CHARACTERISTICS AND USE OF FIRST LACTATION RECORDS IN YOUNG SIRE EVALUATION

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ABSTRACT

CHARACTERISTICS AND USE
OF FIRST LACTATION RECORDS
IN YOUNG SIRE EVALUATION

By

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First lactations of 6,013 daughters of 12 Holstein AI sires were used to compare methods of sire evaluation and their value in young sire selection. Characteristics of first lactations regarding culling, age correction, and extension of incomplete records were also studied.

The sires ranked nearly the same by daughter average, mean weighted difference (MWD), and USDA predicted difference when large numbers of daughters were used. Analysis of variance indicated that there was not a significant difference in ranking by MWD or daughter average. Throughout the study, only daughters in their first lactation that were sired by one of the other sires being evaluated were considered as herdmates. This reduced the number of usable daughters for MWD to 52-75% of those used in the daughter average and may be responsible for the slight superiority of the latter method when all daughters calving within a calendar year were used. The use of records on 50 to 100 daughters showed that the MWD was not as reliable as the daughter average due to the severe reduction in the number of usable daughters. The results for the two methods were similar when the numbers of daughters involved in the calculations were similar. The

sires were evaluated in herds that used all or most of a contemporary group of sires in a year by MWD, daughter average, average of first daughter of each sire in each herd, and mean of sire-herd averages. The results of three samples using 8 to 27 herds and 11 to 38 daughters per sire strongly indicated that sampling sires in these selected herds was more efficient than conventional methods of sampling.

The sire by method of age correction interaction was not significant. Thus, it appears that sire evaluation based on many first lactation records will be little or no different whether the age factors are old or new DHIA, or none. The regressions of yield on age at calving were not significantly different from zero for actual records or those corrected by either factors. The average age at calving for complete first lactations was 27.7 months which was significantly higher than for voluntarily terminated lactations.

The interaction of sire and method of extending voluntarily terminated records was significant, indicating that these records need to be extended by separate factors if the shape of their lactation curve is unique. Voluntary extension factors reduced the projected milk yield to 810 lb below that for normal factors. The percent of removals that were voluntary ranged from 68 to 93% for the twelve sires. Within sire-years, the percent of first lactation daughters removed ranged from 8.5 to 30.0%. Second and third lactations were studied only regarding disposals. Percents of first, second, and third lactations terminated prior to going dry were 17.8, 20.4, and 21.9%, respectively. For these lactations the portion voluntarily removed was fairly constant at 15% while the involuntary portion increased from 3.3 to 7.2%.

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INTRODUCTION

The annual rate of genetic improvement in dairy sires may be described as;

$$\frac{\text{accuracy} \times \text{intensity} \times \text{variation}}{\text{generation interval}}$$

where accuracy is the correlation between a sire's real transmitting ability and our estimate of it, intensity is the number of standard deviations between the average performance of the sires saved and that for the population, variation is the genetic standard deviation, and generation interval is the average age of sires when their replacements are born. Of the four factors, genetic variability is the one most nearly fixed so we concentrate on the other three to make genetic progress. Because of artificial insemination (AI) only a very small fraction of the bulls born need to become sires. Therefore, our intensity of selection among sires may be very large, 3.37 standard deviations when the fraction saved is 0.001, whereas the intensity is only 0.50 if the fraction saved is 0.70 as is common with cows (Lush, 1960). In the evaluation of young sires we are particularly interested in early testing as a means of decreasing the generation interval and thereby increasing the rate of progress. Ideally this would be performed with no decrease in accuracy.

Young sire proving programs in the United States and in Europe generally are designed for about 50 to 100 daughters per sire being evaluated. The resulting records are used in various ways regarding adjustments for age, lactation number, season, incompleteness, environment, frequency of milking, and genetic effects from dams. Adjustments for lactation number generally take the form of inclusion or exclusion of other than first lactation records. Correction for maturity generally is based on age at calving although lactation number has been used and body weight has been suggested. The standard length of lactation is 305 days and those records terminated prior to that time, for reasons other than going dry, should be extended and used for two reasons. First, their exclusion may decrease the number of records by nearly 25%. Second, ignoring them could bias the comparison of bulls. About one-half of the removals are for low production. If the culling rates for low production differ among bulls, then a larger fraction of poor records will be included in calculations for one bull than for another. It has been shown that lactation curves differ between lactations voluntarily terminated and those involuntarily terminated but that the latter parallel those for completed lactations. This is another source of bias resulting from differential culling among sires' daughters. Consequently, use of two sets of extension factors is necessary to reduce or eliminate this bias.

The evaluation of sires sampled has been based on the daughter average, daughter-dam difference, and the daughter-herdmate comparison which is presently used almost universally in some form. Formulas have been derived that attempt to account for numbers of daughters and herdmates, distribution of daughters, residual correlation among paternal sibs, and regression of daughters' production on that of herdmates.

The objective of the present study is to determine the relationship between various methods of ranking young sires. It is assumed that if one method is more accurate than another, using a given number of daughters per sire, or is as accurate using fewer daughters, then the rate of improvement for the first method would be larger. Also, if two methods are equally satisfactory on the preceding criterion, the simpler one would be preferred. This is because it would allow more rapid computation which should operationally decrease the generation interval.

Sires will be compared by the mean weighted differences of their daughters only in herds where more than one of the sires being compared are used and only the daughters of these contemporary sires are considered as herdmates. This method, with and without special factors for extending voluntarily terminated records, will be compared with various daughter averages and predicted differences. Also to be examined are rates and reasons for removals and effectiveness of age correction factors.

REVIEW OF LITERATURE

Sires have been selected on many criteria. The sire's own type plus the type and production records of his sire, dam, sibs, offspring and other relatives have been used singly or in various combinations to estimate the sire's worth. Supervised testing made production information more accurate and readily available to those interested in increasing milk and fat yields. The extensive use of artificial insemination made it possible to use fewer, more select bulls and to obtain information on many more daughters of each. Progeny tests have been accepted for many years as the best way to estimate a sire's breeding value, but a multitude of ideas exist on how the daughter records should be treated and compared. A variety of adjustments have been used in an attempt to eliminate or minimize environmental effects and genetic effects of dams. These corrections and adjustments, whatever the motive, are types of statistical control exercised because physical control is either impossible or at least prohibitive in cost (Lush and Shrode, 1950).

Age Effects on Lactation Production

Perhaps the most obvious difference among cows, other than breed, is that they are of various ages. If production is affected by age, then differences in age will bias estimates of producing ability. It has been repeatedly observed that production increases with age until approximately six to eight years of age and then decreases. In the United States correction of production records for age is done with multiplicative factors which result in a mature equivalent (ME). This estimates the amount a cow would have produced in that specific lactation had she been mature, and is not designed for prediction of later production (Searle and Henderson, 1959). Some argue that correction of records to a two-year old basis is more reasonable. In Sweden, where only first lactation records are used in sire proving, the records are corrected to 28 months of age (Johansson, 1960). In Norway and Great Britain only first lactation records are used and no correction is made for age (Johansson, 1960).

According to Searle and Henderson (1959), Gowen (1920) developed the first method for determining age adjustment factors. The factors are merely ratios of the average production of mature cows at a certain time to the average production of cows of each other age at that same time (Searle, 1960). This is the Gross Comparison method that is now in general use. As cows are culled at various ages, mature cows represent a more select group than do younger cows and these ratios not only show the effects of age but also of selection and are biased upward (Lush and Shrode, 1950). It is also possible that the ratio is biased downward if the genetic ability of the population is increasing. In this situation the younger cows would have the advantage of an upward genetic trend and the factor would be smaller than it would be with age effects only (Lush and Shrode, 1950). One of the more obvious weaknesses of this method is that it does not compare lactations of the same cows (Searle and Henderson, 1959). This defect was corrected by Sanders, who suggested using consecutive pairs of records by the same cow. The difficulty with this method, known as the Paired Comparison method, is that although effects of selection and genetic trend are reduced, records from different times are being compared so that effects due to age are confounded with environmental trends or at least with environmental differences. The factors from either method are regressions, through the origin, of yield of mature cows on the yield of young cows (Searle, 1960). Searle and Henderson (1958) found that the corrections for age should be larger in high-producing herds than in low-producing herds. They further stated that the multiplicative factors used in New York generally, but not completely, accounted for herd differences. In a later report (1959) they repeated that age correction factors should be different at different levels of herd production and added that multiplicative factors did not take into account the differences between herds. Searle and Henderson (1960) used several criteria for comparing age correction factors and none of the analyses showed any difference between the multiplicative and herd-level factors. They point out the difficulty in judging the effectiveness of various correction factors.

Factors derived by Kendrick (1955) had been used by the United States Department of Agriculture (USDA) until 1967 when they were replaced by factors which also consider season of calving and regional differences (McDaniel et al., 1967). These factors are unique for two seasons of calving, November-June and July-October, in each of six regions for Holsteins. If seasons were not considered, the cows freshening in the winter would be underestimated by about 300 lb of milk and those calving in the summer would be overestimated by about 300 lb of milk (Plowman and McDaniel, 1968). Bereskin and Freeman (1965a) state that the herd-by-month interaction is about three times as important as the average difference among months and therefore, adjustments for month of freshening would not be effective unless the corrections can vary from herd to herd.

The comparative effectiveness of the two sets of factors for removing variance was studied by Miller et al. (1968). They found that sire rankings based on either set were virtually identical. Only first lactations were used, and the rankings based on least-squares estimates from actual yield and ME yield from both sets of factors for correcting records showed correlations of 0.99. This was interpreted as meaning that the use of only first lactation records will minimize the effects from any errors in correction factors. The coefficients of variation were very similar for actual records and those corrected by either method. Seasonal differences were magnified by both adjustments with the new factors contributing to apparent seasonal differences more than Kendrick's factors. It was concluded that the new factors may enhance seasonal variance if an age by season interaction exists. However, the factors themselves indicate that this interaction is believed present. Such an interaction was reported by Wunder (1967).

Effects of Season of Calving

It is generally accepted that season of calving will affect milk production with the higher lactation production following fall and winter freshening. Therefore, production records need to be corrected for season of calving if we are to compare records initiated in different seasons. Researchers have studied the effects of various seasons for extending incomplete records and defining herdmates. Using

Michigan data, Lamb (1959) found that two seasons, November-April and May-October, were acceptable for use in extending records. Production was higher for records started in the November through April season. A later study by Lamb and McGilliard (1967a) resulted in a slight shifting of the seasons to August-March and April-July. Branton and Miller (1959) found that season and year of calving had a significant effect on persistency of milk production. Cows that calved in the months of August-November had the highest persistency, December-February had intermediate persistency, and the March-June season showed the least persistency.

Wunder (1967) studied six pairs of months of calving and reported that yields were the largest in the January-February season and declined steadily through July-August when they were the lowest. The difference between the best and worst seasons was 776 lb of milk. All possible six-month seasons of calving were studied by Tucker et al. (1960) who found that seasonal differences were minimized by using the intervals of June-November and December-May for defining herdmates. The latter season was higher by 595 lb of milk.

Corley et al. (1963) found that Holsteins calving in the fall and winter produced 505 lb more milk than those calving in the spring and summer when all lactations are considered and 581 lb more for first lactations. The corresponding values for Guernseys were 413 lb and 505 lb. Gaunt et al. (1964) found higher production for cows freshening in the six-month period of November through April. Tucker and Legates (1962) studied 442 Holstein HIR herds in 35 states and recommended that two seasons be used for effective seasonal division of herdmates. The seasons were May through September and October through

April. Their later report (1965) on information from these same herds concluded that the five-month rolling season is practical and appropriate throughout the United States. USDA workers use such a period to determine the herdmate average (Miller, 1962a). Placing a seasonal restriction on which animals may be compared reduces seasonal differences.

