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A Comparison of Daughters of Sires in Artificial Breeding at Different Levels of Management

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A COMPARISON OF DAUGHTERS OF SIRES IN ARTIFICIAL

BREEDING AT DIFFERENT LEVELS OF MANAGEMENT

by

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INTRODUCTION

One of the largest problems facing the successful dairyman of today is selection of proper sires to mate to his high producing cows. Many breeders and dairymen have the impression that proven sires will give the same increase in production regardless of the dam's production or the level of environment present. Even though sires come from high producing herds, some as high as 600 pounds of butterfat, the average production of all cows in the state of Utah remains at a much lower figure. The average for all cows in Utah is about 250 pounds of butterfat and the average in 1958 of cows on Dairy Herd Improvement test was 403 pounds. This difference in level of production may be attributed to either genetic or environmental factors and possibly an interaction of the two. Most workers agree that the heritability estimates for milk production and fat yield are from .2 to .3. This means that about 25 per cent of the variance in milk yield is due to inheritance, and the other 75 per cent is due to management or environment. Therefore, there is a need to study daughters of the same sire at various levels of production to determine the amount of increase or decrease found at these levels.

This thesis presents a study of daughters of Holstein sires used in artificial breeding. Sires in artificial breeding were used because they have a larger number of daughters, and their daughters come from a wide range of production and management levels.

REVIEW OF LITERATURE

Heritability of Dairy Characters

Heredity as defined by Rice (21) is the resemblance, derived from the ancestry, among organisms related by descent. Heritability then, could be defined as that portion of the variance between two closely related individuals that is a direct result of the genetic makeup of the animals involved. Legates (11) defines it as the degree to which the observed superiority or inferiority of a group of animals selected as parents is transmitted to their progeny.

Heretability is assigned a value of 0 to 1, with characteristics due entirely to environmental influences given a value of 1. The heritability value assigned to butterfat production is usually found to be from .2 to .3. Lush and Straus (16) in some of their studies found it to go as low as .174. "If this .174 is accepted at its face value it indicates that two cows, chosen on the basis of one record each, will probably differ in their breeding values about one-sixth as much as their records differ, and that one selecting cows for high records should expect to find that their breeding values are about one-sixth as far above the average of the group from which they were chosen as their records are." Legates (11) using a heritability value of .25 describes this practical value with the following: Expected progeny average= herd average + (heritability X superiority of parents). He then assigns the following values for illustration: Herd average = 10,000 pounds and superiority of parents equals 1,000 pounds. Using these values in the formula, the expected progeny average equals 10,000 + (.25 X 1,000), or 10,250 pounds.

Often in selecting sires little or no value is placed upon the production records of either the sire's dam or the sire's sisters, and nearly all of the importance is placed on the future sire's type classification. This has proven good and bad depending upon the genotype of the animal. Tyler and Hyatt (27) estimated the heritability of type to be .3. This is higher than the estimate of Legates (11) who assigned a range in value of .15 to .3. It has also been estimated (27) that the correlation between type and production is about .16 to .19. Other studies (7 and 25) give this correlation a lower value. The workers do agree, however, that selection on type alone should automatically bring about some genetic improvement in production. Harvey and Lush (7) indicate that selection for type would require 6-10 generations to obtain the improvement in production that selection on the basis of production would obtain in only one generation.

Selection of Dairy Traits

The economic value of certain dairy traits often influence the dairyman in his selection of breeding stock and his breeding program. For example the purebred breeder may stress the type classification of the animal. The grade dairyman, on the other hand, may be interested only in milk production. For the most part farmers have found that both characteristics are of economic value and plan their breeding program in that direction. Hazel and Lush (8) compared the merits of three types of selection. The "Tandem" method they described as selecting for one trait at a time until it is improved and then selecting for a second trait, etc. In the "Total Score" method, a selection was made for all the traits simultaneously by using an index of net merit calculated by adding into one figure the credits and penalties given each animal. A standard is established and all cows below that standard are culled. In the method of "Independent Culling Levels", a certain level of merit is established for each trait, and all individuals below that level are discarded, regardless of the superiority or inferitrity of their other traits.

From this study (8) they concluded that the total score method was most efficient with the independent culling levels next. They felt, though, that in all three methods there was always the danger that maximum success would not be obtained because too much attention is paid to some characteristics and too little to others.

Tabler and Touchberry (26) agreed that selection with the total score method gave best results. They determined that the genetic value for milk yield can be estimated 10 per cent more accurately by also taking into consideration the cow's fat yield. This, however, gives a faster generation by generation increase in both type and production than if only type or production were used as the selection criterion (7).

Copeland (4) analyzed the production records of daughters of 128 classified bulls that have qualified as "A.J.C.C. Tested Sires". He found the correlation between the classification rating of a sire and the average production of his daughters to be a minus value. He concluded, however, that type and producing ability are not incompatible, and that they can readily be secured in the same animal, yet breeders must pay close attention to both of these essentials in their breeding program.

Progeny Tests

The progeny test is defined by Lush (12) as a general term for estimating the breeding value of an animal by studying the characteristics of its offspring. Rice (21) defines the breeding value of an animal as what the animal actually is. Robertson and Rendel (22) explain that an animals own performance measures its phenotype, but the performance of its offspring estimates its genotype.

