SOME METHODS OF EVALUATING THE GENETIC WORTH FOR MILK AND BUTTERFAT TRANSMISSION OF SIRES USED IN ARTIFICIAL BREEDING

by

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INTRODUCTION

Artificial insemination as an organized cooperative dairy improvement program began in the United States in 1938. Since that time the program has expanded rapidly; in 1955 the number of first services to cows totaled 5,413,874. With the passing of time the trend has been toward fewer organizations with more bulls per organization, but with a great increase in number of first services per bull. In 1955, there were 2661 bulls reported in service, with an average of 1937 first services to cows per bull. Even these facts do not properly reflect the trend because 15 percent of the organizations represented 90 percent of the first services. However, this 15 percent of the organizations reported only 82 percent of the bulls, thus averaging 2321 first services per bull. It has been reported that the semen from individual bulls during their life span has been used to inseminate as many as 150,000 first service cows. During the five year period from 1950 to 1954 inclusive, 235,124 first services were reported by the Kansas Artificial Breeding Service Unit (KABSU), with a maximum of 20,773 from one bull.

These facts emphasize 1. the tremendous potential influence of artificial insemination on the inheritance of dairy cattle as a mass, 2. the concentration of this influence among relatively few bulls, 3. the importance of properly evaluating the results of such an extensive program, and 4. the need for early and valid appraisal of the transmitting abilities of individual bulls, particularly with reference to the milk production of their daughters.

The general purpose of this study was to analyze the data available in Kansas resulting from the operation of KABSU from 1950 to 1955. It is generally recognized that the two limiting factors in milk production are 1. the inheritance of a cow, and 2. the environmental conditions (feeding and management) under which she makes her record. Unfortunately, only about 6 percent of the dairy cows of Kansas are being tested in Dairy Herd Improvement Associations. Therefore, any data available are necessarily selective, and typical only of the class of dairymen in such associations. A tremendous need exists for some effective means of measuring the productive improvement in the vast majority of cows resulting from the artificial insemination program.

Nevertheless, there is a need for further refinement of methods for evaluating the results in Dairy Herd Improvement Associations to more nearly differentiate between the influences of inheritance and environment. Likewise, these same factors are of tremendous importance in selecting bulls to be used in artificial service.

The general purposes of this study include the following:

1. To appraise the results obtained as measured by the

methods being used by the Agricultural Research Service, United States Department of Agriculture.

2. To evaluate several methods of refining the data to more accurately appraise the genetic improvement obtained.

3. To compare the merit of the bulls involved on several bases.

4. To compare the average appraisal of the bulls by the bull selection committee with results obtained, to test the accuracy of past bull selection methods.

LITERATURE REVIEW

In recent years, several attempts to evaluate the effectiveness of artificial breeding programs have been made. These studies have been concerned with the assessment of the genetic improvement in the production of artificially-sired animals. Such estimates were based on progeny tests. In this review consideration has been given to some of the various forms of the progeny test, to factors affecting the usefulness of the progeny test, to methods increasing the accuracy of the progeny test, and finally to those studies that parallel this study in being attempts to evaluate the effectiveness of certain aspects of an artificial breeding program.

Lush (1935) stated that the bases for estimating breeding value of animals are pedigree, own performance, and progeny test. Because milk production is a sex-limited characteristic, bulls must be rated by the performance of his female relatives. The progeny test is the most valuable base because it gives results from a sample of the bull's inheritance in a certain set of environmental conditions.

Some form of progeny test is customarily used to evaluate bulls to be used or already in use in artificial breeding studs. Lush (1945) stated that a sire's progeny test may be expressed in a single figure, the sire index. He believed that all indexes, accurate enough to deserve further consideration, must start with the average production of the daughters as a base,(Lush, 1933). Rice (1953) stated that the simplest way to evaluate a bull is by his daughters' production alone. This method does not consider differences in the probable contributions of mates of different sires. Lush (1933) believed that suitable indexes differ only in the use and emphasis which they place on the difference between daughters and dams.

Lush (1945) stated that the index which seems most useful and accurate under many conditions is the average of a bull's daughters plus the average increase of the daughters over their dams. Differences in the average genetic merit of the cows to which the bull was mated which are neglected in the daughter average are discounted in this equal-parent index (Lush, 1933).

In cases of characteristics such as milk production that are controlled by the interactions of many pairs of genes, the offspring are usually about half-way between the parents. This idea forms the basis for the equal-parent index. This index is simple and easily understood, but it will not reflect truly the genetic differences among bulls because environmental effects not common to the daughters and mates of all bulls are included in the index (Lush, 1945).

An alternative method for evaluating a bull is the direct comparison of dams' and daughters' standardized averages. The Agricultural Research Service, United States Department of Agriculture, used daughter and dam averages and daughter-dam differences in reporting on the bulls used in Dairy Herd Improvement Association herds (Kendrick, 1953). The interpretation of these proved sire records is left to the individual interested in or concerned with the record.

Rice (1944) observed that daughters of dams which are below breed average will tend toward breed average, while daughters of dams above breed average will tend down to breedaverage. This regression results because the extreme dams represent extremes in Mendelian segregation and in environmental effects that are not likely to be duplicated in their offspring. Rice proposed a regression index to account for this phenomenon. He stated that the best standard point of reference of all records would obviously be the breed average. All dairy bulls could then be rated in comparison to the breed average and could be fairly compared, one with another.

Lush (1944) stated that nearly all sire indexes which have been proposed can be described by the general equation $I = a + c\ (X - bY)$, in which a, b, and c are constants, X is the average production of the daughters, Y is the average production of their dams and I is the index. The size of a affects only the general level (the mean) of the indexes. The size of c affects the variability of I but not its accuracy for comparing the breeding values (G) of two or more indexed sires. The size of b affects the accuracy of the index as well as the variability.

Lush (1933) stated that no index will give infallible results. Differences in herd environment affect all indexes since they enter into the daughter average which is the base of all indexes.

According to Lush (1944) the daughter average is most vulnerable to error from differences in environment from herd to herd. The difference between daughters and dams is most vulnerable to error from environments not having been the same for daughters and dams or from the dams having been selected more highly than is fully discounted. The difference between daughters and dams is least subject to error from variations in environment from one herd to another. An index cannot be guaranteed correct, since indexes will often contain considerable error from Mendelian sampling and from incomplete corrections for other circumstances. Hence a sire should be estimated nearer the average of the breed than his index is, especially if his index is extremely high or extremely low.

Lush, et al (1941) found the major source of error in estimating the breeding worth of cows or interpreting the progeny test of bulls from production records to be in environmental circumstances known and unknown which may make one record higher or lower than another, even for the same cow kept for another lactation under what are intended to be the same conditions.

Lush (1933) stated that the sources of error cannot be absolutely eliminated. All that can be done is to minimize them. The more one knows about the conditions under which the records were made, the more he can reduce these errors. Even if all other possibilities of error were overcome, there would still remain the sampling error intrinsic in the Mendelian nature of inheritance.

These theoretical considerations have elicited many attempts to adjust production records to increase the accuracy of the progeny test. Four general types of adjustments have received most consideration. The first is correction for specific environmental factors affecting production records. Second is general correction for environmental differences by use of the herd average. The third is a gross adjustment based on repeatability and heritability estimates. Fourth is the increased accuracy or reliability obtained by wider and repeated sampling.

Corrections for specific environmental factors such as age at calving, length of lactation and frequency of milking have been generally accepted as desirable. Various aspects of the correction theory have been discussed by Bayley (1950), Dickerson (1940), Copeland (1941), Legates and Lush (1954), Gethin (1950), Plum and Lush (1934), Lush (1944) and many others.

Recently Bayley (1950) evaluated the effects of nine environmental factors on production. Together these factors accounted for approximately fifty percent of the variation in milk and fat yields. Bayley (1950) proposed an environmental index to be used in conjunction with standard sire proofs. The practicability of this index is presently being studied under field conditions. Although these workers believe such correction may have utility other investigators (Lush and McGilliard, 1955) are not in agreement. Lush and McGilliard (1955) feel that records when corrected for many variables become overcorrected and artificial.

Although Wright (1931) stated that it is conceivable that the differences between large herds might be due wholly to management, other workers, particularly those of the German school whose work has been cited by McGilliard (1952) have shown that this extreme assumption is not valid.

McGilliard (1952) has shown that a simple and effective use of the yearly average in a herd is to correct each record for yearly differences in environment, especially if the yearly average of the herd is changing irregularly. This can be done readily by substracting from each record the herd average for the year in which it was made. The herd average used in McGilliard's study is obtained by averaging all standardized lactation records completed in a testing year. Improvement by selection based on an average of deviations from the yearly herd averages may progress as much as twenty percent faster than that based on single records.