Estimation of 305-Day Production from Partial Lactations

Extension factors are valuable because they assist in earlier culling of cows and promote the use of in-progress or terminal incomplete records in sire proofs. The proper use of the latter records should eliminate the bias in proofs due to the exclusion of culled daughters (Aulerich, 1965). The two most common procedures for determining extension factors are ratio and regression (Aulerich, 1965). The ratio extension factors are the direct ratio of records of various part lactations to the record of the whole lactation and are generally used because of their simplicity. Another advantage of the ratio factors is that the resulting records vary more like actual records than do those extended by regression factors. The regression factors take into account the incomplete repeatability of parts of the lactation as well as the incompleteness of the record. Extension factors may be further classified as cumulative or non-cumulative, depending upon the amount of information they use. Lamb and McGilliard (1960) report that extension by either the ratio or regression methods will result in the same females being culled and the same sires being selected. The order of records is not changed although the ratio factors spread them out more. They found lactation number had a larger influence on the relationship of part to total lactation production than did age. The factors derived for either basis were so similar that it was concluded that either would be acceptable. However, it was noted that age factors were more appropriate when age and lactation do not coincide normally, such as first lactations initiated after 36 months of age or second lactations started prior to that age.

It has been known for many years that although younger cows have a lower lactation curve, it is a flatter one. In other words, they are more persistent. The most distinct change in persistency occurs between the 35th and 36th month of age at calving (Lamb and McGilliard, 1967a; Madden et al., 1955). Extension factors for milk yield are generally grouped by age with those less than 36 months of age in the first group and the older cows in the second group. A third age group is useful for extending records of fat production (Lamb and McGilliard, 1967a). Madden et al. (1955) indicated that separate extension factors were especially necessary for the first 150 days. Lamb and McGilliard (1960, 1967a) report that season of calving should be considered in extension factors. Branton and Miller (1959) found that season had a highly significant effect on persistency of production. Extension factors were derived by Lamb (1959, 1962) and Aulerich (1965) with two seasons in each age group, while Madden et al. (1959), and McDaniel et al. (1965) considered only age.

Aulerich (1965) studied the differences among extension factors derived from non-terminal lactations and those voluntarily and involuntarily terminated. Voluntary removals were those for dairy purposes, low production, hard milker, or old age. It was found that factors for non-terminal records were applicable to involuntarily terminated records while voluntarily terminated records needed separate factors. However, if rates for the two types of removals are similar among sires, then the method of extension would not have much impact on the ranking of sires. Dayton (1966) reported that there was a disproportionate rate of removal of daughters of AI sires and it was especially evident in first lactations. Van Vleck (1962) used records initiated prior to 36 months of age to study the effect of incomplete records on sire evaluation. He found that the difference between incomplete records and complete stablemate records varied among herd levels and sire production levels. The bias from ignoring incomplete records in sire evaluation was small and unimportant. This was attributed to the relatively constant fraction of incomplete records for sires over all levels, 5-7%. Van Vleck and Henderson (1963) found no evidence of bias in evaluating sires based on first and second lactation records even though there was a pronounced differential culling rate after the first lactation.

The use of part lactations for young sire evaluation has been advocated as a means of increasing the rate of genetic progress. Van Vleck and Henderson (1961e) state that the use of only five-month records would increase the rate of genetic progress by 10%. This assumes that the time from the beginning of inseminations to the time that complete daughter records are processed is 50 months and that the accuracy of five-month records is the same as for complete records. They proposed a three-stage program for evaluation of sires. The first stage considered only five-month records, the second used both part and complete records, and the third based the final evaluation on complete records only.

A key point in the use of part records is their accuracy in predicting lactation production. Van Vleck and Henderson (1961c) report the number of part records required to be as accurate as a specified number of complete records. As an example of their results, it takes 58 fifth month records or 92 cumulative five-month records to be as accurate as 50 complete records. However, in another report (1961a) their estimates of genetic progress from selecting on part records relative to complete records were 0.92 for both single fifth month and cumulative five-month yield. Madden et al. (1959) reported phenotypic correlations between single test day milk yield and the sum of production for all ten test days. They ranged from 0.93 for the fifth and sixth month of two-year olds to 0.67 for the first month of older cows. Correlations between five cumulative months and total production were 0.95 and 0.93 for two-year old and older cows, respectively. Spike (1968) found phenotypic correlations with total production were 0.88 and 0.90 for single fifth month and cumulative five-month production, respectively, for Holsteins. Corresponding genetic correlations were 0.89 and 0.81. The center months of lactation are much better predictors than those toward the extremes (Madden et al., 1959; Spike, 1968; Van Vleck and Henderson, 1961c).

Similar phenotypic correlations between cumulative test day production and total production were found by Fritz et al. (1960) using four breeds. All were 0.7 or above in the first month and were about 0.9 in the fourth month. Lamb and McGilliard (1967b) found the genetic correlations between single month and lactation yield to be generally 0.9 or larger. They concluded that total production can be estimated with sufficient accuracy from cumulative yields for five or six months to make it impractical to wait for ten-month total production. Van Vleck and Henderson (1961c) suggested sire selection based on production from the first seven or eight months.

Arguments have been advanced for using records of less than 305 days for reasons other than increasing the rate of genetic progress. Research studying the effect of feeds or treatments often will compare production from only the first half or two-thirds of the lactation to avoid an effect of gestation. This effect is generally not apparent until the fifth month of gestation. Smith and Legates (1962a) found that age was responsible for only 0.8 and 0.4% of the variation in persistency for first and later records, respectively, while number of days open accounted for 7 and 5%, respectively. They later reported (1962b) that the number of days open accounted for 6.5, 4.3, and 4.2% of the variation in lactation production for first, later, and all lactations, respectively. A portion of a study by Van Vleck and Henderson (1963) dealt with first records for which more than 20 months elapsed between the first and second calving. Production was noticeably higher than other first records and this was attributed to not having to support a fetus. In these cases it was thought that five-month production might give a better indication of genetic worth. Johansson (1960) suggested that lactation records of 200 or 250 days would be useful in eliminating the effects of gestation.

Lactation(s) to Use

Even in the best young sire programs it is common that when a sufficient number of records are available for all sires being compared, one or more of them will have some daughters with second lactation records. To include them will possibly introduce a bias due to selection and to ignore them is to not use all the information available. It is necessary that we review the characteristics of first lactations. Some question has been raised concerning first lactation or primarily first lactation production as the basis of sire selection since it might favor reduced lifetime output. In studying five breeds, each stratified into four levels of first lactation production, Van Vleck (1964) reported that cows that produced more milk in the first lactation not only continued to outproduce those with lower first lactation production but also had a longer herd life. Those in the high group for Holsteins were over 1,500 lb higher than the low group in the fifth lactation. Parker et al. (1960) found that in the Holstein and Jersey herds at Beltsville there was a small positive correlation between longevity and first lactation production and that the higher producers tend to remain in the herd longer than the lower producers even when there is no selection on production. Hickman and Henderson (1955) concluded that selection based on first lactation production would tend to increase lifetime production. In a study of the relationship between production and longevity in Holsteins, Gaalaas and Plowman (1963) stated "there seems to be little doubt that on the average in these data, the higher producing first lactation cows had a somewhat longer productive life in these herds ...". Work by Robertson and Khishin (1958) indicated that selection on the basis of first lactation production should not affect the increase with age since the regression of increase with age on first lactation yield is nearly zero.

Carter (1968) studied 110,319 daughters of AI sires to determine when they were removed from the herd. Cows were divided into four groups based on their sire's production proof. The percents of daughters having second, fourth, and sixth lactations were higher for the higher sire production groups and the difference in percent increased with advancing age.

Freeman (1960) reported that the heritabilities of first lactation milk and fat production were higher than those for second or third lactations. For the three lactations they were 0.36, 0.24, and 0.26 for milk, and 0.43, 0.35, and 0.26 for fat, respectively. Such was not the case for fat test, however, where the respective heritabilities were 0.63, 0.72, and 0.58. In the report of Martojo et al. (1963) first or second lactation production was compared with all records in selecting cows. Their findings indicated that the preliminary evaluation of the breeding value of a cow may be safely based on first and/ or second lactation yield.

The results of Molinuevo and Lush (1964) suggest that the first lactation yield gives a better estimate of the breeding value of a cow than does the second or third and would be most useful in proving AI sires. However, the second and third records would aid considerably in estimating the breeding value of cows. Deaton and McGilliard (1964) reported that their analyses of the first three records indicated that the second and third gave little or no information beyond that from the first record. They further stated that the first record is a more dependable indicator of a cow's breeding value than is the average of the first three records.

Perhaps a more pertinent discussion of which lactations to use concerns the herdmates. The older the herdmates, the more select we expect them to be. In a study of 8,984 cows in 194 herds by Deaton and McGilliard (1965), the mature equivalents of first lactation records averaged 114 lb of milk below those of the other cows in the herds. Allaire and Gaunt (1965) studied selection biases in 4,855 records and found that the use of all lactation contemporaries overestimated the environmental situation by 258 lb of milk. They stated that using comparisons across lactations may confound inaccuracies in age correction factors with the effect of selection. The biases may not be enough to warrant reducing the number of herdmates by restricting them to the same lactation. If the proportions of first records in the proofs of sires being compared are not very different, there would be no change in the ranking. Van Vleck and Henderson (1963) found little difference among using first records, average of the first and second, or the index of weighted first and second records for sire evaluation. The second records were about 200 lb of milk higher than the first records. This was attributed to selection and perhaps undercorrecting of first records relative to second records. However, they concluded that any selection bias present is so small that the ranking of sires will be essentially unaffected.

Tucker et al. (1960) used the contemporary comparison of AI and natural service (NS) daughters in first lactations and found a superiority of 366 lb milk for AI daughters. This was reduced by 90 lb when all NS herdmates were used with the restriction that at least one first lactation NS herdmate be in each comparison. Dropping this restriction more than doubled the number of comparisons but reduced the advantage by an additional 30 lb. This bias was attributed to selection of the older animals.

Robertson and Rendel (1950) suggested the use of only first lactations in sire selection because of the decreased age of the sires when progeny tests become available. It was recommended by Tucker and Legates (1962) that first lactations of daughters be compared only with first lactation herdmates since their study had indicated a significant bias against first record daughters when all herdmates were used. Legates (1960) asked if perhaps first lactation animals should be compared with only first lactation herdmates. Later (1964), he stated that as herd size increased, this comparison should be given more study since the effects of both differential selection and discrepancies in age correction factors would be minimized.

Fairchild et al. (1966) reported that the progeny testing programs of northwestern Europe generally use the actual first lactation production of daughters compared with the actual production of first lactation herdmates. In their study 11% of the first lactation daughters had no first lactation herdmates and the average number of such herdmates was only 4.6. Therefore, they concluded that the additional information from using all herdmate information would outweigh any errors resulting from the use of age correction factors or from selection biases. According to Searle (1964) all sire proofs in Great Britain use only first lactations of daughters compared to the herdmates having first lactations in the same year, thereby avoiding age correction and the influence of culling. Progeny testing in Norway, Denmark, and Sweden also use only first lactations (Johansson, 1960).

Consideration of Mates of Sires

When the daughter-herdmate comparison replaced the daughter-dam comparison, we no longer accounted for production level of a sire's mates. If there is selective mating of sires, conscious or accidental, there will be a bias present in the comparison of those sires unless the mates' production levels are considered. Miller and Corley (1965) examined 24,853 daughter-dam comparisons for 263 Holstein sires to determine the value of considering the mates' performance in sire evaluation. The sires were ranked using daughters' deviations from herdmates alone and also in combination with their dams' deviations. The rank correlation was 0.998 indicating that information from sires' mates had little effect on their relative standing. There was a mean bias in the index of +41 lb of milk per sire due to selection of the mates. Including the dams' production when nondeviated records are used will increase genetic gain by about 23% according to Bereskin and Freeman (1965b) but adds very little when deviations from herdmates are used.

If herds use both AI and NS it might be that the better cows merit the cost of AI while others do not. If this happens in many herds and a few AI sires especially impress these dairymen it could inflate the proofs on these sires. Beal and Madden (1959) reported that there was not a significant difference in production between either purebred or grade mates of AI and non-AI sires.

