A COMPARISON OF METHODS OF EVALUATING BUTTERFAT PRODUCTION FOR DEVELOPING A DAIRY BREEDING PROGRAM

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A COMPARISON OF METHODS OF EVALUATING BUTTERFAT PRODUCTION FOR DEVELOPING A DAIRY BREEDING PROGRAM

By

Marlowe E. Nelson

AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan
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MARLOWE E. NELSON ABSTRACT

A study was made of 721 butterfat records of 288 Guernsey cows in five herds to develop a breeding program for the future that would reduce the mistakes involved in the selection of herd sires and breeding females.

Environment of the herds was found to be similar. All records were 2X and were converted to ME-305 days except short records (200 to 300 days), which were converted for age only.

Six methods of ranking the cows and first-calf heifers presently in the herds were used:

1. Cow's records as a deviation from annual herd average.

2. Estimated real producing ability.

3. Legates' Index.

4. ME-2X-305 day average of all of a cow's records.

5. Cow's records as a deviation from a three-year moving herd average.

6. Owner's or herdsman's opinion,

   a. including first-calf heifers,

   b. excluding first-calf heifers,

Rank correlation coefficients were calculated, using Legates' method as a standard for comparison. All other methods except owner's opinion were highly significantly correlated. Owner's opinion was less valid than any other method in most instances.

Reasons for variations in rankings, and factors affecting correlation values were discussed.

In order to see how much yearly variation there is in a cow's Legates value, a group of heifers in one herd was ranked as heifers (using Legates' heifer index), as one-record cows, and again as two-record cows (using Legates' cow index for the last two). Correlations between rankings showed that the heifer ranking was not an accurate measure of what the value would be after completion of one or two records.

Sixteen bulls of all ages were evaluated by Legates' bull index and/or by the values of their future daughters as determined by Eldridge's prediction equations. The accuracy of these evaluations can only be determined with the passage of time.

Proposals for a future breeding program for the five herds were made. The emphasis would be placed on the use of desirably proved bulls and their sons from the highest ranking cows.

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INTRODUCTION

A long-term project to improve Guernsey cattle through breeding was begun three years ago, and this present study was to evaluate the basic data. As the project continues, a yearly evaluation will be made to determine the progress resulting from the use of breeding plans as developed from this study.

Interested Guernsey breeders throughout the state were contacted and five herds were made available by the owners for a detailed study of past and present records of production, type, and management. The most important feature of the project is the owner interest and cooperation.

In order to develop a breeding program, several factors must be considered:

1. A goal must be determined. The complexity of inheritance of characteristics of dairy cattle is so great that it appears impossible to make improvement in all characteristics at the same time. The individual breeder must decide for himself the relative importance of various characteristics such as production of milk, production of butterfat, butterfat test, type, longevity, size, reproductive efficiency,

and others. Since dairying is an economic adventure for the herds in this study, production of milk and fat was considered by the owners to be the most important target for improvement. They were also desirous of improving type, size, and some of the other characteristics. If there is a positive correlation between these characteristics and production, they can be improved along with production, but probably at a slower rate. If faster improvement of type, for example, is desired, then a selection index combining production and type should be used. This would possibly result in sacrificing some in production in order to gain in type. If there is a negative correlation between production and type or any of the other characteristics, progress in one will result in a decline of the other.

Another method of combining factors for improvement is to set minimum levels for all important characteristics and eliminate animals that do not meet the minimum requirements for any one characteristic.

2. If improved production with improved type is the goal, methods of evaluating production and type records must be studied and the one that gives the most accuracy should be adopted for use for the future. A high degree of accuracy of record evaluation should reduce the mistakes involved in the selection of breeding

stock and should thereby raise the hereditary production potential of the herds involved.

Evaluation of records is not an easy task. Often important information is lacking or incomplete. Environment variations in the past are immeasurable, and their effects on the available records can only be estimated. In addition, since the Mendelian theory of inheritance is based on the principles of gene segregation and recombination, the various types of gene interaction complicate the process of comparing relatives for learning more about heritability and its effects.

Butterfat production is easily and accurately measured in pounds, and most of the studies in dairy cattle breeding have used butterfat records as the measure of a cow's ability. Type is measured by comparison with the standard of perfection, with six classification grades according to percentage of perfection. In this study, fat production in pounds and type by classification grades were used. However, there were no type records from the past, so no dam-daughter type comparisons could be made at this time.

Butterfat production and type of dairy cows have been evaluated by several indexes. These indexes have been derived from correlations between relatives and usually include correction factors for standardizing the more easily measured environmental effects. Type and production are often combined in one selection index, but the relative values of type and production must be determined beforehand. By using separate indexes for production and type, each can be weighted separately or in any combination, at the discretion of the breeder. Hazel (1943), in discussing selection indexes which include several traits (milk and fat production and type, for example), states that the genetic gain made by selecting for several traits at the same time is the product of:

1. The selection differential (value placed on each trait).

2. Multiple correlation between breeding value (heritable part of the traits concerned) and the selection index.

3. Genetic variability.

Methods of breeding (inbreeding, outcrossing) can affect (3), and (1) is subject to human error. An attempt to make (2) as large as possible will minimize the error in selection. Hazel states that the best way to test whether selection indexes work is to compare several indexes, constructed from data from different herds, on one herd. Testing one index on several herds would be a method of determining the reliability of the index. In order to achieve any degree of success using selection indexes in breeding programs, the best index should be chosen, and it must have a high degree of reliability from year to year and from herd to herd.

Legates and Lush (1954) and Eldridge (1948) have developed the production indexes used in this study. Legates' index is designed to give every animal a value as a deviation from herd average. Eldridge's index is a prediction equation used for estimating the production of a bull's daughters from their close relatives. Bulls are evaluated primarily on progeny performance for both type and production, but no selection indexes for type were used in this study because of the lack of past type records.

Evaluation of records in this project must also take into account the interherd environmental variation. Some attempt must be made to compare the environment of the herds, and if there is sufficient variation to warrant their use, correction factors should be applied. One of the most common ways of measuring environment is by the use of annual herd averages. However, extreme fluctuations in herd averages within a herd which has not changed management or had an outbreak of disease is probably due to genetic variability in the herd. Mistakes made in bull selection will usually show up later as slight to extreme fluctuations in herd averages. It is the extreme decreases in herd averages due to genetic change within the herds that this project was designed to prevent in the future.

REVIEW OF LITERATURE

Genetic Basis for Selection Indexes

There are certain basic principles that must be considered in attempting to improve cattle through breeding. The variance between cows, between herds, and between years must be recognized and, if possible, separated into environmental and genotypic portions. The genotypic variance can be further divided into additive and nonadditive genetic portions. Thus, $\sigma_o^2 = \sigma_g^2 + \sigma_d^2 + \sigma_i^2 + \sigma_e^2$, where σ_o^2 is the total (observed) variance, σ_g^2 is variance resulting from additively genetic factors, σ_d^2 and σ_i^2 denote variance due to nonadditive factors (dominance and epistatic, respectively), and σ_e^2 is environmental variance. The portion of the total variance which is heritable is σ_g^2, and the relationship between σ_g^2 and σ_o^2 is used as a measure of heritability ($h = \sigma_g^2/\sigma_o^2$). Lush (1945) defines heritability as the fraction of the phenotypic variance which is caused by the difference between the genotypes of the individuals. This, then, would be $(\sigma_g^2+\sigma_d^2+\sigma_i^2)/\sigma_o^2$. In practice, the difficulty arises in not being able to separate out all environmental influences, and, as a result, it has been necessary to develop statistical methods for discounting environmental effects.

Estimates of Repeatability and Heritability

Many studies of repeatability and heritability have been made on interherd and intraherd data, between and within both sire and year. The variation in results may possibly be attributed to the manner in which the data were selected and handled. Random errors can be reduced by increasing the numbers of trials, or, to be specific in evaluating bulls, by increasing the numbers of daughters of the bulls. However, biased errors cannot be reduced in the same way, and so all data must be carefully examined for biased errors, the four sources of which are given by Lush and Nelson (1943) as:

1. General environment may vary for daughters of different sires.

2. General environment may vary for dams and their daughters.

3. Average genetic merit of mates may vary from sire to sire.

4. Selection of mates may be more intensive for some sires than others, thus making the average records of mates farther above their transmitting ability in some cases than in others.

Of course, if there is selection within the daughters, this also becomes an important source of bias.

In order to adjust for the inequality of different numbers of records between cows, Lush (1945) uses a formula for computing the

estimated real producing ability of a cow: ERPA = herd average + nr/[1+(n-1)r] x (cow's average - herd average), where n = number of records of the cow, and r = repeatability (correlation between records of a cow). Various authors also refer to this as Probable Producing Ability or Estimated Producing Ability. This is not a measure of the cow's transmitting ability, but, by substituting h (heritability) for r in the numerator, it becomes a measure which Lush (1945) and others call Estimated Breeding Value.

The reported results of most determinations of intraherd repeatability (r) fall into a fairly narrow range. Lush and Arnold (1937) report 0.43, Legates and Lush (1954) calculated it at 0.41, Berry (1945) gave 0.29, but suggested that 0.40 was more nearly correct. Gowen (1920) calculated repeatability of milk production on the basis of correlation between one record of a cow and any of her other four records. His range in the value of r was 0.21 to 0.73, with a mean of 0.54. This wide range would be expected with this type of correlation. He also correlated each record of a cow against the average of all five records, and came out with r ranging from 0.74 to 0.86, which can probably be explained on the basis of the contribution one record has to the over-all average.

Berry and Lush (1939) found a high correlation (r = 0.70+) between a cow's highest or lowest and average of all the other records, but considered this due to statistical effects. Since they did not use cows that all had five records, they found the number of records was an important variable. Their conclusion was that averages appear to be more dependable than either selected or unselected single records.

In a later study, Berry (1945) reported that the major increase in reliability of a cow's record comes with the addition of her second record to her first. The addition of the third record also adds considerably, but beyond that, the contribution is so small that it is not important.

Estimates of the heritability (h) of dairy production traits are usually derived from the regression of daughters on dams. On a dam-daughter regression basis, Lush and Strauss (1942) calculated heritability of butterfat production at 0.17, with 5 percent limits at 0.03 and 0.31; Lush and Legates (1954) report the heritability of butterfat (Jerseys) as 0.20; Lush and Schultz (1936) got an approximate value of 0.25; Tyler and Hyatt (1947) calculated it at 0.28 from single, unselected records; Lush, Norton, and Arnold (1941) got several approximate values of 0.25 to 0.30. Beardsley, Bratton, and

Salisbury (1950) reported that the heritability of butterfat production was curvilinear, varying inversely with the level of production.