McGilliard (1952) also showed that the usefulness of the herd average in estimating breeding values of dairy cattle where the cows are in a single herd may differ from the usefulness when animals from different herds are being compared. In both instances, however, the type of use and the usefulness of the herd average depend on how much of the differences between averages is genetic variation.

The third general method involves adjustment by using estimates of repeatability and heritability of production records. Repeatability is a measure of the similarity of production records of individual cows. If there were no differences in individual production records of a cow it could be assumed that the differences in production records among several cows were essentially genetic. However, such differences in the individual production records of a cow are well-recognized. Therefore, the differences among cows must be tempered by knowledge of the variation among the records of individual cows. Records are not completely repeatable because of temporary environmental differences. Furthermore, these records include the effects of gene-environment interactions that are not entirely recoverable in succeeding generations; these previously mentioned effects, of dominance, epistasis, etc. must be excluded. This is accomplished in the heritability estimate. Heritability is a means of expressing the additive genetic variance among cows as a percentage of the phenotypic variance (Lush, 1945).

There is evidence that within herds the heritability of milk yield is in the range from 20 to 40 percent, Lush (1942), Johansson (1950), Korkmann (1953), Laben and Herman (1950). It is generally assumed that the effective heritability is about 0.25.

Gowen (1934) estimated that one-half of the variation in milk yield, and four-fifths of the variation in fat percentage was due to heritable differences. Lush and Shultz (1936) state that these heritability estimates if reduced to an intra-herd basis would be of the lower order usually found.

They estimated the heritability of butterfat production to be 0.25 and of butterfat percentage to be 0.50. Johansson and Hansson (1940) estimated the genetic portion of the intra-breed variance in single records to be 0.30 to 0.40 for fat yield and 0.70 to 0.80 for fat percent. Lush et al. (1941) using the intra-sire regression of daughters on dams estimated heritability to be 0.33 for milk yield and 0.28 for fat yield.

Lush and Strauss (1942) calculated heritability on the basis of records in single lactations. The heritability of differences between cows mated to the same sire was found to be 0.174 with 5 percent fiducial limits of 0.03 and 0.31 respectively. This 0.174 is a little less than the 0.2 to 0.3 usually found in other studies. If this 0.174 is accepted at 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.

Lush and Strauss (1942) found that when only the data pertaining to sires used in but one herd are considered, heritability was 0.140 instead of 0.174. The small difference between 0.140 and 0.174 was not significant but suggests that environmental correlations contribute a little to the intra-sire likeness between daughter and dam when sires are proved in more than one herd, and that heritability is a little lower than 0.174. Heritability was not significantly higher in one breed than in another. There was a faint indication that differences in records corresponded a little less closely to differences in breeding values in the dual purpose breeds than in the more specialized dairy breeds but the difference was far below the level of statistical significance in this volume of data. Differences between group averages within a breed are mostly due to differences in management or other environmental circumstances, but about six to seven percent of them are due to differences in the average genetic merit of those groups.

Korkmann (1953) estimated the heritability of the deviation of the yield of cows from their herd averages. The calculated coefficients of heritability for the Swedish Red and White breed (SRB) and the Swedish Friesian cattle (SLB) respectively, are as follows: milk yield 0.39 and 0.40, butterfat yield 0.49 and 0.36, and the fat percentage of the milk 0.59 and 0.46.

Plum (1935) showed that differences between cows (26%) are mostly hereditary, but include the effects of any permanent change taking place in the cow before she starts giving milk and the effects of continually giving one cow better or poorer feeding and management than her herd mates. Variation in butterfat production among these cows seems to have been determined about one third by differences in their heredity.

Johansson (1950) analyzed the butterfat production records from twelve low and seventeen high producing herds of Swedish Red and White cattle. None of the low producing herds had a higher average annual yield than 124 kg. (272.8 pounds) butterfat, while none of the high producing herds averaged less than 145 kg. (314.6 pounds). There was little difference between the two groups in average age at first calving, dry period and calving interval. Bulls of the same or related lines were used in all herds, which were descended from the same stock. It is therefore, considered that the genetic differences between the low and high producing groups were small, and that the differences in production were due almost entirely to differences in feeding and management.

The following values were obtained for repeatability and heritability of butterfat yield and percent fat in the low and high producing herds.

Table 1. Heritability and repeatability estimates for Swedish Red and White cattle.

	High	Low
Yield heritability	.39	.32
Yield repeatability	.43	.41
Percent heritability	.68	.54
Percent repeatability	.64	.59

It may be seen that the values for the low producing herds were only slightly lower than those for the high producing herds. These results, therefore, do not support the contention that genetic difference in quantitative characters are more clearly manifested in an optimum than in a less favorable environment.

Greater reliability in the use of these environmental adjustments may be had by using more records for each individual and more individuals in the study. Berry (1946) described a formula that gives the relative reliability of estimates of real producing ability or breeding value based on different numbers of records. The major gain in reliability occurs when a second record becomes available to be used along with the first. The third record adds considerably to the reliability of the estimate. Records beyond the third add little, not enough to warrant waiting to cull on this basis.

Lush et al. (1941) also stated that the use of lifetime averages automatically corrects for much of the bias which exists in selected groups between the records on which they were selected and their real abilities. Daughters whose dams were untested can be included in sire indexes, by using the herd average in place of the record of each dam. Such a procedure is more likely to improve than to lower the accuracy of the index, although there is some risk of the latter.

Repeatability and heritability estimates also can be made more reliable by using greater numbers of daughter-dam comparisons, thereby improving the sire index which may be calculated from these comparisons.

Davidson (1925) was one of the first to show that the progeny test to be accurate must include at least six unselected daughters and that the accuracy gained by using more than fifteen was not worth the additional time necessary to secure the information. Lush (1935) stated that the relaibility of the progeny test should increase as the number of daughters increases, but at an ever-decreasing rate. He further stated that when the common environment and heritability are low it is necessary to use more numbers.

The increased use of artificial insemination and the widespread usage of individual sires has focused more attention on the problem of successfully evaluating progeny tests of these sires. Hancock (1952) named three general methods of testing bulls to be used in artificial insemination. In order of decreasing accuracy (assuming the same number of daughters to each bull) they are 1. the progeny station scheme, 2. the sire survey scheme, and 3. the A.I. scheme.

In the progeny test station scheme, the daughter groups of all bulls selected for comparison are assembled at a special station where they are subjected to a strictly uniform and strictly controlled environment. This method is used in Denmark.

In the sire survey scheme, bulls are compared on the basis of their daughters' records achieved under ordinary farm conditions. In general, all daughters of each bull are tested in one herd. The progeny groups are subjected to widely different environment, depending on the feeding and care of the owner farmer, but there are relatively small differences within the groups. This is the method used at the present time in New Zealand.

In the A.I. scheme, the daughters of each bull are evenly dispersed over a whole range of environments, because they are tested in a great many different herds. On the average, all progeny groups are thus subjected to the same environment. Schemes of this type have begun in Great Britain and New Zealand.

Several investigators have studied the relative merit of one or more of these progeny testing schemes. Korkmann (1953) using the A.I. scheme, reported that if the bulls have daughters in the same herd or in herds on the same plane of nutrition, the usual methods of progeny testing, obviously, give a reliable indication of the relative order to their breeding values. However, most of the methods do not permit comparison of sires on the basis of results from herds on different planes of nutrition. Korkmann examined the possibilities of calculating comparable breeding values of bulls under different planes of nutrition. A modified regression formula was used to calculate the breeding value of the individuals in his study.

Korkmann (1953) found no differences between herds on different planes of nutrition; neither between the heritabilities nor between the standard deviations of the deviations of the yield of the cows from the contemporary herd averages. The results suggest that when the milk or butterfat yield of a cow deviates greatly from the herd average, this deviation is caused by specific environmental influences, and that the heritability therefore, in such cases is lower than the average heritability for the corresponding character.

Robertson and Rendel (1954) analyzed the production records of over 1400 English heifers got by sires at five "non-board" centers. These heifers were compared with other heifers in the same herd in the same year. There was no significant increase in yield but a significant increase in fat content was observed. The difference in yield of A.I. and contemporary non-A.I. heifers was not significantly different in herds at all levels of production. This would suggest that only a small portion of the differences in yield between the herds in the sample was genetic in origin. In fat percentage there was some evidence though not very conclusive, that rather more of the inter-herd variation was genetic.

Hickman and Henderson (1955) studied New York Artificial Breeding Association data. They showed that the level of herd production has far more influence on the relationship between level of production for successive lactations than does level of production among progeny groups of sires, the latter association being essentially zero. An increase in level of production among herds is accompanied by a decrease in the increase from first to second lactation production. Herd variation was found to be the largest single source of variation in production traits. The fraction of herd variation which is genetic was not estimated, but it was found that sires may be expected to be ranked in the same order according to daughter production in different herds.