Hillers and Freeman (1966) used the average deviated production of the dams of the first 10, 20, and 40 daughters of AI sires. The differences among sires were significant for the first 10 but were not when more were considered. Van Vleck et al. (1962) state that sire evaluation will not be greatly influenced by selectivity of dams. Similar opinions have been expressed by Robertson and Khishin (1958) and Miller (1962a). However, Miller (1962b) indicates that selective mating may hamper the disclosure of which are the best sires.

The AI Situation

One of the advantages of AI is that it operates in a sufficiently large population to make progeny testing feasible. It is necessary to have 100 to 200 cows before progeny testing is superior to selecting sires on the basis of their dams' production (Specht and McGilliard, 1960). Robertson and Rendel (1950) report that about 1% is the maximum rate of annual improvement in a closed herd without progeny testing but it can be raised to 2.05% in a population of 10,000 with progeny testing. This latter value is similar to the 1.7 to 2.3% found by Specht and McGilliard (1960). Searle (1961) estimates that AI with herd-testing doubles the progress from testing alone.

In 1966, 47.9% of the nation's dairy cows and heifers were bred artificially (USDA, 1967). The average number of dairy sires per stud was 58.5 with 35% used in progeny testing. Over one-half of the 43 studs having dairy sires had less than 25 Holstein sires. When compared with 1965, the trend seems to be for more extensive use of AI, larger studs, and fewer dairy services from beef bulls.

In a study by Robertson and Rendel (1954) it was concluded that AI had not offered sires that were genetically superior to the NS bulls. Thompson et al. (1958) studied the production of NS and AI daughters in

Virginia herds and found little difference. Guernsey AI groups averaged 12 lb more milk but 1 lb less butterfat while Holstein AI groups averaged 9 lb more milk and 7 lb more butterfat than the NS progeny. These latter figures indicate that more emphasis may have been placed on fat production than milk production in selecting Holstein sires. This apparent emphasis on fat has been observed by Van Vleck and Henderson (1961d), Corley et al. (1963), and Kucker and Tucker (1967). Miller et al. (1963) divided tested and non-tested herds into four levels of AI use; 0, less than 50, more than 50, and 100%. No significant difference in production was found between any of the levels of AI use. The tested herds averaged 1,600 lb more milk than non-tested herds. Gaunt and Legates (1958) analyzed the records of 6,949 Guernsey and Holstein daughters of AI and NS sires. The NS daughters averaged 611 and 691 lb of milk more than the AI daughters, respectively. Wadell and McGilliard (1959) reported that there appeared to be little genetic difference between AI and NS sires used in Michigan. A study of New York AI Holstein progeny was reported by Van Vleck and Henderson (1961b). Only first lactation records initiated in 1951-1959 were used in comparing AI offspring with their NS contemporaries. The AI daughters produced significantly more milk per cow except in 1952 and 1953. However, if one heavily used AI sire was excluded there would have been little or no advantage of AI progeny. Using the same data, Van Vleck and Henderson (1961d) reported that the genetic ability of the NS population increased by 399 lb of milk while the AI population increased by 512 lb. Hahn et al. (1958), in a limited study of NS and AI daughters of three breeds, found the only significant difference was the advantage of AI Holsteins for fat percentage over their NS herdmates.

Guderyon et al. (1958) divided first lactation records of Wisconsin Holsteins and Guernseys into three groups according to yearly actual butterfat yields. The differences, AI-NS, for Holsteins were +225, +175, and +79 lb of milk for low, medium and high herd levels. The last difference and all Guernsey differences were not significant. When using all lactations without stratification the AI-NS difference was +157 and -20 lb of milk for Holsteins and Guernseys, respectively. Van Vleck and Burke (1965) reported that AI progeny of all five breeds had consistently higher production than their NS herdmates in New York when using first lactations of the 1950-1963 period.

Tucker et al. (1960), using 6,888 first lactation records from North Carolina, found that the contemporary comparison of AI and NS progeny showed a 366 lb milk advantage of AI. Corley et al. (1963) reported that Holstein AI daughters were significantly superior to their NS herdmates by 270 lb of milk. The difference was similar at each of three levels of herd production. Guernsey differences were generally not significant.

Everett (1966) reported that the annual genetic improvement in the Michigan AI population was 2.4% compared to 1% for NS. Kucker and Tucker (1967) compared the ME production of 6,281 AI Holstein progeny with their NS herdmates in North Dakota, South Dakota, and Nebraska. The 143 lb milk superiority for AI when all lactations were included was highly significant as was the 164 lb advantage for AI when second and later lactations were used. The 92 lb milk advantage for AI in first lactations was not significant but the advantage in fat was.

It is important to remember that not all bulls starting a testing program will be available when the results are obtained. Becker and Arnold (1957) reported on the tenure of AI bulls born before 1940. Of 491 that were called desirable, 25% were used less than one year, 46% were used less than two years, and 63% did not survive past three years. Therefore, over half of the desirable bulls did not live until their first AI daughter freshened. In a later report (1959) they observed that the average tenure increased from 1.72 years in the 1939-1947 period to 3.19 years during 1948-1957. Wilcox et al. (1967) used 3,774 AI sires in a study of the portion of sires surviving until a proof was available. All sires entered service at less than three years of age. It was assumed that the 2,934 sires that entered service at less than two years would be proven at six years and the remaining 840 would be proven at seven years. The percent alive at proving was significantly higher for both age groups in the 1951-1961 period than for the 1939-1950 dates of entry into service. Pooling of sires of six breeds in the more recent years revealed that only 64% of the younger group and only 52% of the two-year olds were available for culling on the basis of daughter performance. Of those not available, 36 and 44% were removed for reproductive failure in the two age groups, respectively.

This review of the AI situation points out the extensive use of AI but that it does not automatically provide superior sires. The latter portion emphasizes the need for early decisions on sires since some of the better sires may otherwise be removed for reasons not closely related to their genetic merit.

Disposals

The reasons for disposals of cows and the percent for each reason provide useful information on management and selection problems and possibilities. The fraction involuntarily removed needs to be decreased in order to have greater freedom to cull for low production rather than to increase longevity (O'Bleness and Van Vleck, 1962). A recent addition to the information in USDA Sire Summaries has been percent of daughters sold for beef or died during the first lactation.

Using 2,792,188 DHIA records of the 1932-1949 period, Asdell (1951) found that the annual removal rate was 21.9%. This included 7.3% for low production, 5.1% for dairy purposes, 2.5% for udder troubles, and 1.8% for sterility. The yearly changes in the reports of removals exhibited no linear trend for most reasons but sterility generally rose in importance. The percent of each age group removed annually increased with age in most instances. The total number of cows was based on the sum of monthly totals of cows in herds divided by twelve. Calculations were done similarly for Michigan DHIA data presented in table 1 (Michigan DHIA Summary, 1966, 1968). This shows the rate of removal to be about 32% annually. Although 1964 is much lower than the other three years, it seems to be peculiar rather than an earlier point in a rapid trend because 1961-1963 showed 26.6, 27.9, and 29.9% (Michigan DHIA Aummary, 1963). Physical injury, mastitis, brucellosis, hard milker, and old age are decreasing as reasons among those culled. About two-thirds of those removed are voluntary removals, i.e. dairy purposes, cull cow, temperament, hard milker, or old age.

Table 1. Percent of removals in all lactations from Michigan DHIA annual summaries [a]

Reason	Year 1964	1965	1966	1967
Sold				
Dairy purposes	9.2	9.2	7.4	8.7
Cull cow	47.5	52.2	55.7	55.2
Physical injury	9.6	7.0	6.1	5.8
Mastitis	6.2	5.4	5.3	4.4
Brucellosis	0.3	0.2	0.2	0.1
Temperament	- [b]	0.9	1.0	1.1
Hard milker	1.9	1.1	0.7	0.6
Sterility	17.2	16.6	15.5	16.5
Old age	2.3	2.3	1.6	1.4
Hardware	-	0.7	1.0	0.7
Died				
Milk fever	0.8	0.5	0.8	0.8
Hardware	0.7	0.5	0.6	0.5
Bloat	0.5	0.3	0.5	0.3
Accident	2.4	1.0	1.3	1.5
Calving trouble	-	0.8	1.3	1.5
Other [c]	0.7	0.5	0.9	0.9
Voluntary	60.9	65.7	66.5	67.1
Involuntary	38.4	33.5	33.4	32.9
Percent incomplete of all lactations	24.7	31.9	32.2	32.5

[a] Percents may not sum to 100 because of rounding

[b] Not included in report

[c] Includes deaths specified as acetonemia, old age, forage poisoning, pneumonia, and leukemia

Specht and McGilliard (1960) found that 26.3% of the cows in their study were removed annually. One-tenth were removed involuntarily in each of the first four lactations and one-quarter in later lactations. Johansson (1960) reported that in Sweden 10-12% of first lactation Swedish Red and Whites are culled before 305 days and the corresponding figure for the Swedish Friesians is 15-20%. O'Bleness and Van Vleck (1962) conducted a mail survey over a six-month period in New York DHIA herds to determine the reasons for disposals. Responses were obtained on 7,362 cows of which 80% were Holsteins. Of those removed the percent of Holsteins disposed of for major reasons were; low production 26%, sterility 16%, dairy purposes 14%, and mastitis 9%. Voluntary disposals, as a percent of all removals, dropped from 71.9% for first lactations to 38.1% for those 6-7 years old.

Aulerich (1965) presents data from Michigan DHIA records showing that voluntary removals account for 72% of first lactation disposals and only 58% of later disposals. The data were not of a suitable nature for accurate calculation of percent of lactations terminated by removal but it was estimated that 16% of first lactations and 23% of later lactations were in this category. Dayton (1966) used Michigan records to determine that culling rates differed among sires. Production projected by normal factors and percents for each reason for disposal were reported. Cows removed voluntarily averaged 2,002 lb of milk less than non-disposals while those removed involuntarily averaged 656 lb less. Lactations were divided into three groups; first, second and third, fourth and later. Percents removed were 21.5, 25.6, and 32.3% with 68, 60, and 41% of these being voluntary, respectively. For all lactations combined 25.9% were removed with 58% of these voluntary. Within each age group the percent of all cows removed voluntarily remained fairly constant; 14.6, 15.4, and 13.2%; while the portion involuntarily removed increased from 6.9% to 10.2% to 19.1% in the oldest group. Carter's (1968) report on the analysis of 110,319 AI daughters showed that 20.6% failed to return for a second lactation.

Methods of Sire Selection

Milk production is a sex-limited trait and therefore we are limited in our estimation of a sire's breeding value for the trait. Daughter records have been used alone and in combination with production information from herdmates, dams, and other relatives.

Johansson (1960) relates that cooperative milk recording was begun in 1895 in Denmark. DHIA records provide production information indicating potential dams of sires. Information on close relatives of the dam may also be desired. Legates and Lush (1954) reported that progress in fat production may be increased by 10 to 15% by using information on close relatives combined with the cow's own performance in a selection index. Deaton and McGilliard (1965) found that the correlation of a daughter's first record was higher with the dam's index than with the dam's first record and that the index increased accuracy by nearly 19%. The index was viewed as being especially valuable to select the dams of future sires.

Henderson (1964) emphasized the need for accurate progeny testing even though a bull may be outstanding based on the information for other relatives. Since the upper limit of the correlation between the actual and estimated breeding value of a sire is $\sqrt{1/2}$ without progeny testing, and using 1000 lb as the standard deviation of breeding values for milk production, the standard deviation of error in predicting will be at best nearly 740 lb. This means that even with the most complete information for relatives other than offspring, we will be at least that much in error in one-third of our predictions. With an AI progeny test of 100 or more daughters we have a nearly perfect estimate of the value of that sire for the general situation in which it was tested.

The first progeny tests were made in 1902 (Johansson, 1960). Whether sires should be selected on their dams' records or performance of daughters depends on the size of the cow population available. Specht and McGilliard (1960) found that in herds with less than 100 cows more progress could be made by selecting young sires on the basis of their dams' production rather than attempting to progeny test. However, in herds of 100 or 200 cows the latter had the advantage. This generally limits effective progeny testing to AI populations.

