will be fairly certain that the majority of the bulls

bred will be prepotent. It is more difficult to judge the transmitting power of the dams, because of their limited number of offspring, and also because very often many of the offspring will be by one sire. On the other hand, the sire has a considerable number of offspring, usually from different dams, so that his transmitting ability can be more accurately gauged.

A sire's transmitting ability is determined by the chance inheritance of factors governing production, which he received at the time of his conception. Should he by chance have received all his inheritance governing production from some of his ancestry which carried only factors for low production, then he will transmit only low production to his offspring, regardless of how many high-producing ancestors he may have.

Once a bull has proved himself to be a poor sire it would seem that there is little chance of his transmitting any of the ability of his more worthy ancestors.

WHICH PARENT HAS THE GREATER INFLUENCE ON MILK YIELD, BUTTERFAT PERCENTAGE, AND BUTTERFAT YIELD?

A study was made of the correlation between the daughters and their dams, with respect to total yield of butterfat, for each of 23 sires having 6 or more tested daughters from tested dams. The results of this study are shown in Table 10. The correlation coefficients range from -0.39 for sire N to $+0.90$ for sire P.[4]

[4] Perhaps a brief explanation of the meaning of correlation should be made before discussing Table 10. A correlation coefficient shows to what extent the variation in one character follows or is coordinated with the variation in some other character. For example, many are of the opinion that in order to get high production in dairy cows we must have large cows If this assumption is true, then there should be a positive correlation with respect to production and size. If milk and butterfat were produced more economically with small cows then there would be a negative correlation with respect to economical production and size. Or, a correlation coefficient may indicate to what degree the same character, such as yield of milk or butterfat, exists between parent and offspring; and that is the thing intended to be determined in this table.

This relation of the yield of milk and butterfat between parent and daughters is expressed as a coefficient. If a high yield of milk or fat in the dam is followed by a correspondingly high yield in the daughter, the correlation would be perfect and the coefficient would be 1. If, on the other hand, the highest-yielding daughters all came from the lowest-yielding dams, and the lowest-yielding daughters all came from the highest-yielding dams, then there would be a perfect negative correlation and the coefficient would be -1. Again, if there is no relation between the yield of the daughter and the yield of her dam, indicating that there is no correlation, then the coefficient would be 0. It is seldom that a perfect correlation is found; usually the correlation is between 0 and $+1$, or between 0 and -1.

The correlation coefficient is arrived at by a rather complicated mathematical formula. It expresses in mathematical terms the extent of the relation which exists between two characters, or the extent to which a character is common to two individuals. If the coefficient is low, it indicates that there is very little relation; if it is high, there is a close relationship; and if it is so high as to indicate a perfect correlation, then it may be said that one is probably the cause of the other. The correlation coefficient when expressed in writing is followed by the probable error; that is, the amount to be added to or subtracted from the correlation coefficient to get the two limiting figures within which there is an even chance that the true value will lie.

The following rules are suggested in Babcock and Clausen (*2*) for the interpretation of coefficient of correlation:

1. If r (the coefficient of correlation) is less than the probable error, there is no evidence whatever of correlation.
2. If r is more than six times the size of the probable error, the existence of correlation is a practical certainty.
3. In cases where the probable error is relatively small:
   a. If r is less than 0.3, the correlation can not be considered at all marked.
   b. If r is above 0.5, there is decided correlation.

TABLE 10.—*Correlation between daughters of each sire and their dams with respect to total yield of butterfat*