Larson, Chapman, and Casida (1951), in an attempt to study the heritability of butterfat production, found no evidence of heritability per day of life at any of the ages from 36 to 84 months. Their estimate of heritability of butterfat production from the first lactation was 0.30 ± 0.12.

Because Legates' study (1949) was on a large amount of data, and also because of the manner in which his study was made, his estimates of repeatability (0.4) and heritability (0.2) were selected for use in this study to evaluate cows on an intraherd basis.

Selection Methods

There are basically two types of selection that can be used in any problem involving genetics. Genotypic or family selection (pedigree and progeny) and phenotypic or individual (mass) selection are the extremes, although in cases of few or simply expressed characters, these may give very nearly the same results.

In complexly inherited factors such as milk and fat production, the individual's actual production is only the phenotypic expression of the animal's genotype. Selecting for genotype on the basis of one or a small number of (phenotypic) lactation records would naturally embrace a high degree of inaccuracy, particularly if the effects of environment are also considered.

Family selection. In order to minimize the risks of phenotypic selection, the alternative is selection on a family basis, wherein a truer picture of the genetic make-up of an animal could be gotten by comparing it with its close relatives. This is a particularly important means of selecting when characteristics involved are sex-limited (milk and fat production); bulls must be selected not on their own production, but on the basis of the production of their families; i.e., dams, sisters, and daughters.

According to Lush (1945), selection purely on a family basis produces $\frac{1+(n-1)r}{\sqrt{n[1+(n-1)t]}}$ times as rapid progress as does individual selection, where r = the genetic relationship between members of a family of infinite size, t = the phenotypic resemblance between members of a family of infinite size, and n = the number of members in the family. This formula exceeds 1.0 only when t is less than $r^2 - (1-r)^2/n$. If t is large and r is small, individual selection will make faster progress than family selection. When r is high and t is very low, increasing the number (n) of members in the family will increase progress made by family selection. Lush indicates that family selection is most superior to individual selection when the members of the family phenotypically resemble each other least (when r is considerably larger than t). Tabler, Tyler, and Hyatt (1950), in a comparison of Ayrshire cow families, confirm this formula and further indicate that family selection (keeping all members of a family) is not as effective in improving production levels as selection within families--which is a combination of individual and family selection. In studying type in these same Ayrshire cow families the same authors (1951) concluded that the correlation of relationship within families is usually too low to make family selection for type very effective, and also, under present breeding practices, there appears to be more variation within families because of environmental effects and different sires than there is between families.

Family selection, on pedigree alone, can be made the earliest of any method, and time is often an important factor. Actually, most purebred dairymen are considering that when they plan matings for several years in the future. The inaccuracy of pedigree selection is noticeable, however, since not only is pedigree information often incomplete or uninterpretable (genetically), but it can often change considerably from year to year as more is learned about the close relatives.

Lush and Schultz (1938), in studying pedigree promise and progeny tests, conclude that a pedigree is worth something in selecting a bull, but should not be valued too highly, since the daughters of a bull will get only a small part of the superiority which the bull's parents and grand-parents showed. The more one knows about the different environments under which the records in the pedigree were made, and allows for those differences, the more accurate the pedigree becomes as an indicator of the bull's breeding value. Eldridge (1948) believes that the proof of the sire is the most important information to consider in selecting by pedigree, and Copeland (1934) indicates that, in studying the ancestry of a bull calf, the records of the sire's daughters are of more value than the records of the dam alone. He further indicates that if the dam has a record and has two or more tested daughters, and if the dam's sire has other tested daughters, this information gives a good "index" of the bull calf's germinal composition as far as the contribution from the bottom side of the pedigree is concerned. His suggested pedigree to minimize the element of chance is as given on the following page.

paternal grandsire

sire

10 or more daughters avg.
600 pounds fat 2X-365-ME
(520 pounds fat 2X-305-ME)

same as grandsires

bull calf

maternal grandsire

dam

same as paternal grandsire

(520 pound average 2X-305-ME)
600 pound average 2X-365-ME
2 daughters with same average

Legates (1949) made a study using Jersey data and developed a regression equation for evaluating cows. It uses estimated real producing ability of the cows, their dams, daughters, and maternal and paternal sisters: ($I = X_1 + 0.4X_2 + b_3X_3 + b_4X_4 + b_5X_5$). He also developed a heifer and bull index ($I = 0.63Z + b_oO + b_pP$), using pedigree information only. These will be discussed in more detail in Methods and Procedures.

Individual selection. Selection on the basis of individuality is possible for milking females, and is the most widely used. Here, too, accuracy depends on the amount of information involved.

Dunbar and Henderson (1954) have reported a comparison of several types of selection indexes, some of which are based on the individual performance of a cow and some that consider pedigree information (relatives). The rank correlations between the method they have developed as best, which includes a lot of information on relatives, and the other methods that are similar to those used in this study are given in Table I (from Dunbar and Henderson, 1954).

The index which Henderson refers to as a modified Legates index is merely Legates' index with estimated real producing ability figured as a deviation from the arithmetic mean of all of the records in the study instead of from a moving herd average as Legates suggests.

The criticism of this type of ranking procedure is that all results are relative, and are dependent for their validity on the accuracy of the "best" method. If the prediction line would happen to be curvilinear, the inclusion of more information might decrease the accuracy of the "best" method, and correlating the methods using that index as base would then increase the possibility of not using the most accurate index.

Whereas Copeland (1938) stated that the highest record of an animal is the best index of that animal's actual inherited production capacity under "normal" conditions, it is now agreed that more information must be considered to improve accuracy. For selection between cows using the average of n records, Lush and Strauss (1942) show that progress is $\sqrt{n/(1-r+nr)}$ times as fast as when selecting on

TABLE I

RANK CORRELATION COEFFICIENTS BETWEEN HENDERSON'S "BEST" METHOD AND MORE APPROXIMATE METHODS

"Best" Method and:	Coef-ficient	"Best" Method and	Coef-ficient
Legates' Index	0.935	Cow's average production as deviation from annual herd average	0.881
"Modified" Legates . .	0.959	Estimated real producing ability	0.893
Cow's average production (ME-2X-305)	0.874	Owner's opinion	0.593

only one record. When n = 3 records, and repeatability is 0.4, 1.29 times as much progress could be made as if all cows had but one record.

<u>Progeny selection</u>. By far the most accurate measure of a bull's genetic worth is his progeny, remembering, of course, the contribution of the other parent as well. The progeny test is most important for traits that are sex-limited or only slightly hereditary (low heritability), such as milk and fat production. Quoting Lush (1935), "Any general resemblance between offspring for any other reason than that they are half-sibs sets serious limits on the accuracy of the progeny test. On the other hand, if parents or their

records are more highly selected than the offspring or their records, the progeny test may become relatively more accurate." This is borne out by the fact that bulls proved in artificial breeding with daughters under varying environmental situations usually have lower but probably more-accurate proofs than they had as natural-service bulls in one or two herds (Kendrick, 1954). Bull proofs have long been the subject of discussion, and the consensus seems to be that they are of value only when the information regarding the circumstances under which they were made is completely known. Edwards (1932) suggested that the minimum number of pairs should be six, but it is more recently agreed that ten pairs is a minimum for an accurate picture and that the more pairs, the better. Albrechtsen (1953) suggests an artificial breeding proof on fifty pairs as being important in selecting "analyzed" unproved bulls for artificial-breeding studs.

Washbon (1951) has shown that the highest percentage of sons improved production when their sires were plus-proved bulls with ten or more daughters averaging above 475 pounds fat.

Graves (1947) studied the performance of sixteen sires in an attempt to determine whether using the best records or the average of all records of dams and daughters gave the best information for evaluating the sires. He concluded that, if the number of records on the dams exceeds that on the daughters, the average of all records is more likely to be favorable to the bull. The same was found to be true when the first records of the daughters were compared with all of the records of the dams. However, comparison of the best records of the dams against the best records of their daughters is a more rigorous test of the bull's ability, since the dams are likely to be more highly selected, and also because of the added opportunity they have had for making higher records (more years of production). Of course, only after both dam and daughter are dead is it really possible to compare their best records. Putnam, Bowling, and Conklin (1943) showed that there was only a small (insignificant) difference in the results of bull proofs when using the first records of the dams and daughters as compared with the averages of all records. They found the average of the first records (ME - 2X - 305) of dams and daughters to be slightly higher than the averages of all records.

In any evaluation of bull proofs, the sources of the biased errors as given by Lush and Nelson in an earlier part of this review must be considered.

Many times the mates of the bull have no records, or records of questionable value. Edwards (1932) stated that the average of the daughters' records is the best measure of a bull, but that attention should be paid to the number of offspring involved and also to the "prepotency" of the sire--the consistency of raising or lowering the yields of the daughters above or below (herd) average. The average of all of a bull's unselected daughters is now accepted as being a measure of the bull's transmitting ability when the number of daughters becomes as high as fifteen or twenty.

For females, the progeny test is usually not accurate, due to the smaller number of offspring. It is rare when a cow has more than three producing daughters or one proved son. Also, the fact that a cow's daughters' records will usually be made in the same herd as the dam's, under very nearly equal environmental conditions, tends to increase the correlation between the records of dam and daughter.

A special committee of the Purebred Dairy Cattle Association (1950), in recommending rules for proving dams, suggested that at least three offspring (daughters with records and/or proved sons) be used in evaluating and proving cows. The average of the dam's converted records would be counted three times, and the average of each offspring's production value would be used once, the final value of the cow being the over-all average.

The Prediction Index for Bulls

Most bulls that are selected as herd sires are chosen, before they have progeny, on the basis of pedigree and individuality. In an attempt to save time and money, dairymen like to cull unprofitable members of a herd as quickly as possible. They are therefore interested in a prediction of what a bull's daughters will do. Predicting is always hazardous. Studies have been made and indexes developed, but as yet they have not been applied to large enough quantities of data to determine their degree of accuracy.

Eldridge (1948) shows that most-important information in predicting the average production of daughters of a bull is the average production of the bull's mates. (This is probably due to the fact that the similarity of environment is great when the dams and daughters are in the same herd at nearly the same time.) Eldridge also showed that the dams and maternal sisters of the bull had very little contribution in predicting what his daughters would do. (This would also be quite logical if the bull and his close relatives are in different herds.) Eldridge's study was on a large group of interherd butterfat data, and his dam-daughter correlations were 0.60 and 0.62. Copeland (1931) got a value of 0.40, and Gowen (1934), in three different breeds, reported values of 0.30, 0.36, and 0.50 for correlation of milk yield between dam and daughter. Berry (1945) reported an intraherd dam-daughter correlation of 0.10, which seems to be abnormally low.

