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The influence of sires used in artificial insemination on dairy cattle production traits in upper East Tennessee dairy herds

John B. Brower

To the Graduate Council:

I am submitting herewith a thesis written by John B. Brower entitled "The influence of sires used in artificial insemination on dairy cattle production traits in upper East Tennessee dairy herds." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

Don O. Richardson, Major Professor

We have read this thesis and recommend its acceptance:

J.T. Miles, E.W. Swanson, Joe A. Martin

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

March 9, 1964

To the Graduate Council:

I am submitting herewith a thesis written by John B. Brower, Jr. entitled "The Influence of Sires Used in Artificial Insemination on Dairy Cattle Production Traits in Upper East Tennessee Dairy Herds." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Dairying.

Don O. Richardson
Major Professor

We have read this thesis
and recommend its acceptance:

Eric W. Swanson

J. T. Miles

Joe A. Martin

Accepted for the Council:

Hilton A. Smith
Dean of the Graduate School

THE INFLUENCE OF SIRES USED IN ARTIFICIAL INSEMINATION ON DAIRY CATTLE PRODUCTION TRAITS IN UPPER EAST TENNESSEE DAIRY HERDS

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

John B. Brower, Jr.

March 1964

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CHAPTER I

INTRODUCTION

The genetic improvement of production traits in the dairy herds necessitates the use of breeding animals that are genetically superior to the average of the population. Since approximately 60 per cent of the dairy heifers born are required for normal herd replacements, genetic improvement is largely produced by the extensive use of outstanding dairy sires through artificial insemination programs.

Artificial insemination (A.I.) provides an opportunity for the selection and extensive use of dairy sires that have demonstrated their genetic superiority. The extensive use possible via artificial insemination is illustrated by the following figures: In 1962 (13) the average number of first services was 3155 per sire in A.I. The average number of first services varied from 1322 to 4629 per sire for organizations inseminating less than 100,000 cows and over 200,000 cows, respectively. The East Tennessee Artificial Breeding Association reported 25,164 first services to dairy sires with an average of 922 per dairy sire for 1963.

The acceptance of artificial insemination of dairy cows has increased in the East Tennessee area in recent years. In 1963, it was estimated that over 20 per cent of the dairy cow population was inseminated artificially. A majority of these inseminations were to dairy sires in service in the East Tennessee Artificial Breeding Association. Since the East Tennessee Artificial Breeding Association was organized in November, 1947, there have been 332,614 inseminations to dairy sires.

The best available estimates indicate that this represents over 90 per cent of the inseminations by commercial concerns in this area.

It is evident that East Tennessee Artificial Breeding Association has had major responsibility for genetic improvement in dairy cattle production traits in this area. As the acceptance of A.I. continues to increase, sire selection committees will have more responsibility for the genetic improvement in dairy cattle production traits in the East Tennessee area.

Therefore, it is important to determine the genetic improvement which has resulted from the use of A.I. in the upper East Tennessee area. Some preliminary studies in a few herds have shown the A.I. progeny to be superior to their dams and the DHIA herd average. Since these studies were limited to a few herds, and involved small numbers, their conclusions are inconclusive. The results could have been influenced by uncontrolled environmental conditions. Some environmental biases which could have been introduced are: the selection of herds studied, the change in the feeding and management practices, or differences in the season of freshening.

This study was conducted to evaluate critically the influence on dairy cattle production traits that has resulted from the use of artificial insemination in the East Tennessee area.

CHAPTER II

REVIEW OF LITERATURE

The most serious limitation in sire evaluation, or evaluation of artificial insemination, is the lack of an adequate number of herds on production test. Only about 12 per cent of the national dairy cow population is on DHIA production testing and in Tennessee only approximately 5 per cent are tested. The inadequacy of production records becomes more striking when we realize that approximately half of the upper East Tennessee dairy herds on DHIA tests, do not keep complete identification records.