Sire	Number of daughters with yearly records	Average production of butterfat		Standard deviation				Correlation between daughters and dams
		Daughters	Dams	Daughters		Dams		
		Pounds	*Pounds*					
A	5	657.9	466.9	90.9	±19.3	85.0	±18.1	−0.09±0.30
B	13	745.3	581.5	131.9	±17.4	80.6	±10.7	−0.23±0.18
C	12	786.6	647.9	100.8	±13.9	113.4	±15.6	+0.17±0.19
D	9	688.7	562.4	95.6	±15.2	128.9	±20.5	+0.60±0.14
E	6	783.9	663.5	103.1	±20.1	25.6	±5.0	+0.15±0.27
F	9	760.3	651.3	144.7	±23.0	92.6	±14.7	+0.71±0.11
G	7	795.9	697.2	161.9	±29.2	110.5	±19.9	+0.43±0.21
H	6	659.4	567.0	68.7	±13.4	78.5	±15.3	+0.48±0.21
I	6	632.8	541.8	170.3	±33.2	62.7	±12.2	+0.47±0.22
J	20	735.3	658.7	158.0	±16.8	217.7	±23.2	+0.34±0.13
K	6	622.2	548.3	107.4	±20.9	91.2	±17.8	+0.67±0.15
L	11	623.6	578.8	99.0	±14.2	86.1	±12.4	+0.71±0.10
M	6	523.5	492.9	47.0	±9.2	72.7	±14.2	−0.22±0.26
N	9	607.2	589.7	76.3	±12.1	148.7	±23.6	−0.39±0.19
O	6	556.3	543.1	136.7	±26.6	142.9	±27.8	+0.51±0.30
P	6	532.2	525.8	95.7	±18.6	66.9	±13.0	+0.90±0.05
Q	11	585.7	589.6	95.8	±13.8	80.3	±11.5	−0.15±0.20
R	6	432.3	442.7	51.5	±10.0	63.1	±12.3	+0.66±0.16
S	7	503.8	536.0	61.0	±11.0	64.3	±11.6	+0.09±0.25
T	7	634.5	685.8	71.2	±12.8	35.5	±6.4	−0.27±0.24
U	7	452.3	510.5	30.2	±5.5	78.0	±14.1	−0.23±0.24
V	7	508.0	568.5	48.5	±8.7	77.7	±14.0	+0.06±0.25
W	16	621.2	693.5	89.4	±10.7	61.6	±7.3	+0.06±0.16

The number of tested daughters that these 23 sires have is rather small for the determination of a coefficient of correlation that is really indicative. A study of the coefficients of correlation between the daughters and their dams indicates that with the daughters of three sires there is a marked correlation. These three decided correlations are between the daughters and their dams of sire L (+0.71 ±0.10), sire F (+0.71 ±0.11), and sire P (+0.90 ±0.05). The last is the most significant of the three. In Table 2 it may be noted how closely both the milk and butterfat yields of the daughters of sire P follow those of the dam (from the highest daughter out of the highest dam down to the lowest daughter out of the lowest dam). The ranking of the records of the dams according to size of record does not follow that of the daughters so closely with the other two sires, though the similarity of sequence is very apparent.

The daughters of four other sires show evidence of correlation with their dams with respect to yield of butterfat, though the probable error is rather high. These four sires are: Sire D (+0.60 ±0.14); sire H (+0.48 ±0.21); sire K (+0.67 ±0.15); sire R (+0.66 ±0.16).

A study of the records of the daughters of these bulls and their dams indicates somewhat the same general ranking of the dams' records with reference to size as that of the daughters; for instance, with 2 of the 4 sires the lowest-record daughter is out of the lowest-record dam, and with 3 of the 4 sires the highest-record daughter is out of the highest-record dam.

Of the three sires whose daughters have a distinct correlation with their dams relative to butterfat yield, all have daughters with a greater average yield than their dams, though in the case of the daughters of sire P this average increase amounts to only 6.4 pounds, whereas the average milk yield of his daughters is somewhat less than that of their dams. The four sires whose daughters show evidence of correlation have daughters with rather a large average increase in both milk and butterfat yield over their dams, excepting in the case of sire R, whose daughters show a decrease in butterfat, owing to a lower percentage of fat in the milk. With sires whose daughters had smaller average yields of butterfat than their dams, the daughters show no correlation at all with their dams with respect to butterfat yield.

Does the correlation coefficient indicate the relative influence of the parent on the offspring? Does the fact that the daughters of sire P show a correlation of +0.90 to their dams in butterfat yield indicate that the dams had far greater influence on their producing capacity than did sire P? Where there is no significant correlation between daughters and dams, meaning that the size of a daughter's record does not have any particular relation to the size of her dam's record, does this indicate that the sire is exerting greater influence on the producing capacity of the daughters than are the dams? If so, what would a marked negative correlation indicate, a case where the lowest-producing daughters were from the highest-producing dams, and the highest-producing daughters from the lowest-producing dams? The daughters of sire N are the only ones showing any significant negative correlation, though the probable error is so great as to neutralize its significance. The relative rank of the coefficients of correlation of the daughters of each sire to their dams in butterfat yield is shown in Table 11, and in comparison is shown the relative rank among the 23 sires as given in Table 5. The sires are ranked in this table according to the size of the coefficient of correlation without regard to the significance of the probable error. It should also be remembered that in ranking the sires in Table 5 milk yield as well as butterfat yield were considered.