The daughter performance has been used in a number of ways. The simplest is the daughter average. This is acceptable if daughters of the sires being sampled are under similar conditions but may lead to serious errors (McDaniel and Corley, 1967). The daughters' average ($\bar{O}$) may be compared to the dams' average ($\bar{D}$), the latter being a measure of the maternal genetic contribution and of herd environment. The Equal Parent Index (EPI) was developed independently by Hansson in Sweden in 1913 and Yapp in the United States in 1925 under the assumption that the daughters' performance is intermediate between the sire's and dams' hereditary levels (Johansson, 1960). This is computed as $2\bar{O}-\bar{D}$. The Regression Index considers breed average ($\bar{B}$) and is somewhat more useful than the EPI. Its formula is $\frac{EPI + \bar{B}}{2}$.

The comparison of daughters with herdmates was done as early as pre-World War I by a German extension specialist named Peters (Johansson, 1960). The USDA changed their method of summarizing sires from the daughter-dam comparison to the daughter-herdmate comparison in 1962 (Plowman and McDaniel, 1968). Robertson and Rendel (1954) concluded that the contemporary comparison is the best for dealing with milk yield and the simple average is best for fat content. The "contemporary comparison" often referred to and used is an application of the mean weighted difference (MWD) method of comparing two groups of cows, 1 and 2. The difference between the average yield of each of the two groups within herd-seasons is weighted by the inverse of the variance, $\frac{n_1 n_2}{n_1 + n_2}$. The MWD is the sum of the weighted differences divided by the sum of the weights when used for evaluation of sires; groups 1 and 2 refer to the daughters of the sire currently being studied and all other cows, respectively. Generally the term contemporary comparison implies that all cows are in their first lactation but may also be used among second, third, or some other lactation. The term contemporary, as used in this paper, follows the precedent of Legates (1966) who defines a contemporary as a herdmate (cow calving in the same herd-year-season) that is also in the same lactation.

Carter et al. (1956) studied daughters of 21 sires that had 50 or more AI tested daughters and had complete information on their NS daughters. It was found that the difference between daughters and their herdmates in the NS situation was no better or worse than the daughter-dam comparison for selecting sires to use in AI. Further, the NS daughter average has little, if any, value and the EPI is a little less dependable than the daughter-dam comparison. The opinion that much of the disappointment in the performance of AI daughters stems from inadequate accounting for environmental differences among herds from the natural proof was expressed by Gaunt and Legates (1958). It was suggested that the annual herd average be used to correct this situation. However, in a small scale application they found that the simple daughter average was about as reliable as the EPI or daughter-herd index for predicting the production of future AI daughters from present AI or NS daughters.

O'Bleness et al. (1960) compared seventeen ranking procedures with the New York method. The procedures were various forms of deviations of daughter records from herdmates, deviations from first records of herdmates, percent of daughters exceeding herdmates, percent of first records exceeding herdmates, actual averages, and actual averages adjusted for herdmates. Correlations were highest for the first method when all records were considered and when groups of 20, 50, and 100 first records were used. Van Vleck et al. (1961) used eighteen methods of sire evaluation to reach the conclusion that the use of means of individual daughter averages will provide nearly the same evaluation as the standard New York State procedure (which was the same as the 1962 USDA method) provided that each sire has at least 50 first record daughters. Relationships between sire proofs were investigated by Meek and Van Vleck (1964). The evaluation tools were daughter-dam and daughter-herdmate comparisons for both AI and NS daughters, USDA daughter-herdmate difference, and the Cornell daughter level. It was concluded that the NS daughter-dam comparison is of little value and that the NS herdmate comparison requires a much higher regression to correct for numbers.

USDA procedures for sire evaluation modify the daughter average by considering the performance and number of herdmates and regional and national breed averages. The herdmate average ($\overline{HM}$) is adjusted by considering the regional breed-year-season average ($\overline{BS}$) and the number of herdmates (N_h). The adjusted herdmate average ($A\overline{HM}$) is computed as; $A\overline{HM} = \overline{BS} + \frac{N_h}{N_h + 1} (\overline{HM} - \overline{BS})$. The daughter average is adjusted (regressed) in an attempt to remove environmental effects. The regression factor (b_1) of 0.9 has been used by USDA and the adjusted daughter average ($A\overline{O}$) is derived from $\overline{O} - b_1 (A\overline{HM} - \overline{B})$. The value of b_1, the regression of daughter production on herdmate production, was found to be only 0.6 for 7,850 first lactations studied by Henderson et al. (1954). Henderson and Carter (1957) reported it to be 0.911 with no significant breed differences. Pirchner and Lush (1959) found that 10 and 14% of the differences between herd averages were heritable for Holsteins and Jerseys, respectively. They expressed the opinion that AI will eventually erase all genetic differences between herds other than that due to their limited size. Johansson (1960) reported that the regression used in Sweden is 0.651 for Swedish Red and Whites and 0.620 for Swedish Friesians. In Great Britain, 0.80 was being used. Van Vleck (1963a) studied first lactation records for nearly 45,000 New York AI Holsteins and concluded that the regression of 0.88 is suitable except in extreme cases.

The difference between the adjusted daughter average and breed average is regressed according to the number of daughters, N_o. This regression of future daughters on those tested is represented by b_2. In Great Britain this factor is $\frac{0.25h^2 \Sigma w}{1 + (\Sigma w - 1)0.25h^2}$ where Σw = sum of the weights and h^2 = heritability (Johansson, 1960). If $h^2 = 0.25$, the regression equals $\frac{\Sigma w}{\Sigma w + 15}$. The correction for numbers used in Sweden is 1.00 when the number of daughters is 50 or more in many herds. USDA used a b_2 of $\frac{N_o}{N_o + 12}$ until 1965 when the denominator was changed to $N_o + 20$. The predicted difference (PD) equalled $b_2(A\bar{O} - \bar{B})$. McDaniel et al. (1966) used 12 cumulative sets of 10 daughters and correlated the herdmate difference between these and 120 later daughters. The correlation for milk was 0.52 for the first 10 progeny, 0.73 for the first 50, and 0.82 for the first 120 daughters. They reported that a regression of $\frac{N_o}{N_o + 20}$ was suitable to correct for number of daughters.

In 1967, b_2 became a formula known as repeatability which additionally considers the distribution of daughters over herds and residual environmental and other correlations (C^2). The repeatability figure is the square of what geneticists usually refer to as accuracy (Van Vleck, 1968). It has been observed by Bereskin and Lush (1965) that paternal sisters are more similar than warranted by the fact that they have the same sire. This extra correlation is designated C^2. This residual correlation may be due to correlated environmental effects, correlations among the mates of the sire or between the mates and the sire, or a combination of genetic and environmental effects. Van Vleck (1966) reported that environmental correlations among artificially sired half-sibs are small or nonexistent if the half-sibs are grouped by time intervals corresponding to an initial sire evaluation. The correlations between initial and later groups of 20 or 40 daughters were very close. Touchberry (1961) states that the main advantage of the daughter-herdmate comparison over the daughter-dam comparison, daughter average, or equal parent index is the removal of more of the environmental correlation among the daughters with the resulting index having a higher correlation with the sires' breeding values.

Henderson (1959) investigated expected genetic progress from progeny testing and found that the best ratio of selected to sampled sires is approximately a linear function of the square root of the total number of tested daughters. The genetic progress resulting from the use of the optimum ratio is approximately a linear function of the 0.2 power of the total number of tested daughters. The rate of genetic progress depends upon heritability and the number of sires selected. He further states in a later paper (1963) that this rate of improvement is dependent upon the merit of the sires sampled compared to the population, and upon the superiority of those selected for extensive service above the average of those sampled.

Sendelbach et al. (1957) report that the regressions of 10 cumulative sets of 5 AI daughters on the next 50 AI daughters indicated that 20 to 30 AI daughters are sufficient to estimate future performance. Similar analysis of the first 50 AI daughters and groups of NS daughters showed that the predictive ability from NS records is about one-half that of AI records. Fairchild et al. (1966) report little advantage in using more than 20 daughters to evaluate a sire. Touchberry (1966) related his views on the numbers we should be using in a sampling program. The daughter-herdmate test should use from 20 to 40 daughters per sire with each daughter of each sire being in a separate herd and having at least five herdmates. The test should include from 4 to 8 bulls for each sire to be added to the stud. Gaunt (1967) expressed his opinion that the production of a sire's daughters means very little unless we also know the opportunity they had to produce, the kinds of herds they are in, and so forth. It is suggested that many young sires be sampled with at least 5 for every one needed, and that production information on 50 daughters is highly reliable. Johansson (1960) relates that in Great Britain the sum of the weights should be at least 20 which corresponds to about 30 daughters. About 8 of 10 bulls entering the test are active upon completion and 4 of 5 are culled.

Van Vleck (1968) states that the records of a cow provide most of the information possible concerning her breeding value. Even with only one record on the individual the accuracy is 50% compared to 71% with 6 records and 200 paternal half sisters plus dam or a daughter. The accuracy of sire proofs is 50% with 5 daughters each in a different herd and jumps to 63, 76, 85, 88, and 93% with 10, 20, 40, 50, and 100 daughters in different herds (Van Vleck, 1968). Heidhues et al. (1960) compared the expected and actual accuracy of sire evaluation under the New York system. Single and successive groups of ten daughters of 100 daughters were used in predicting the performance of future daughters which was estimated from a separate 200 daughters. The expected and actual correlations were only slightly different for milk and equal for fat. There appeared to be little difference between first and later daughters for predicting future performance.

McDaniel and Corley (1967) used AI progeny of 40 Holstein sires having at least 1000 daughters to compare sire evaluation at four different herdmate levels. The daughter average rose with the herdmate level. However, the average predicted difference of all sires decreased 637 lb, from 227 to -410 as the herdmate level increased. The correlations among sire progeny averages at each of the levels were high (0.88 to 0.96) which indicated that the sires ranked in about the same order at all levels. A further conclusion was that use of the daughter average for selection of sires could lead to serious errors. Mason and Robertson (1956) studied 13,000 cows from Denmark that were divided into three groups based on herd levels within areas. Sires were evaluated using the inverse of the variance as the weighting factor. The results showed no evidence of herd-by-sire interaction, but it was suggested that progeny testing be done in high level herds because of the higher heritabilities found there.

SOURCE OF DATA

First lactation Michigan DHIA records, initiated in 1963 through 1966, were selected for 6,013 Holstein daughters of twelve sires from Michigan Animal Breeders Cooperative. These lactations were coded as first or unknown and initiated at 20 through 35 months of age. Information available included herd, identification of parents and cow, age at calving, month and year of calving, production, times milked per day, and the reason for any disposals. Cows were rejected if they were on three-time per day milking, coded as other than Holstein, or their dam was coded as other than either Holstein or unknown. These reasons accounted for the 31 records removed from 6,044 that met lactation and age requirements. Later lactations were studied only concerning frequency of disposals.

Table 2 includes the number of first lactation daughters in each of the 28 sire-years. Group I and II sires entered AI service in 1960 and group III sires entered in 1962. Figure 1 shows the distribution of daughters for age. Figure 2 gives the calving pattern but does not include 1966 freshenings.

Table 2. Distribution of daughters by group, sire, and year

Sire Group	Sire Code	1963	1964	1965	1966
I	1	72	307		
I	2	81	181		
I,II	3	429	376	181 [a]	
I,II	4	139	341	327	
I,II	5	71	127	163	
I,II	6	70	546	358	
II	7		157	128	
II	8		153	156	
III	9			104	201
III	10			88	140
III	11			181	303
III	12			292	341

[a] One daughter of the 181 is not included in any analysis pertaining to production as her removal was prior to the first test day.