In a study of genetic influences it is necessary to control as much of the environmentally induced variation as possible, in order to obtain unbiased estimates of differences. Many of these possible biases have been thoroughly studied in sire evaluation techniques; therefore, this review of literature will be concerned mainly with methods of sire evaluation, factors effecting the validity of sire proofs, the contemporary method of evaluating A.I. results, and the estimates of genetic progress expected.

Some Methods of Sire Evaluation

Many methods of obtaining more accurate sire proofs have been suggested. These include standardizing environment, increasing the number of daughters, and using the herd average to correct for herd-to-herd environment differences. Guant and Legates (7) compared five measures of a dairy sire's transmitting ability. Their results showed no measure was superior when based on the fraction of the total variance which was represented by the sire component of variance. The five measures compared were: daughter-dam comparison, daughter average, equal parent index, daughter-contemporary-herd index, and daughter-contemporary-herd difference.

These authors suggested that the use of the contemporary herd average, in the daughter-contemporary-herd index and the daughter-contemporary-herd difference, should improve their merit as a measure of a dairy sire's breeding value when compared to the other methods used in this study. These conclusions and suggestions are in agreement with the results reported by Henderson and Carter (12), who found that the linear regression of the daughter record on the contemporary herd average accounted for 30 per cent of the variation among daughters of the same sire freshening during the same year season.

The contemporary method of sire evaluation provides for a more complete use of available records. In the daughter-dam or equal parent index many comparisons are lost due to dams not being tested or records not being reported.

The contemporary method was compared to the special testing stations used in Denmark by Mason (19). The special testing station results for 62 sires were compared to results on a contemporary basis in herds with high levels of production, since the feeding standards in the special testing stations were considered to be above the level of commercial herds. This study showed the range between the best and poorest sires in the contemporary comparisons was 356 gallons of milk as compared to 478 gallons of milk at the special testing stations.

Also, the merit rating of the 12 best and 12 poorest sires as rated at the special testing station did not agree with the merit rating, for the same sires, in the contemporary comparison. The range between the 12 best and 12 poorest sires was 273 gallons of milk in the testing station's comparison, but the range was only 56 gallons of milk in the contemporary comparison.

When the herds were divided into high, medium, and low herds, and 120 sires were tested in each group, the order of merit ratings of these sires was roughly, but not exactly, the same in each production level. The conclusions were that there was no real difference in the order of merit ratings for the three levels of management. Thus, given a sufficient number of daughters, sires would be ranked in the same order when tested in the high or low level herds. In this study the top 20 per cent of the sires as ranked in the high-level herds increased production 35 gallons of milk in the medium and low-level herds; whereas, the top 20 per cent of the sires as rated at the special testing station, increased milk production by only 25 gallons in the medium and low-level herds. These findings were in agreement with those reported by Robertson and Mason (25), and later studies of Mason and Robertson (20) which represented 152 sires with 13,000 progeny in 1500 herds. A later study by Touchberry et al. (30) showed the estimated genetic correlations between Danish special testing station evaluations and field tests were 0.68 for milk and 0.75 for butterfat; whereas, the genetic correlations between successive independent field tests were 0.94 and 0.92 for milk and butterfat, respectively. They concluded that there was either a large interaction between sires and level of management or that the between-sire components from special testing station data were inflated with environmental differences. The latter appears to be the more logical explanation since all available data indicate the interactions between sires and herd are usually very small.

These conclusions are in agreement with the results reported by Legates et al. (16), who found no significant herd by sire interaction in a study of 24,754 records of daughters of sires used by artificial breeding associations. It was apparent that specific sire by herd differences were not of major importance in this study. Therefore, the ranking of a group of sires based on the performance of their daughters in a given group of herds would be approximately the same when these sires are compared on the basis of daughter performance in other herds.