TABLE 11.—*Rank of sires according to coefficient of correlation between daughters and dams with respect to butterfat production, and the comparative ranking of sires as in Table 5*

Sire	Coefficient of correlation of daughters to dams	Rank of sires in Table 5	Sire	Coefficient of correlation of daughters to dams	Rank of sires in Table 5
P	+0.90 ±0.05	18	E	+0.15 ±0.27	1
F	+0.71 ±0.11	6	S	+0.09 ±0.25	21
L	+0.71 ±0.10	10	W	+0.06 ±0.16	19
K	+0.67 ±0.15	12	V	+0.06 ±0.25	23
R	+0.66 ±0.16	20	A	−0.09 ±0.30	5
D	+0.60 ±0.14	4	Q	−0.15 ±0.20	14
O	+0.51 ±0.30	17	M	−0.22 ±0.26	16
H	+0.48 ±0.21	7	U	−0.23 ±0.24	22
I	+0.47 ±0.22	9	B	−0.23 ±0.18	2
G	+0.43 ±0.21	8	T	−0.27 ±0.24	15
J	+0.34 ±0.13	11	N	−0.39 ±0.19	13
C	+0.17 ±0.19	3			

The sires in Table 11, ranked according to the size of the apparent correlation coefficients of their daughters with respect to butterfat yields, are divided in Table 12 into the three following groups:

(1) Eight sires in group, from sire P, coefficient of correlation +0.90 to sire H, coefficient of correlation +0.48.

(2) Eight sires in group, from sire I, coefficient of correlation +0.47, to sire V, coefficient of correlation +0.06.

(3) Seven sires in group, from sire A, coefficient of correlation −0.09, to sire N, coefficient of correlation −0.39.

In each group, the sires are arranged in the order of their ranks as found in Table 5, and with each sire is given the average increase or decrease in pounds of butterfat.

TABLE 12.—*Sires divided into three groups according to correlation of daughters and dams, showing increase or decrease in butterfat production of daughters (each group in order of ranking)*

Group 1			Group 2			Group 3		
Sire		Change in butterfat production	Sire		Change in butterfat production	Sire		Change in butterfat production
Letter	Rank		Letter	Rank		Letter	Rank	
		Pounds			*Pounds*			*Pounds*
D	4	+126.3	E	1	+120.4	B	2	+163.8
F	6	+109.0	C	3	+138.7	A	5	+191.0
H	7	+92.4	G	8	+98.7	N	13	+17.5
L	10	+44.8	I	9	+91.0	Q	14	−3.9
K	12	+73.9	J	11	+76.6	T	15	−51.3
O	17	+13.2	W	19	−72.3	M	16	+30.6
P	18	+6.4	S	21	−32.2	U	22	−58.2
R	20	−10.4	V	23	−60.5			

In Group 1, where the apparent correlation between daughters and dams with respect to butterfat yield is most marked, and where it might have been expected that the dams were exerting greater influence than the sires on the producing capacity of the daughters, the sires are found to be fully as effective in increasing the producing capacity of their daughters as are the sires in Group 2, where apparently little correlation between the daughters and the dams exists, or in Group 3, where the correlation between daughters and dams is apparently negative. Indeed, some of the best and some of the poorest sires are found in each group.

In this study the fact that the records of the daughters of a sire do or do not follow the relative size of the records of their respective dams seems to indicate nothing as to the relative influence of the sire and dams on the daughter's producing capacity.