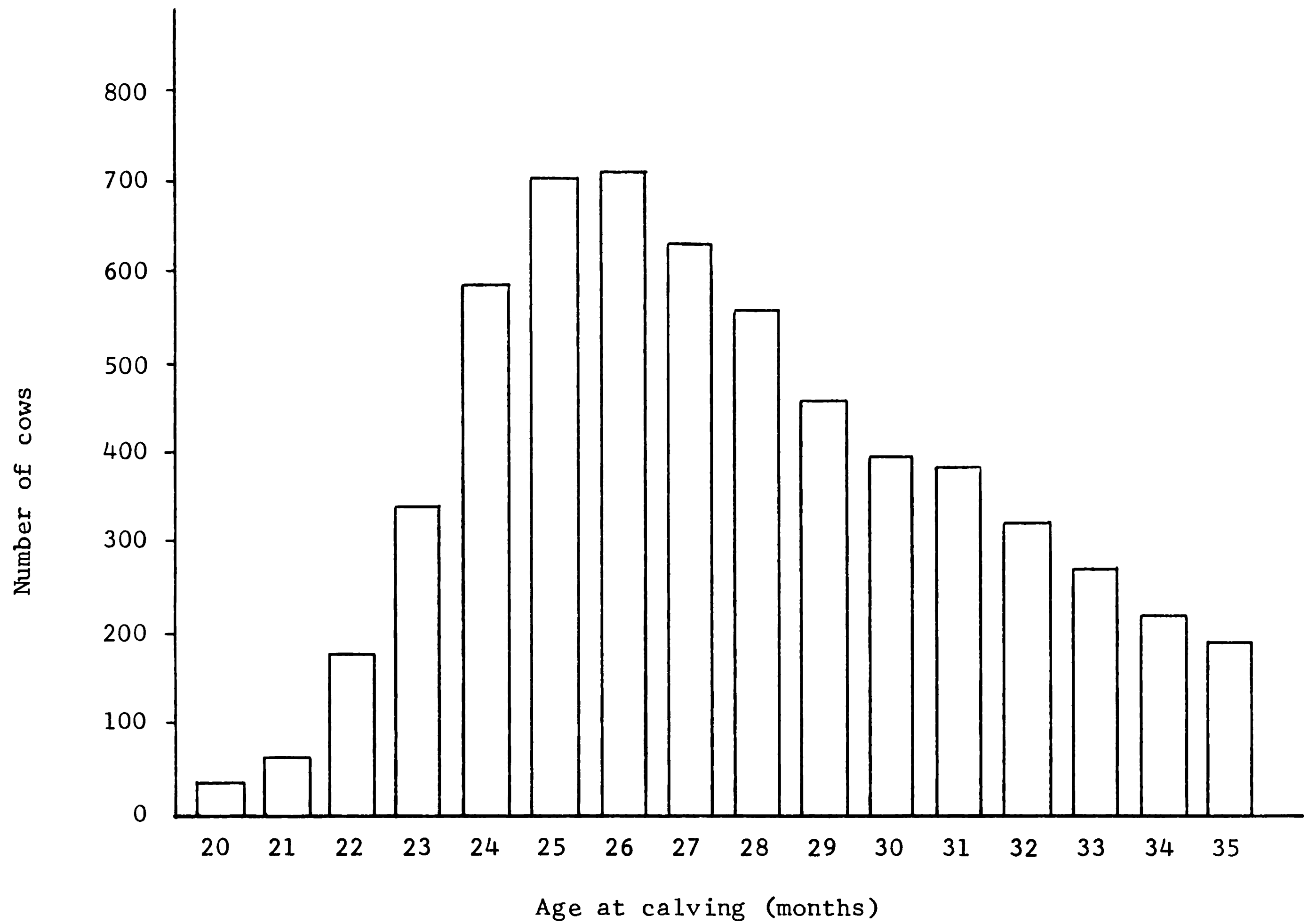

Figure 1. Distribution by age at calving

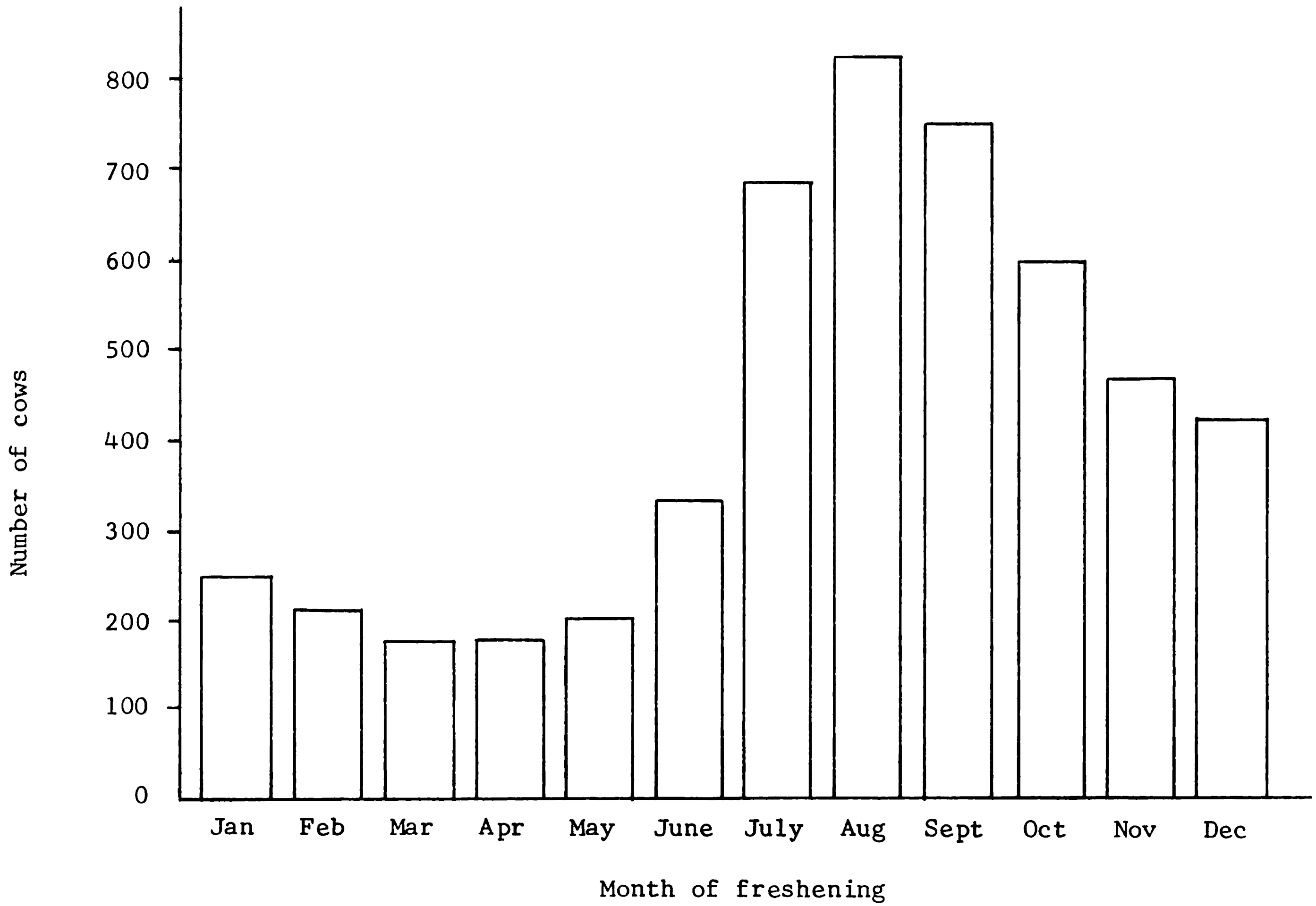

Figure 2. Distribution by month of freshening

METHODS

As shown in table 2, there were three groups of sires, I, II, and III, composed of four or six bulls. When groups are identified by years, the reference is to year of calving by the daughters. Each group was compared in two successive years to provide independent samples. Results of research previously cited and the fact that effective sire selection must occur early, led to the use of only first lactation records. Limiting contemporaries to only daughters of the other sires of interest is the most direct method of sire comparision. It eliminates herds that had daughters from only one of the sires within a lactation-year so the effects of preferential treatment and selective mating should be reduced. This method also practically eliminates the need for assuming that the sires of herdmates are representative of the population.

The mean weighted difference (MWD) within herd-years was computed for each sire as was the daughter average. The MWD for a sire (j) was computed as follows: $MWD_j = \frac{\Sigma(w_{ij}d_{ij})}{\Sigma w_{ij}}$ where $w_{ij} = \frac{n_{ij}n_{ik}}{n_{ij} + n_{ik}}$, and $d_{ij} = Y_{ij} - Y_{ik}$. n_{ij} is the number of daughters of sire j within the i^{th} herd-year and n_{ik} is the number of daughters of the other sires (k) with which sire j is being compared in that herd-year. Y_{ij} is the average yield of the daughters of sire j within the i^{th} herd-year and Y_{ik} is the average for daughters of the other sires in the i^{th} herd-year. Background information on this approach is on page 28.

Reference to final PD implies the use of the latest methods of calculation as discussed by Plowman and McDaniel (1968), while any groups of specific numbers of daughters means that the PD was computed as $PD = \frac{N_o}{N_o + 20} (\overline{AO} - \overline{B})$, (see pages 30 and 31 for further information). All references to daughter average, PD, and MWD are in pounds of milk.

Information on all non-terminal and some terminal lactations initiated in the last four months of 1966 was not available so some calculations on disposal rates do not include 1966.

The reasons for disposal classified as voluntary are dairy purposes, cull cow, temperament, hard milker, and old age. Cows sold because of physical injury, mastitis, brucellosis, sterility or hardware, and all deaths were placed in the involuntary category. Extension factors for each category were interpolated from test day data presented by Aulerich (1965). The appropriate set of factors was used except where it is specified that all were extended using involuntary factors. Both non-terminal and extended terminal records are used in all computations except as otherwise stated. Percents contained in tables are correct but in some cases rounding has caused a total to be different than the sum of its parts.

Age correction was accomplished using factors reported by either Kendrick (1955) or McDaniel et al. (1967). For brevity they are referred to as the old and new factors, respectively. The Kendrick factors are implied where neither is specified.

The eight group I and II sires were those having 70 or more first lactation daughters in successive years among the twelve bulls entering service in 1960. One sire of the five entering service in 1962 was disregarded due to small numbers of daughters. The average of the final PD's was -60 lb of milk. For these reasons, sires are assumed to be random and general results may be extended to all sires.

Final PD is a reasonable standard with which to compare other indexes since it is generally accepted and considers a large number of daughters. The large numbers would tend to reduce errors due to selection among daughters and herdmates and due to disregarding the sires of herdmates. It is assumed that the final PD is independent of the daughters in this study and represents the merit of all future daughters.

RESULTS AND DISCUSSION

The effects of manner of indexing, manner of extension, and age correction on sire ranking were analyzed. The manners of indexing were MWD and daughter average. Incomplete records were extended either using two sets of factors, depending on whether the reason for removal was voluntary or involuntary, or using only the factors for involuntary incomplete records. The three approaches to age correction were the old DHIA factors, new DHIA factors, and no correction. Observations in two years were included for each of the twelve sires. The following model was used.

$$\begin{aligned} I_{ijklm} = {} & \mu + M_i + E_j + (ME)_{ij} + A_k + (MA)_{ik} + (EA)_{jk} + (MEA)_{ijk} \\ & + S_l + Y/S_{(l)m} + (MS)_{il} + (ES)_{jl} + (MES)_{ijl} + (AS)_{kl} \\ & + (MAS)_{ikl} + (EAS)_{jkl} + (MEAS)_{ijkl} + (MY/S)_{i(l)m} \\ & + (EY/S)_{j(l)m} + (MEY/S)_{ij(l)m} + (AY/S)_{k(l)m} \\ & + (MAY/S)_{ik(l)m} + (EAY/S)_{jk(l)m} + (MEAY/S)_{ijk(l)m} \\ & + e_{(ijklm)} \end{aligned}$$

where I_{ijklm} is the index value resulting from the i^{th} manner of indexing, the j^{th} set of extension factors for voluntarily terminated lactations, and k^{th} approach to age correction for the l^{th} sire in the m^{th} year within that sire. M, E, A, S, and Y/S are deviations from μ due to manner of indexing, extension factors used, manner of age correction, sire, and year within sire, respectively. M, E, and A were assumed to be fixed while S and Y/S were assumed to be random.