Gilmore (6) states that the progeny test has more worth for quantitative characters that: 1) are expressed in only one sex, 2) have a low correlation between type and performance, 3) have long intervals between generations and 4) have only one or few offspring at a time. This makes progeny testing for dairy cattle worth while, as milk production is a quantitative character and the correlation between type and production is low.

In comparing the progeny test with a pedigree evaluation, Lush (12) estimated that a progeny test gives as good relults as the pedigree evaluation if more than three offspring are used. This depends, however, on whether the individual merits of the offspring are as certainly known as the individual merits of the ancestors, on how much environment the offspring have had in common, and on how much the variation among the ancestors had already been reduced by selection among them. When compared with the animals individual merit the progeny test is more useful if: 1) there are at least five offspring, 2) the characteristic has a fairly low heritability, 3) there is no environmental correlation between the offspring, and 4) the individual merits of the offspring are known at least as accurately as the merit of the parent being tested.

Progeny tests have a number of disadvantages. The main practical limitation as pointed out by Rice (21) is that it is expensive. To illustrate this he determined that before the results of a progeny test can be tabulated the sire being tested is at least four years old, and that of the number tested only a relatively small percentage of them would be proved good in any event. Feed cost, labor cost and in too many cases loss in production makes this expensive. A lot of the expense and risk is reduced, however, by giving more care in the selection of the animals to be progeny tested.

Some of the things that prevent the progeny test results from being perfectly accurate are listed by Lush (12) as: 1) the sampling nature of inheritance. This makes it possible for a parent to transmit to its offspring inheritance that is either superior or inferior to the average. 2) the offspring receives half of its inheritance from the other parent, which could have either a higher or lower breeding value than is average of the breed. 3) environmental effects, dominance, and epistatic deviations may be deceptive in estimating the merit of either the offspring or the other parent.

Lush (12) also states that by increasing the number of offspring the sampling error can be made as small as we need. With five or more offspring the error from this source is usually small in comparison with errors from other sources. Where the mates are unselected or chosen at random the error from neglecting the merit of the mates tends toward zero. This is due to an equal number of better and worse mates which leaves the resulting figure near the breed average. Environmental error is subdivided into random and systematic errors. Random errors are usually eliminated by increasing the number of offspring in the progeny test, but systematic errors can be corrected only by studying the conditions of the environment and making allowance for them. Environmental errors are the most serious limitation on the accuracy of the progeny test.

Environmental influences cause 50-70 per cent of the total variation in production records of dairy cattle. Environment, as defined by Gilmore (6), is all non-hereditary influences to which cattle are subjected. These environmental influences include feeding and management practices.

A great deal of literature is available describing the effect ofnenvironment on production, and most writers agree that it is the biggest single problem in developing and maintaining high producing herds. Starkey (25), in studying the effect of 14 environmental influences on production, found that they contributed 27 per cent of the variation found in butterfat records. This figure differs from the 50-70 per cent previously used by other authors. This is explained by noting that Starkey studied records that had already been standardized to a 305 day mature equivalent value. Starkey also determined that on a within herd basis 15 per cent and on a total basis 10 per cent of this variation can be traced to pounds of total digestible nutrients fed daily. This was the largest single source of environmental variation found by his study. He concluded that an environmental index could be devised and suggested the following influences as the most significant: 1) TDN fed daily, 2) length of preceding dry period, 3) calving interval, 4) number of cows in the milking herd, and 5) housing (cow comfort).

The effect of environment and heredity is summarized by Rice (21).

He states that both are important, and that good production cannot be obtained from either poor genes and good environment or good genes and poor environment.

The Sire Index

Because sires do not give milk their producing ability has to be figured indirectly. This limitation is minimized by calculating an index through comparison of a sire's daughters production with the production of their dams. Nibler (18) describes an index as a single figure which indicates a sire's transmitting ability for milk and butterfat.

To help understand the basis for indices, Lush (13) lists eight genetic principles that must be considered before a sire index can be accurately tabulated.

1) Inheritance is by units that are present in pairs and which maintain their identity and later segregate out unchanged.

2) These units are not adaptively modified by their environment.

3) They do, however, interact with environment to affect yields.

4) The number of units affecting milk and butterfat production is large. Gilmore (6) estimates at least 18 pairs of genes are involved.

5) Gene frequency is changed at a rate which would be appreciable only by selection.

6) The homozygosity of a breed or group is changed appreciable only by selection, or some form of inbreeding or its opposite.

7) Genes often exhibit dominance.

8) Genes interact with one another.

Lush (13) also lists these applications to the problem of sire indices:

1) Offspring average half-way between parents. The offspring average midway, but any individual offspring may vary widely from that average. Increasing the number of offspring will tend to reduce error due to extremes.

2) If dominance is present the offspring will average midway between parents if they have the same amount of heterozygosity as the parents. Increase in numbers will also reduce most of the error due to dominance.

3) Environmental errors are more difficult to reduce. The methods most frequently used are the use of correction factors and increasing the number of daughters in the index. There are some environmental influences that are unknown that cause bias for which there have been no correction factors developed.