TABLE 13.—*Rank of 23 sires according to the average yield of butterfat of their daughters, and rank of same sires according to yield of milk of their daughters*

Sire	Average butterfat yield		Sire	Average milk yield	
	Daughters	Dams		Daughters	Dams
	Pounds	*Pounds*		*Pounds*	*Pounds*
G	795.9	697.2	E	23,467.4	20,044.4
C	786.6	647.9	C	22,074.6	18,670.2
E	783.9	663.5	F	21,755.4	18,854.1
F	760.3	651.3	D	21,351.3	17,580.9
B	745.3	581.5	B	21,273.8	17,138.5
J	735.3	658.7	G	20,137.4	19,066.0
D	688.7	562.4	J	20,034.8	18,912.1
H	659.4	567.0	H	19,872.9	16,957.2
A	657.9	466.9	A	19,575.7	14,464.8
T	634.5	685.8	I	19,128.4	15,467.7
I	632.8	541.8	T	18,542.0	18,811.4
L	623.6	578.8	L	18,305.6	15,978.0
K	622.2	548.3	W	17,855.1	18,880.6
W	621.2	693.5	Q	17,613.6	17,249.[illegible]
N	607.2	589.7	K	17,418.4	16,355.7
Q	585.7	589.6	N	16,822.9	14,907.5
O	556.3	543.1	O	15,676.6	14,783.7
P	532.2	525.8	P	15,584.6	16,328.7
M	523.5	492.9	V	15,454.4	17,564.2
V	508.0	568.5	M	14,825.2	14,015.8
S	503.8	536.0	R	14,175.6	13,991.4
U	452.3	510.5	U	14,046.7	14,666.0
R	432.3	442.7	S	14,009.2	15,117.9

The ranking of these sires in the order of average butterfat yield does not place them in the same order as when they are ranked according to the average milk yield. Table 13 shows that the better-producing daughters were on the average out of the better-producing dams.

It will be noted that there is a gradual decline in average milk yield of the dams in somewhat the same order as that of the daughters, though the decline is not uniform. The average production of butterfat of the daughters of the 10 sires at the head of the list is 724 pounds, and the average production of their dams is 618 pounds. The average production of the daughters of the 10 sires at the bottom of the list is 532 pounds and the average production of their dams 549 pounds. The same comparison holds with the milk yield, showing that on the average the sires at the head of the list were mated with better cows than the sires at the bottom of the list, and that the dams as well as the sires are contributing to the inheritance that determines the producing capacity of the daughters.

The number of cases, however, in which sires raise or lower the production of the great majority of their daughters (see Table 2) regardless of the production of their dams, apparently indicates that if the sire is homozygous for the factors that govern high or low milk yield he is likely to have more influence on the production of a group of daughters than have the dams, because of the probability of some or all the dams being heterozygous in their inheritance governing production capacity.

Even in the case of the sire who improves approximately half his daughters and lowers the production of the other half, the production of neither the poorer nor the better daughters seems to follow very closely that of the dams. Take the case of sire N; 5 of his 9 daughters are better than their dams and the other 4 are poorer. Here there is something of a negative correlation between the daughters and their dams with respect to production; that is, his better daughters on the whole are from the lower-producing dams and his lower-producing daughters from the higher-producing dams.

In the list of a small number of daughters of a sire, the production of the daughters may not follow very closely that of the dams, owing perhaps to the sire's being more homozygous for the factors that will govern high-producing ability than the dams with which he is mated. But when a large number of daughters and dams are considered, the higher-producing daughters will as a rule be found to have good dams. This is to be expected, for the high-producing dam is certain to have at least a part, if not all, of her germinal factors governing production, those that will determine high production, and she will therefore transmit high production to a part or all of her offspring.

The evidence seems to point to both parents' contributing equally to the inheritance governing the milk and butterfat producing capacity of their daughters. But if one parent is homozygous or pure for the hereditary factors determining high production and the other parent is heterozygous in its inheritance, then the homozygous parent will have the greater influence on the producing capacity of the daughter; yet this daughter will transmit to a part of her progeny the inheritance for low production that she may receive from her heterozygous parent. From two heterozygous parents, it is to be expected that the daughters will show a great range in producing capacity, from very poor to very good.

THE PERCENTAGE OF BUTTERFAT

Roberts (*3*) found a significant negative correlation between the percentage of butterfat and the yield of milk for Jerseys, Guernseys, and Holsteins, but did not find so significant a correlation for Ayrshires. That is, as the yield of milk increased, the percentage of butterfat in the milk decreased. Wilson (*4*) studying Ayrshire records, concluded that the yield of milk and the percentage of butterfat were independent of each other. Pearson (*5*) also found a small but significant negative correlation between percentage of butterfat and yield of milk.