The results of the analysis of variance are shown in table 3. The main effects are highly significant, as expected. The significance of the ME, MA, and MES interactions is difficult to explain. A portion of the magnitude of these mean squares may be due to using only a fraction of the records contributing to the daughter average in the calculation of MWD. These two groups may differ in rates or reasons for disposal and in age at calving and thus produce a larger mean square than if the same records had been used by both methods of comparison. The significant ES interaction indicates that the manner of extending voluntarily terminated records will affect sire evaluation. This is likely due to the among-sire variation in the percent of total records contributed by voluntarily terminated records which ranged from 6.8 to 24.4%. Because of the high negative relationship between percent of daughters voluntarily removed and the sire's merit, (discussed later with disposals), the use of both sets of extension factors will increase the apparent difference between sires but will have little effect on their ranking. Correlations between averages or MWD's with and without the factors for voluntary removals were above 0.99 in all years. The effect of method of extending voluntarily terminated records is different among sires and was detected by analysis of variance but could not be detected in the correlations.

The effects of years and interactions involving years were tested by assuming the effect of MEAY/S was zero and using 1,138 as the error mean square. The MWD comparison of a sire in one year did not have contemporaries from the same group of sires in the adjacent year.

Table 3. Analysis of variance of sire indexes

Source	df	SS	MS	F
M	1	11,978,372,607	11,978,372,607	45,526.3**
E	1	223,335	223,335	18.7**
ME	1	281,500	281,500	96.0**
A	2	137,007,495	68,503,748	772.9**
MA	2	132,163,269	66,081,634	18,104.6**
EA	2	6,767	3,383	2.6
MEA	2	1,038	519	0.5
S	11	157,540,048	14,321,823	14.7**
Y/S	12	11,684,750	973,729	855.6**
MS	11	2,894,195	263,109	1.0
ES	11	131,593	11,963	3.5*
MES	11	32,257	2,932	3.7*
AS	22	1,949,885	88,631	2.0
MAS	22	80,304	3,650	0.4
EAS	22	28,852	1,311	1.3
MEAS	22	21,869	994	0.9
MY/S	12	3,035,539	252,962	222.3**
EY/S	12	40,690	3,391	3.0**
MEY/S	12	9,607	801	0.7
AY/S	24	1,089,184	45,383	39.9**
MAY/S	24	197,458	8,227	7.2**
EAY/S	24	24,998	1,042	0.9
MEAY/S and error	24	27,306	1,138	

*Significant at 0.05 level
**Significant at 0.01 level

This, plus the expected variation in evaluation of different groups of daughters, is responsible for the significant effect of year within sire. The significance of MY/S, EY/S, AY/S, and EAY/S are attributed to differences in characteristics of the sires' daughters and their contemporaries from one time to another.

The most interesting result is the non-significant MS interaction. There is no evidence that sires will not rank in the same order by either MWD or daughter average.

Any inaccuracy in accounting for season of freshening or age at calving would be minimized if the average age and month of freshening were nearly the same for all sires. Tables 4 and 5 provide these averages. The overall standard deviations for these characteristics were 3.46 and 3.02, respectively. The standard errors would be in the vicinity of 0.3 or less. The sire means are obviously different for both characteristics except for month of calving in 1966 where our records are incomplete. Even though significantly different, they are not necessarily different from a practical standpoint in sire evaluation. For example, the age factor by sire interaction was not significant.

For the first year that a sire is included, the average age is less and the month of the year is later than for subsequent years. This is easily explained by the date of entry into service. For all sires the average time of entry was early September. A daughter from a September insemination could not be over 30 months of age in the third calendar year. If this daughter calved at 22 months, the month would be June. Therefore, the average month and age will be later and younger, respectively, than would be the case in subsequent years.

Table 4. Average age at calving

Sire	Year				
	1963	1964	1965	1966	Combined
1	24.2	29.2			28.3
2	25.2	29.3			28.0
3	27.5	28.5	30.0		28.3
4	25.8	28.4	27.9		27.7
5	26.8	27.5	27.5		27.4
6	25.3	27.1	29.0		27.7
7		27.5	29.2		28.3
8		27.0	28.7		27.9
9			24.6	28.1	26.9
10			25.1	28.5	27.2
11			24.5	27.2	26.2
12			26.2	28.0	27.1

Table 5. Average month of calving [a]

Sire	Year 1963	1964	1965	1966	Combined
1	10.4	6.1			6.9
2	9.6	6.9			7.7
3	8.0	7.3	5.9		7.3
4	9.2	7.9	7.5		8.0
5	8.7	8.0	7.6		8.0
6	9.4	7.7	6.4		7.4
7		8.2	6.8		7.6
8		7.7	6.7		7.2
9			9.4	5.0	6.5
10			9.6	5.9	7.3
11			9.4	5.7	7.1
12			8.9	5.5	7.1

[a]Calendar months coded as 1 through 12

Effectiveness of Age Correction Factors

Average production for each of sixteen ages at calving is shown in figure 3 for actual yield and ME yield determined using the old and new age correction factors. The curve for actual production does not appear as expected since there is not a significant increase among the means after 27 months. The regression coefficient is +2 lb in this region. The curves for ME production do not clearly show whether the corrections aided or not. Table 6 shows that the standard deviations (SD) differ for actual and age corrected records but the coefficients of variation (CV) are very similar. This observation is in agreement with that of Miller et al. (1968) who used first lactation Michigan Holstein records initiated in 1961-1963.

Table 6. Mean, standard deviation, and coefficient of variation of production records

Method	Mean	SD	CV
Actual	10,989	2,402	21.9
Old ME	13,951	3,025	21.7
New ME	13,678	2,994	21.9

Regression analysis of the means resulted in regressions of +108, +2, and +19 for actual, old, and new age adjustment factors, respectively. Although the slope was decreased by age adjustment and the old factors appeared to be better, none of the three were significantly different from zero and therefore not significantly different from each other. The average yield resulting from the six ways of handling records is presented in table 7. As expected, the use of voluntary

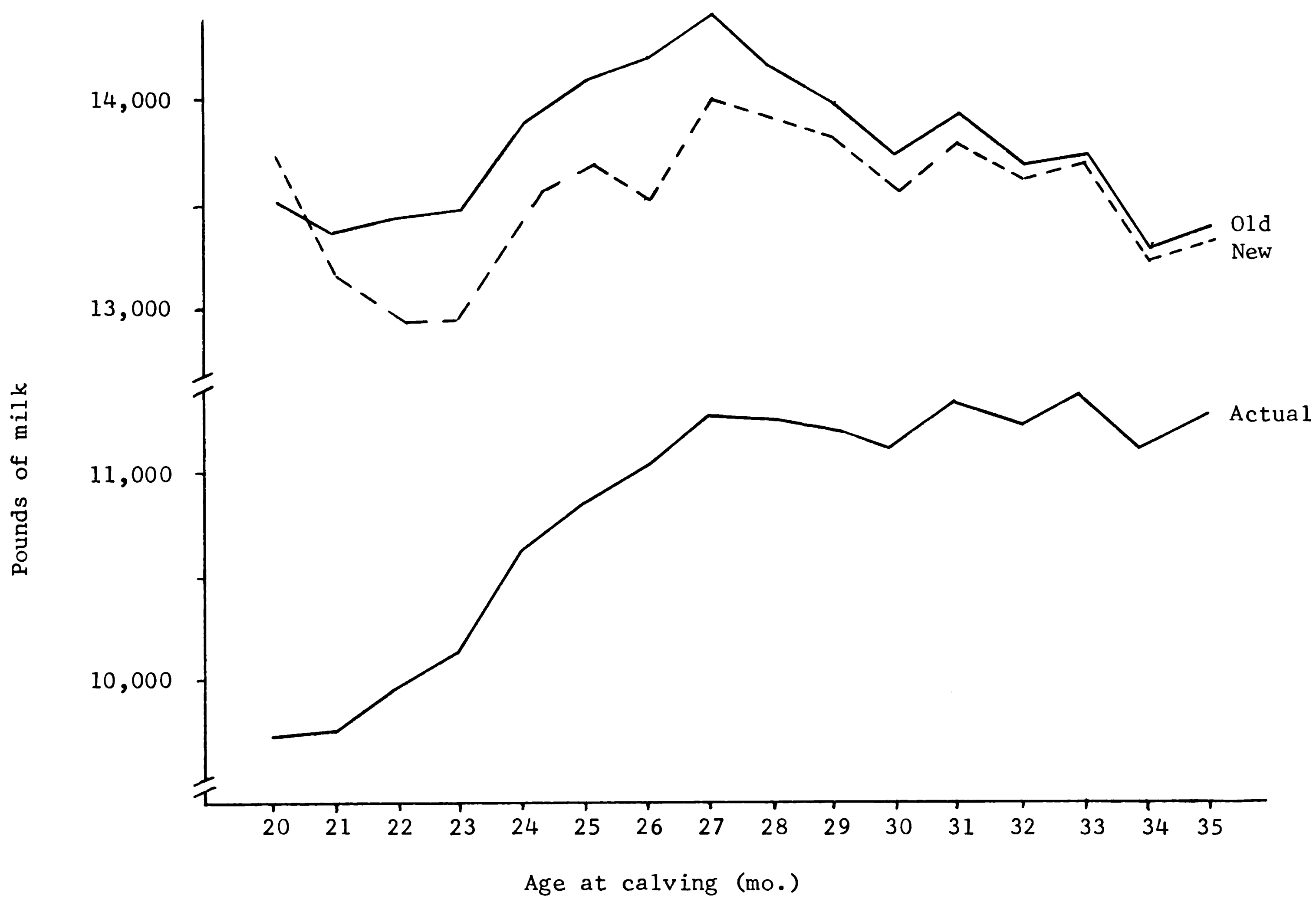

Figure 3. Average production at first calving and age corrected using old and new factors

Table 7. Average production from six methods of adjusting records

Extension factors used	Age adjustment		
	None	Old	New
Voluntary and involuntary	10,989	13,951	13,678
Involuntary only	11,090	14,080	13,804

extension factors decreased the average. Complete as well as incomplete lactations are included. The old age correction factors made the production appear two percent higher than the new factors.

The unexpected shape of the actual production curve may be due to relatively favorable season effects for calvings at ages of 25 through 29 months. This would be possible if many of these cows were born in the fall. No study was made of any relationship between age and season of calving.

Disposals

Tables 8 through 13 contain information on disposals. Disposals referred to as occurring in the third lactation include 14% from fourth and later lactations. All daughters are from the twelve sires. The only removal for old age occurs in the first lactation group and is obviously an error. During the period comprising the years of this study, the reason for selling termed "low production" was changed to "cull cow" as used in this paper. Most cows removed for the latter reason are probably the same cows that would be sold for low production so no distinction was made between the two reasons. However, the flexibility of the new terminology could include many more reasons.

Table 8 allows comparison of disposal reasons in various lactations as a percent of the lactations started. Most of them are quite similar across age groups. Upward trends appear for physical injury, mastitis, and sterility. Perhaps the most interesting relationship is between voluntary and involuntary percentages. The voluntary fraction is reasonably stable with small changes in the removal of cull cows while the involuntary percent rises steadily. From this table we would estimate that 48.5% do not start their fourth lactation, compared to 46.4% reported by Carter (1968). Table 9 shows the relative importance of the reasons for removal. The voluntary fraction decreases as involuntary removals gain in importance. Those removed as cull cows become less frequent while physical injury, mastitis, and sterility trend upward.