4) The effect of gene interaction can be either good or bad. The term used to describe this is "nicking". While genetic activity is blamed for nicking the effect may actually be caused by some other influence such as environment, or differences in dams. Johnson et al. (9) in studying 17 Jersey sires found that, "There was only one bull that showed clear cut signs of 'nicking', and this could possibly be explained by environmental differences." Seath and Lush (23) studied data from 13 proven sires and confirmed the results of other studies when they failed to find evidence that nicking is of any great importance. Errors due to nicking can usually be reduced by increasing the number of daughter-dam comparisons.

5) The influence of the dam on the daughter of a sire may cause some bias to show up in the sire's index. Lush et al. (15) found that in unselected populations each cow is as likely to have had

better than average environment as she is to have had worse than average environment. Therefore, the descrepancies tend to cancel each other out, and the average record of the population tends to equal the average ability of those cows under the average environmental conditions prevailing in that population. They conclude that if the dam's records are unselected or lifetime averages are used, little, if any bias will result. They also state that daughters whose dams are untested can be included in sire indices by using the herd average in place of the dam's record. There is a risk of lowering the accuracy of the index with this prodedure, but more than likely it will improve the accuracy.

6) The dam contributes as much toward the inheritance of a daughter as does the sire. Copeland (3) found that there is a correlation between a dam and daughters and a slight correlation between the dam and her son's daughters, but that the record of a dam is nearly twice as reliable a measure of the production of her own daughters as it is of her son's daughters.

7) The minimum number of daughter's records used in the calculation of a sire's index varies somewhat with different workers. Lush (14) estimates that the records of three daughters will give as much information as a pedigree test, and that 5-8 daughter's records are sufficient for an index. Nibler (18) lists 5-9 as necessary for a preliminary proof, but feels that ten or over are necessary in the final index. When a sire is used in artificial breeding he feels that 25 or more comparisons are necessary. Lush (13) stated in summary that an increase in the number of daughters could add a great deal to the accuracy of the index, but would never detract from its accuracy.

There are many kinds of indices, but most of them are modifications of a few standard types. Lush (13) points out that, "With one exception all indexes are based on the daughter average as a starting point. The one exception is the proposal to rate sires solely on the increase or decrease of their daughters over the dams". The following are the most important of the proposed indices.

1) The daughter average is listed by Rice (19) as the earliest and easiest of all the indices. It utilizes records of all the daughters of a sire which would eliminate any error due to selection. In comparing it with four other types of indices Gaunt and Legates (5) found it to be equally as relaible as other indices in predicting the production of future daughters. In using it as a basis for sire selection, however, it has one big fault. Rice (19) points this out as the failure of the index to give any credit to the relative merits of the dams. Any credit or debit goes automatically to sires in this system.

2) The equal-parent index is based on the principle that the production of a sire's daughters should average half-way between the sire's transmitting ability and the average of their dam's inheritance. The index is calculated by following the formula (1), index= daughter average + (daughter average - dam's average) or 2(daughter average) - dam's average.

Lush (13) lists the specific weaknesses of this index as: 1) selection of records of daughters and dams. The lowest record of the dams versus the highest record of the daughters. 2) Environmental influences. Records of dams and daughters may have been made under widely varying conditions. 3) The index does not use information about tested daughters out of untested dams. Lush (13) recommends this index as the soundest in principle and most nearly complies with practical considerations. He adds, however, that no index will give infallible results.

3) The regression index is a modification of the equal-parent index and was proposed by Rice (20). It is calculated by using the formula, index = w + d - e, where w represents the breed or population average, d equals the daughter's average, and e is the daughter's expectation. e is found by adding the breed average to the dam's average and dividing by 2.

Laben (10) points out that the regression index is less variable than the equal-parent index and has the same accuracy; it will rank sires in the same order. It has the advantage of predicting expected daughter performance more conservatively. Because it is an adaptation of the equal-parent index, it would have the same disadvantages, and also it requires more labor and information in its construction.

Nearly all writers agree that proofs and indices can be misleading, and that some of the factors to be considered are: 1) level of production, 2) range in production, 3) environment, and 4) natural or artificial proof.

Natural proofs differ from artificial proofs not only in how they are made, but also in results. A natural proof or index of a sire is usually made of daughter-dam comparisons from only one or two farms, and is usually limited to a small number of records. An artificial proof, on the other hand, is made of comparisons from many farms and has many records.

In too many cases high proofs measure the ability of the herd manager rather than the sire. Schaefer (24) studying the indices of 90 Holstein sires found that five sires whose natural daughters produced an average of 385 pounds of butterfat had artificial breeding indices that averages 424 pounds. 30 sires had 427 pound natural proofs and 416 pound artificial proofs. 35 sires averaged 473 pounds when used in natural service and only 429 pounds artificially. In the highest group 20 sires with natural indices of 521 pounds of butterfat averaged only 431 pounds when their artificial proof was computed. When these facts were statistically analyzed the correlation coefficient was found to be plus .0938. This coefficient is not statistically significant and indicates that there is very little correlation between the natural daughter level and the results obtained from artificial breeding.