The material for the study by Roberts was made up largely of advanced-register and register-of-merit records of the various breeds. The animals in each breed were classed according to age, and the correlation was between the milk yield and the percentage of butterfat for the group of animals in each class. The negative correlation was significant for the Jerseys and Guernseys; but the coefficient for the Holsteins, when judged by the probable error, was not significant in any of the classes.

Evidence on the question whether a bull which has the ability to increase the milk yield of his daughters can also increase the percentage of butterfat in the milk, or whether if he increases the milk yield he will decrease the percentage of butterfat (as is indicated in the results obtained by Roberts with Jersey and Guernsey records), is offered in Tables 14 and 15. These tables show that most of the sires making the greatest increase in milk yield also increased the average percentage of fat very materially, whereas a few sires that increased the average milk yield of their daughters decreased the percentage of fat. Several sires whose daughters showed an average decrease in milk yield also had a decrease in percentage of fat. In those cases where the daughters showed the greatest decline in milk yield (see sires S and V), the increase in percentage of fat was very small. In the daughters of sire G, the sire showing the greatest average increase in percentage of fat, there was an average increase in milk, as was also the case with the daughters of sire N, the sire showing the greatest decrease in percentage of fat. These data show that the percentage of fat and the milk yield in Holstein-Friesian cattle are inherited independently, and that it is entirely possible for a sire to increase both the milk yield and the percentage of butterfat.

TABLE 14.—*Sires with daughters showing greatest percentage increase in milk yield and their percentage increase or decrease in butterfat test*

Sire	Average increase (+) or decrease (−) in milk yield of daughters compared with dams	Average increase (+) or decrease (−) of daughters compared with dams in fat test	Sire	Average increase (+) or decrease (−) in milk yield of daughters compared with dams	Average increase (+) or decrease (−) of daughters compared with dams in fat test
	Per cent	*Per cent*		*Per cent*	*Per cent*
A	+35.3	+4.02	J	+5.9	+5.46
B	+24.1	+3.24	M	+5.8	+0.28
I	+23.7	−5.43	G	+5.6	+7.92
D	+21.4	+0.94	Q	+2.1	−2.63
C	+18.2	+2.59	R	+1.3	−3.48
H	+17.2	−0.60	T	−1.4	−6.30
E	+17.1	+0.91	U	−4.2	−7.47
F	+15.4	+1.16	P	−4.6	+5.90
L	+14.6	−5.80	W	−5.4	−5.18
N	+12.8	−8.84	S	−7.3	+1.41
K	+6.5	+6.57	V	−12.0	+1.54
O	+6.0	−3.27			

TABLE 15.—*Distribution of daughters of each sire with respect to corresponding increases and decreases in both yield of milk and percentage of butterfat*

Sire	Number of daughters				
	Total	Yield of milk increased; percentage of butterfat increased or left unchanged	Yield of milk increased; percentage of butterfat decreased	Yield of milk decreased; percentage of butterfat increased or left unchanged	Yield of milk decreased; percentage of butterfat also decreased
A	5	3	1	1	0
B	13	8	3	0	2
C	12	5	5	2	0
D	9	4	3	1	1
E	6	4	2	0	0
F	9	3	4	2	0
G	7	2	1	2	2
H	6	1	4	1	0
I	6	0	4	1	1
J	20	8	3	8	1
K	6	4	0	2	0
L	11	1	8	1	1
M	6	1	3	1	1
N	9	3	2	1	3
O	6	1	2	2	1
P	6	0	1	5	0
Q	11	2	5	2	2
R	6	1	2	1	2
S	7	0	3	3	1
T	7	1	3	0	3
U	7	0	2	1	4
V	7	0	1	5	1
W	16	0	5	2	9
Total	198	52	67	44	35

In those daughters where both the milk yield and the percentage of butterfat were increased over those of their dams, and in those daughters where both the milk yield and the percentage of butterfat were lower than those of their dams, there may be said to be evidence of a positive correlation between the yield of milk and percentage of butterfat. That is, the percentage goes up or down with the yield of milk, though whether or not in the same ratio only a correlation coefficient would determine.