Eldridge also gave the correlation between a bull's daughters and the bull's dam as 0.01 and 0.19 in two separate sets of data. Copeland (1931), using only the highest records of dams and daughters, reported 0.34, and the same author (Copeland, 1934), using average of all records, also reported 0.33. Both of these latter studies were made using Jersey data.

Correlation between a bull's daughters and his maternal sisters has been reported as 0.04 and 0.01 (Eldridge, 1948); 0.36, 0.38, and 0.47 (Copeland, 1934); and 0.37 (Copeland, 1931). Correlation between a bull's daughters and his paternal sisters has been reported as 0.19 and 0.28 (Eldridge, 1948), and 0.56 (Copeland, 1934). The variation in these reported values would indicate a degree of unreliability in their use. However, because of the relative simplicity of Eldridge's regression indexes, they were used in this study in order to evaluate them in the future.

Schaefer (1953) determines apparent transmitting ability of a bull from his pedigree, using sire proof information from Washbon's Dairy Breeding Guide (1951). Under each bull in the pedigree he lists the number of proved sons, the sons' daughters' average and fat differences. Then he averages these sons' daughters' averages and fat differences, weighted according to their position in the pedigree, and uses the derived average as the apparent transmitting ability. Unfortunately, only a small percentage of the bulls in a pedigree ever have enough proved sons to be listed in Washbon's Guide. Copeland (1931) merely suggests using the average of the bull's dam's, maternal sisters', and dam's paternal sisters' records as the bull's index.

Often there is a desire for predicting a bull's daughters' production in a herd on the basis of what his previous daughters have done in a different herd. The equal-parent index was the theoretical basis for determining a proved bull's value, but the restrictions are evident (management factors contribute heavily). Rice (1944) developed the NEW Regression Index, in an attempt to take breed average into consideration, and his formula is NEW = breed average + daughters' average - daughters' expectation. (Daughters' expectation = [breed average + dams' average]/2.)

Dickey and Labarthe (1945) compared the equal parent and regression indexes for predicting a sire's transmitting ability, and concluded that the regression index method was more accurate except at low levels. Their formula was: bull's value = ([regression or equal parent][index of sire + dam's value])/2.

Another modification of the two extremes of equal parent and regression is a formula developed by Wright (1931): sire's value = herd average + (n/[n+2])(two times daughters' average - dams' average - herd average). n = number of daughters.

Allen (1944) suggested a revision, using regression, for Norton's expectancy tables for evaluating proved sires. Allen doubled the deviation (daughters' actual from daughters' estimated production) and added this to breed average. This gives the effect of standardizing dams so that different sires can be compared. The daughters' estimated production is arrived at from the tables, with consideration for dams' records included.

Herd Averages and Environmental Considerations

In any index, management must be considered. This is usually done by using herd average or deviations from it in arriving at final values on individuals. One of the most valid statements is that by Lush (1947), wherein he says that the most common error of people concerned with dairy cattle breeding is in not using the herd averages, but making direct comparisons between a cow's records and the population average. His idea of comparing a cow to the herd average and then comparing the herd average to the population average is sound, although more complex, inasmuch as herd average and population average are difficult to determine with accuracy. Herd average can be figured in many different ways: yearly, lactational, actual, mature equivalent, moving, cumulative, and various combinations of these and others. Efforts have been made by maximum likelihood method (Harvey, 1953; Henderson, 1949), by least squares (Nelson, 1943; Henderson, 1949), and by direct computation of differences in production in consecutive years (Nelson, 1943) to measure the amount of genetic change in year-to-year herd averages. Varying degrees of accuracy have been obtained, but Henderson does give correction factors to use.

Since his index is derived from estimated real producing ability, which is, in turn, a factored deviation from herd average, Legates discusses the complexity in selecting a proper herd average to use with his index. His data (1949) showed that there was considerably more variation due to cow differences than to yearly differences, and, consequently, his suggestion was to use a four- or five-year moving herd average. While it would appear from Legates' study that error due to changes in cow composition of the herd would be minimized by use of a moving herd average, it also seems apparent that these same errors would be reintroduced by the process of using a cow's deviation from a moving herd average, especially if there is considerable yearly difference as is the case in some of the herds in this study. Of course, for cows in the herd three or more years, deviations from annual herd average and moving herd average will be more nearly alike than for those cows with only one or two records.

In other attempts to reduce environmental effects on records, Kendrick (1935) and Dickerson (1940) agree that the use of 2X-305 day ME records is the most satisfactory way of reducing variation due to number of milkings, length of records, and age, because they have a higher repeatability than do 365 day or first-305 day records.

The effects of other environmental factors have been studied by many workers. Erb and Shaw (1953) used correction factors for length of lactation (extend short records to 305 days), length of dry period, and days carrying calf, and found that these corrections reduced differences between cows by 18 percent. They estimated that another 5 percent difference was due to length of calving interval.

Bayley and Heizer (1952) evaluated the effect of these and five other environmental factors (selection rating, pounds T.D.N. fed daily per 1,000 pounds of body weight, nutritive ratio, condition at calving, and herd size). The effects of the latter four and also length of dry period and days carrying calf were combined in an index that is now being studied further.

The progress that can be made by different culling procedures was measured by Copeland and reported by Gilmore (1952). Copeland found that culling the bottom 10 percent of the herd resulted in an increase of approximately 20 pounds of fat, regardless of level of herd average, and culling the bottom 25 percent resulted in approximately 40-pound increase in herd average, regardless of level.

Gilmore (1952) shows that most cows leave the herd at four to five years of age, and that the average DHIA cow completes only three lactations. He indicated that it takes two lactations to pay the cost of raising a heifer and put her on a paying basis. It is certain, then, that length of productive life and culling procedures have a very direct effect on genetic improvement.

Another important fact to keep in mind is the role that regression seems to have in all phases of dairy cattle breeding. Regression diminishes as homozygosity increases (Yapp, 1938). This tendency for offspring to be closer to the herd average than the parents is closely related to heritability, and is a major consideration. Regression toward breed average does not automatically make a breed more uniform with every generation. The offspring from each parent will vary among themselves and environment will shove some of them far up and others far down. The extreme ones thus produced will replenish the supply of extreme individuals in the next generation (Lush, 1947).

METHODS AND PROCEDURES

Collection of Data

There were 288 Guernsey cows with 721 lactation records included in the five herds studied in this project. A period of eight years, starting with June 1, 1945, was chosen because this closely coincided with the resumption of testing in one herd after the war. Not enough records were available prior to 1945 to make it worth while to extend the project.

Almost all the records were made available by means of individual cow work sheets which the owners have completed for their own use in conjunction with their herd analyses. Extremely good interest and cooperation in the project on the part of the herd owners was evident. This is probably due to the fact that they are all good cowmen and are interested in their herds and in breed activities.

A herd environment analysis sheet was developed and used. It is reproduced in Figure I. This herd analysis served several purposes:

FIGURE I

DAIRY HERD ENVIRONMENT ANALYSIS

Name of owner__________________ Farm Location________________

Acres of Cropland_____ Soil Type_______________ Size of Herd____

No. of milking cows____ Breed___________ Reg. or Grade_________

Type of Stalls____

Operated by: Owner_________ Manager_________ Share basis______

No. of men employed with cattle________________________________

MANAGEMENT:

Gen. appearance of cows________ Heifers_______ Calves________

Last 5 years Herd Av:	No. cows	Times Milked	Lbs. Milk	Lbs. Fat	%

No. cows freshening in: Winter___ Spring___ Summer___ Fall___

Type of testing_____________ No. of years testing______________

Herd classified for type?_______________ Average Score________

HEALTH: No. cows affected past year:

Mastitis_________________ Lost quarters___________________

Bangs___________________ Vaccination Program_____________

T. B.___________________ Acetonemia or Milk Fever________

Udder Injuries___________ Feet & Leg trouble______________

No. of Cows: 2 Yrs.___ 3-6 Yrs.___ 7-10 Yrs.____10+ Yrs.____

BREEDING:

Method of breeding cows____________________Own bull?_________

How long is one bull used?______________________________________

Age at first calving_________ Length of dry period______________

Calving Interval______________ Size at first calving______________

Services per calf___________ Cow turnover per year____________

(Continued)

FIGURE I (Continued)

Selection or culling: Heifers______________ Cows______________

Breeding Program:____

FEEDING:

Roughage quality:

Hay______________ Mos. Fed_________ Times per day______
Silage____________ Mos. Fed_________ Times per day______
Other_____________ Mos. Fed_________

What roughage, if any, was fed during pasture season?_____

Pasture:

a. Acres________________ d. Quality______________________
b. Mos. used____________ e. Rotation_____________________
c. Mixture______________

Grain:

a. Milk-Grain Ratio_____________________ % Protein________
b. Home Grown Grains_________________________________
c. Purchased Feeds__________________________________
d. Mos. Fed_______________________________________
e. Grain Fed During Dry Period__________________________
f. Grain Fed Heifers__________________________________

If e and f have different % protein than for milking cows, how does it differ?_________________________________

____

____

1. It enabled the author to get better acquainted with the herd owner and his operation.

2. It served as a basis for comparing environmental levels between herds.

3. It may have made the owners more aware of some of their management problems.

Summarizing the five analysis reports was not too difficult. One herd operates in a pen barn. Two herds (college operated) have full-time herdsmen. Size of herds (all stock) varied from about twenty-five to ninety-five head. All have been testing over 17 years. Answers to questions concerning breeding practices were practically identical. All but the Michigan State College herd use barn hay driers and all prefer to use alfalfa-brome as the basis for their hay and pasture programs. Two feed grass silage, and all five feed corn silage. Grain feeding practices (type, amount, and quality) are very similar.

A standard method of converting and handling records was followed for all herds. The 2X-305-ME conversion factors used were a slight modification of the DHIA factors, with age calculated at six-month instead of the usual monthly intervals.

All butterfat records of over 200 days in length were used and converted to mature equivalent basis (ME). Since all records were 2X, there was no necessity for conversion for number of milkings. Records over 310 days were reduced to 305 days by conversion factors, but records under 300 days were not extended (to 305 days), but were converted for age only. It was felt that converting a 240, 260, or 280 day record to 305 days was apt to give a cow more credit than she was due. It is probably more advantageous to chance underrating a cow than overrating her.

The average of all the ME records started between June 1 and the following May 31 was considered to be the herd average for that year. Exceptions were made where a cow had two lactations starting within the same period, in which case one record was shifted to the next period so as to best represent her contribution to the herd average. Table II gives the numbers of cows and butterfat averages by years for each of the five herds.