Mason (1956) studied records of 13,000 Red Danish heifers sired artificially. To compare the performance of bulls in herds at different levels of production, all the herds at each A.I. center were divided into three equal groups on the basis of the herd average milk yield. Over all twenty-eight A.I. centers the average yields of the heifers in the 'high', 'medium' and 'low' groups of herds were 966 gallons (9950 pounds), 862 gallons (8899 pounds) and 758 gallons (7807 pounds) respectively. Each bull then was evaluated according to the Contemporary Comparison of his daughters in the three groups of herds. For this comparison there were sufficient records for 120 bulls.

In the good herds the true range of genetic variation between bulls was much greater than in the poorer herds. This is an important point. It is possible to pick out superior sires more accurately in high than in low yielding herds if the same number of daughters are used in each case. For selection of equivalent accuracy nearly twice as many daughters would be needed in medium as in high herds, and about twice as many again in low herds.

The order of merit of the 120 bulls in each group of herds (high, medium and low) was worked out separately. It was roughly, but not exactly, the same in each. Indeed, exact agreement was not to be expected. Some of the variation in order would be due to the effect of sampling, i.e. to the fact that a sample of only 23 daughters per bull was available, and their average would not necessarily be the same as that of the very large number needed for complete accuracy.

Mason also compared the performance of progeny of a number of sires under test station conditions and under average farm conditions. He concluded that the results from the farm herds were likely to be more suitable under British conditions than the test station method.

Robertson and Rendel (1950) have presented a theoretical approach to the genetic gain to be expected in artificially inseminated herds. They estimated the maximum rate of genetic improvement in a unit of 200 cows to be of the order of 1.5 percent of the average yield per annum, i.e. under present conditions at about ten gallons (one gallon equals 10.32 pounds) per year. Efficient use of progeny testing must include the breeding of young bulls from the selected progeny-tested sires. Each sire progeny-tested for milk yield would also have been tested for deleterious recessives by matings to twenty of his daughters. The optimum structure depends little on the assumed heritability of milk yield. The rate of advance increases with the size of the unit.

EXPERIMENTAL PROCEDURE

A postal survey was conducted in an effort to locate as many of the tested progeny of Kansas Artificial Breeding Service Unit bulls as possible. On June 3, 1954 a questionaire was mailed to all Dairy Herd Improvement Association members whose names also appeared on the "Bull Tales" mailing list of the Kansas Artificial Breeding Service Unit (Appendix, Form 1). A card was enclosed on which the member could indicate the number of daughters of Kansas Artificial Breeding Service Unit bulls which he owned that had resulted from artificial insemination (Appendix, Form 2). He also was requested to indicate the number of such females over two years of age, those one to two years of age, and those under one year of age. By July 16, 171 replies to the questionaire had been recieved. On July 16, a second letter was mailed to the 179 members who had not replied to the first. On September 10, 1954, 263 cards had been returned by the 308 members contacted. Thus 85 percent of the questionaires were returned (Appendix, Table 1).

A preliminary herd survey was conducted in Dickinson and Geary counties during October, 1954. This preliminary survey was made for the purpose of estimating the number of Kansas Artificial Breeding Service Unit progeny which could be found that were positively identified, which were on test, and which had tested dams. From this survey it was estimated that at least 1500 tested progeny from Kansas Artificial Breeding Service Unit bulls might be found which met these qualifications. It was estimated also that there might be approximately 500 Holstein progeny.

During September 1955 farm visits were made in counties where sufficient numbers of Kansas Artificial Breeding Service Unit Holstein-sired progeny were to be found (Appendix, Form 3). On 37 of these farms there were Kansas Artificial Breeding Service Unit progeny which could be identified positively and that had completed a lactation record. Of the 500 Holstein progeny expected to be found, records on approximately 250 were found. This difference in the number of actual records from the estimated number was due to the exclusion of those animals for which incomplete information was available (Appendix, Table 2). The animals excluded were those that could not be identified positively, those whose records were unidentified and those whose dams were untested. Some were excluded for lack of completed lactation records.

At each farm visited, the records of the progeny and their dams were copied from Dairy Herd Improvement Association herd books onto Bureau of Dairy Industry 718 cards (Appendix, Form 4). All records of the daughters and dams were copied. The herd averages for the years in which the records were made were copied also on the cards. The herd averages copied were those computed by the Dairy Herd Improvement Association supervisor. This is the only type of herd average used in this study.

The management conditions were rated according to a numerical scale ranging from one to nine. The number one was assigned to the poorest type of management and nine to the best. This management rating system was an objective system based on the judgement of the author (Appendix, Form 5).

Only complete lactation records of 305 days or less were used. All production records were corrected for age at calving. The correction factors used were the Bureau of Dairy Industry correction factors (Kendrick, 1953). All lactation records for each individual were averaged. These 201 daughter-dam comparisons will be arranged in standard Agricultural Research Service sire proving form.

One of the purposes of this study is to remove as nearly as possible the genetic and environmental differences not common to each sire group. In these data the Dairy Herd Improvement Association herd average will be used as an environmental correction measure to evaluate the general level of nutrition in these herds. An objective management rating will be used to measure the skill and ability of the dairy farmer as it affects the environmental portion of these records. The dams' lifetime average will be used to help adjust for maternal genetic differences among these daughters.

The effects of these three variables in herds of different production levels will be studied with the aid of correlation analyses. The records then will be adjusted by covariance analysis for differences in the general effects of these three variables. The effectiveness of these adjustments will be measured by comparison of the adjusted data with the original data.

The last phase of this paper is to rank these bulls. Each sire will be ranked according to the covariance-adjusted mean production of his daughters. This ranking will be used as a reference standard. All other rankings will be compared to this standard ranking and the accuracy of the ranking method will accordingly be judged. Each sire will be ranked by his daughters' average production, daughter-dam production difference, and Wright's regression index. These rankings also will be compared to the bull selection committee ranking in an effort to help the bull selection committee evaluate their selection methods.

RESULTS

From the 37 herds, 851 suitable records were collected. These records represented 201 cows and their dams. These 201 cows were offspring resulting from the artificial insemination of their dams with semen from bulls in the Kansas Artificial Breeding Service Unit. Daughters of eleven such bulls were included in this study.

A comparison of the production of the 201 cows with the production of their dams is presented in Table 1.

Table 1. Comparison of the production of the 201 cows with the production of their dams.

Animals number	Records averaged	Milk pounds	Butterfat pounds
201 daus.	228	12367	437
201 dams	623	11363	403
Diff.	(132-125)	+1004	+34

The average milk production of 66 percent of the 201 cows equaled or exceeded their dams' milk production. Also, 62 percent of the 201 cows equaled or exceeded their dams' butterfat production. The difference in the average production of these 201 cows and their dams may be considered to be an estimate of the general effectiveness of the Kansas Dairy Improvement Program. As pointed out previously, such differences among daughters and dams in production may not be due entirely to superior inheritance. As was also pointed out, the superiority of the inheritance of the artificially-sired daughters must be estimated from some form of the progeny test.

A total of eleven sires were represented in these data. These eleven sires had a varying number of daughters in several different herds. The number of daughters and the number of herds in which the daughters of each sire were tested are presented in Table 2.

Table 2. Number of daughter-dam comparisons per sire and the number of herds from which these daughter-dam comparisons were taken.

Bull		No. of herds in which daughters were tested	No. of daughter-dam comparisons
No.	Name		
H-2	Dictator	22	54
H-3	Don Lad	10	15
H-5	Tidy	6	6
H-7	Triune	23	53
H-8	Man-O-War	2	15
H-9	Burke Lad	6	8
H-10	Oostie	6	8
H-11	Duke	16	18
H-12	Captain Bold	13	17
H-13	Utmost	2	3
H-14	Quartermaster	4	4

Although the average number of daughter-dam comparisons per bull was 18.2, there was a wide range among bulls in the number of comparisons. Two bulls had 50 or more comparisons while two bulls had four or fewer comparisons. These unequal numbers of daughter-dam comparisons made it difficult to compare these bulls equitably. Furthermore, the average number of herds in which these bulls had daughters was ten. The number of herds ranged from two for two bulls to 23 for one bull. These herds represent different types of environment. The inequalities in the numbers of herds and the concomitant types of environment may have had some effect on the production records.

If these differences had not existed, the bulls might have been rated solely on the basis of their daughter-dam comparisons. However, in view of the differences, it was necessary to evaluate the effects of some of these factors. In these data the herd average was used as a measure of the environmental level, primarily feeding, in which cows were tested. The herd management rating was used as a general measure of the herd owner's skill and ability in dairying. The dam's average production also was included to measure both environmental differences in records and genetic differences among mates of the sires.

As pointed out in the literature review it has been shown that there may be gross differences in the effectiveness of the herd average in adjusting for environmental differences among animals in different herds. Furthermore the effectiveness of the management rating as an environmental correction factor was not known. Therefore, it appeared desirable to study the interrelationships of these factors in low, medium and high producing herds before making any adjustments in the production records.