On the other hand, in those daughters whose percentage of butterfat increased, but the milk yield decreased, and in those daughters whose percentage of butterfat decreased and the milk yield increased, there may be said to be evidence of a negative correlation. That is, as the milk yield increases the percentage of butterfat decreases, and as the milk yield decreases the percentage of butterfat increases.

Of the 198 daughters of these 23 sires (Table 15), 52 are better than their dams in milk yield and as good in percentage of butterfat; 67 have a larger milk yield and a lower percentage of butterfat than their dams; 44 have a lower milk yield and either an increased or an equivalent percentage of butterfat as compared with their dams; and 35 have both a lower milk yield and a lower percentage of butterfat than their dams. This would seem to offer fairly good evidence that the milk yield and the percentage of butterfat are independent in Holstein-Friesian cattle, though the total number of daughters inclined toward a negative correlation, 111, is somewhat greater than that of those inclined toward a positive correlation, 87. The uniform distribution of the daughters of each sire in these several classes would seem to indicate that but few of these sires were prepotent in controlling the percentage of butterfat. No sire has all his daughters in any one of these classes, and only four sires have their daughters in only two classes, whereas nine sires have their daughters in all four classes.

Coefficients of correlation between the daughters of 23 sires and their dams, with respect to percentage of butterfat, are given in Table 16. These indicate the extent to which high or low production in the dam is followed by similar production in the daughter. The correlation coefficients range from −0.39 for sire N to +0.98 for sire H.

Table 16.—*Correlation between daughters and dams relative to per cent of butterfat*

Sire	Number of daughters	Correlation of daughters to dams: Coefficient	Correlation of daughters to dams: Probable error	Sire	Number of daughters	Correlation of daughters to dams: Coefficient	Correlation of daughters to dams: Probable error
A	5	−0.07	±0.30	M	6	+0.93	±0.04
B	13	+0.49	±0.14	N	9	−0.39	±0.19
C	12	+0.34	±0.17	O	6	+0.65	±0.16
D	9	+0.32	±0.20	P	6	+0.59	±0.18
E	6	+0.49	±0.21	Q	11	+0.11	±0.20
F	9	+0.75	±0.10	R	6	+0.94	±0.03
G	7	+0.31	±0.23	S	7	+0.75	±0.11
H	6	+0.98	±0.01	T	7	+0.06	±0.25
I	6	+0.47	±0.21	U	7	−0.06	±0.25
J	20	+0.15	±0.15	V	7	+0.79	±0.09
K	6	+0.52	±0.20	W	16	+0.56	±0.12
L	11	−0.001	±0.20				

Because the daughters of most of these sires are so few in number, allowance should be made in interpreting the coefficients derived.

There is a significant correlation between the daughters and their dams with respect to percentage of butterfat in the cases of the following seven sires (Table 17):

Table 17.—*Sires between whose daughters and their dams there is a significant correlation*

Sire	Correlation	Sire	Correlation
F	+0.75 ±0.10	S	+0.75 ±0.11
H	+0.98 ±0.01	V	+0.79 ±0.09
O	+0.65 ±0.16	M	+0.93 ±0.04
R	+0.94 ±0.03		

This marked correlation is easily seen when the percentages of butterfat of daughter and of dam are placed side by side and ranked according to the size of the daughters' tests, as shown in Table 18 for the daughters of sires S, H, and R.

Table 18.—*Percentage of butterfat of daughters of sires S, H, and R, and their dams, showing positive correlation*

Sire	Daughters	Dams	Sire	Daughters	Dams	Sire	Daughters	Dams
	Per cent	*Per cent*		*Per cent*	*Per cent*		*Per cent*	*Per cent*
S	4.30	4.44	H	3.75	3.72	R	3.40	3.53
	4.00	3.88		3.66	3.74		3.31	3.25
	3.88	3.22		3.37	3.39		3.23	3.33
	3.44	3.37		3.13	3.14		3.20	3.53
	3.28	3.63		3.04	3.08		2.75	2.74
	3.27	3.34		3.01	2.92		2.61	2.74
	3.18	3.24						

These figures show, as does the coefficient of correlation, that the butterfat test of the daughters of these sires follows very closely that of their dams. The average percentage of butterfat of the daughters was very close to the average percentage of butterfat of the dams, with each of these three sires. The average percentage of butterfat of the daughters of sires R and H were slightly less than the average of the dams, whereas the average for the daughters of sire S was slightly greater. On the other hand a comparison of tests of the daughters of other sires and their dams shows that the test of the daughters does not follow that of their dams. The comparative tests of the daughters of the two sires G and J and their dams, shown in Table 19, illustrate this point.