Type classification ratings were unofficial. The owner got a copy with complete breakdown of all females of milking age. These ratings were made for several reasons:

1. To evaluate cows within herds.
2. To evaluate cows between herds.

TABLE II

NUMBER OF COWS AND (ME-2X-305) BUTTERFAT AVERAGES BY YEARS AND BY HERDS

Years	Herds										Weighted Yearly Avg. by Herds	
	Kellogg		M.S.C.		Nye		Smith		Watson			
	No. of C.[a]	Lbs. Butterfat	No. of C.	Lbs. Butterfat	No. of C.	Lbs. Butterfat	No. of C.	Lbs. Butterfat	No. of C.	Lbs. Butterfat	No. of C.	Lbs. Butterfat
1945	16	441	11	441	9	509	18	448	18	461	14	456
1946	29	466	9	419	6	558	17	396	16	497	15	459
1947	26	427	12	369	5	497	26	431	22	454	18	431
1948	24	421	10	411	9	484	22	446	26	436	18	436
1949	29	350	9	380	9	510	28	452	27	470	20	427
1950	26	364	9	388	8	502	25	435	23	458	18	422
1951	23	435	8	371	13	507	28	445	18	526	18	461
1952	28	449	11	357	12	491	37	461	19	481	21	454
8-Yr. Avg.	25	418	10	392	9	505	25	442	21	470	18	443

[a] Cows.

3. To serve as a basis for choosing dams of future herd sires.

4. To assist in culling procedures.

5. To help the owner learn more about type.

On different occasions, one, two, and three men classified together, with the final results being an average of opinion. Pictures were taken of most of the animals that might be considered key animals in the future. This included groups of daughters of the best sires used in the past, outstanding individuals for type and/or production, close relatives of the bulls in the project, and the bulls themselves, insofar as they were available. The pictures will be used more in the future after the animals themselves are gone, or, if the need arises, for reference purposes.

Methods of Ranking

Six methods of ranking all cows within each herd as of July 1, 1954, were used, as follows:

1. Ranking by deviation from annual herd average. Each cow's yearly record was calculated as a deviation from the yearly herd average. Cows with two or more records were figured by averaging all the cow's records and deviating that average from the

mean of the herd average for the years she was in the herd (weighted according to number of cows contributing to yearly herd average).

2. Ranking by estimated real producing ability (ERPA). The deviations from annual herd average were multiplied by the factor $nr/(1+[n-1]r)$ to arrive at the ERPA (n = number of records; r = estimate of repeatability which was assumed to be 0.4 in this study). The use of the ERPA corrects for different numbers of lactations between cows.

3. Ranking by Legates' index (1949). His index is $I = X_1 + 0.4X_2 + b_3X_3 + b_4X_4 + b_5X_5$ where X_1 is the ERPA of the cow herself, X_2 is the ERPA of her dam, X_3, X_4, and X_5 are the sums of the ERPA of her daughters, maternal and paternal sisters (respectively), weighted according to b_3, b_4, and b_5, regression coefficients that vary with the numbers of each. Heifers currently milking in their first lactations were ranked according to the results of Legates' heifer index: $I = 0.63Z + b_oO + b_pP$, where Z is the ERPA of the dam, O and P are the sums of the ERPA of the maternal and paternal sisters (respectively), weighted according to b_o and b_p, regression coefficients that vary with the numbers of each. These first-lactation heifers were then ranked with the older cows that are presently in the herds.

Heifers between one year of age and freshening were also calculated by Legates' heifer index, but were ranked separately.

The values for b_3, b_4, and b_5 are given in Table III, and values for b_o and b_p are given in Table IV (Legates and Lush, 1954).

4. Ranking by cow's Mature Equivalent (ME-2X) average of all records (305 days or less).

5. Ranking by deviation from moving herd average. In order to correct for some of the error obtained in figuring one- or two-lactation cows as deviations from only one or two years, a method using a three-year moving herd average was tried. This involved some inaccuracy in itself, as the choice of a starting place makes the first two years incorrect. The weighted average of the desired year plus the two preceding years was considered to be the moving herd average. Cows with more than one record were measured against the nonweighted mean of the moving herd averages for the years they were in the herd, in the same manner as when they were calculated according to yearly herd average. Naturally there was not as much variation between yearly and moving herd average rankings with the older cows as with the one- and two-lactation cows. However, the trend of the yearly herd averages also had an effect. In herds where the yearly average showed considerable fluctuation

TABLE III

VALUES OF b_3, b_4, AND b_5 FOR DIFFERENT NUMBERS OF DAUGHTERS (n_3), MATERNAL SISTERS (n_4), AND PATERNAL SISTERS (n_5).

n_3	b_3*	n_4	b_4*	n_5	b_5*
1	0.385	1	0.099	1	0.053
2	0.365	2	0.093	2	0.079
3	0.336	3	0.087	3	0.070
4	0.314	4	0.081	4	0.063
5	0.288	5	0.077	5	0.057
				6	0.052
				7	0.047
				8	0.044
				9	0.041
				10	0.038
				11	0.036
				12	0.034
				13	0.032
				14	0.030
				15	0.029
				16	0.027
				17	0.026
				18	0.025
				19	0.024
				20	0.023
				25	0.019
				29	0.017

* These values decrease because of the use of sums of ERPA.

TABLE IV

VALUES FOR b_o AND b_p FOR DIFFERENT NUMBERS OF MATERNAL (n_o) AND PATERNAL (n_p) SISTERS

n_o	b_o*	n_p	b_p*
1	0.236	1	0.353
2	0.220	2	0.316
3	0.197	3	0.285
4	0.818	4	0.260
5	0.170	5	0.239
		6	0.220
		7	0.205
		8	0.192
		9	0.180
		10	0.170
		11	0.160
		12	0.152
		13	0.145
		14	0.138
		15	0.132
		16	0.126
		17	0.121
		18	0.116
		19	0.112
		20	0.108

* These values decrease because of the use of <u>sums</u> of ERPA.

the cows with records in the year immediately following the low years got an advantage by having the low years averaged in for herd average but not affecting their own average. Of course, the converse is true for those cows with records in years immediately following the high years. Table V gives the weighted moving herd averages for the five herds.

6. Ranking by owner's or herdsman's opinion. This was supposed to be done solely on the basis of production, but it is reasonable to assume that other factors had some influence. This ranking was done without the results of the other methods of rankings being known, so that there was no bias due to the cows' values as calculated by other methods.

Correlations

Inasmuch as Legates' index includes the most information on a cow and her family, the ranking resulting from its use was used as a basis for comparison of the other methods. Rank correlation coefficients were determined by the formula $r = 1 - \frac{6\Sigma d^2}{N(N^2-1)}$, wherein N = the number of ranked pairs, and Σd^2 = the sum of the squared differences between the numerical rankings of each pair (Dixon and Massey, 1951).

TABLE V

WEIGHTED THREE-YEAR MOVING HERD AVERAGES (ME-2X-305) FOR THE FIVE HERDS

Years	Herds									
	Kellogg		M.S.C.		Nye		Smith		Watson	
	No. of C.[a]	Lbs. Butter-fat	No. of C.	Lbs. Butter-fat	No. of C.	Lbs. Butter-fat	No. of C.	Lbs. Butter-fat	No. of C.	Lbs. Butter-fat
1945[b]	16	441	11	441	9	509	18	448	18	461
1945-46[b]	45	458	20	431	15	528	35	423	34	478
1945-46-47	71	446	32	408	20	521	61	426	56	469
1946-47-48	79	440	31	397	20	510	65	427	64	457
1947-48-49	79	397	31	386	23	497	76	443	75	454
1948-49-50	79	376	28	394	26	499	75	445	76	455
1949-50-51	78	380	26	380	30	507	81	444	68	481
1950-51-52	77	416	28	371	33	500	90	449	60	486
Over-all Average		419		401		509		438		468

[a] Cows.

[b] A three-year average could not be determined for 1945 and 1946.

In order to determine the amount of change in a cow's Legates index value from one year to another, and particularly from the time she is a heifer through the time when she had completed a lactation, one herd was ranked for the last three years on the basis of Legates' index. Rank correlation coefficients were determined for these rankings. This was too complex a process to carry out in all five herds, but further investigation along this line might be of value in developing a method of selection among first-calf heifers.

Bull Evaluation

There are sixteen bulls of all ages that are being or will be used in the five herds. The future production of their daughters in these five herds was estimated according to the index developed by Eldridge and Salisbury (1949). While some of the bulls have daughters with completed records in other herds, all bulls were considered equally unknown as far as the herds of this project are concerned. The twelve bulls whose sires have daughters with records were evaluated by both of the indexes which Eldridge (1948) derived. One index (Y_B) was developed from using only data on the bull's mates, dam, paternal sisters and their dams, and dam's paternal sisters, whereas the other index (Y_A) was developed using pedigree information on the bull's mates, dam, maternal sisters, paternal sisters and their dams.

Eldridge's equations are as follows:

$$Y_A = 29.6 + 0.75X_1 + 0.03X_2 + 0.01X_3 + 0.34X_4 - 0.21X_5$$

$$Y_B = 0.1 + 0.75X_1 + 0.01X_3 + 0.23X_4 - 0.22X_5 + 0.24X_6$$

where Y_A and Y_B are predicted values for daughter averages.

X_1 = average production of mates.

X_2 = average production of maternal sisters.

X_3 = Average production of dam.

X_4 = average production of paternal sisters.

X_5 = average production of dams of paternal sisters.

X_6 = average production of dam's paternal sisters.

Because of using the bulls in all five herds, the X_1 (mates) component was left out and the Y_A and Y_B values then became deviations from 0.75 times (average of mates) in each of the herds, or, to be more general, deviations from 0.75 (herd average). This should put all bulls on a comparable basis without the interherd effect.

The young bulls that were bred in the herds in the project were also rated by Legates' index for young bulls. The older (purchased) bulls could not be rated in this manner because of the absence of necessary information in regards to their close relatives (herd averages and ERPA of dams, maternal and paternal sisters).

Because of not having values on all bulls by all methods, rank correlations were not determined.

RESULTS AND DISCUSSION

Cow Rankings

The rankings, by six methods, of the cows in the five herds as of July 1, 1954, are presented in Tables VI, VII, VIII, IX, and X. Rankings by Legates' index and by owners include first-calf heifers without a completed lactation, whereas the other four rankings include only the cows that have completed one or more lactations. Plus and minus values given in rankings by estimated real producing ability (ERPA) and Legates' index are modified deviations from herd average. ME-2X-305 day averages are given in terms of pounds of butterfat. The owners did not place a specific value on each cow; they divided the herd into four groups: (1) top cows, (2) above-average cows, (3) below-average cows, and (4) bottom cows. These groups were not necessarily meant to represent four quadrants. As can be seen from the tables, there was considerable variation in numbers of cows in the groups. The cows were ranked in order within the groups, however.