Daughters from extremely high producing cows seldom produce as high as their dams, and daughters from low producing cows rarely produce as low as their dams. Copeland (3) determined that in general the daughters show about 32 per cent as much variation from the breed average as do their dams. Rice (20) estimated the correlation between daughter and dam for butterfat production to be .2 to .5.

The use of contemporary herd averages to evaluate the breeding value of sires has not been used extensively. Gaunt and Legates (5) found this method to be as reliable as either the simple daughter average or the equal-parent index. The herd average used by these researchers was the regular Dairy Herd Improvement yearly average completed as close as possible in the same year as the record of the daughter of the sire being proved. Carter et al. (2), in some work done at Cornell University, found that the difference between the production of a sire's natural service daughters and their contemporaries was equal to daughter-dam comparisons for selecting sires to use in artificial insemination.

Workers in England have used daughter-contemporary herd average comparisons to evaluate sires in some of their studies. Two English workers, Mason and Robertson (17), conducted a progeny test of sires at different levels of production. In their study only the records of first calf heifers were used, and the herd averages excluded the daughter's record of the sire being tested. The records were not extended or standardized, and were made over a period of twelve months; from the first of October one year to the end of September the next year. The herd averages were calculated by dividing the total pounds of milk produced by the number of cows producing it. The herds were divided into "low", "medium", and "high" groups based on average production.

These workers (17) concluded that a policy of selecting sires on the basis of their daughter's performance in high-yielding herds should be the most satisfactory way of progeny testing sires used in artificial insemination. They found that the variance of yield increased as the average yield increased making it easier to select sires of superior genetic quality. Their study indicated that this method of progeny testing gave the accuracy that was expected in theory. However, they reported that the true ranking of sires for breeding value was apparently the same at all levels.

PROCEDURE AND DESCRIPTION OF DATA

Data for this problem included production of daughters of the Holstein sires in the Cache Valley Breeding Association along with the dams of the daughters and the contemporary herd averages. The sires used in artificial breeding were selected because they had a larger number of daughters and their daughters come from a wider range of production levels, or management levels, than sires used in natural service. The list of sires selected included only H-1 through H-18. Other sires in the Cache Valley Breeding Association did not have a sufficient number of tested daughters.

Production records of the daughters, their dams, and the herds in which they made their records were taken from Utah Dairy Herd Improvement Association records. All records of individual cows had been computed by the testing association to a 305 day lactation, milked twice daily, and mature equivalent basis using U.S.D.A. factors. Records for the years 1954 through 1957 were included in the study.

When daughters were compared with their dams the records of both animals were made in the same herd, and as nearly as possible in the same year. When a daughter was compared with her contemporary herd average records of the same year were used. Standardized records and records made in the same year were used as an attempt to reduce error due to environment.

To calculate the various indices, daughter's records and dam's records were compared. The daughter average index is not a true daughter average, as it does not include all available records of tested daughters. It includes only the average of the daughters used in making the equal-parent and regression indices. Selection indices were calculated by selecting the high daughter records for comparison with their dams.

RESULTS AND DISCUSSION

The data for this study included 533 daughter-dam comparisons and 1406 daughter-herd average comparisons. Table 1 contains a list of the Holstein sires used by Cache Valley Breeding Association whose daughters were used to make this study. This table also includes the number of daughter-dam and daughter-herd average comparisons each sire contributed to the total. If a dam had more than one tested daughter by one of these sires she will appear as many times as she has daughters. Likewise, herd averages are repeated if the sires had more than one daughter in the herd.

In studying table 1 it is noted that H-6 is missing from the list. He did not have any tested daughters. It is also noted from this table that only six sires have enough daughter-dam comparisons to meet the minimum requirements of 25 comparisons that Nibler (18) recommends as necessary in an artificial proof. These six sires (H-9, H-10, H-14, H-15, H-16, and H-18) will be the only ones used to compare daughters of individual sires at the various levels of production.

Daughter-dam Comparisons

Table 2 includes the daughter-dam comparisons for all seventeen sires in the study, and tables 3-8 list the daughter-dam comparisons for individual sires. To make comparisons at various levels of production the dams were divided into nine groups according to their production. Averages were computed by adding the production of all the animals in each group and dividing by the number of animals involved. The total average was computed in the same way, by adding all of the production records and dividing by the total number of animals.

In table 2 the difference column presents a picture of the daughter-dam regression. When the sires were mated to low producing dams the resulting daughters out-produced their dams. However, when the sires were mated to higher producing dams, on the average, the daughters produced less than the dams. This is in harmony with work done by the United States Department of Agriculture in 1949. Their study included 4568 sires and the daughter-dam comparisons of these sires. It was found that when these sires were mated to low producing dams 86 per cent of them had daughters which produced as high or higher than the dams. When mated to high producing dams only 36 per cent of these sires had daughters which produced equal to or higher than the dams. The butterfat range of the dams started at a low of 250 and went to a high of 475 pounds of butterfat. Literature published by Rice (19) also supports this regression pattern. His writings claim that in the study of a population the groups of daughters will regress from their respective dam's average toward the population average. This can be observed in table 2 by noting that the daughter average production increased as the dam's average production increased, but the increase becomes smaller as the production levels become higher.