Usefulness of Herd Average and Management Rating as Environmental Indexes in Three Production Level Groups.

The records of the 201 cows were separated into three equal-sized groups according to the average production of the herd from which the records had been taken. These three groups represented low, medium and high herd averages. This gross division was necessary because of the paucity of data. By using this stratification procedure, sufficient data for analysis were included in each group. The range in the herd averages of the low group was from 288 to 371 pounds of butterfat, a range of 83 pounds of butterfat. The range in the medium group was from 371 to 403 pounds, a range of 32 pounds of butterfat. The range in the high group was from 403 to 495 pounds of butterfat, a range of 92 pounds of butterfat. These ranges are inclusive. The range in the medium group was only one-third the magnitude of the other ranges.

The numerical management rating ranged from two to eight in the low group, from three to eight in the medium group and from five to eight in the high group.

The interrelationships of the daughters' production, and the dams' production, the herd average and the management rating were studied within each of these production groups with the aid of correlation analysis.

Usefulness of Herd Average and Management Rating in the Low Production Group. The relationships found among these variables in the low group are presented in Table 3.

Table 3. The correlations among the daughters' production, the dams' production, the herd average and the management rating in the low group.

	Herd average	Management rating	Daughters' production
Dams' production	0.090	0.160	0.082
Herd average		0.265*	0.258*
Management rating			0.367**

* $P < .05$
** $P < .01$

Within this low group the daughters' production was most closely correlated with the herd management rating. Hence the daughters' production was markedly influenced by the type of management under which she produced. The daughters' production also was strongly correlated with the herd average. The difference in these two correlations was an indication that the production of these daughters was affected to a lesser degree by those factors which cause low and high herd averages than by the factors which cause low and high management ratings.

The daughters' production and the dams' production were only slightly associated. The strong correlation between the environmental indexes and the daughters' production and the weak correlation of the daughters' and dams' production indicated that the differences in production records of the daughters are primarily due to environmental differences.

The dams' production was only slightly associated with the herd average. The difference in the size of the correlation between the dams' production and the herd average and the correlation between the daughters' production and the herd average may be caused by a rapid turnover in the cows in these herds or to rapidly changing environmental conditions. The dams' production and management rating were slightly correlated. This correlation and the occurance of the rather strong correlation between daughters' production and the management rating suggested that the factors measured in the management rating of these herds were more stable than those that affected the herd average.

Herd management and herd average were significantly correlated. This correlation was an indication that the two variables measured some of the same factors.

The correlations in this low production group demonstrated that environmental differences account for much of the differences among daughters in their production. In this group the management rating was about 50 percent more effective in explaining differences in daughters' production than was the herd average.

Usefulness of Herd Averages and Management Rating in the Medium Production Group. The correlation analysis of the data from the medium group indicated that the relationships in this group were somewhat different from those in the previous group. The interrelationships found among the four variables are presented in Table 4.

Table 4. The correlations among the daughters' production, the dams' production, the herd average and the management rating in the medium group.

	Herd average	Management rating	Daughters' production
Dams' production	0.267*	0.355*	0.225
Herd average		0.143	0.039
Management rating			0.147

* $P < .05$

In this group genetic differences in the daughters' production appeared to be more important than the environmental differences measured by the herd average and management rating. This is evidenced by the high correlation of the dams' production with the daughters' production and the low correlations between the daughters' production and the environmental indexes. The daughters' production and the herd average were apparently unrelated.

Unlike the results observed in the low group the dams' production was closely associated with the management rating. This relationship was also observed in the dams' production and the herd average. However, here again the management rating was more effective in explaining the differences in the dams' production than was the herd average. The management rating and the herd average apparently had much less in common in this group than in the low group. The differences in the effect of the environmental influences in this group as compared to the low group may have been due to the narrower range in herd averages and management ratings in the medium group.

Usefulness of Herd Average and Management Rating in the High Production Group. In the high group as in the medium group there were no significant correlations between daughters' production and any of the three other variables. The correlations found in the high group differed from those found in the preceding groups. The relationships in the high group are presented in Table 5.

Table 5. The correlations among the daughters' production, the dams' production, the herd average and the management rating in the high group.

	Herd average	Management rating	Daughters' production
Dams' production	0.296*	0.135	0.213
Herd average		0.568***	0.218
Management rating			0.105

* P < .05
*** P < .001

The correlation between the daughters' production and the dams' production in this group was greater than in the low group. This difference indicates that genetic differences are of more importance in this group than in the low group in determining differences in daughters' production. Unlike the relationship in the preceding group the daughters' production and the herd average were closely associated in this group.

Also the herd average was more effective in explaining the differences in the daughters' production than the management rating. In the preceding groups the management rating was more effective than the herd average in accounting for differences in the daughters' production. Both the dams' production and herd average and daughters' production and herd average were closely associated. The similarity in these associations suggested that the environmental conditions were fairly constant within herds in this group. The dams' production and the management rating were correlated in all three groups. However, the management rating was not as effective in determining the differences in the dams' production in the high group as in the preceding groups. The herd average and management rating correlation suggests that the management rating measures many of the same things measured by the herd average in these high records.

Summary of Findings Concerning the Usefulness of Herd Average and Management Rating as Environmental Indexes in these Three Production Level Groups. To assess the relative importance of the herd average, the management rating and the dams' average in determining differences in daughters' production, standard partial regression coefficients were used. The amount of variation in the daughters' production which might be accounted for by considering the independent effects of each of these factors were determined by the size of these standard partial regression coefficients. These coefficients are presented in Table 6.

Table 6. Relative importance of variations in dams' average herd average, and management rating in determining differences in production of the 201 cows.

Production Group	Standard partial regression coefficients for daughters' production on		
	Dams' average	Herd average	Management rating
Low	0.016	0.172	0.319
Medium	0.225	-0.111	0.083
High	0.162	0.182	-0.020

In the high and medium groups genetic variation was of considerably more importance than in the low group. This is evidenced by the relative size of the daughter-dam regression coefficients. In the high and low groups the herd average apparently accounted for much of the variation in daughters' production. In the medium group, probably due to the narrower range in herd averages, the herd average lost its utility.

In the low group the management rating was quite efficient in explaining the differences in daughters' production. The management rating lost its effectiveness in the higher groups.

Apparently the records in the high and medium herd average groups were more valuable in evaluating genetic improvement than the records in the low herds. The herd average apparently was a good measure of the environmental influences in production records. It appeared that a management rating could be quite helpful in accounting for differences in daughters' production in the low herd average group.

Adjustment of Production Records of the 201 Cows for Differences in Herd Average, Herd Management and Dams' Production

The magnitudes of the effects of these variables have been shown as they appear in three production level groups. Many of the relationships observed were not statistically significant. It appeared that the adjustment of records should have been done within such production groups before comparing bulls. Because of the limited data, this adjustment by multiple covariance analysis was performed on the entire body of data without regard to the previously mentioned production groups.

The simple correlation coefficients and the standard partial regression coefficients from this analysis are presented in Table 7.

Table 7. Correlation and standard partial regression coefficients for the relationships between daughters' butterfat production and the three variables: dams' butterfat average, herd average and management rating.

Coefficient	Daughters' butterfat production and: Dams' butterfat	Herd average	Management rating
Simple correlation	0.22**	0.28**	0.28**
Standard partial regression	0.10	0.16	0.16
$R^2 = 0.11$; $R = 0.33$**			

** $P < .01$

This analysis led to the following estimation formula:

$$1.\quad \hat{y} = \bar{y} + b'_{y1.23} (s_y^2)^{1/2} (s_{x_1}^2)^{-1/2} (X_1 - \bar{x}_1) +$$

$$b'_{y2.13} (s_y^2)^{1/2} (s_{x_2}^2)^{-1/2} (X_2 - \bar{x}_2) +$$

$$b'_{y3.12} (s_y^2)^{1/2} (s_{x_3}^2)^{-1/2} (X_3 - \bar{x}_3)$$

which upon substitution of numerical values led to the following formula:

$$2.\quad \hat{y} = 436.6 + (0.101)\ (1096/1313)\ (X_1 - 406.2) +$$

$$(0.157)\ (1096/660)\ (X_2 - 390.6) +$$

$$(0.162)\ (1096/22.06)\ (X_3 - 6.23)$$

This formula was modified slightly and simplified to the following equation:

$$3.\quad Y - \hat{y} = Y - 249.9 - 0.084X_1 - 0.262X_2 - 8.75X_3$$

The deviation ($Y - \hat{y}$) was added to $\bar{y}$ to provide an understandable estimate of Y, freed of the effects of X_1, X_2 and X_3.

Every daughter's records were adjusted by means of this formula. About 11 percent of the variation in the daughters' production was controlled by considering these three factors. The adjusted production records of the 201 cows were thought to be more suitable bases for comparing bulls.