The short dividing lines in the tables represent the divisions between production groups, assuming ± 0 to be average of the herd.

TABLE VI

RANKINGS OF COWS IN KELLOGG HERD BY VARIOUS METHODS

R.[a]	Legates' Index		Estimated Real Producing Ability		ME-2X-305 Day Average		Deviation from Annual Herd Average		Deviation from Moving Herd Average		Owner's or Herdsman's Opinion
	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.
1	241	+170	241	+124	270	616	241	+186	241	+211	241
2	273	+116	270	+ 67	241	602	270	+167	270	+200	284*
3	293*	+ 92	273	+ 58	273	593	273	+144	273	+177	270
4	283	+ 76	249	+ 50	283	546	283	+ 97	283	+130	273
5	249	+ 70	248	+ 42	274	537	274	+ 88	274	+121	269
6	301*	+ 64	213	+ 42	266	531	266	+ 82	266	+115	294*
7	270	+ 60	184	+ 40	269	520	249	+ 75	269	+104	293*
8	269	+ 57	283	+ 39	265	510	269	+ 71	249	+100	290*
9	248	+ 52	274	+ 35	272	500	248	+ 63	255	+ 97	268*
10	268*	+ 40	266	+ 33	279	498	265	+ 61	265	+ 94	266
11	274	+ 40	255	+ 30	255	495	213	+ 53	253	+ 93	249
12	279	+ 37	253	+ 29	249	491	255	+ 53	248	+ 88	248
13	255	+ 36	269	+ 28	253	491	272	+ 51	272	+ 84	274
14	213	+ 36	265	+ 24	248	479	253	+ 50	279	+ 82	283
15	266	+ 34	272	+ 20	184	474	279	+ 49	213	+ 50	253
16	291*	+ 31	279	+ 20	213	459	184	+ 48	184	+ 49	213
17	296*	+ 28	242	0	242	398	242	0	242	+ 6	184
18	280*	+ 28	277	- 38	277	355	225	- 77	277	- 61	272

TABLE VI (Continued)

R.[a]	Legates' Index		Estimated Real Producing Ability		ME-2X-305 Day Average		Deviation from Annual Herd Average		Deviation from Moving Herd Average		Owner's or Herdsman's Opinion
	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.
19	184	+ 27	225	- 59	225	325	277	- 94	225	- 77	278*
20	278*	+ 26									280*
21	272	+ 23									297*
22	302*	+ 22									296*
23	298*	+ 19									279
24	295*	+ 18									287*
25	265	+ 18									255
26	253	+ 13									242
27	286*	+ 11									288*
28	242	+ 9									298*
29	290*	- 3									265
30	284*	- 5									277
31	297*	- 6									302*
32	287*	- 10									295*
33	294*	- 11									286*
34	292*	- 40									292*
35	288*	- 48									301*
36	225	- 56									291*
37	277	- 60									225

[a] Rank.

* First-calf heifers.

TABLE VII

RANKINGS OF COWS IN M.S.C. HERD BY VARIOUS METHODS

R.[a]	Legates' Index		Estimated Real Producing Ability		ME-2X-305 Day Average		Deviation from Annual Herd Average		Deviation from Moving Herd Average		Owner's or Herdsman's Opinion
	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.
1	76	+ 53	76	+ 39	76	427	76	+ 54	76	+ 44	76
2	92	+ 42	72	+ 22	72	403	92	+ 45	92	+ 31	72
3	72	+ 28	92	+ 18	92	402	95	+ 37	95	+ 23	2002*
4	2006*	+ 25	95	+ 15	68	398	72	+ 30	72	+ 20	2003*
5	95	+ 22	68	+ 12	95	394	68	+ 16	68	+ 13	2006*
6	2003*	+ 17	98	- 6	98	342	98	- 15	98	- 29	83
7	2002*	+ 3	96	- 14	67	327	96	- 35	96	- 49	67
8	2001*	- 0.7	83	- 32	83	323	83	- 48	83	- 59	68
9	68	- 6	67	- 42	96	322	67	- 54	67	- 59	96
10	98	- 8									95
11	96	- 15									98
12	2004*	- 15									2000*
13	2005*	- 20									2001*
14	2000*	- 25									2005*
15	83	- 31									92
16	67	- 45									2004*

[a] Rank.

* First-calf heifers.

TABLE VIII

RANKINGS OF COWS IN NYE HERD BY VARIOUS METHODS

R.[a]	Legates' Index		Estimated Real Producing Ability		ME-2X-305 Day Average		Deviation from Annual Herd Average		Deviation from Moving Herd Average		Owner's or Herdsman's Opinion
	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.
1	27	+109	27	+100	27	650	27	+150	27	+148	27
2	21	+ 38	21	+ 55	21	570	21	+ 71	21	+ 67	21
3	48*	+ 19	35	+ 23	35	549	35	+ 58	35	+ 49	23
4	22	+ 17	33	+ 8	23	523	33	+ 20	23	+ 28	22
5	31	+ 16	31	+ 7	31	512	31	+ 13	33	+ 11	31
6	35	+ 13	23	+ 7	33	511	23	+ 11	31	+ 9	35
7	33	+ 11	22	+ 4	22	507	22	+ 5	22	+ 6	36
8	43*	+ 5	36	- 6	36	477	36	- 14	36	- 23	33
9	49*	+ 4	30	- 27	30	452	30	- 47	30	- 51	30
10	47*	0	28	- 67	28	347	28	-118	28	-122	49*
11	46*	- 6									43*
12	23	- 8									46*
13	36	- 11									47*
14	30	- 28									48*
15	28	- 52									28

[a] Rank.

* First-calf heifers.

TABLE IX

RANKINGS OF COWS IN SMITH HERD BY VARIOUS METHODS

R.[a]	Legates' Index		Estimated Real Producing Ability		ME-2X-305 Day Average		Deviation from Annual Herd Average		Deviation from Moving Herd Average		Owner's or Herdsman's Opinion
	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.
1	95	+102	95	+100	95	711	95	+250	95	+262	43
2	79	+ 92	79	+ 84	79	602	79	+148	79	+156	79
3	100	+ 90	43	+ 67	93	542	43	+ 87	43	+ 95	101*
4	110*	+ 87	59	+ 47	98	538	93	+ 81	93	+ 93	100
5	43	+ 71	67	+ 37	43	533	98	+ 77	98	+ 89	47
6	59	+ 66	93	+ 32	100	531	100	+ 70	100	+ 82	93
7	93	+ 55	98	+ 31	59	515	59	+ 65	59	+ 70	67
8	108*	+ 53	54	+ 29	67	505	67	+ 56	67	+ 59	108*
9	109*	+ 46	100	+ 28	47	500	47	+ 45	54	+ 49	95
10	67	+ 41	77	+ 21	84	497	54	+ 44	84	+ 48	16
11	98	+ 35	75	+ 20	77	491	77	+ 37	47	+ 46	59
12	75	+ 31	47	+ 18	75	489	84	+ 36	77	+ 45	54
13	54	+ 28	66	+ 16	66	472	75	+ 35	75	+ 43	77
14	101*	+ 27	16	+ 15	90	472	66	+ 22	66	+ 27	84
15	84	+ 23	84	+ 14	54	471	16	+ 18	83	+ 24	66
16	47	+ 19	83	+ 9	83	470	83	+ 16	90	+ 23	64
17	66	+ 17	74	+ 5	64	470	90	+ 11	16	+ 22	74
18	111*	+ 11	90	+ 4	96	469	74	+ 9	96	+ 20	85

TABLE IX (Continued)

R.	Legates' Index		Estimated Real Producing Ability		ME-2X-305 Day Average		Deviation from Annual Herd Average		Deviation from Moving Herd Average		Owner's or Herdsman's Opinion
	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.
19	16	+ 11	64	+ 4	74	463	96	+ 8	74	+ 17	83
20	83	+ 9	96	+ 3	16	460	64	+ 6	85	+ 14	102*
21	85	+ 9	60	+ 3	85	460	85	+ 6	60	+ 13	98
22	96	+ 9	85	+ 3	94	450	60	+ 5	64	+ 11	99*
23	106*	+ 9	94	- 4	60	443	94	- 11	94	+ 1	105*
24	105*	+ 8	49	- 10	49	429	49	- 13	49	- 8	24
25	77	+ 6	92	- 17	63	424	63	- 26	63	- 21	76
26	60	+ 3	89	- 17	76	422	71	- 32	71	- 24	89
27	102*	0	71	- 18	89	419	89	- 42	92	- 30	75
28	99*	0	63	- 19	92	419	92	- 42	89	- 30	110*
29	103*	0	76	- 28	24	399	24	- 43	24	- 39	109*
30	64	- 2	88	- 28	48	397	76	- 49	76	- 41	94
31	94	- 14	87	- 32	88	388	48	- 56	48	- 48	96
32	74	- 17	24	- 36	71	386	88	- 69	88	- 57	111*
33	104*	- 18	48	- 37	86	385	87	- 80	87	- 68	86
34	90	- 18	86	- 42	87	381	86	-105	86	- 93	49
35	87	- 21									60
36	49	- 23									63
37	88	- 24									104*
38	71	- 24									92

TABLE IX (Continued)

R.[a]	Legates' Index		Estimated Real Producing Ability		ME-2X-305 Day Average		Deviation from Annual Herd Average		Deviation from Moving Herd Average		Owner's or Herdsman's Opinion
	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.
39	24	- 34									88
40	92	- 43									48
41	63	- 43									87
42	89	- 49									106*
43	76	- 50									90
44	48	- 54									71
45	86	- 61									103*

[a] Rank.

* First-calf heifers.