In this study 82% of first lactation removals were voluntary compared to 68% (Dayton, 1966), 72% (Aulerich, 1965), 72% (Van Vleck, 1962), and 74% (Specht and McGilliard, 1960). Voluntary removals in second and third (with some later) lactations contributed 77 and 69%, respectively. Specht and McGilliard (1960) presented 67 and 62% as the percents for these lactations. Aulerich (1965) reported 58% for second and later lactations and Dayton (1966) found 60% among second and third lactations and 41% for fourth and later lactations.

Within sire-years, the percent of daughters removed ranged from 8.5 to 30%. Table 10 gives results of combining information for all years of each sire. The range is from 10 to 25% removed. Voluntary removals make up 68 to 93% of the total disposals. These differences could result in exaggerating or masking differences between bulls especially if cows voluntarily removed are of inferior merit to those

Table 8. Percent of first, second, and third lactation cows removed

Reason	First	Second	Third
Sold			
Dairy purposes	1.5	1.4	1.6
Cull cow	12.4	13.6	12.5
Physical injury	0.9	1.2	2.1
Mastitis	0.3	1.1	1.2
Brucellosis	-[a]	0.0	-
Temperament	0.3	0.4	0.2
Hard milker	0.3	0.2	0.4
Sterility	1.5	2.0	3.3
Old age	0.0	-	-
Hardware	0.1	0.0	0.2
Died			
Acetonemia	-	0.0	-
Hardware	0.1	0.0	-
Bloat	0.2	0.0	0.4
Accident	0.2	0.0	-
Pneumonia	0.0	0.0	0.0
Other [b]	-	-	-
Voluntary	14.5	15.6	14.6
Involuntary	3.3	4.8	7.2
Total	17.8	20.4	21.9 [c]

[a] No observation

[b] Includes deaths specified as due to milk fever, old age, forage poisoning, leukemia, or calving trouble

[c] Apparent disagreement due to rounding

Table 9. Percent of removals assigned to various reasons in three lactation groups

Reason	First	Second	Third
Sold			
Dairy purposes	8.4	6.6	8.8
Cull cow	70.0	67.4	56.6
Physical injury	4.6	5.8	9.3
Mastitis	2.0	5.2	7.7
Brucellosis	- [a]	0.1	-
Temperament	2.4	2.4	1.6
Hard milker	1.5	0.8	1.6
Sterility	7.8	8.7	10.4
Old age	0.1	-	-
Hardware	1.0	1.1	1.1
Died			
Acetonemia	-	0.1	-
Hardware	0.4	0.5	-
Bloat	0.8	0.5	1.1
Accident	1.0	0.4	-
Pneumonia	0.1	0.1	0.5
Other [b]	-	-	-
Voluntary	82.4	77.3	68.7
Involuntary	17.6	22.7	31.3
Number removed	1161	743	182

[a] No observation

[b] Includes deaths specified as due to milk fever, old age, forage poisoning, leukemia, or calving trouble

Table 10. Removals of first lactation daughters for each sire

Sire	Percent removed [a]			Voluntary percent of removals
	Total	Voluntary	Involuntary	
1	10.3	6.8	3.0	69.2
2	21.0	17.9	3.0	85.4
3	17.2	12.8	4.5	74.1
4	12.9	10.0	2.9	77.9
5	13.9	10.2	3.6	74.0
6	25.4	22.5	2.9	88.7
7	14.4	9.8	4.6	68.3
8	23.0	19.4	3.6	84.5
9	11.5	9.6	1.9	79.7
10	14.8	13.6	1.1	88.7
11	22.7	19.3	3.3	92.9
12	17.5	14.4	3.1	84.3

[a] Values for the last four sires are for 1965 only

involuntarily removed and only one set of extension factors is used.

Tables 11 through 13 contain information on the disposals in each of three lactation groups. In first lactations the average ages at calving for those voluntarily removed and for its major components, dairy purposes and cull cow, were significantly less than the average age at calving of 27.7 months for non-terminal lactations. The number of days in milk for voluntary and involuntary removals exhibit no consistent trend. Dayton (1966) reported data that can be used to show that the average days in milk for voluntary and involuntary removals were 172 and 170. The expectation that cows culled because of sterility would have gone further into the lactation than other disposals appears to be correct in all three groups. Dayton (1966) found that Holsteins removed for sterility were significantly further into their lactations than cows removed for other reasons. The number of days was 232 as compared to 216, 217, and 222 for the three lactation groups in the present study.

The data on disposals from Asdell (1951), and Michigan DHIA Summaries are figured using cow-years rather than the total number of records initiated. This will overestimate the removal rate since a one cow herd where the cow is replaced each month would show a 1200% removal rate per cow-year. The percents from the present study are calculated by cows removed divided by total lactations considered. To further examine the situation, let X represent the removals for every 100 cow-years. One-hundred cow-years is equivalent to a herd that is constant at the 100 cow level for a year. The number of cows to initiate a lactation annually is 100 plus the X needed to replace the X removed. Therefore, X% is the apparent removal rate often

Table 11. Frequency, age at calving, age at removal, and days in milk of terminated first lactations

Reason	Number	Calving age	Removal age	Days in milk
Sold				
Dairy purposes	98	27.0*	30.8	116
Cull cow	813	27.0**	32.3	159
Physical injury	54	27.6	32.3	142
Mastitis	23	28.0	32.1	123
Brucellosis	0			
Temperament	28	27.8	33.4	168
Hard milker	17	28.3	31.3	90
Sterility	90	27.2	34.4	216
Old age	1	26.0	34.6	258
Hardware	11	29.7	35.5	173
Died				
Milk fever	0			
Acetonemia	0			
Hardware	5	28.0	33.6	167
Bloat	9	28.1	33.9	175
Accident	11	26.7	31.1	131
Old age	0			
Forage poisoning	0			
Pneumonia	1	29.0	29.5	14
Leukemia	0			
Calving trouble	0			
Voluntary	957	27.1**	32.2	154
Involuntary	204	27.6	33.4	175

*Significantly less than for non-terminal lactations at 0.05 level
**Significantly less than for non-terminal lactations at 0.01 level

Table 12. Frequency, age at calving, age at removal, and days in milk of terminated second lactations

Reason	Number	Calving age	Removal age	Days in milk
Sold				
Dairy purposes	49	39.6	43.9	127
Cull cow	501	40.0	45.9	177
Physical injury	43	39.7	44.2	137
Mastitis	39	39.7	44.8	153
Brucellosis	1	39.0	46.5	224
Temperament	18	40.6	45.9	161
Hard milker	6	40.8	45.8	149
Sterility	65	40.8	48.0	217
Old age	0			
Hardware	8	43.9	47.3	104
Died				
Milk fever	0			
Acetonemia	1	43.0	46.6	108
Hardware	4	40.2	41.8	48
Bloat	4	41.8	44.5	82
Accident	3	40.3	43.9	108
Old age	0			
Forage poisoning	0			
Pneumonia	1	39.0	41.7	80
Leukemia	0			
Calving trouble	0			
Voluntary	574	40.0	45.7	172
Involuntary	169	40.4	45.9	166

Table 13. Number and average days in milk for cows removed in their third lactation

Reason	Number	Days in milk
Sold		
Dairy purposes	16	102
Cull cow	103	171
Physical injury	17	113
Mastitis	14	103
Brucellosis	0	
Temperament	3	200
Hard milker	3	210
Sterility	19	222
Old age	0	
Hardware	2	50
Died		
Milk fever	0	
Acetonemia	0	
Hardware	0	
Bloat	2	122
Accident	2	74
Old age	0	
Forage poisoning	0	
Pneumonia	1	11
Leukemia	0	
Calving trouble	0	
Voluntary	125	164
Involuntary	57	142

reported but the percent removals of all cows starting lactations is $\frac{X}{100 + X}$. If the data from Michigan DHIA (table 1) is adjusted by this formula the percents removed for the three most recent years become 24.2, 24.4 and 24.5% which do not greatly differ from that of 25.9% for all lactations taken from Dayton's (1966) data or the 26.3% reported by Specht and McGilliard (1960). Still these values are generally greater than found in the present study although inclusion of later lactations would probably increase the percent removals, according to the trend shown in table 8 and that reported by Dayton (1966) and Specht and McGilliard (1960). The 17.8% culled during first lactation can be compared with 21.5% reported by Dayton (1966) and 20.6% found by Carter (1968).

Work by Aulerich (1965) indicated that records terminated involuntarily should be extended as though they were in progress but that voluntarily removed cows have a lower and steeper lactation curve. Although the lactation curve for involuntary removals parallels that for completed records, it is lower and we would expect their extended records to be less than for non-terminal records. If the voluntary removals' records were extended using the normal factors, they should still be below the other two types, even though overestimated. Dayton's (1966) figures show that involuntary removals averaged 656 lb of milk below non-disposals and voluntary removals averaged 2002 lb less. Both groups were extended as though they were involuntary disposals. When all disposals were pooled they averaged 1376 lb less than the average of completed lactations and 1251 lb less if only first lactations are considered. Analysis of the ME records in this study show that the average for complete lactations is 14,591 lb.

The average for the involuntarily terminated records is 13,153 lb or 1,438 lb less than complete records. Voluntarily terminated records were 2,900 lb less than non-disposals and averaged 11,691 lb when extended using the involuntary factors. If they were projected using the factors for voluntary removals they would drop to an average of 10,881 lb. Therefore, the effect of using special factors to extend voluntarily terminated records was to reduce them by 810 lb from that calculated using the factors for normal lactations.

High correlations exist between final PD and removals. The correlation between final PD for the twelve sires and the corresponding percent of records incomplete was -0.90. Rausch et al. (1968) found this relationship for 271 Holstein sires to be only -0.46. Carter (1968), using data from 227 Holstein sires, reported a correlation of 0.41 between production and percent of daughters having a second record. The correlations between final PD and percent removed, percent voluntarily removed, and voluntary percent of removals were -0.89, -0.92, and -0.91, respectively, for this study.

Relationship between MWD, PD, and Daughter Average

The high relationship among the measures of merit in table 14 indicate that they will generally rank sires in the same order when large numbers of daughters are used. Correlations of MWD are lower than for daughter average. This may be due to reduced numbers of daughters and/or to some sires occurring together in herds more than warranted by chance. The latter was suspected but not investigated. The average numbers of daughters per sire in the MWD, daughter average, and PD were 157, 215, and 701, respectively. The average number of

Table 14. Correlations among estimators of sire merit

Year	Method	Final PD	Final Ave	MWD
1963	MWD	0.96	0.94	
	Ave	0.97	0.94	0.98
1964	MWD	0.94	0.87	
	Ave	0.98	0.96	0.96
1965	MWD	0.96	0.90	
	Ave	0.94	0.91	0.97
1966	MWD	0.93	0.83	
	Ave	0.98	0.90	0.98

contemporaries for MWD per sire-year was 346 or 2.2 per daughter. This is substantially less than the average of 15-20 herdmates common in USDA calculation of predicted difference. Are 2 enough or do we need 6, 10, or 20? Legates (1966) indicates that it may not be profitable to worry about the number of contemporaries after four or five. The practice of restricting the lactation and sire of the contemporaries may make each herdmate equivalent to more than one regular herdmate.

The standard deviation of a mean weighted difference was calculated according to the formula presented by Tucker et al. (1960). The standard deviation was significantly related to the sum of the weights and, therefore, varied as the number of sires varied and as the number of daughters changed. In 1964, the average of the eight standard deviations was 240 with a range of 190 to 309.

Usefulness of Measures on Limited Numbers of Daughters

Nine samples consisting of 50 daughters from each sire in each group-year were analyzed. The resulting MWD and average yield were compared to the MWD for all daughters in the adjacent year. The average correlations for MWD and daughter average were 0.52 and 0.72, respectively. Six samples of 100 daughters per sire were similarly compared with resulting average correlations of 0.70 and 0.88.

The apparent advantage of the daughter average may be explained by examining table 15. The restricting of daughters to those with contemporaries among the 50 or 100 daughters of the other sires in a group-year substantially decreased the number of daughters involved in MWD comparison. The daughter average may be placed in a more nearly proper perspective by comparing the apparent accuracy of the average of 50 daughters with the MWD resulting from 100 daughters. For the six group-year classifications the usable daughters were 52-75% of all daughters.