Factors Effecting the Validity of Sire Proofs

The influence of season of freshening has been studied by many investigators (3, 4, 6, 9, 14, 29). These studies have generally agreed that fall and winter freshening cows out-produce spring and summer freshening cows. Cannon (3) used 68,000 yearly records to study the effect of season of freshening on milk production in Iowa. He found that the group of cows freshening each month from November through June produced less milk than the group of cows freshening the preceding month. While those freshening from June through October tended to increase in milk production over those freshening the previous month. Tucker et al. (31) found in a North Carolina study that a six-month interval of December through May and June through November appeared to remove most of the seasonal differences.

Corley et al. (4) reported that milk production in Wisconsin was highest for cows freshening in the period of September through February, and lowest for the period of March through August. These results are in agreement with the New York study by Hickman and Henderson (14), and the Connecticut study by Frick et al. (6). Hammond (9) reported very similar results using mostly Shorthorn cattle in England.

The study by Hickman and Henderson (14) showed that the largest single source of variation in butterfat production of artificially sired cows in New York could be attributed to herds, which was approximately one-half of the total variation. This study covered a period of eight years and included 3912 cows by 126 different sires located in 1094 herds. Since the major variation seemed to be attributed to herds, Henderson et al. (11) attempted to correct progeny tests for these differences by adjusting daughter records in accordance with the intra-sire regression of daughter on contemporary herd average (excluding the daughter in question). The estimate of the regression was approximately 0.6. This regression has been re-estimated by Henderson and Carter (12), using mostly new data representing records of 10,292 daughters of 595 A.I. sires. The new estimate of the regression was found to be 0.911 with a 95 per cent confidence limit of between .883 and .939. They did not find any significant differences among regressions for the various years and seasons. However, they did find the linear regression of the daughter record on the contemporary herd average accounted for 30 per cent of the variation among daughters of the same sire freshening during the same year and season. They concluded from these findings that the accuracy of progeny tests could be improved by expressing each record as a deviation from the average of all other cows freshening in the same herd-year season.

Selection of dams could bias the evaluation of sires used in A.I. A comparison of the production of dams of A.I. progeny with dams of non-A.I. progeny was made by Tucker et al. (31). A weighted difference (non-significant) of 149 pounds of milk and 11.7 pounds of butterfat was shown in favor of the non-A.I. dams. These results are in agreement with those reported by Beal and Madden (2).

<u>Contemporary Method of Evaluating A.I. Results</u>

Robertson and Rendel (24) analyzed the lactation records of 1423 artificially sired daughters to determine the genetic effect of the A.I. program in England. The contemporary method was used to compare the A.I. progeny with the non-A.I. contemporary herd-mates. Their results showed no significant difference between the two groups. The Friesian breed showed an increase of 26 gallons of milk in favor of the A.I. progeny, but the Shorthorn and Guernsey breeds showed a decrease of 5 and 14 gallons of milk, respectively.

Similar results were reported by Waddell and McGilliard (34). All available DHIA-IBM first lactation records from Michigan herds were used in their comparison of A.I. progeny with the non-A.I. contemporary herd-mates. Comparisons were made within herd-year-seasons to measure the genetic progress in production realized from the use of A.I. The

Holstein A.I. progeny produced 124 pounds of milk and 3.7 pounds of butterfat more than their non-A.I. contemporary herd-mates. The Guernsey A.I. progeny produced 6 pounds less milk and 3.9 pounds more butterfat, and the Jersey A.I. progeny produced 16 pounds more milk and 2.7 pounds less butterfat than their non-A.I. contemporary herd-mates.

They found the differences, A.I. progeny minus non-A.I. progeny, tended to increase slightly as the herd average of the contemporary cows increased, except for the Jersey breed, where the tendency was to decrease slightly; but these differences were not significant.

Thompson et al. (29) compared A.I. progeny with non-A.I. herd-mates using all available Virginia lactation records made in the same year-season of freshening. Weighted summaries of differences for milk and butterfat production were made for all herds. They showed the Guernsey A.I. progeny produced 12 pounds more milk and 1 pound less butterfat than their non-A.I. contemporary herd-mates. The A.I. Holstein progeny showed an increase of 9 pounds of milk and 7 pounds of butterfat over their non-A.I. contemporary herd-mates.