Table 19.—*Per cent of butterfat of daughters of sires G and J and their dams, showing no correlation*

Sire	Daughters	Dams	Sire	Daughters	Dams
	Per cent	*Perc ent*		*Per cent*	*Per cent*
G	4.39	3.83	J (continued)	3.70	3.58
	4.31	4.30		3.70	4.01
	4.25	3.61		3.66	3.60
	4.21	3.25		3.61	3.70
	3.81	3.88		3.59	3.29
	3.43	3.60		3.59	3.29
	3.32	3.52		3.55	3.55
J	4.29	3.42		3.55	3.33
	4.14	3.55		3.48	3.46
	4.04	3.46		3.44	3.42
	3.80	3.61		3.40	3.46
	3.79	3.45		3.39	3.27
	3.78	3.59		3.24	3.60
	3.77	3.28			

The daughters of sire N show stronger indications of a negative correlation with respect to percentage of butterfat between daughters and dams than the daughters of any other sire. To some extent this is also true of his daughters with respect to their milk yield and butterfat yield, as stated before. The comparative percentages of butterfat of his daughters and their dams are shown in Table 20.

TABLE 20.—*Percentage of butterfat of daughters of sire N and their dams, indicating negative correlation*

Sire	Daughters	Dams	Sire	Daughters	Dams	Sire	Daughters	Dams
	Per cent	*Per cent*		*Per cent*	*Per cent*		*Per cent*	*Per cent*
N	3.87	3.81	N	3.75	4.41	N	3.40	3.54
	3.78	3.54		3.71	3.71		3.38	4.32
	3.77	3.55		3.48	3.94		3.33	4.41

It will be observed that, in general, the higher-testing daughters of sire N come from the lower-testing dams and the lower-testing daughters from the higher-testing dams.

WHICH PARENT HAS THE GREATER INFLUENCE ON THE PERCENTAGE OF BUTTERFAT?

There are a larger number of significant correlation coefficients between dams and daughters with respect to percentage of butterfat than with respect to fat yield. As explained under fat yield, it is doubtful to what extent a significant correlation indicates dependence on either parent, because of the lack of homozygosity of the parents for yield or percentage of fat. There are other indications than the correlation coefficient showing that the dams do contribute to the daughters' inheritance for percentage of fat. A study was made of all dams to which these sires were mated that had extremes of percentage of butterfat of 3.3 or below, and 3.8 or above, and the percentage of butterfat of the daughters of the dams in these two classes. There were 57 dam-daughter pairs, representing 19 sires, in the class for dams having 3.3 per cent butterfat or less. The average percentage of fat for these 57 dams and daughters was 3.155 for the dams and 3.314 for their daughters. There were 33 dam-daughter pairs representing 13 sires in the class for dams having 3.8 per cent or over. The average percentage of fat for these 33 dams and daughters was 3.966 for the dams and 3.633 for the daughters. This would seem to show that the dams do contribute to the inheritance for the percentage of fat of their daughters. It further shows, as does Table 15, that the sires also contribute to the inheritance of their daughters for percentage of fat.

The tables giving the production records of the daughters of each sire and their dams have seemed to show that the daughters' percentage of fat follows that of the dams fairly closely. This might be due to the following reasons:

(1) There may be less variability in the percentage of fat than in the milk yield.

(2) The inheritance for percentage of fat may be better fixed (purer) than is the inheritance for the milk yield.

The fact that the percentage of fat and the milk yield are inherited independently, at least within limits, and that both the sire and dam contribute to the inheritance of their daughters, governing both milk yield and percentage of fat, indicates that improvement in yield of butterfat can be brought about by selection for both milk yield and percentage of fat.