When the dams are grouped together they have an average production of 453 pounds of butterfat, while their daughters have a 499 pound average. This might be interpreted to mean that when dams are mated to these sires the female offspring will have an inheritance for butterfat production that will enable them to produce an average of 46 pounds of butterfat more than their dams. Study of table 2 indicates, however, that this 46 pound increase is only average, and that a greater or larger increase can be expected at lower levels of production. At higher levels, however, instead of an increase, a decrease might be expected.

Table 2 contains daughter-dam comparisons of all sires at various levels of production. For example, these sires had a total of 533 daughters which averaged 499 pounds of butterfat. To obtain this average some sire must have had daughters whose averages were less than this, while other sires had daughters whose averages were higher. Tables 3-8 list six of these sires individually with their own daughter-dam comparisons. In studying these tables it can be seen that these sires, as individuals, had daughters whose averages were higher than the average of their dams at the lower levels of production, but at the highest levels their daughters averaged less than the dams. It can also be noted, however, that the daughter-dam regression pattern is vastly different when the sires are compared. Some sires (H-9 in table 3, H-16 in table 7, and H-18 in table 8) have daughter-dam regression patterns with almost as many levels where the daughters produced less than the dams as they do where the daughters show an increase over the dams. Other sires (H-10 in table 4 and H-15 in table 6) have daughters that average higher than the dams in every level except in the highest levels.

The number of comparisons in each production level becomes more important as these tables are studied. As an illustration it can be observed in table 5 that H-14 daughters in the 475-525 pound group average 44 pounds less than their dams. In the 525-575 pound group the daughters show an average increase of 47 pounds over their dams. The decrease in the 475-525 pound level was made on eleven daughter-dam comparisons and fits into the already established regression pattern for H-14. The increase in the 525-575 pound level, however, included only four comparisons and is not in harmony with the difference in the groups at higher and lower production levels. This descrepancy might be explained by assuming that there were not enough comparisons made or that some environmental factor caused the daughters records to be out of line with their dam's records.

Data in tables 3-8 indicates that selection of sires on the difference between daughter and dam records has its limitations. If these six sires were selected on a difference between daughter and dam basis they would rank in the following order: H-15 with a 56 pound difference, H-10 with 42 pounds, H-9 with 32, H-16 with 29, H-14 with 15, and H-18 with only a six pound difference. A check of the daughter averages in these tables shows that the last place sire, H-18, has 42 daughters with an average production of 502 pounds of butterfat. This sire is second only to H-15 with 508 pounds for high daughter average. Yet, H-18, with a daughter average of 502 pounds, would be ranked behind H-9 whose daughters averaged 464 pounds of butterfat if selection were based only on difference between daughter production and dam production.

Comparing daughters of a sire with their dams at various production levels provides the dairyman with information he cannot get with any other type of comparison or proof. For example, suppose a dairyman had a cow that was producing 500 pounds of butterfat per lactation. The dairyman would want to mate this cow to a sire with superior inheritance for butterfat production in order that the offspring might produce more than the dam. Data in tables 3-8 indicate that only two sires have a positive difference at this level of production. H-15 has a plus 38 pound difference on eight daughter-dam comparisons. H-10 has a positive 11 pound difference with 18 daughter-dam comparisons. The other sires have positive differences at lower levels of production, but have minus differences at this higher level. From such information, a dairyman could determine that H-15 or H-10 would more likely increase production on high producing cows than would the other sires studied.

TABLE 1.

Sire names and numbers. Listing the number of daughter-dam comparisons and the number of daughter-herd average comparisons

Sire	Name and registration number	Daughter-dam Comparisons	Daughter-herd average comparisons
H-1	Klaver Paul Gerben Walker 848257	8	34
H-2	Sir Segis Burke Doede 877766	6	46
H-3	Gov. Inka One Nine Five Bess Hero Pr. Pl. 877820		3
H-4	Twi Kla Utah F Pride Paul 906555	5	34
H-5	LeonGard Frost Burke Spot 906106		4
H-7	Colantha Burke Sevens 995039	14	63
H-8	Sego Road Chieftain Burke 1049179		14
H-9	Weber Burke Frost 819479	90	204
H-10	Burkgov Inka De Kol 1038509	97	278
H-11	Carnation Progressor Spofford 1072341	15	35
H-12	Burke Imperial Sevens 1001822	9	47
H-13	Carnation Imperial Advocate 903205	20	49
H-14	Sleepy Hollow Royal Governor Inka 806294	47	165
H-15	Sleepy Hollow Fobes Wayne Cupid 919383	102	205
H-16	Winterthur Fobes Star Dagan 1035459	69	147
H-17	Carnation Revelation of Utah 1056514	9	22
H-18	Clyde Hill Perfection Rock 917134	42	56
		533	1406

TABLE 2.

Daughter-dam comparisons of all sires at various levels of production

Butterfat range of dams	Number of comparisons	Dam's average	Daughter's average	Butterfat range of daughters	Difference
Under 275	13	238	414	241-542	+176
275-325	30	305	406	240-579	+101
325-375	70	356	457	310-660	+101
375-425	103	400	452	229-743	+52
425-475	122	453	479	291-724	+26
475-525	81	497	483	212-744	-14
525-575	61	545	529	342-718	-16
575-625	32	594	551	360-851	-43
Over 625	21	718	579	321-735	-139
Total and averages	533	453	499	212-851	+46

TABLE 3.