Significance of Differences in Average Butterfat Production of Sire Daughter Groups. The complete production data on the progeny and the mates of the 11 sires in this study were grouped by sires to show daughter and dam production averages and daughter-dam differences. These daughter-dam comparisons were prepared according to the methods used by the Agricultural Research Service (Kendrick, 1953). The covariance-adjusted daughter averages were computed also.

The differences among the daughter averages of each of the 11 sires were tested for significance. The differences among the covariance-adjusted daughter averages of the 11 sires also were tested for significance. These analyses were performed to determine if there were any differences in the general transmitting abilities of the 11 sires. Likewise, similar analyses of the daughter averages of individual sires within the three production level groups were performed to determine if there were significant differences in the transmitting abilities of the sires in different levels of production.

The daughter-dam comparisons for each of the 11 bulls are presented in Table 8.

Table 8. Daughter-dam comparisons for the 11 Holstein bulls.

Name of bull	Animals number	Records averaged	Milk pounds	Butterfat pounds
H-2 Nemaha Dictator Inka	54 daus.	60	11885	412
Pride 911120	54 dams	145	10932	390
Used in 22 herds	Diff.	(33-30)	+ 953	+22
H-3 Springrock Don Lad	15 daus.	21	12461	445
1063733	15 dams	58	11357	406
Used in 10 herds	Diff.	(11-11)	+1104	+39
H-5 Heersche Polkadot	6 daus.	8	12548	430
Tidy 936033	6 dams	26	12072	443
Used in 6 herds	Diff.	(3-3)	+ 476	-13
H-7 Meierkord Netherland	53 daus.	61	12332	443
Triune 886182	53 dams	167	11164	398
Used in 23 herds	Diff.	(39-36)	+1168	+45
H-8 U Mo Man-O-War	15 daus.	18	12795	439
Monarch 876629	15 dams	54	13559	474
Used in 2 herds	Diff.	(7-5)	- 764	-35
H-9 Lilac Valley Burke	8 daus.	8	12440	468
Lad 1036830	8 dams	21	10458	391
Used in 6 herds	Diff.	(5-7)	+1982	+77
H-10 Oostie Imperial Pride	8 daus.	8	11961	437
979850	8 dams	20	10538	392
Used in 6 herds	Diff.	(6-5)	+1423	+45
H-11 Heersche Polkadot	18 daus.	18	11656	416
Duke 936020	18 dams	60	12294	447
Used in 16 herds	Diff.	(9-8)	- 562	-31
H-12 Rainbow Captain	17 daus.	17	14446	502
Bold 11th 934020	17 dams	59	11476	406
Used in 13 herds	Diff.	(13-14)	+2970	+96
H-13 Kanstacol Madcap	3 daus.	5	13189	441
Utmost 997953	3 dams	6	10585	350
Used in 2 herds	Diff.	(3-3)	+2604	+91
H-14 Kanstacol Eyebright	4 daus.	4	11532	423
Quartermaster 939457	4 dams	7	9848	362
Used in 4 herds	Diff.	(3-3)	+1684	+61

The differences in the average butterfat production of the daughters of each sire were examined by means of analysis of variance. The results of this analysis are presented in Table 9.

Table 9. The analysis of variance of the butterfat records of daughters of the 11 sires.

Source of variation	Degrees Freedom	Mean Squares	F
Among sire groups	10	13,945.77	2.46*
Within sire groups	181	5,678.78	

* $P < .05$

The average production of the daughters of H-12 was significantly greater than the average production of all 192 cows included in this analysis. Similarily the average production of the daughters of H-11 was significantly less than that of all 192 cows included in this analysis. The average production of the remaining sire groups did not differ significantly.

The records of the daughters of each sire were assembled by production groups to determine if there were differences in the producing abilities of each sire's daughters within each production group. Presented in Table 10 are the means for each sire group within the three production groups.

Table 10. Mean butterfat production of each sire group in low, medium and high production groups.

Name of Bull	No. daus.	Low	No. daus.	Medium	No. daus.	High
H-2 Dictator	30	396	15	427	9	437
H-3 Don Lad	4	411	3	436	8	465
H-5 Tidy	2	471	3	394	1	455
H-7 Triune	12	438	13	406	27	447
H-8 Man-O-War	1	383	14	443	--	---
H-9 Burke Lad	1	286	1	503	6	493
H-10 Oostie	4	437	3	422	1	483
H-11 Duke	3	425	8	392	6	438
H-12 Captain Bold	5	481	6	477	6	432
H-13 Utmost	2	463	1	398	--	---
H-14 Quartermaster	3	430	--	---	1	403

These means were then subjected to an analysis of variance. The analysis is presented in Table 11.

Table 11. Analysis of variance of the butterfat records of sire groups within each production level.

Source of variation	Degrees freedom	Mean squares	F
Low herds			
Among sire groups	8	6,214.01	1.32 ns
Within sire groups	56	4,709.14	
Total	64		
Medium herds			
Among sire groups	7	4,772.38	0.92 ns
Within sire groups	57	5,164.51	
Total	64		
High herds			
Among sire groups	5	12,059.87	1.64 ns
Within sire groups	56	7,370.63	
Total	61		

There appeared to be no statistically significant differences in the transmitting ability of these sires within each level of production. However, possible differences in the transmitting abilities of these bulls might have been obscured by the environmental and genetic factors discussed previously. Therefore, the covariance-adjusted records of the daughters of each sire also were assembled by production groups to determine if there were differences in producing abilities of each sire's daughters within each production group. These means are presented in Table 12.

Table 12. The covariance-adjusted mean butterfat production of each sire group in low, medium and high production groups.

Name of Bull	Low Group		Medium Group		High Group	
	No. daus.	B'fat pounds	No. daus.	B'fat pounds	No. daus.	B'fat pounds
H-2 Dictator	30	405	15	420	9	432
H-3 Don Lad	4	427	3	429	8	450
H-5 Tidy	2	505	3	375		
H-7 Triune	12	466	12	438	27	445
H-8 Man-O-War			14	430		
H-9 Burke Lad					6	466
H-10 Oostie	4	467	3	425		
H-11 Duke	3	438	8	389	6	417
H-12 Captain Bold	5	504	6	474	6	532
H-13 Utmost	2	493				
H-14 Quartermaster	3	450				

The significance of the differences among these means was tested by analysis of variance. This analysis is presented in Table 13.

Table 13. Analysis of variance of the adjusted production records of the sire groups within each production level group.

Source of Variation	Degrees Freedom	Mean Squares	F
Low			
Among sire groups	8	8,163.58	2.05 ns
Within sire groups	52	3,974.35	
Medium			
Among sire groups	7	4,997.26	0.98 ns
Within sire groups	53	5,055.60	
High			
Among sire groups	5	12,963.14	1.77 ns
Within sire groups	52	7,336.85	

The effect of the covariance adjustment was to make the production of the daughters within sire groups more uniform. Again the differences among sire daughter groups were not significant within any of the production groups.

Those bulls whose daughters appeared in two or more of the production groups were then compared. This analysis is presented in Table 14.

Table 14. Analysis of variance of the adjusted production records of the sire groups which appeared in two or more of the production level groups.

Source of Variation	Degrees Freedom	Mean Squares	F
Among sire groups	6	17,676.17	3.55**
Among production groups within bulls	12	4,976.06	1.01 ns
Error	154	4,904.74	

** $P < .01$

In this table significant differences among bulls were shown. In the analysis presented in Table 9 the sire variance had accounted for approximately seven percent of the total variation in the production averages whereas in this analysis it accounted for more than 12 percent. This indicated the effectiveness of the covariance adjustments. The heritability of the differences in the unadjusted production records was approximately 30 percent. The heritability of the differences in the adjusted production records was approximately 50 percent, an increase of 63 percent. These analyses have demonstrated that although the amount of variation controlled by covariance was small, control has increased the accuracy of the estimation of the breeding value of these sires.

These analyses also demonstrated that the limited amount of data and the great variation among individual production records makes any ranking of these sires problematic. The daughters of sires H-11 and H-12 were the only sire groups that have been shown to be significantly different in their producing ability in these data.

Although there were no significant differences in the average production of the remaining sire groups the best estimate of these sires breeding value can be made on the basis of their daughters' covariance-adjusted averages.

The statistical analyses were performed according to methods outlined by Snedecor (1946) and Anderson and Bancroft (1952).

Ranking of Bulls

In the previous section it was shown that the best method for comparing the breeding value of the bulls should be on the basis of these covariance-adjusted daughter averages. The adjusted production averages of the daughters and the rank of each of the 11 bulls according to these averages are presented in Table 15.

Table 15. The rank of each bull by covariance-adjusted daughter averages.