Table 15. Number of daughters and their contemporaries in herds where comparisons exist

Daus. per sire	Number of sires	Ave. daus. usable	Percent usable	Ave. number of contemporaries
50	4	15.8	31.6	19.4
50	6	17.4	34.8	23.8
100 [a]	4	46.0	46.7	62.1
100 [a]	6	44.4	46.4	65.6

[a] Some sires had less than 100 daughters in some years

Correlations of final PD with MWD and daughter average from 50 and 100 daughters were higher than those previously mentioned. All of these correlations are presented in table 16.

Table 16. Correlations between sire indexes calculated from different samples of daughters

Index	Number of daughters	MWD	Final PD
MWD	50	0.52	0.54
Average	50	0.72	0.72
MWD	100	0.70	0.79
Average	100	0.88	0.93

The MWD method of handling 50 daughters does not appear satisfactory because of the limited number that are in herds where comparisons are available. However, if the distribution of daughters were controlled, the same accuracy could be obtained from 17 or fewer daughters per sire, which was the number actually used. The same argument may be extended to the MWD for 100 daughters where about 45 were used. The correlations with final PD are not as high as for the PD or its accompanying daughter average from about 50 to 100 daughters. This difference in accuracy is due to using different daughters in the different methods. Meaningful comparisons among methods depend upon all methods having access to the same records.

The MWD was not superior to daughter average in either size of sample. Generally, this may be attributed to the decreased number of daughters and contemporaries due to the restrictive definition of both.

Although the MWD with 100 daughters is more highly correlated with final PD than is the average of 50 daughters, this is due to group III sires in 1965 where the latter correlation was negative. The average was superior in four of the other five group-years and similar in the fifth. Therefore, neither method can be termed superior when the number of daughters involved in the computations is similar.

Even though the sires of contemporaries are restricted, we have no assurance that some sires do not have daughters in the same herds more often than warranted by chance and thus confuse our evaluation. For example, consider four sires, A, B, C, and D, whose true merits are 10, 9, 5, and 1 on some scale. If the better two and the poorer two are paired together more than justified by chance, it is possible that C will appear to not only be better than he is, but the best of the group. In 1966 there were twelve herds having daughters of all four sires. An evaluation based on this information would be relatively free of the previously described error. The average number of daughters per sire was 22.5. The correlation between the resulting MWD and the final PD was 0.77. The daughter average had a correlation of 0.80 with final PD. Restricting the latter information to only the first daughter of each sire in each herd reduced the correlation to 0.40 as the average number of records was halved. Although the first two measures appear quite effective, there is still the problem of unequal numbers of daughters in each herd. A herd with exceptionally high production may have half a dozen daughters of one sire, one from each of two other sires, and a cull daughter of the fourth sire. The first sire is given relatively too much credit. In small samples this may need special attention. In an attempt to partially circumvent this

problem, the sire-herd averages were averaged across herds. Each herd was then treated as though it had four cows, each by a different sire. The correlation between these sire averages and their final PD's was 0.89.

All sires were not represented in enough herds in other group-years to repeat this analysis. However, there were twenty-seven herds in 1965 that had daughters of three of the four sires. The average number of daughters was 37.5. The average number of contemporaries per daughter was 2.0. The correlations between final PD and each of the methods mentioned in the previous paragraph are shown for both years in table 17.

Table 17. Correlations between final PD and four methods of evaluation using daughters in selected herds

Method	1964	1965	1966	Average
MWD	0.85	0.61	0.77	0.74
Daughter average	0.74	0.76	0.80	0.77
Mean of first daughters	0.80	0.62	0.40	0.61
Mean of sire-herd averages	0.83	0.73	0.89	0.81

Although the results in 1965 are not as impressive as for 1966, they are considerably higher than the correlation between PD based on approximately 50 or 100 daughters and final PD. The latter correlations were only 0.30 and 0.24, respectively, and are generally derived from records initiated in 1965. This indicates that the early information on these four sires was not representative of all daughters to be sired by them. However, the use of fewer daughters and herdmates

in the selected herds led to a more accurate estimate of the sires' relative merits. The average of only the first record for each sire in each herd included approximately one-half of the records used by the other three methods.

There were eight herds that had daughters of five or all of the six group I sires freshen for the first time in 1964. The average numbers of daughters per sire and contemporaries per daughter were 11.3 and 4.3, respectively. The correlations between each of the four methods and final PD are presented in table 17. All four correlations are substantially higher than we would expect using $\sqrt{N_o/(N_o+20)}$ as our expected accuracy. These results are especially promising in view of the low number of daughters and herds used. We might speculate that part of the success is due to doubling the number of contemporaries by comparing six sires rather than four.

There is fairly good evidence that attempts at ranking group III sires in 1965 will be less successful than would be expected. If we discount the results from that sample, it appears that an accuracy of about 0.82 could be expected from 20 daughters per sire in 10 herds. This accuracy corresponds to 40 daughters in conventional sire proving. A conservative estimate is that 30 daughters in selected herds would be at least as accurate as 50 daughters as commonly used. For the three samples, the mean of sire-herd averages appears to be the best of the four methods but daughter average and MWD are fairly close behind. These results indicate that the use of a few daughters in herds using all or nearly all of the sires being studied is effective and efficient.

CONCLUSIONS

The analysis of variance yielded a non-significant age correction by sire interaction indicating that no effect of age factors could be detected among sires. The three approaches to age correction were the old and new DHIA factors and no adjustment. Therefore, actual records may rank sires in the same order as age corrected records. For fewer daughters per sire than in this study, the average age for daughters of each sire would probably be less similar and age correction would be more necessary. The most frequent ages at first calving were 25 and 26 months with an average of 27.6. These are probably less than for all two-year olds because 25% of the records are from the first year that the sire was represented. The regression of yield on age at calving was not significantly different from zero for actual or age corrected records.

Analysis of variance showed a significant extension method by sire interaction since the effect of extending the voluntarily terminated records was different among sires. However, correlations between estimates of sire merit with and without the special factors for voluntarily incomplete lactations were essentially perfect, indicating no change in the apparent relative values of the sires. The ranking of sires would be affected more as the negative correlation between percent of voluntary removals and sire merit goes toward zero. In this study the relationship was -0.92 but it is felt that other groups of sires might have a correlation closer to -0.41 or -0.46 as found by Carter (1968) and Rausch et al. (1968), respectively, between percent of daughters removed and sire merit. Therefore, two sets of extension factors, depending on reason for removal, are recommended. The average effect of using the voluntary factors was a decrease of 810 lb in the estimate of 305-day ME milk production. Such a difference would have a large impact when a small number of records is used as in an index for cows.

At the outset it was decided that the better method of ranking, MWD or daughter average, would have the higher correlation between rankings in successive years and the higher correlation with the evaluation from the use of all daughters (final PD or corresponding daughter average). In all four years, the correlations with either measure using all daughters were as high and generally higher for daughter average than for MWD. Correlations between results in adjacent years for the three sire groups were 0.91, 0.85, and 0.78 for MWD and 0.96, 0.97, and 0.99 for daughter average. Thus, there appears to be no increase in efficiency inherent in the contemporary comparison that can compensate for the reduction in the number of daughter records used. In the portion of the study concerned with the usefulness of information on a limited number of daughters, both methods appeared to be quite similar in their accuracy when comparable numbers of daughters were used in the respective calculations. There also was little difference between the two methods in the selected herds. There was no significant interaction of method by sire. The correlations between MWD and daughter average were 0.98, 0.96, 0.97, and 0.98, respectively, for the four years. The daughter average was much less affected by whatever conditions caused problems in ranking the group III sires in 1965. Here the correlation between MWD and final PD was only 0.83 while for daughter average and final PD it was 0.96. The former correlation increased to 0.93 when the daughters of group II sires were included as contemporaries, thus allowing 83% of the group III daughters to be included in calculations of MWD. Therefore, the MWD, at least in the restricted sense in which it was used, is at best only as accurate as the daughter average, whether the number of daughters per sire is large or small. On the other hand, the daughter average is a reasonable method of sire evaluation when sires are used in similar herds. Apparently the sires were used with similar frequency at all herd levels.

Sire evaluation in selected herds appears to make the most efficient use of a given number of daughters. If a conventional daughter-herdmate comparison is to be made on 50 daughters it will require about 1000 inseminations. This assumes 70% conception rate, 48% female offspring, 70% of daughters come into milk, and 23% of them are tested. This results in 50.6 daughters. If only tested herds were used the required number of inseminations drops to 215. From the data presented concerning selected herds it appears quite possible that 30 or fewer of these daughters may provide results as accurate as those from the conventional 50. If this is correct then only 128 inseminations would be necessary. Analysis by comparing means of sire-herd averages could readily be accomplished locally and time saved. If the AI unit waits for the records to be forwarded from a DHIA center to USDA for processing to decide on sires to save, the delay could be about six months. It seems reasonable that the time saved here, plus that by needing fewer services in the selected or cooperator herds, could easily amount to a year and thus substantially increase the rate of genetic progress.

Sires selected by evaluation in selected herds should be appropriate for use in all types of herds. Carter (1961) reported that sires can be reasonably compared in selected herds. Herd by sire interaction has been found to be non-existent or unimportant (Burdick and McGilliard, 1963; Gaunt, 1958; Harville and Henderson, 1967; Legates et al., 1956; Mason and Robertson, 1956; McDaniel and Corley, 1967; Van Vleck, 1963b; Wadell and McGilliard, 1959). We expect that sires will rank the same in all types of herds and therefore would expect no adverse effects from selection based on performance in selected herds.

Further research appears warranted on the benefits of young sire evaluation in selected herds. The characteristics of lactation curves for each reason for removal is another fertile area as there is likely to be a more appropriate breakdown of terminal incomplete lactations than voluntary and involuntary.

SUMMARY

First lactations of 6,013 daughters of 12 Holstein AI sires were used to compare methods of sire evaluation and their value in young sire selection. Characteristics of first lactations regarding culling, age correction, and extension of incomplete records were also studied.

The sires ranked nearly the same by daughter average, mean weighted difference (MWD), and USDA predicted difference when large numbers of daughters were used. Analysis of variance indicated that there was not a significant difference in ranking by MWD or daughter average. Throughout the study, the only herdmates considered were the first lactation daughters of the other sires being evaluated. This reduced the number of usable daughters for MWD to 52-75% of those used in the daughter average and may be responsible for the slight superiority of the latter method when all daughters calving within a year were used. The use of records on 50 or 100 daughters showed that the MWD was not as reliable as the daughter average due to the severe reduction in the number of usable daughters. The results for the two methods were similar when the numbers of daughters involved in the calculations were similar. The sires were evaluated in herds that used all or most of a contemporary group of sires in a year by MWD, daughter average, average of first daughter in each herd, and mean of sire-herd averages. The results of three samples using 8 to 27 herds and 11 to 38 daughters

per sire strongly indicated that sampling sires in these selected herds was more efficient than conventional methods of sampling.

The sire by method of age correction interaction was not significant. Thus, it appears that sire evaluation based on many first lactation records will be little or no different whether the age factors are old or new DHIA, or none. The regressions of yield on age at calving were not significantly different from zero for actual records or those corrected by either method. The average age at calving for complete first lactations was 27.7 months which was significantly higher than for voluntarily terminated lactations.

The interaction of sire and method of extending voluntarily terminated records was significant, indicating that these records need to be extended by separate factors if the shape of their lactation curve is unique. Voluntary extension factors reduced the projected milk yield to 810 lb below that for normal factors. The percent of removals that were voluntary ranged from 68 to 93% for the twelve sires. Within sire-years, the percent of first lactation daughters removed ranged from 8.5 to 30.0%. Second and third lactations were studied only regarding disposals. Percents of first, second, and third lactations terminated prior to going dry were 17.8, 20.4, and 21.9%, respectively. For these lactations the portion voluntarily removed was fairly constant at 15% while the involuntary portion increased from 3.3 to 7.2%.

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