TABLE X

RANKINGS OF COWS IN WATSON HERD BY VARIOUS METHODS

R.[a]	Legates' Index		Estimated Real Producing Ability		ME-2X-305 Day Average		Deviation from Annual Herd Average		Deviation from Moving Herd Average		Owner's or Herdsman's Opinion
	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.
1	51	+ 81	51	+102	51	591	51	+121	51	+123	51
2	42	+ 68	42	+ 66	72	589	72	+ 86	72	+106	42
3	48	+ 67	48	+ 65	70	561	42	+ 83	42	+ 80	48
4	72	+ 58	45	+ 53	42	547	48	+ 79	70	+ 78	45
5	70	+ 42	72	+ 49	75	546	75	+ 65	48	+ 76	47
6	46	+ 37	47	+ 37	48	542	45	+ 64	45	+ 65	46
7	47	+ 34	70	+ 33	45	531	70	+ 58	75	+ 60	72
8	75	+ 31	75	+ 26	47	516	47	+ 45	47	+ 47	70
9	45	+ 29	46	+ 20	76	510	76	+ 29	46	+ 32	44
10	76	+ 19	76	+ 12	74	507	46	+ 26	76	+ 24	61
11	71	+ 13	44	+ 9	46	501	44	+ 11	74	+ 24	75
12	90*	+ 13	61	+ 4	61	486	61	+ 5	61	+ 17	69
13	61	+ 8	74	+ 2	69	481	74	+ 4	44	+ 12	76
14	92*	0	69	- 3	44	479	69	- 5	69	+ 7	74
15	85*	- 1	82	- 17	71	457	82	- 43	71	- 26	71
16	89*	- 4	71	- 26	82	438	71	- 46	82	- 48	82
17	80*	- 7	81	- 26	81	417	81	- 64	81	- 69	81
18	74	- 8	84	- 58	84	336	84	-145	84	-150	84

TABLE X (Continued)

R.	Legates' Index		Estimated Real Producing Ability		ME-2X-305 Day Average		Deviation from Annual Herd Average		Deviation from Moving Herd Average		Owner's or Herdsman's Opinion
	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.	Value	Cow No.
19	79*	- 10									
20	44	- 10									
21	91*	- 16									
22	82	- 25									
23	69	- 27									
24	88*	- 29									
25	81	- 33									
26	84	- 66									

[a] Rank.

* First-calf heifers.

The lines separating top cows from above-average cows, and below-average cows from bottom cows, are much more arbitrary. Setting certain standards to use on all five herds would result in a comparison of all cows on an interherd basis, whereas using a different level in each herd in order to place a certain percentage of the cows in each herd in each group would result in some cows of very mediocre value (on an interherd comparison) being considered among the top cows. Since one of the aims of this project is to find the cows which might be dams of potential herd sires, comparison of cows on an interherd basis was felt to be justified, especially since age, number of records, and herd average have already been taken into consideration. It was felt that only the top 10 percent of the cows on a production basis should be considered as dams of potential herd sires, and only then if they meet the minimum standards for type. The line between top and above-average cows was then drawn at +65. This placed sixteen, or 11 percent, of the 139 cows in the project as top cows. Table XI utilizes the information on these top sixteen cows in order to further analyze them. They are ranked at the left according to their Legates or intraherd value. Adding this value to the eight-year herd average (from Table II) for the respective herds gives the value in column five. Ranking in column six is on the

TABLE XI

PRODUCTION RANKING AND TYPE RATING OF THE TOP COWS IN THE FIVE HERDS

Cow No.	Herd	Legates Value	Herd Avg.	Value	Rank	No. of Completed Records
241	Kellogg	+170	418	588	2	3
273	Kellogg	+116	418	534	8	1
27	Nye	+109	505	614	1	3
95	Smith	+102	442	544	4	1
293	Kellogg	+ 92	418	510	13	0
79	Smith	+ 92	442	534	9	2
100	Smith	+ 90	442	532	10	1
110	Smith	+ 87	442	529	11	0
51	Watson	+ 81	470	551	3	8
283	Kellogg	+ 76	418	494	15	1
43	Smith	+ 71	442	513	12	5
249	Kellogg	+ 70	418	488	16	3
42	Watson	+ 68	470	538	6	6
48	Watson	+ 67	470	537	7	7
59	Smith	+ 66	442	508	14	4
21	Nye	+ 38	505	543	5	5

TABLE XI (Continued)

Classification Breakdown								
Over-all Rat-ing	Gen. Ap-pear-ance	Dairy Char-acter	Body Ca-pac-ity	Mammary System			Feet and Legs	Rump
				Over-all	Fore	Rear		
VG	VG	VG	VG	D	D	VG	D	VG
D	D	VG	D	A	A	D	D	D
VG	VG	VG	VG	VG	VG	VG	D	VG
D	D	VG	D	D	D	D	A	A
VG	VG	D	D	VG	Ex	VG	D	D
D	D	VG	VG	D	A	A	D	D
D	D	Ex	D	A	A	D	VG	VG
D	D	VG	D	D	D	A	D	D
D	D	VG	VG	D	D	D	VG	D
D	D	D	D	D	D	D	D	D
D	D	D	VG	D	A	D	D	D
D	D	D	VG	D	D	D	D	D
D	D	VG	VG	D	D	D	A	VG
VG	VG	VG	VG	D	D	D	D	VG
F	F	A	D	A	F	F	A	P
D	D	VG	VG	D	D	D	D	VG

basis of this latter (interherd) value. Classification breakdown is given for each cow according to the following standards:

Ex	= Excellent	90+ points
VG	= Very Good	85-89 points
D	= Desirable	80-84 points
A	= Acceptable	75-79 points
F	= Fair	65-74 points
P	= Poor	-65 points

In the case of cow number 21, her intraherd Legates value is below the arbitrarily set +65, but the average of that herd is enough higher than the others that her interherd value becomes 543, which is enough to rank her as fifth-high cow in the project.

In selecting cows to be dams of herd sires, it would be reasonable to eliminate those that classify lower than Desirable in either over-all rating or over-all mammary system. This would still leave 13 out of 139, or 9.3 percent. If, to be on the safe side, the first-calf and one-record cows are also not considered (until they have another record), the number is reduced to 9. If half of these have bulls, that would give about four or five calves each year to save for prospective herd sires. If these interherd values are accurate indications of the cows' worth, and if the sires of the bulls prove to be good, then the calves should have a reasonably high chance of being herd improvers. It would be interesting, but expensive, to select a bull calf or two from the bottom-ranking cows, and sired by the same bulls, to see what difference there will be in the granddaughters of the top and bottom cows.

In Tables VI, VII, VIII, IX, and X, a line drawn at -20 placed 19 percent of the cows in the bottom-cow group. This is the group from which culling should take place for maximum genetic improvement. This is only a hypothetical situation, however. Annual cow turnover is usually considered to be from 20 to 25 percent of the herd, with health and disease factors causing culling of some cows that would not be culled on a production basis. Increasing the average number of lactations of a cow is primarily a problem of health and management. The average number of completed lactations of the 288 cows in this study was 2.5. (This does not include those that left the herd without 200 days in milk.) The average cow in DHIA completes about three lactations, according to Gilmore (1952). Table XII gives a breakdown of number of cows in and removed from the herds, and numbers of lactations completed before removal. The table shows that in the eight years covered by this project, 66.7 percent, or exactly two-thirds of the cows that left the herds did not complete four lactations, and that 54 percent completed only one or two records. Since it is generally assumed that a cow must milk two lactations to pay the cost of raising her (Gilmore, 1952), it

TABLE XII

NUMBERS OF COWS IN PROJECT BY NUMBERS OF COMPLETED RECORDS AND BY HERDS

Herd	Number of Lactations Completed											
	0	1	2	3	4	5	6	7	8	9	10+	Total
Kellogg:												
*	X	17	20	7	8	5	3	1	1	0	2	64
**	18	10	2	3	1	1	1	1	0	0	0	37
Smith:												
*	X	16	12	9	4	7	0	1	1	1	0	51
**	11	13	9	5	3	2	0	0	2	0	0	45
M.S.C.:												
*	X	11	2	3	1	1	1	1	1	3	0	24
**	7	4	0	1	3	1	0	0	0	0	0	16
Nye:												
*	X	3	4	3	2	1	1	2	0	1	1	18
**	5	3	3	1	2	1	0	0	0	0	0	15
Watson:												
*	X	9	13	3	6	3	2	1	1	2	1	41
**	8	5	4	1	1	1	2	2	1	1	0	26
Total:												
*	X	56.	51.	25.	21.	17.	7.	6.	4.	7.	4.	198.
**	49.	35.	18.	11.	10	6	3.	3	3.	1.	0	139.
Pct. of total:												
*	X	28.3	25.8	12.6	10.6	8.6	3.5	3.1	2.0	3.5	2.0	100.0
**	35.2	25.2	12.9	7.9	7.2	4.3	2.2	2.2	2.2	0.7	0	100.0

* Cows out of herd.
** Cows in herd.
Total cows = 288.
Number of records = 721.
Number of records per cow = 2.5.

appears that half of the cows in these five herds were kept without returning any income. However, since the herd averages of these five herds is considerably higher than population average, these cows probably paid for themselves in less than two lactations. Even at that, nearly one-third of the cows probably did not make much profit for their owners.

Of the cows still in the herds, 35.3 percent are in their first lactation, and only 11.9 percent have completed five or more lactations. It is apparent, then, that since cow turnover is so rapid, often the best cows do not have opportunity enough to replace themselves before they leave the herd, and they are replaced by daughters of the average cows. Or if, through mistakes in selection, a poor bull is used in the herd, the good cows may be replacing themselves with daughters that are only average cows. It is also apparent that culling is nearly as great from the top groups, due to age and health factors, as it is from the bottom group. Until management factors can be reduced as a cause for culling, and cows can be culled on the basis of production (and type, if desired), it appears that improvement in production will continue to be slow.

Because the first-calf heifers were ranked with the cows but by the heifer index, it was felt that their rankings might not be as valid as the cow rankings, or as valid as their own rankings a year later after completion of a record. In order to get an idea of the amount of change between the value of a heifer without a record, after she has completed one record, and after she has completed two records, the cows in the Smith herd were ranked by Legates' indexes for the years 1950, 1951, and 1952. The results of these rankings are shown in Table XIII. Asterisks indicate the cows that left the herd; the numbers underlined were first-calf heifers in 1950, had completed one record in 1951, and two records in 1952. Rank correlation (all cows in the herd) between 1950 and 1951 was 0.81, and between 1951 and 1952 was 0.78. These are significant at the 1 percent level of probability. However, when only the heifers were considered, the correlation between their rankings as first-calf heifers (1950) and one-record cows (1951) was only 0.31 (not significant). Further correlation between the rankings of these same cows with one record (1951) and two records (1952) was 0.833, which is the 1 percent level of significance.