A total of 51,023 Holstein and 13,725 Guernsey lactation records were used in a Wisconsin study made by Guderyon et al. (8). Production of A.I. progeny was compared with their contemporary non-A.I. herd-mates on a within-herd-year-season basis. When all available lactation records were used, the differences were a plus 157 pounds of milk and a plus 9 pounds of butterfat for the Holstein A.I. progeny, and a minus 20 pounds of milk and a plus 2 pounds of butterfat for the Guernsey A.I. progeny. When 11,945 first lactation records were used, the Holstein A.I. progeny showed a superiority of 163 pounds of milk and 8 pounds of butterfat and the Guernseys were 89 pounds of milk and 4 pounds of butterfat superior to the non-A.I. contemporary herd-mates. Herds were stratified into low, medium, and high level herds, according to the actual yearly herd averages of butterfat production. Comparisons of first lactation records showed the Holsteins A.I. progeny to be superior to their non-A.I. herd-mates by 10, 13, and 1 pound of butterfat, and 225, 175, and 79 pounds of milk in low, medium, and high level herds, respectively. Corresponding differences for Guernsey A.I. progeny were 0, 7, and 5 pounds of butterfat and 79, 220, and a minus 39 pounds of milk.

A similar study was made by Tucker et al. (31), to determine the genetic improvement in dairy cattle production attributable to sires used in A.I. in North Carolina. First lactation records of all A.I. progeny were compared with first lactation records of non-A.I. herd-mates on a within-herd-year-season basis. Their results showed the combined (Guernsey, Holstein and Jersey breeds) A.I. progeny superiority was 366 pounds of milk and 15.7 pounds of butterfat; these differences were significant. The differences were a plus 371, 355, and 396 pounds of milk and 8.8, 17.8, and 14.7 pounds of butterfat for the Guernsey, Holsteins, and Jersey breeds, respectively. Differences were significant for all breeds which indicates that the A.I. progeny were genetically superior to their non-A.I. contemporary herd-mates.

Hahn et al. (10) did not find A.I. progeny superior to non-A.I. herd-mates. This study used 705 DHIA first lactation records of artificially and naturally sired cows in Georgia. First lactation records of all A.I. progeny were compared with first lactation records of non-A.I. herd-mates on a within-herd-year-season basis. The results of this study showed the A.I. progeny produced 61.5 pounds less milk and 6.8 pounds more butterfat than their non-A.I. contemporary herd-mates. However, these differences were not the same for all breeds. Jersey A.I. progeny showed an increase of 456 pounds of milk and 10.4 pounds of butterfat over their non-A.I. herd-mates; while the differences were a minus 256 pounds of milk and a plus 3.6 pounds of butterfat for the Guernsey A.I. progeny, and a minus 172 pounds of milk and a plus 6.5 pounds of butterfat for the Holstein A.I. progeny.

First lactation records of 24,995 Hölstein A.I. progeny and 32,831 non-A.I. progeny were compared on a within-herd-year-season contemporary basis, over a ten-year period by Van Vleck and Henderson (32). They reported the A.I. progeny were superior in milk and butterfat production for each year of freshening from 1951 through 1959. The range in the superiority was 11.5 to 357.4 pounds of milk, and 3.2 and 17.6 pounds of butterfat. The trend of superiority was shown to be generally upward over the ten-year period with the low point being in 1953. Following the low point in 1953, there was an increase in the superiority in 1954 and 1955 with another decline in the superiority until 1959 when the superiority was the highest for the entire period studied.

Another report by Van Vleck (33) showed the A.I. progeny were superior to their non-A.I. herd-mates in all dairy breeds in New York. The estimated superiority of first lactations of A.I. progeny over the first lactations of non-A.I. herd-mates within the same herd-year-season of freshening was 248 pounds more milk and 11.4 pounds more fat for Holsteins, 175 pounds more milk and 10.6 pounds more fat for Guernseys, and 148 pounds more milk and 8.4 pounds more fat for Jerseys. This study covered the period of 1950 to 1960.