Name of Bull	No. daus.	Covariance-adjusted averages	Rank
H-12 Captain Bold	17	503	1
H-13 Utmost	3	487	2
H-9 Burke Lad	8	451	3
H-10 Oostie	8	448	4
H-14 Quartermaster	4	441	5
H-3 Don Lad	15	440	6
H-7 Triune	53	438	7
H-8 Man-O-War	15	429	8
H-5 Tidy	6	427	9
H-2 Dictator	54	419	10
H-11 Duke	18	408	11

Several other methods of indexing these bulls were used. These indexes were 1. daughter averages, 2. Wright's index, 3. daughter-dam differences. The daughter averages and the daughter-dam differences were taken from Table 8. Wright's (1931) index was calculated from the following formula:

$$S = \frac{2A}{n + 2} + \frac{n\,(2O - D)}{n + 2},$$

where S = sire's index; A = breed or herd average; n = number of daughter-dam comparisons; O = daughters' average production; and D = dams' average production. This index accounts for differences in the reliability of comparisons based on different numbers of daughter-dam comparisons. This is accomplished by regressing the differences towards some average. The average used in calculating Wright's index was the average obtained by averaging all the herd averages for the daughters included in the index.

These indexes have been compared with the covariance-adjusted averages in Table 16.

Table 16. The mean production index of 11 sires by 4 different indexing methods.

Name of Bull	No. daus.	Covariance-adjusted averages	Dau. average	Wright's index	Dau.-dam diff.
H-12 Captain Bold	17	503	502	476	+96
H-13 Utmost	3	487	441	441	+91
H-9 Burke Lad	8	451	468	446	+77
H-10 Oostie	8	448	437	414	+45
H-14 Quartermaster	4	441	423	443	+61
H-3 Don Lad	15	440	445	449	+39
H-7 Triune	53	438	443	438	+45
H-8 Man-O-War	15	429	439	393	-35
H-5 Tidy	6	427	430	406	-13
H-2 Dictator	54	419	412	432	+22
H-11 Duke	18	408	416	353	-31

<u>Comparisons of Bulls by Four Different Indexes</u>. The butterfat production indexes for each bull are very similar. However, the differences are best seen in the comparison of the ranks of each bull as presented in Table 17.

The similarity of the rankings presented in Table 17 was measured by use of Spearman's rank correlation method (Snedecor, 1946). The correlations between the ranking by the covariance-adjusted averages and the other three methods were: 1. daughter-dam difference, $r_s = 0.91$ ($P < .01$); 2. daughter average, $r_s = 0.77$ ($P < .01$); and 3. Wright's index, $r_s = 0.74$ ($P < .01$).

Table 17. Ranking of the 11 bulls according to four indexes.

Name of Bull	No. daus.	Ranking according to: Covariance-adjusted averages	Dau. average	Wright's index	Dau.-dam diff.
H-12 Captain Bold	17	1	1	1	1
H-13 Utmost	3	2	6	5	2
H-9 Burke Lad	8	3	2	3	3
H-10 Oostie	8	4	4	8	5
H-14 Quartermaster	4	5	9	4	4
H-3 Don Lad	15	6	3	2	7
H-7 Triune	53	7	5	6	5
H-8 Man-O-War	15	8	7	10	11
H-5 Tidy	6	9	8	9	9
H-2 Dictator	54	10	11	7	8
H-11 Duke	18	11	10	11	10

The bulls were ranked in very similar orders by each of these methods. The ranking according to daughter-dam differences most closely resembled the ranking according to the covariance-adjusted daughter averages. The daughter average and Wright's index are affected more readily by differences in herd averages than are the other two indexes. This may account for some of the differences among the rankings.

Bull Selection Committee Rankings. In an effort to evaluate the selection methods used by the bull selection committee a letter was sent to each member of the bull selection committee asking him to rank the 11 bulls (Appendix, Form 6). Enclosed in this letter were the original data which were available to the committee at the time the bull was selected for service. The members were asked to imagine all the bulls in one group with only the original data available for comparison. They were asked to rank them for production tmansmitting ability on these original data only. They were asked to disregard any information which may have become available to them after the bulls had been put in service. The ranks given each bull by the individual members of the committee were combined into a single rank(Appendix, Table 3). This combined rank was compared to the covariance-adjusted daughter averages. These mankings are presented in Table 18.

Table 18. Comparison of the rankings of the bull selection committee and covariance-adjusted daughter averages.

Name of Bull	Ranking according to: Covariance-adjusted averages	Bull selection committee
H-12 Captain Bold	1	1
H-13 Utmost	2	8
H-9 Burke Lad	3	11
H-10 Oostie	4	3
H-14 Quartermaster	5	2
H-3 Don Lad	6	6
H-7 Triune	7	7
H-8 Man-O-War	8	4
H-5 Tidy	9	9
H-2 Dictator	10	5
H-11 Duke	11	10

The correlation between these two rankings was 0.31 ($P < .05$). If the correlation is accepted at face value even though it is not significantly different from zero, it may be taken to indicate a slight association between the two rankings. Five of the bulls were unproved at the time of selection. These bulls were H-3, H-5, H-9, H-11 and H-13. These bulls were ranked 6th, 9th, 11th, 10th and 8th respectively by the bull committee. It appears that the major differences that exist between the covariance-adjusted average ranking and the committee rankings resulted from the committee placing of proven bulls above unproven bulls.

Summary of Rankings. To facilitate comparison of the results of the various ranking schemes, the bull rankings by each method were compiled into one table. This summarization is presented in Table 19.

Table 19. Rankings of 11 bulls by 5 different methods.

Name of Bull	No. daus.	Ranking according to: Covariance-adjusted averages	Bull comm.	Dau. ave.	Wright's index	Dau.-dam diff.
H-12 Captain Bold	17	1	1	1	1	1
H-13 Utmost	3	2	8	6	5	2
H-9 Burke Lad	8	3	11	2	3	3
H-10 Oostie	8	4	3	4	8	5
H-14 Quartermaster	4	5	2	9	4	4
H-3 Don Lad	15	6	6	3	2	7
H-7 Triune	53	7	7	5	6	5
H-8 Man-O-War	15	8	4	7	10	11
H-5 Tidy	6	9	9	8	9	9
H-2 Dictator	54	10	5	11	7	8
H-11 Duke	18	11	10	10	11	10

The rankings of the bulls in these data have been made on the basis of butterfat production of their daughters. The rankings according to the daughters average milk production and the daughter-dam difference in milk production can be found in Appendix Table 4.

DISCUSSION

The average milk production of the 201 progeny of the 11 Holstein bulls was 1004 pounds greater than that of their daughters; the average butterfat production was 34 pounds greater. These increases have been attributed primarily to the Kansas Dairy Improvement program. The improvement was brought about by a combination of better breeding through the use of better sires, and better environment through better feeding and management. From these data it appeared that about 30 percent of this increase should be attributed to better breeding while most of the remaining portion was due to better environment. A part of this environmental increase may have been due to the Kansas Artificial Breeding Service Unit's efforts to increase breeding efficiency. Perhaps some of this environmental increase was the result of better care and management due to pride of ownership. Pride of ownership is intangible and could not be measured. However, this might have been one of the factors that contributed to this general increase for pride of ownership was observed on many of the farms which were visited. The entire environmental effects of this program may have resulted from a more efficient relationship between the dairy farmer and the educational interests of the state school.

Environmental differences were measured by using three general indexes: the annual herd average, a herd management rating and the dam's lifetime production average. The annual herd average and the herd management rating were employed as indexes to environmental differences primarily among herds. The dam's lifetime average was used as a dual measure of genetic and environmental variations. The effectiveness of these measures was studied in three different levels of production. The records of all the 201 cows were divided into three equal production groups according to their annual herd average. These groups represented high, medium and low production groups.

The herd average used in this study was the Dairy Herd Improvement Association average computed by the Dairy Herd Improvement supervisor. In previous studies of this type a breed average or an average of all lactation records completed in a herd one year have been used. The Dairy Herd Improvement Association herd average is computed by Dairy Herd Improvement Association supervisors, whereas the other averages are not computed by Dairy Herd Improvement Association supervisors nor are they readily available. The utility of the Dairy Herd Improvement Association herd average as an environmental index has special significance because of its availability. The herd average was apparently a good measure of the environmental influence on the individual production records of these 201 cows. These findings are similar to those reported by McGilliard (1952). McGilliard using an average of all the cows to complete a testing year found that the average when subtracted from the yearly production record gave a good index of the environmental influences.

A management rating was devised for this study in which the herds were given a numerical rating for management conditions. This was an objective rating based on the author's judgement of the individual herd owner's skill and ability in dairying. Correlations with the herd average and management rating show that they measure some of the same things. These results show that the management rating was more effective in accounting for the variation in the production of the daughters in the low groups than in the other production groups. However, the management rating lost its effectiveness in the higher production level groups. As a single measure of the variation of the daughter's production the management rating was nearly as effective as the herd average and the dams' production in the high and medium groups. The management rating as used in this study was a gross judgement of the owner's skill and ability. If it were possible to define management rating and apply it more carefully it might be possible for it to have utility at all levels of production.