Correlation between the rankings of the first-calf heifers of 1951 and themselves as one-record cows of 1952 gave 0.60 (significant at 5 percent level). Unfortunately, this method of following through with the heifers was quite complex, and the trials here were

TABLE XIII

THREE-YEAR COMPARISON OF LEGATES RANKINGS OF COWS IN SMITH HERD

R.[a]	1950		1951		1952		R.[a]	1950		1951		1952	
	Cow No.	Value	Cow No.	Value	Cow No.	Value		Cow No.	Value	Cow No.	Value	Cow No.	Value
1	31*	+132	100	+ 97	95	+102	26	49	- 24	90	- 8	77	+ 6
2	60	+117	43	+ 86	79	+ 92	27	76	- 26	92	- 12	60	+ 3
3	68*	+ 83	93	+ 62	100	+ 90	28	71	- 28	94	- 15	102	0
4	43	+ 80	60	+ 57	110	+ 87	29	70	- 28	85	- 16	99	0
5	59	+ 51	79	+ 52	43	+ 71	30	48	- 33	46*	- 16	103	0
6	66	+ 40	59	+ 48	59	+ 66	31	74	- 35	86	- 18	64	- 2
7	54	+ 28	67	+ 47	93	+ 55	32	69*	- 39	89	- 20	94	- 14
8	67	+ 17	84	+ 44	108	+ 53	33	63	- 47	49	- 22	97*	- 15
9	81	+ 13	88	+ 36	109	+ 46	34	19*	- 49	72	- 23	74	- 17
10	85	+ 3	54	+ 28	67	+ 41	35	24	- 53	74	- 23	104	- 18
11	64	+0.1	66	+ 26	98	+ 35	36	57*	- 58	48	- 23	90	- 18
12	75	0	75	+ 24	75	+ 31	37	30*	- 86	77	- 24	87	- 21
13	78	0	47	+ 19	54	+ 28	38	55	- 87	82*	- 31	49	- 23
14	80	0	83	+ 19	101	+ 27	39			70	- 35	88	- 24
15	83	0	87	+ 18	84	+ 23	40			63	- 40	71	- 24
16	39*	- 1	97	+ 18	81*	+ 20	41			24	- 44	24	- 34
17	79	- 6	98	+ 14	47	+ 19	42			80	- 48	72*	- 36
18	20*	- 7	95	+ 11	66	+ 17	43			76	- 53	92	- 43
19	56	- 12	96	+ 9	111	+ 11	44			55*	- 94	63	- 43
20	72	- 14	81	+ 4	16	+ 11	45					89	- 49
21	16	- 15	78*	+ 4	83	+ 9	46					76	- 50
22	77	- 17	71	+ 3	85	+ 9	47					48	- 54
23	65*	- 19	16	+ 1	96	+ 9	48					70*	- 54
24	82	- 19	64	+0.5	106	+ 9	49					86	- 61
25	46	- 19	56*	- 6	105	+ 8	50					80*	- 62

[a] Rank

* Cows that left the herd.

on too small a quantity of data to give conclusive results; however, it would appear that more work should be done in an attempt to determine more-accurate means of evaluating first-calf heifers.

Within each herd, rank correlations between the Legates ranking and each of the other five methods were calculated. The results are shown in Table XIV. Legates' index was used as a standard of comparison for three reasons:

1. It includes the most information, and therefore ought to be the most accurate.

2. Dunbar and Henderson (1954) showed it to be closely correlated with their "best" index.

3. It includes first-calf heifers, which other methods (except owner) do not.

Rank correlations for Legates' and owner's methods were made both including and excluding first-calf heifers. The values of r for the former were lower than those when only cows with completed records were considered. Values of r when the heifers were not included were significant at the 1 percent level in four of the five herds, but when heifers were included, r values were insignificant in two herds, significant at the 5 percent level in one herd, and at the 1 percent level in one herd. The other herd was not ranked with first-calf heifers included.

TABLE XIV

RANK CORRELATION VALUES BETWEEN LEGATES' AND APPROXIMATE METHODS

Method	Herds				
	Smith (34 cows)	Watson (18 cows)	M.S.C. (9 cows)	Nye (10 cows)	Kellogg (19 cows)
Estimated Real Producing Ability	0.943	0.92	0.983	0.84	0.80
ME-2X-305 day average	0.916	0.90	0.900	0.82	0.74
Deviation from weighted annual herd average . . .	0.944	0.91	0.983	0.84	0.87
Deviation from moving herd average	0.947	0.94	0.983	0.79	0.82
Owner's opinion excluding two-year-olds . .	0.800	0.88	[0.05[a]] [0.320[a]]	0.85	0.83
Owner's opinion including two-year-olds . .	(45 cows) 0.700	(26 cows) -	(16 cows) 0.37[a]	(15 cows) 0.50[a]	(37 cows) 0.48[b]

[a] Not significant.

[b] Significant at 5 percent level.

All others significant at 1 percent level.

[ ] Two herdsmen ranked these cows independently.

The similarity between the other methods of rankings is important even though the values for r vary considerably from herd to herd. The value of the owner's or herdsman's opinion varied with relation to other methods of ranking in the same herd, but the similarity between the ways the owners ranked their own herds when the first-calf heifers were not considered was noticeable (with one exception). The high value (0.88) in the Watson herd is probably due to the group of old cows in that herd which are obviously the top cows, no matter how they are rated, while the low values (0.05 and 0.32) in the M.S.C. herd were partly due to the fact that the herdsmen do not milk the cows themselves, and partly due to the fact that they do not keep as well informed on the cows (due to other duties) as perhaps they should.

The low Legates-Owner correlation when first-calf heifers are included can probably be credited to such considerations as:

1. Legates' index rated them on their dam, maternal and paternal sisters, whereas the owner probably ranked them on what they were currently doing in their lactation.

2. The owner would be much less likely to give a first-calf heifer a high ranking even if she were doing well and was out of a good family, whereas the Legates index would give a heifer out of a good family a high value regardless of her age.

3. Conversely, the owner would be less likely to give a first-calf heifer an extremely low ranking (unless she was very poor) just because of her family, whereas the Legates index would be very critical of her.

There are several other factors that seem to have an effect on the value obtained for the rank correlation coefficients:

1. Selection of data. Variation in the size of herd from year to year, and particularly in the early years (see Table II) indicates that there may have been some cows whose records were not included in the study. This would affect herd average, which could reasonably affect final rankings. The same is true if short lactations were excluded, or if there were some other abnormality in the records. In this study, all abnormal records were included if they were over 200 days in length. An example was cow number 277, ranked last in the Kellogg herd. She had one lactation affected by lumpy jaw, and because her next record, presently in progress, is considerably better, she was rated slightly higher by her owner than by any other method.

2. Information on cow families. For some cows, information on the dams and/or maternal and paternal sisters was missing, and consequently the index value of those cows was much closer to their own ERPA than it would be if the complete pedigree information were

available. Such incomplete information could either rank cows higher or lower than their true rank. Index values on purchased cows, unrelated to the rest of the herd, should be used with these considerations in mind.

3. Age of cows. The effect of age of cows (number of lactations) has been discussed with regards to first-calf heifers and the changes in their values as they complete one and two lactations. Table XIV indicates some of the effect that old cows have in ranking. The Watson herd has one-third of the cows (not including first-calf heifers) with six lactations or more. The Kellogg herd, by contrast, has only 10 percent of the cows with six or more lactations, but has 79 percent with three lactations or less. In the Watson herd, all correlation values are higher, but in the Kellogg herd, the highest value was given to the method using annual herd average.

If all cows had the same number of lactations, rankings by deviation from annual herd average and by ERPA would be exactly the same. Cows with more records would be expected to benefit more by ERPA ranking and cows with one or two lactations would have the advantage in ranking on deviation from annual average, because of the formula: ERPA = $nr/(1+[n-1]r)$ times cow's deviation from the annual herd average (see Review of Literature).

The correlation values for the methods of ranking that Dunbar and Henderson (1954) used do not evaluate the methods in the same order as do the results of this study (see Table I). According to their results, use of Legates' index as best would have given the highest correlation between it and ERPA, and the ranking by deviation from herd average would have been slightly less valid. In the results of this study (which included ninety cows and five herds, as contrasted with fifty-seven cows in one herd used by Dunbar and Henderson), the two methods were reversed, with deviation from annual average giving slightly better validity. However, deviation from moving herd average was as good or better in three of the five herds. In those same three herds, owner opinion ranked at the bottom, which coincided with the results of Dunbar and Henderson.

It would seem, though, that r values differing only by very small amounts would be about equally valid in large amounts of data. Therefore, the most important consideration will probably be the ease of calculating the various methods so that practical application can be made by the dairyman. He would be justified in sacrificing a little in accuracy to get a measure that was relatively quick and easy, and one that would keep the herd up to date.

Discounting the owner's opinion, the easiest of the other methods is, of course, the ME-2X-305 day average, since converted records are used as the basis for all other methods. Several breeds now convert individual records to that basis for the breeder, and it would not be too difficult to calculate ME herd averages in those breeds. In comparing cows with equal numbers of records, the ME-2X-305 day average would probably be the best from the standpoint of accuracy and ease combined.

If annual herd averages on a ME-2X-305 day basis could be easily determined, then ranking by deviation from annual herd average would not be difficult. It appears from this study that application of the ERPA formula to these deviations does not result in any more accuracy unless the herd consists of older cows. Deviation from moving herd average is the most difficult to calculate, except for the Legates index itself, and is probably not worth the extra effort.

The Legates index is not so difficult to use if an automatic calculator is available, but to recommend that a dairyman go through the lengthy processes of computing, multiplying, and summing, using varying numbers for b_3, b_4, and b_5 would be unwise. The higher degree of accuracy would not be worth the time spent. Furthermore, it appears that, with very few exceptions, the five methods (excluding owner) all selected the same cows as top and bottom cows. The variation between the methods showed up most in the group on either side of average. Since a dairyman is more concerned with which are his top cows (to breed from) and his bottom cows (to cull from) than with the middle cows in his herd, it would seem that an easier way than the Legates method could be used for making a quick evaluation. The most important bit of advice, regardless of method used, is to be wary of cows with an extremely high value as the result of one high record as a two-year-old. From the comparison of a cow's value throughout her first three years of production, it appears that the bottom one-record cows are more likely to stay near the bottom as they grow older than the top one-record cows are likely to stay near the top (environmental effects and injuries could be partly the cause). Therefore, selecting bulls from high-record two-year-olds should be done with extreme caution, especially if little or nothing is known about the bull's sire and/or maternal granddam.

Bull Evaluations

The use of Eldridge's formulas (1948) for predicting the values of a bull's daughters gave results as shown in Table XV. The estimated values Y_A and Y_B are in terms of pounds of butterfat, and

TABLE XV

PREDICTION VALUES FOR BULLS BY ELDRIDGE'S TWO EQUATIONS AND BY LEGATES' BULL INDEX

Bull	Eldridge Y_A	Rank	Eldridge Y_B	Rank	Legates	Rank
Foreman	+118	8	+143	5	**	-
203	+137	1	+151	2	+ 28	8
230	+121	6	+113	10	+ 79	2
Mactor	+132	4	+137	8	**	-
Baby's Max	+117	9	+108	11	**	-
Warrior	+134	2]	+138	6	+136	1
Majesty	+134	3]	+137	7	**	-
Nyland King	+102	12	+ 86	12	**	-
Jessamine	+105	11	+125	9	**	-
209	+120	7	+145	4	+ 60	4
Trixie Majesty . . .	+124	5	+147	3	+ 46	5
Honor Majesty . . .	+112	10	+162	1	+ 31	7
Julius	*	-	*	-	+ 63	3
252	*	-	*	-	+ 11	10
270	*	-	*	-	+ 42	6
293	*	-	*	-	+ 14	9

* Not sufficient information on sire.