Corley et al. (4) compared the production performance of A.I. progeny with the non-A.I. herd-mates on an intra-herd year-season basis. Their study included 84,694 Holstein and 20,742 Guernsey lactation records. Among Holsteins, comparisons were made using both first lactation records and all available lactation records, but in the Guernsey breed only available lactation records were used, since the number of herds with records were relatively small. The results indicated that the Holstein A.I. progeny were significantly superior, producing 270 pounds of milk and 13 pounds of butterfat more than their non-A.I. herd-mates. Although the Guernsey A.I. progeny were not significantly superior to their non-A.I. herd-mates, the differences, 5 pounds of butterfat and 22 pounds of milk, were in favor of the A.I. progeny. These results were for the comparisons using all available lactation records. Assuming that the use of M.E. factors did not introduce any bias, they reported that the selection bias was not shown to be greater when all available lactation records were used than when only the first lactation records were used with respect to butterfat production for all Holstein herds. Had the analysis been restricted to the first lactation records for the A.I. progeny and non-A.I. herd-mates, the number of records would have been reduced from 23,023 to 13,362 and the number of herds would have been reduced from 6,876 to 2,574.

Bayley (1) summarized six different studies that have attempted to evaluate the genetic improvement in dairy cattle production traits attributable to sires used in A.I. His conclusion was that A.I. progeny have shown a small but positive gain when compared to the non-A.I. contemporary herd-mates. He reported that various geneticists have estimated that milk and butterfat production has been increased about 0.5 per cent per year under natural service programs, and that the upper limit is about 1.0 per cent per year. He estimated that the genetic superiority realized by the use of A.I. sires was 2 to 3 times as great as the expected annual genetic improvement for one year using natural service sires.

Genetic Progress That Can Be Expected

Assuming that attention would be concentrated entirely on production, Lush (18) has estimated that genetic improvement could approach 1.0 per cent per year with natural service breeding and selection. This is in agreement with the report of Rendel and Robertson (22), who estimated the maximum possible rate of genetic progress under optimum conditions for mass selection to be approximately 1 per cent of the average production per year. In their study of one herd the actual genetic progress achieved by selection was 0.7 per cent per year. Since the generation length was 3 years for this herd as compared to the mean generation length of 4 and one-half years, the maximum progress expected would be reduced to about 0.6 per cent per year.

A study by Plum and Rumery (21) showed that the genetic improvement was 7 pounds of butterfat per generation, or 1.3 pounds per year, by the use of natural breeding and selection. This study covered forty years of dairy cattle breeding results at the North Platte Experiment Station. Dillon et al. (5) showed that the average real production ability in the University of Illinois dairy herd had changed very little from 1901 when it was founded to 1954. These studies indicate that genetic improvement of dairy cattle by natural breeding and selection is very small, and in these two herds probably less than 0.5 per cent per year.

It was shown by Robertson and Rendel (24) that A.I. along with optimum use of progeny testing could raise the rate of genetic improvement from 1.0 to 1.69 per cent, if 2,000 cows were being tested in a unit. Most of these 2,000 cows would be used for progeny-testing young sires, but the very best cows would be bred to the very top proven sires to produce the next crop of young sires. When 10,000 cows were being tested in a unit, they showed it would be possible to increase the rate of genetic improvement to 2 per cent. Specht and McGillard (28) estimated that a genetic improvement rate of 1.7 to 2.3 per cent of the average annual yield could be obtained with progeny testing in an A.I. population of 10,000 cows. The rate of progress would depend upon the number of sires sampled and the proportion of those sampled which were selected for future service. They concluded that further progress would be possible if the percentage of cows on test were increased and if more efficient use were made of A.I. tested sires.

CHAPTER III

PROCEDURE

Source of Data

Lactation records for this study were collected from the DHIA herd books in the upper East Tennessee area. Since this method required considerable time, only dairy herds which had used A.I. services of the East Tennessee Artificial Breeding Association were included in the study.