Comparisons of H-9 daughters with their dams at different levels of production

Butterfat range of dams	Number of comparisons	Dam's average	Daughter's average	Butterfat range of daughters	Difference
Under 275	3	235	365	333-426	+130
275-325	8	309	405	327-469	+96
325-375	14	359	452	362-581	+93
375-425	20	396	448	229-743	+52
425-475	21	452	478	312-616	+26
475-525	10	498	480	390-563	-18
525-575	5	552	531	405-658	-21
575-625	7	593	502	436-562	-91
Over 625	2	677	588	436-638	-89
Total and averages	90	432	464	229-743	+32

TABLE 4.

Comparisons of H-10 daughters with their dams at different levels of production

Butterfat range of dams	Number of comparisons	Dam's average	Daughter's average	Butterfat range of daughters	Difference
Under 275	2	229	463	389-537	+235
275-325	3	304	402	376-435	+98
325-375	13	355	474	350-660	+119
375-425	17	402	476	279-616	+74
425-475	29	448	474	371-629	+26
475-525	18	496	507	416-744	+11
525-575	10	545	550	411-655	+5
575-625	2	610	590	583-596	-20
Over 625	3	672	537	321-701	-135
Total and averages	97	448	490	279-744	+42

TABLE 5.

Comparisons of H-14 daughters with their dams at different levels of production

Butterfat range of dams	Number of comparisons	Dam's average	Daughter's average	Butterfat range of daughters	Difference
Under 275					
275-325	4	310	436	364-510	+126
325-375	7	357	428	310-510	+71
375-425	6	401	444	342-651	+43
425-475	12	453	451	356-620	-2
475-525	11	499	455	364-669	-44
525-575	4	538	585	445-677	+47
575-625	2	586	508	463-553	-78
Over 625	1	683	566		-117
Total and averages	47	448	463	310-677	+15

TABLE 6.

Comparisons of H-15 daughters with their dams at different levels of production

Butterfat range of dams	Number of comparisons	Dam's average	Daughter's average	Butterfat range of daughters	Difference
Under 275	2	234	315	241-389	+81
275-325	7	294	398	240-579	+104
325-375	14	354	482	378-654	+128
375-425	20	400	448	295-626	+48
425-475	26	455	522	345-724	+67
475-525	8	500	536	489-715	+36
525-575	11	547	585	464-718	+38
575-625	9	597	637	473-851	+40
Over 625	5	672	519	361-630	-153
Total and averages	102	452	508	240-851	+56

TABLE 7.

Comparisons of H-16 daughters with their dams at different levels of production

Butterfat range of dams	Number of comparisons	Dam's average	Daughter's average	Butterfat range of daughters	Difference
Under 275	3	265	450	362-542	+185
275-325	3	297	413	298-515	+116
325-375	10	360	456	327-622	+96
375-425	10	399	460	328-597	+61
425-475	13	460	478	335-604	+18
475-525	11	493	475	345-600	-18
525-575	11	544	556	419-683	+12
575-625	6	594	432	360-586	-162
Over 625	2	735	702	670-735	-33
Total and averages	69	459	488	298-735	+29

TABLE 8.

Comparisons of H-18 daughters with their dams at different levels of production

Butterfat range of dams	Number of comparisons	Dam's average	Daughter's average	Butterfat range of daughters	Difference
Under 275					
275-325	1	307	328		+21
325-375	5	358	471	433-497	+113
375-425	9	406	461	399-542	+55
425-475	7	454	487	334-655	+33
475-525	8	496	490	212-646	-6
525-575	6	538	500	397-588	-38
575-625	1	606	643		+37
Over 625	5	824	656	607-717	-168
Total and averages	42	496	502	212-717	+6

Daughter-herd Average Comparisons

An important objective of this study was to determine if artificial inseminated daughters of a sire show an equal or higher increase in production over dams in high level environment herds compared to low level herds. In making daughter-herd average comparisons it is assumed that herd averages represent management levels.

With this assumption table 9 was compiled. In this table the daughters of all the sires in the study were separated into groups according to the level of production of their respective herds. Included in the table are production levels, the number of daughter-herd average comparisons in each level, average production of the herds in each level, average production of the daughters in each level, and the difference between the herd average and daughter average in each level. The production levels are in 50 pound intervals, starting with herds that average under 275 pounds of butterfat and ending with herds that have high averages in the 574-625 pound range. 1406 comparisons were included. Data in this table indicates that most of the comparisons were in the middle four production levels, whereas there were only 13 comparisons in the low level and four in the highest level.

Study of table 9 indicates that daughter yield increases as the herd average or management level increases. From this table it can be noted that the daughters of the sires in this study give a relatively uniform increase in production over the herd average at all levels of production. This increase at all production levels is in harmony with the results of other workers. It should be noted, however, that these other workers were not comparing daughters of sires with contemporary herd averages, but were studying heritabilities at the various production levels. Legates (11) summarized the findings of six such studies. Five of these studies observed no significant difference between heritability values at different production levels. The sixth study reported significant differences between low herds and high herds with higher heritability values at the higher production levels. It is observed from table 9 that the difference between daughters and herd averages is approximately the same at the various levels of production.