SUMMARY

A study of the transmitting ability for milk yield, percentage of butterfat, and butterfat yield, of 23 Holstein-Friesian sires each having six or more daughters with yearly records, out of dams with yearly records, brought out the following results:

1. A remarkable variation between the records of the daughters of any sire and their dams is evidenced. Prepotency in a sire is not indicated by the size of the coefficient of variability of his daughters.

2. No sire in the list shows a complete prepotency in raising or lowering both the milk yield and the percentage of butterfat of all his daughters. Some sires are capable of raising both the milk yield and the percentage of butterfat; some raise one and lower the other; and some lower both. Not so many sires are prepotent in increasing the percentage of butterfat as are prepotent in increasing the milk yield.

3. The coefficient of correlation for butterfat yield between daughters and dams varies widely for the different sires, regardless of whether the daughters of the sires are better or poorer than their dams. For only three sires is there a marked correlation; one of these sires has daughters that made an average increase of some 15 per cent in both milk and butterfat production over their dams; another of these three sires had daughters that showed an average increase of 14.6 per cent in milk, but owing to a decrease in percentage of butterfat, there was only about half that average increase in total butterfat; the third sire's daughters varied little from their dams in the production of either milk or butterfat.

The fact that there is a correlation between the daughters and their dams with respect to yield of milk and butterfat does not mean that the sire is not prepotent in either raising or lowering the yield. It only indicates that where a number of daughters and dams are considered, the record of the daughter will be of the same relative size as that of her dam, though it may be larger or smaller. For instance, if a sire is mated with a cow of 10,000 pounds capacity and to another cow of 20,000 pounds capacity, the daughter of the first cow is likely to be in the 10,000 class, though she may produce from 8,000 to 12,000 pounds, depending upon the germinal make-up of the sire with reference to milk yield; the daughter from the second cow is likely to be in the 20,000-pound class, though she may produce from 16,000 to 24,000 pounds.

4. When the records of a large number of daughters are compared with the records of their dams there is a limited correlation or a tendency for the high-record daughters to come from high-record dams. The breeding record of each individual sire indicates, however, that a sire may be prepotent in increasing the milk yield and decreasing the percentage of butterfat of his daughters as compared with the production of their dams, or he may be prepotent in lowering

the yield of milk and increasing the percentage of butterfat, or he may be prepotent in either raising or lowering both the milk yield and the percentage of butterfat.

This ability of the sire seems to depend upon the combination of factors governing the yield of milk and percentage of butterfat that he has inherited from his parents. If he is homozygous for dominant factors that will determine high milk yield and high percentage of butterfat, he will be prepotent in impressing these characters on his offspring. If he and the dams he is mated with are heterozygous for these factors, as most sires and dams are, a variety of combinations in the different offspring will follow, and they will be of varying degrees of producing ability.

5. The percentage of butterfat and the milk yield seem to be inherited independently in Holstein-Friesian cattle. This is contrary to the findings of other investigators. The theory generally accepted is that, as the milk yield increases, there will be a decrease in the percentage of butterfat. Though this study showed that in the majority of cases there was a tendency toward a negative correlation, there was a sufficient number showing a tendency toward a positive correlation to indicate that the two are independent of each other. It is also shown that it is possible for a sire to increase both the milk yield and the percentage of butterfat of his daughters.

6. A great sire of production is one whose daughters have a high average yield of milk and butterfat, a high average increase in milk and butterfat yield over the yield of their dams, and a high percentage of their number better than their dams. All these things must be considered. No one of them alone offers sufficient evidence of the sire's worth. The production of each sire's daughters must be considered in comparison with the production of other sires' daughters. Provided a sufficient number of tested daughters are available for each sire the ranking system shown in this bulletin seems to indicate the comparative merit of the sires in a group.

7. The production records of the dams of the 10 highest-ranking sires average higher than the records of the dams of the 10 lowest-ranking sires. In neither of these cases, however, does the rank of the sire follow the size of the record of his dam.

8. Six of the 10 highest-ranking sires and 6 of the 10 lowest-ranking sires are classed as outbred. This seems to indicate that the mere fact that an individual, his sire, or his dam, is line bred, inbred, or outbred is not indicative of the prepotency of that individual for high production.

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1926