The dams' average production was used to adjust for genetic differences among the mates of each sire. Genetic variation was of more importance in the high and medium groups than in the low group. This supports Mason's (1956) work and is contrary to Korkmann's (1953) work in which he found no differences in genetic variation at all levels of nutrition.

Covariance analyses were used to adjust the records of these 201 cows, for the effects of the three variables: herd average, herd management and dams' production. This adjustment removed about 11 percent of the variation, increasing the heritability estimate from 0.3 to 0.5. These heritability estimates were slightly higher than those cited in the literature. This was thought to be due to the use of lifetime averages for the dams and first production records for the daughters.

The sires in these data were ranked in several different ways. The covariance-adjusted daughter averages were thought to form the best estimate of the breeding value of these sires. The average daughter-dam difference in butterfat production most closely approximated the covariance-adjusted daughter averages. The daughter average and Wright's index were not quite as accurate as the daughter-dam difference. This was probably due to the limited amount of data and to the sensitivity of these indexes to environmental changes.

There were several limitations in the rankings of these sires. The first and most important of these was the limited amount of data used in this study. There are several causes of the limitations in the amount of data, 1. the small number of progeny resulting from artificial insemination which are on test, 2. the inability to positively identify some of these tested progeny or to identify their production records, and 3. the inability to find the production records of their dams. It was evident from this study that a more vigorous testing program is necessary if the sire selection and evaluation program is to become more effective.

SUMMARY AND CONCLUSIONS

This study was undertaken to appraise from one aspect the results of the artificial breeding program in Kansas. Production records representing mates and progeny of 11 Holstein bulls used in the Kansas Artificial Breeding Service Unit were studied. The average milk production of the 201 progeny resulting from artificial insemination exceeded the average milk production of their dams by 1004 pounds. Also the average butterfat production of these progeny exceeded that of their dams by 34 pounds. This increase in production of daughters over dams gave tangible evidence of the value of the Kansas Dairy Improvement Program to dairy farmers of Kansas.

The progeny of these sires were tested in 37 different herds. Differences in the feeding and management of these herds were known to exist. These differences and the possible differences in the genetic merit of the mates of the bulls made more difficult the equitable comparison of these bulls. Therefore the production records of the progeny were adjusted for environmental differences by the use of two environmental indexes: the annual herd average and a management rating. Also the production records of the progeny were adjusted for differences in average genetic merit of the dams by use of the dams' lifetime averages. About 11 percent of the variation in the daughters' production records was controlled by considering these variables.

The Dairy Herd Improvement Association annual herd average was found to be useful in adjusting production records for herd differences. Approximately 8 percent of the variation in the butterfat records of the daughters could be accounted for solely by differences in herd averages.

When used as a single measure of herd differences, the management rating devised for this study was effective in accounting for approximately 8 percent of the variation in the butterfat records of these progeny.

Differences in the lifetime production records of the dams were correlated with differences in the production records of the progeny. This variation among the records of the dams accounted for approximately 5 percent of the variation among the daughters' records.

The relative usefulness of these three measures in accounting for differences in the production records of the progeny was studied in low, medium and high production herds. The management rating was approximately 80 percent more effective than the herd average within the low herds. However, in the high herds the herd average was nine times as effective as the management rating. Genetic differences as measured by the correlation of the production of daughters and dams were greater in the higher herds.

After the production records of the progeny of these 11 bulls were adjusted for these differences the bulls were compared. The average production of the daughters of only two of the bulls were found to be significantly different.

The 11 sires were ranked by covariance-adjusted daughter averages. The bulls were ranked also by three other easily calculated indexes. These rankings were compared to the rankings based on the covariance-adjusted daughter averages. Each of the rankings was found to be very similar to the covariance-adjusted ranking.

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APPENDIX

Table 1. Results of postal survey of Dairy Herd Improvement Association members using Kansas Artificial Breeding Service Unit sires.

County	Number of Farmers	No. cows Freshened	No. Yearlings to Freshen	Total
Allen	5	6	36	42
Barton	3	12	25	37
Bourbon	1	2	5	5
*Butler	4	18	25	43
*Clay	3	8	12	20
*Cloud	6	27	41	68
*Coffey	4	18	42	60
Comanche	5	7	25	32
*Dickinson	14	52	79	131
Elk	3	2	13	15
Ford	8	15	74	89
Franklin	4	7	28	35
*Geary	9	43	75	118
*Harvey	2	4	9	13
Jackson	3	8	12	20
Jefferson	1	2	1	3
*Johnson	2	10	13	23
Kingman	3	6	18	24
Leavenworth	2	2	2	4
*Lyon	4	6	16	22
*McPherson	7	14	25	39
*Marion	14	37	94	131
Miami	1	3	1	4
Mitchell	2	2	4	6
Montgomery	3	6	23	29
*Morris	8	24	78	102
Nemaha	4	13	30	43
Osage	1	2	24	26
Ottawa	3	6	15	21
Pawnee	5	7	27	34
Pottawatomie	1	6	13	19
Pratt	6	9	22	31
*Reno	6	24	43	67
Republic	4	12	30	42
Rice	3	4	27	31
Russell	2	30	20	50
Saline	2	5	28	33
*Shawnee	4	63	64	127
Sumner	3	17	28	45
Wabaunsee	1	4	12	16
Thomas	1	2	0	2
Cheyenne	1	1	2	3
Neosho	1	4	6	10
Total	169	550	1165	1715

* Counties worked in

Table 2. Reasons for incomplete information about the production records of the estimated Holstein progeny by KABSU bulls.

Herd visited	Herd size	No tested progeny	No. with complete records	Records could not be used because: Cows or records not identified	No tested dams	Owner no longer testing	Records not complete
20002	29	4					4
20010	45	3	1				2
20020	23	11	5		4		2
20001	30	25	7		7		11
72023	37	20					
80008	18	7			7		
10004	5	3	2				1
84015	30	5				5	
81024	20	12	7				5
81005	10	8	2				6
81008	10	3	3				
81025	20	9	3		2		4
81021	16	12	7				5
81015	21	14	6		1		7
81014	25	17	10				7
81018	19	3					
14001	27	24	11				13
86006	32	16		7			9
86018	15	13		6			7
86011	24	13	5		2		6
86003	21	6			2		4
86013	15	8		8			7
86015	20	16		1	3		12
86009	22	8		5			3
86008	21	14		8			6
86002	13	9		4			5
86001	26	22	15				7
22031	46	10	3				7
22009	15	5	1	1			3
99011	26	9	4				5
95006	28	24				24	
95019	19	12				12	
82026	17	8	4				4
82009	20	8	6				2
82019	12	7					7
82009	20	12	4				8
91005	11	8					8
91004	18	10	6				4
91003	28	15	6				9

Table 2 (cont.)

Herd visited	Herd size	No tested progeny	No. with complete records	Records could not be used because:			
				Cows or records not identified	No tested dams	Owner no longer testing	Records not complete
91001	13	5	2				3
82021	22	10	3				7
96010	12	4		4			
96021	21	8				8	
44039	31	27	23				4
71006	29	15		15			
95007	30	24		24			
00001	50	31	22				9

Table 3. Rankings of bulls by individual committee members and composite rank for each bull by the entire committee.

Name of Bull	Individual ranking							Combined ranking
H-12 Captain Bold	1	1	1	1	1	4	5	1
H-13 Utmost	8	2	9	7	8	8	10	8
H-9 Burke Lad	11	11	10	11	11	11	7	11
H-10 Oostie	4	4	3	2	3	3	2	3
H-14 Quartermaster	3	3	2	5	2	1	11	2
H-3 Don Lad	7	8	7	4	7	10	3	6
H-7 Triune	5	9	6	8	6	7	6	7
H-8 Man-O-War	2	5	4	3	4	2	9	4
H-5 Tidy	9	7	8	9	9	6	1	9
H-2 Dictator	6	10	5	6	5	5	8	5
H-11 Duke	10	6	11	10	10	9	4	10

The combined ranking was obtained by giving 55 points for first place ranking, 50 for second and 5 points were subtracted for each succeedingly lower rank. These were totaled and averaged and the mean formed the basis for the combined ranking.

Table 4. Ranking of 11 bulls according to average milk production of their daughters and the average difference in milk production of daughters and dams.

Name of Bull	Daughter average		Daughter-Dam difference	
	Milk	Bull Rank	Milk	Bull Rank
H-12 Captain Bold	14446	1	+2970	1
H-13 Utmost	13189	2	+2604	2
H-9 Burke Lad	12440	6	+1982	3
H-10 Oostie	11961	8	+1423	5
H-14 Quartermaster	11532	11	+1684	4
H-3 Don Lad	12461	5	+1104	7
H-7 Triune	12332	7	+1164	6
H-8 Man-O-War	12795	3	- 764	11
H-5 Tidy	12548	4	+ 475	9
H-2 Dictator	11885	9	+ 953	8
H-11 Duke	11656	10	- 562	10

Form 1. Letter of inquiry.