This study included contemporary comparisons between daughters of the sires and their herd mates. Use of Dairy Herd Improvement records, however, makes it difficult to separate the daughters record from the herd average. Also, the Dairy Herd Improvement herd averages include a twelve month period, and the daughters record may end in any month of that period. Thus, the herd average may not include exactly the same twelve month period as the daughter's record.

Table 9 includes the daughters and herd averages of all the sires in this study. Tables 10-15 are similar to table 9 but are concerned with individual sires and their daughters. These tables show the same general trend as table 9 with the increase of daughter production over herd average remaining relatively uniform at all production levels. However, as would be expected there are differences between sires. As an illustration H-15 in table 13 has a higher increase of daughter production over herd average in every level than does H-14 in table 12.

TABLE 9.

Daughter-herd average comparisons of all sires at various levels of production

Butterfat range of herds	Number of comparisons	Herd average	Daughter average	Butterfat range of daughters	Difference
Under 275	13	267	300	207-401	+33
275-325	40	304	370	226-604	+66
325-375	273	353	401	328-743	+48
375-425	486	404	442	204-660	+38
425-475	361	448	489	229-781	+41
475-525	171	494	538	311-831	+44
525-575	58	541	590	364-851	+49
575-625	4	586	662	596-808	+76
Total and averages	1406	418	461	203-851	+43

TABLE 10.

Comparisons of H-9 daughters with their contemporary herd averages at various levels of production

Butterfat range of herds	Number of comparisons	Herd average	Daughter average	Butterfat range of daughters	Difference
Under 275					
275-325	9	315	415	226-604	+100
325-375	46	354	406	238-743	+52
375-425	73	402	433	280-602	+31
425-475	52	447	471	228-620	+24
475-525	19	499	535	407-831	+36
525-575	5	536	601	555-658	+65
575-625					
Total and averages	204	411	450	226-831	+39

TABLE 11.

Comparisons of H-10 daughters with their contemporary herd averages at various levels of production

Butterfat range of herds	Number of comparisons	Herd average	Daughter average	Butterfat range of daughters	Difference
Under 275	6	269	308	253-401	+39
275-325	10	298	351	234-533	+53
325-375	45	354	414	284-550	+60
375-425	86	406	443	252-660	+37
425-475	75	449	491	329-661	+42
475-525	47	495	554	311-770	+59
525-575	7	544	638	467-845	+94
575-625	2	592	702	596-808	+110
Total and averages	278	422	455	234-845	+33

TABLE 12.

Comparisons of H-14 daughters with their contemporary herd averages at various levels of production

Butterfat range of herds	Number of comparisons	Herd average	Daughter average	Butterfat range of daughters	Difference
Under 275	2	271	265	207-323	-6
275-325	2	303	223	208-238	-80
325-375	35	354	385	244-471	+31
375-425	51	402	429	317-590	+27
425-475	41	446	490	342-695	+44
475-525	25	492	518	355-677	+26
525-575	9	534	548	364-669	+14
575-625					
Total and averages	165	421	450	207-695	+29

TABLE 13.

Comparisons of H-15 daughters with their contemporary herd averages at various levels of production

Butterfat range of herds	Number of comparisons	Herd average	Daughter average	Butterfat range of daughters	Difference
Under 275					
275-325	1	308	515		+207
325-375	36	349	385	241-518	+36
375-425	73	406	460	204-645	+54
425-475	56	448	536	361-781	+88
475-525	24	491	539	393-626	+48
525-575	14	541	637	401-851	+96
575-625	1	580	622		+42
Total and averages	205	427	490	204-851	+63

TABLE 14.

Comparisons of H-16 daughters with their contemporary herd averages at various levels of production

Butterfat range of herds	Number of comparisons	Herd average	Daughter average	Butterfat range of daughters	Difference
Under 275					
275-325	4	300	371	325-429	+71
325-375	33	356	413	239-658	+57
375-425	59	405	457	298-644	+52
425-475	35	449	505	363-622	+56
475-525	14	493	568	364-735	+75
525-575	2	531	694	683-704	+163
575-625					
Total and averages	147	412	470	239-735	+58

TABLE 15.

Comparisons of H-18 daughters with their contemporary herd averages at various levels of production

Butterfat range of herds	Number of comparisons	Herd average	Daughter average	Butterfat range of daughters	Difference
Under 275					
275-325	1	289	293		+4
325-375	7	348	396	328-502	+48
375-425	13	403	486	399-646	+83
425-475	20	446	473	285-604	+27
475-525	9	495	552	438-717	+57
525-575	5	538	613	534-655	+75
575-625	1	580	623		+43
Total and averages	56	439	491	285-717	+52

Indices

Three of the indices most frequently used in sire proofs are the daughter average, the equal-parent index, and the regression index. The formula for a daughter average is merely the average production of all the daughters of a sire. The equal-parent index is based on the principle that offspring receive half of their inheritance from both parents. This index is determined by multiplying the daughter's average by two and subtracting the dam's average. The regression index is based on the principle that a daughter's record tends to regress toward the breed average. Included in the formula is the breed average and the daughter's expectation. The daughter's expectation is determined by adding the breed average to the dam's average and dividing by two. The breed or population average for the years 1954-1957 in the state of Utah was estimated to be 430 pounds of butterfat.