There were 7,330 lactation records obtained from 87 dairy herds. Of these records 4,970 were obtained from 47 Holstein herds, 1,796 records from 21 Guernsey herds, and 640 records from 19 Jersey herds. Only records that started with normal calving and ended with dry dates were included; however, lactation records of less than 305 days were used.

Each lactation record was punched on an I.B.M. card to increase the accuracy and speed of the many calculations and comparisons. Each record was corrected for age by the use of the DHIA age conversion factors developed by Kendrick (15). Records of less than 305 days in length were not extended since all abnormal and incomplete records were excluded at the time of collection.

The records used in this study were made during the period from April, 1951 through March, 1963 for the A.I. progeny and non-A.I. herdmate comparison. In order to estimate the bias that may have resulted from selection of dams, the comparison records of the dams of A.I.

progeny and non-A.I. herd-mates from the period October, 1948 through March, 1963 were used.

Methods of Analysis

Of the 87 herds from which information was obtained, there were 49 herds, 57.3 per cent of the total herds involved in the study, that have not used any natural service breeding since the East Tennessee Artificial Breeding Association was organized in November, 1947. Therefore, production records were obtained from only 38 herds for the comparison of A.I. progeny with non-A.I. herd-mates. Since all available production records could not be used in this comparison, the analysis of records was made in two parts. Part one included the contemporary comparison and part two included the A.I. daughter average and the daughter-dam comparison.

In the first part of the analysis three comparisons were made to measure the amount of progress, or lack of progress, that had been realized from A.I. These comparisons were: (1) a comparison of the difference in milk production and butterfat production of A.I. progeny with the non-A.I. herd-mates, using first lactation records and using all lactation records; (2) a comparison of the difference in milk production and butterfat production of the A.I. progeny and non-A.I. herd-mates out of tested dams; (3) a comparison of the difference in milk production and butterfat production of the dams of A.I. progeny and the dams of non-A.I. herd-mates.

Many investigators (3, 4, 6, 9, 14, 29) have shown that the year and season of freshening can influence the results of dairy cattle breeding research. Therefore, in this study year and seasonal effects were removed by expressing each record as a deviation from a year-season subclass mean. These subclasses were obtained by arbitrarily dividing each year into two year-season subclasses. These subclasses covered two six-month periods of October through March and April through September.

The analysis of variance as outlined by Snedecor (27) was used to compare the differences in milk production and butterfat production of the A.I. progeny and non-A.I. herd-mates on a within breed and within herd basis. This procedure was used for first lactation, all lactations, all lactations for the A.I. progeny and non-A.I. herd-mates out of test dams, and all lactations of the dams of A.I. progeny and non-A.I. herd-mates.

Since the number of A.I. progeny and non-A.I. herd-mates varied within herds and among herds, it was necessary to use a method of weighting in order to obtain an estimate of the unbiased differences in milk and butterfat production. Therefore, the disproportional number of A.I. progeny and non-A.I. herd-mates was accounted for by using a weighting factor of $N_1 \cdot N_2 / N_1 + N_2$, where N_1 represents the number of A.I. progeny and N_2 represents the number of non-A.I. herd-mates. This same procedure was used in the comparison of the dams of A.I. progeny with the dams of non-A.I. herd-mates.

The second part of the analysis was included to utilize all available information on A.I. progeny since information was available from 49 herds that were not included in the contemporary comparison. A daughter average and a daughter-dam comparison was computed using all available information from 87 upper East Tennessee dairy herds that had used A.I. services. No attempt was made to correct the mature equivalent milk and butterfat records for year-season effects of freshening. However, the deviation from the year-season subclass mean of herd-mates was computed in order to evaluate the time trends that may have occurred in the daughter-dam comparisons. The same procedure was used in computing the deviation from the year-season subclass mean as outlined in the first part of the analysis.