** Not sufficient information on Estimated Real Producing Ability of relatives to apply index.

are to be added to 0.75 of the average of the prospective mates, which would be, in general, 0.75 of the average of the herd in which the bull is to be used. Since Eldridge's data were calculated on interherd records converted to ME-2X-305 day basis, the formulas should be applicable to this study.

Both of the prediction formulas were used on all bulls except for four, where pedigree information was lacking. The variation in results between the two formulas when applied to the same bull reflects the importance of the amount of information on close relatives. Bulls with no or only fair maternal sisters have a high value for Y_B, which does not consider maternal sisters, but a low value for Y_A, where maternal sisters have some influence. Bulls with good maternal sisters have high Y_A values and lower Y_B values unless their dams' paternal sisters are good. The question arises, of course, as to which of the values is more accurate. since there is a variation from three pounds (Majesty) to fifty pounds (Honor Majesty) between the results of the formulas. One of the major discrepancies in Eldridge's formulas is that there is no consideration given for the numbers of maternal and paternal sisters of the bull. It would seem logical that there should be a weighting factor, especially in regards to paternal sisters. Nor is any consideration given to the numbers of records averaged to ascertain values on the dam or sisters. A cow with eight records averaging 550 pounds of fat gets no more credit than a cow with one record at that level. The difficulty in obtaining a valid figure for herd average complicates the possibility of basing Eldridge's formulas on such a value as ERPA or Estimated Breeding Value, as did Legates.

Predicted values using Legates' heifer and bull index were also determined for those bulls which were bred in the five cooperating herds. Table XV also gives the resulting values as deviations from herd averages and compares the rankings with the rankings by Eldridge's methods. However, in six out of sixteen instances, there was no valid information on the bull's sire that could be used in calculating by Legates' index. USDA bull proofs cannot be utilized unless the daughter average is taken as a deviation from breed average, and even that is merely an approximation. As a result, one bull (203) that rated very high by both of Eldridge's formulas, being sired by a bull with a high USDA proof, rated very low by Legates' method.

It will be most interesting to watch the progress made by these bulls as their daughters come into production, and to compare their daughters' actual production with the predicted values. In this study it does not appear that the Legates index value of a bull has any relationship to the sum or the average of the ERPA of his daughters, after they come into production. Theoretically, it seems that there should be a relationship between the sire's index value and the daughters' ERPA with consideration for the contribution from the daughters' dams. This can be measured better five years from now when more information is available.

CONCLUSIONS

Developing a breeding program for the future by use of data such as are presented in this study revolves around a few basic questions:

1. In selecting bulls, is it wiser to choose from large or popular well-known herds than to choose from a smaller herd which has better-than-average cattle?

2. If the foundation of a group of herds is based on four or five good bulls (selected on the basis of pedigree, individuality, and progeny), can these herds continue improvement by selecting sons of these bulls from their own top cows (production and type)?

3. How good must a cow be to be the dam of a herd sire?

4. Will the "good" cows this year be the "good" cows all their lives?

5. How can the average number of lactations per cow be increased, so that the best cows will have more offspring?

6. What can be done to enable the dairyman to cull largely from the bottom cows, rather than, as at present, nearly the same proportion from each group?

7. What plan of mating should be made to provide a succession of good males and females?

8. Can improvement in type and production be continuous?

Unfortunately, the results of this study point out the problems better than the answers. Time is an important factor in giving the final solution to (1) and (2). The discussion of Table XI would indicate some of the probable requirements for the dam of a herd sire (3), since both production in the pedigree and type are considered. The information from Table XIII would seem to indicate that, after completion of three or more lactations, a cow's value will not vary much, barring accident to the cow. However, unless the average number of lactations per cow can be increased, too few cows will complete three lactations.

(4) Considerably more work needs to be done to evaluate heifers before they calve and cows with only one or two records.

(5 and 6) There are three suggestions that may have practical value for increasing number of lactations per cow and thus change culling procedures (which would help to increase genetic progress made in the herds:

a. Keep better breeding records and use them to cut down on breeding troubles which take too large a toll from the herds each year.

b. Pay more attention to management practices that will reduce injuries to feet, legs, and udders. This means better milking practices and barn management.

c. Take better care of the good old cows that have proved themselves as valuable brood cows. Provide for their increasing age, and if they are extremely good, keep them as long as they reproduce, if only as nurse cows. This will provide more heifer replacements from the best cows.

(7) Planning sound matings should be started with bulls that are known to be good. Unfortunately (in this project) the older bulls, while they were purchased on the strength of their individuality, pedigrees, and insofar as possible, their progeny, are mostly unknown and will not be proved in these herds for two to four more years. Only after their real value is known can the success of the project be predicted. Fortunately, there are several good groups of cows (groups of paternal sisters) to breed from, and the most progress will be made, it is hoped, by mating these cows with the older bulls, and using their offspring for building high-producing herds.

The older bulls have been used quite heavily in the five herds for the past year or more. Their calves are under a year of age. A proposed plan for making future matings is as follows:

a. Top cows, as ranked by the Legates index, would be bred only to the top ranking proved bulls, and all offspring, male and female, would be saved for future use in the project (except bulls whose dams are below type requirements or have not completed a record).

b. Cows in the two groupings around herd average would be bred to proved and unproved bulls in an attempt to (1) provide replacements for the herd, and (2) prove the young bulls in the project.

c. Cows in the lowest grouping should be culled, as economic conditions permit and with consideration for type, and their female offspring should be saved only when it is economically sound to do so. This would actually result in a much more rigorous test of the bulls being used, since the dams of the bulls' daughters would be a somewhat selected group.

An important part of the purebred business is the sale of breeding stock, and since it is usually impossible and impractical to save all heifers for replacements, the following suggestions are made:

a. Heifers or cows sold as purebred breeding stock should come only from the two groupings around herd average, preferably near the herd average line, since they can be expected to do about as well in other herds as the top-grouping cows' daughters will do.

b. Heifers or cows sold as commercial stock should come from below the herd average line.

Bull proofs can be a valuable tool if made and used properly. A proof should be completed on every bull in the project, and an attempt to get thirty unselected pairs in the five herds should be made. Bulls with minus proofs of over ten pounds of butterfat should be considered for removal from the project unless the dams of the daughters average 450 pounds of fat or more. Sound evaluation of the proofs by the cooperators in the project would be highly recommended.

Young bulls should be sampled so that they will each have at least twelve to twenty daughters in at least two of the five herds, and then leased until preliminary provings can be made. The sizes of the five herds warrant the continual use of about eight bulls. A logical situation would include about twice that number:

a. Four proved bulls, rotated between the five herds at six-month to one-year intervals.

b. Four bulls in the process of being proved, and currently leased out to neighboring breeders who are testing for production and will take good care of the bulls.

c. Four young bulls (yearlings and two-year-olds) that are being used in the herds for two years before being placed out.

d. Four calves that are being grown out for use next year.

As the bulls become proved and evaluated, the lowest ones will be replaced.

Positively no bull calves should be sold out of cows ranked below the herd average line. Bull calves from cows above the line could be merchandized, as the market permits, providing they and their dams have desirable type.

(8) Not enough practical, controlled experimentation has been conducted to know if continuous improvement in production and type is possible. Complete information is usually not available. There are few herds in the country that can testify as to the possibility.

If such a thing is possible, it will come about only as the result of accurate record keeping and record evaluation, wise selection and use of bulls, good sound judgment and management practices on the part of the owner and herdsman, and, in all probability, a fair share of luck. Continuous improvement would certainly be made at a decreasing rate, but if the plans are laid soundly, it should be a possibility.

SUMMARY

A study of 721 past and present records of 288 Guernsey cows in five cooperating herds was made in an attempt to outline a breeding program for the future that would reduce the mistakes usually involved in selection of a herd sire. Increased production and improved type were the goals on the part of the cooperating herd owners, whereas an opportunity to evaluate and compare methods of cow and bull evaluation was the important consideration from the research standpoint.

Environment of the herds was compared and found to be quite similar. All herds were classified twice for type at six-month intervals. All butterfat production records over 200 days were used and converted to a mature equivalent basis. All records were 2X. Records over 200 days but under 305 days were converted for age, but not for length of lactation.

Rankings on all cows with records and first-calf heifers in the herds as of July 1, 1954, were made by six methods:

1. Cow's records as a deviation from annual herd averages.
2. Estimated Real Producing Ability (ERPA).

3. Legates' index.

4. ME-2X-305 day average of all of a cow's records.

5. Cow's records as a deviation from a three-year moving herd average.

6. Owner's or herdsman's opinion in two ways:

   a. including first-calf heifers.

   b. excluding first-calf heifers.

Rank correlation coefficients were computed, using Legates' method as best. Highly significant values were obtained in all cases except owner's opinion, which showed considerably lower correlation. Ranking by owner's opinion including first-calf heifers was not significantly correlated with Legates' ranking in two of the four herds ranked by that method. It appeared from this study that rankings by deviation from annual or moving herd averages or by ERPA were the closest to rankings by Legates' index. Rankings by ME-2X-305 day average and by owner's opinion were not as accurate. Reasons for variation in rankings, and factors affecting correlation values were discussed.

In order to see how much yearly variation there is in a cow's (Legates) values, the first-calf heifers of one herd in 1950 were ranked, and then ranked again as cows with one record in 1951 and again as cows with two records in 1952. These rankings were correlated and found to be not significant and highly significant, respectively. The conclusion was that the Legates heifer index did not rank the heifers satisfactorily (perhaps lack of information might have been a factor in some cases), but that the Legates value of a cow does not vary greatly after the completion of three or more records.

Sixteen bulls of all ages that have been selected as herd sire possibilities were evaluated by Legates' bull index, and their future daughters' production was predicted using Eldridge's two prediction indexes. In some cases there was not sufficient information available to make an accurate evaluation. The bulls were ranked by the results of the two methods, but no correlations were calculated.

The top-ranking cows for production were closely analyzed for type, and any classifying less than Desirable in over-all rating or over-all mammary system were eliminated from consideration as dams of herd sires. One-record cows would be considered as dams of herd sires only with hesitation.

A suggested breeding and culling program based on the results of Legates' index and the type classifications was proposed. Using only proved bulls and their sons out of the highest-ranking cows was the primary consideration. To maximize the improvement possible by this type of program, an attempt should also be made to reduce the management factors that necessitate culling of cows from the herds. Culling according to value as derived from this study would give the greatest opportunity for increased production and improved type.

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