Data in table 16 presents a comparison between these three indices as they apply to the six sires in this study with the most daughter-dam comparisons. This table lists the sire, the number of comparisons between daughters and dams for each sire, the average production of the dams, and the indices. With each index is a figure that indicates the rank of each sire as compared with others in the table.

Comparison of the indices in table 16 indicates that the equal-parent and regression indices rank the sires in the same order. Rice (20) found in his studies of indexing sires that the equal-parent and regression indices ranked sires in the same order. Data in table 16 also indicate that the regression index is a lower figure than the equal-parent index figure, but is higher than the daughter average figure. The daughter average, however, give the sires a different ranking.

Table 17 was prepared to show the ranking of sires based on difference between daughter average and contemporary herd average. This type of sire comparison rates H-15 as the first place sire and H-14 as the sixth ranking sire. The most obvious difference is the ranking of H-10 in fifth place compared to second place in both the equal-parent and regression indices as the data in table 16 indicates.

Calculation of a sire index using only the highest daughter records of that sire would be misleading to the dairyman without a knowledge of how that index was compiled. Table 18 was compiled to show what selection of only high records can do to the validity of an index. This table was calculated using daughter-dam comparisons of H-10. H-10 had a total of 97 comparisons. The highest producing 45 daughters of these 97 were selected; then the highest 25, and finally the highest 10. Indices were then compiled using only these top daughter records. Table 18 contains these indices. It can be noted that the equal-parent index rises from 532 pounds with 97 comparisons to 675 pounds with only 45 comparisons. This type of increase also occurs when 25 comparisons are made and when only 10 are used. When 25 comparisons are made the index increases to 765 pounds and with 10 comparisons the average is 847 pounds of butterfat.

TABLE 16.

Comparison of sire indices and the ranking of sires by indices

Sire	Number of comp-arisons	Dam's average	Daus. average	Rank	E-P* index	Rank	Regression ** index	Rank
H-9	90	432	464	5	497	5	464	5
H-10	97	448	490	3	532	2	481	2
H-14	47	448	463	6	477	6	454	6
H-15	102	452	508	1	563	1	497	1
H-16	69	459	488	4	518	3	473	3
H-18	42	496	502	2	508	4	469	4

* Equal-parent index = 2(daus. ave.) - dam's ave.

** Regression index = w + d - e.
w = breed average--430 pounds of butterfat.
d = daughter average.
e = daughter expectation = $\frac{\text{(breed ave. + dam's ave.)}}{2}$.

TABLE 17.

Ranking of sires on the difference between daughter average and contemporary herd average

Sire	Number of comparisons	Daughter average	Dam's average	Difference	Rank
H-9	204	450	411	+39	4
H-10	278	455	422	+33	5
H-14	165	450	421	+29	6
H-15	205	490	427	+63	1
H-16	147	470	412	+58	2
H-18	56	491	439	+52	3

TABLE 18.

Effect of selection on indices and daughter average of H-10

Number of comparisons	Dam's average	Daughter average	E-P index	Regression index
97*	448	490	532	481
45**	437	556	675	552
25**	415	590	765	597
10**	455	651	847	638

* Total number of daughter-dam comparisons.

** Selected daughters with highest production.

SUMMARY

The purpose of this study was to determine if daughters of a sire show an equal or higher increase in production over dams in high level environment herds when compared to low level herds. To obtain this information the Dairy Herd Improvement records for the years 1954-1957 were studied. These records contained enough data to make 1406 daughter-herd average comparisons and 533 daughter-dam comparisons. Only the daughters of the first 17 Holstein sires used by the Cache Valley Breeding Association were used.

The records of any one daughter, her dam, and her contemporary herd average were taken from the same year and were made in the same herd. Daughter records and dam's records were standardized to 305 day 2x mature equivalent records, while the herd averages were regular Dairy Herd Improvement yearly herd averages.

The daughter records were segregated into groups according to the level of production for their contemporary herd averages. Study of these groups indicated that the increase of daughter over herd average was relatively uniform at all levels of production. Individual sires were also studied with similar results; however, there were some differences between sires.

The daughter records were also divided into groups according to their dam's production. When sires were studied as a group, in this manner, their daughters averaged higher than the dams in the lower production levels, but at the higher levels the dams produced more than their daughters. Individually the sires differed considerably. Some sires had nearly as many levels where the daughter average was

less than the dam average as levels where the daughter average was greater than the dam average. Other sires (H-10 and H-15) had daughter averages that were less than the dam's averages only at the highest production levels.

Three types of sire indices were also presented. These were the daughter average, the equal-parent index, and the regression index. The equal-parent and regression indices gave sires the same ranking, but differed slightly from the daughter average. The daughter average was higher than the regression index, but lower than the equal-parent index.

The effect that selection of daughter records can have on a sire index was illustrated. Results indicated that sire indices can be grossly misleading if they are calculated with selected records.

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