June 3, 1954

Dear Sir:

Your name appears on the "Bull Tales" list and also as a member of a Dairy Herd Improvement Association. This indicates that you have artificially-sired daughters that may be on test or will be tested in the future.

At this time we want to locate the largest possible number of females sired by bulls of the Kansas Artificial Breeding Service Unit. Information on the producing ability of these daughters can be obtained at a later date. By assembling such information, we can report back to you the comparative transmitting ability of the bulls you have used.

The success of this study is dependent upon the completeness with which we can obtain the information on artificially-sired daughters in Dairy Herd Improvement Association herds.

Please fill in the blanks on the enclosed, self-addressed, stamped card and mail it at your earliest convenience. An exact count is not necessary but we would like as accurate an estimate as you can make easily.

Very truly yours,

R. F. King, Jr.
Extension Specialist
Dairy Husbandry

Very truly yours,

Ralph Bonewitz
Extension Specialist
Dairy Husbandry

Form 2. Postal card for herd owner's reply.

INVENTORY OF ARTIFICIALLY SIRED OFFSPRING IN THIS HERD

(Only artificially-sired daughters of Kansas Artificial Breeding Service Unit bulls are included)

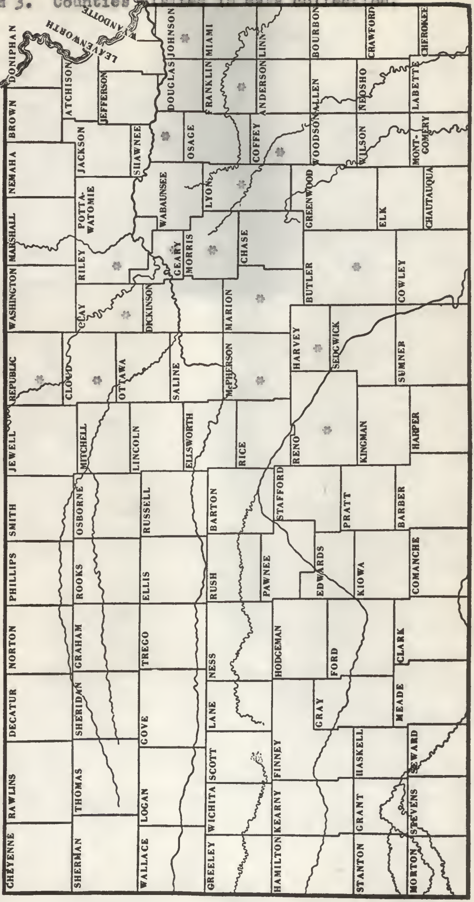
All females that have ever freshened: ____________________

Over one year including all heifers never freshened: ________

Under one year including all heifer calves: ______________

Owner: ____________________

Form 3. Counties visited in data collection.



Form 4. Card used to record data from individual cow.

DHIA PRODUCTION REPORT

FIRST 305 DAYS OF LACTATION PERIOD

USE BLACK INK ONLY — DO NOT FOLD

COW IDENTIFICATION: NUMBER | BREED

SIRE OF COW: NUMBER | BREED

DATE OF BIRTH: MONTH | DAY | YEAR

DAM OF COW: NUMBER | BREED

DATE OF CALVING (MONTH, DAY, YEAR)	DAYS IN MILK	DAYS MILKED 3 TIMES	MILK POUNDS	B'FAT POUNDS	TYPE	WEIGHT

REMARKS:

FOR RECORDS LESS THAN 305-DAYS: DATE DRY | OR DATE COW LEFT HERD

HERD OWNER NAME AND ADDRESS | HERD CODE:

ASSOCIATION:

CERTIFIED BY DHIA SUPERVISOR: | STATE | DATE:

REPORTED THROUGH AND APPROVED BY STATE AGRICULTURAL COLLEGE FORM APPROVED BUDGET BUREAU 40-R-191.1

DHIA—718 (REV. 1953) U.S. DEPT. OF AGRI., ARS—DH

ST | DATE REC'D | COW IDENTIFICATION | BR | SIRE NUMBER

DO NOT WRITE IN THIS SPACE

IBM 848466

Form 5. Factors considered in management rating.

The management rating used in this study was a gross judgement of the herd owner's skill, ability and interest in his dairy project. The factors which were considered in rating each herd were:

1. The owner's interest in his dairy project.
2. The condition of his herd book.
3. The condition of his herd.
4. The condition of his farmstead.
5. The physical facilities which were used in the dairy project.
6. The apparent interest and cooperation of the owner's family.

Form 6. Letter to bull selection committee.

November 8, 1955

Gentlemen:

Since you are or have been on the bull selection committee for the Kansas Artificial Breeding Service Unit, we would like to have you rank the following bulls on a production basis only. We are sending the original pedigree and proof on which you selected these bulls.

For the purpose of ranking the bulls, imagine them all in one group with only this original proof on them. Rank them on this original proof only; if you have information available on these bulls since their service with KABSU, please try to disregard it.

If you were not on the committee at the time of the selection of a particular sire, study the proof and rank him accordingly.

Please do not sign these rating sheets, since we are not interested in the individual selection, but in the selection by the committee as a whole.

____Nemaha Dictator Inka Pride, 911120
____Springrock Don Lad, 1063773
____Heersche Polkadot Tidy, 936033
____Meierkord Netherland Triune, 886182
____U-Mo Man-O-War Monarch, 876629
____Lilac Valley Burke Lad, 1036830
____Oostie Imperial Pride, 979850
____Heersche Polkadot Duke, 936020
____Rainbow Captain Bold 11th, 934020
____Kanstacol Madcap Utmost, 997953
____Kanstacol Eyebright Quartermaster, 939457

I appreciate your help in this matter.

Sincerely yours,

Dwight E. Hull, Jr.
Department of Dairy Husbandry

SOME METHODS OF EVALUATING THE GENETIC WORTH FOR MILK AND BUTTERFAT TRANSMISSION OF SIRES USED IN ARTIFICIAL BREEDING

by

DWIGHT ELLSWORTH HULL, JR.

B.S., Kansas State College of Agriculture and Applied Science, 1951

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Dairy Husbandry

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1956

ABSTRACT

It is generally recognized that sires used in artificial insemination have a tremendous influence on the inheritance of the dairy cattle population in the areas in which they are used. With this potential influence the need for early and accurate appraisal of the sires in use or to be used in artificial insemination can be readily seen.

This study was undertaken to appraise from one aspect the results of the artificial breeding program in Kansas. Production records representing mates and progeny of 11 Holstein bulls used in the Kansas Artificial Breeding Service Unit were studied. The average milk production of the 201 progeny resulting from artificial insemination exceeded the average milk production of their dams by 1004 pounds. Also the average butterfat production of these progeny exceeded that of their dams by 34 pounds. This increase in production of daughters over dams gave tangible evidence of the value of the Kansas Dairy Improvement Program to dairy farmers of Kansas.

The progeny of these sires were tested in 37 different herds. Differences in the feeding and management of these herds were known to exist. These differences and the possible differences in the genetic merit of the mates of the bulls made more difficult the equitable comparison of these bulls. Therefore the production records of the progeny were adjusted

for environmental differences by the use of two environmental indexes: the annual herd average and a management rating. Also the production records of the progeny were adjusted for differences in average genetic merit of the dams by use of the dams' lifetime averages. About 11 percent of the variation in the daughters' production records was controlled by considering these variables.

The Dairy Herd Improvement Association annual herd average was found to be useful in adjusting production records for herd differences. Approximately 8 percent of the variation in the butterfat records of the daughters could be accounted for solely by differences in herd averages.

When used as a single measure of herd differences, the management rating devised for this study was effective in accounting for approximately 8 percent of the variation in the butterfat records of these progeny.

Differences in the lifetime production records of the dams were correlated with differences in the production records of the progeny. This variation among the records of the dams accounted for approximately 5 percent of the variation among the daughters' records.

The relative usefulness of these three measures in accounting for differences in the production records of the progeny was studied in low, medium and high production herds. The management rating was approximately 80 percent more effective than the herd average within the low herds. However, in the high herds the herd average was nine times as effective as the management rating. Genetic differences as measured by the correlation of the production of daughters and dams were greater in the higher herds.

After the production records of the progeny of these 11 bulls were adjusted for these differences the bulls were compared. The average production of the daughters of only two of the bulls were found to be significantly different.

The 11 sires were ranked by covariance-adjusted daughter averages. The bulls were ranked also by three other easily calculated indexes. These rankings were compared to the rankings based on the covariance-adjusted daughter averages. Each of the rankings was found to be very similar to the covariance-adjusted ranking.