CHAPTER IV

RESULTS AND DISCUSSION

Comparison of A.I. Progeny and Non-A.I. Herd-mates

The average mature equivalent milk and butterfat production for A.I. progeny and non-A.I. herd-mates are presented in Table I and II. The unbiased estimated difference in milk and butterfat which was used to estimate the difference in production of the A.I. and non-A.I. herd-mates is also presented. This estimated unbiased difference is the difference of the A.I. progeny minus the non-A.I. herd-mates adjusted for number of animals where each record was expressed as a deviation from the year-season subclass mean. Appendix Table VIII, IX, and X gives the analysis of variance tables for milk production, and Appendix Tables XI, XII, and XIII give the analysis of variance comparisons of butterfat production for Holstein, Guernsey, and Jersey breeds.

In each breed, the estimated unbiased difference showed the A.I. progeny to be superior to the non-A.I. herd-mates. Results of the Holstein comparison of the first lactation records showed the superiority of A.I. progeny to be 420.8 pounds of milk and 18.7 pounds of butterfat. The difference in milk production had a F value which would be expected more than five per cent of the time but less than ten per cent of the time. Although not significant by the usually accepted levels of probability of less than five per cent, this value was approaching significance and warrants some confidence.

TABLE I

COMPARISON OF MILK PRODUCTION BETWEEN A.I. PROGENY AND NON-A.I. HERD-MATES

Breeds	Herds	Type Individuals		Average Milk Production**		Estimated Unbiased Difference*
		A.I.	Non-A.I.	A.I.	Non-A.I.	
	(no)			(lb)		
First Lactations						
Holsteins	21	358	300	11,831	11,322	420.8
Guernseys	13	137	170	8,217	8,318	83.2
Jerseys	4	48	39	7,873	8,019	135.8
All Lactations						
Holsteins	21	369	306	12,018	11,452	452.2
Guernseys	13	154	176	8,159	7,953	266.6
Jerseys	4	51	39	7,644	7,982	7.4

*Positive differences are in favor of A.I. Progeny and negative differences are in favor of non-A.I. herd-mates.

**Has not been adjusted for year-season difference and disproportional numbers.

TABLE II

COMPARISON OF BUTTERFAT PRODUCTION BETWEEN A.I. PROGENY AND NON-A.I. HERD-MATES

Breed	Herds	Type Individuals A.I.	Type Individuals Non-A.I.	Average Butterfat Production** A.I.	Average Butterfat Production** Non-A.I.	Estimated Unbiased Difference*
	(no)			(lb)		
First Lactations						
Holsteins	21	358	300	442	416	18.7
Guernseys	13	137	170	407	410	5.8
Jerseys	4	48	39	388	391	11.1
All Lactations						
Holsteins	21	369	306	407	421	17.7
Guernseys	13	154	176	405	392	12.2
Jerseys	4	51	39	456	397	2.6

*Positive differences are in favor of A.I. progeny and negative differences are in favor of non-A.I. herd-mates.

**Has not been adjusted for year-season difference and disproportional numbers.

The Guernsey and Jersey information presented in Tables I, II, III, and IV at first glance appears to be contradictory in that the production levels indicate that the non-A.I. progeny are superior and the estimated unbiased difference indicates the A.I. progeny are superior. One logical explanation for this apparent discrepancy is that the production average is not adjusted for the effects of year-seasons on production nor for the effects of disproportional numbers. A close study of the Guernsey data illustrates that the combination of these two factors causes this discrepancy. The difference in the mature equivalent daughter average in two of the herds was 768 pounds of milk in favor of the non-A.I. herd-mates; while the estimated unbiased difference for the 27 A.I. progeny and the 65 non-A.I. herd-mates was 40 pounds of milk in favor of the A.I. progeny. This illustrates that in these two herds the A.I. daughters initiated their lactations in year-seasons in which production was much lower than when the non-A.I. progeny were making their records. In addition the disproportional numbers tended to magnify this difference. These effects were removed in the estimated unbiased difference.

In the Guernsey and Jersey breeds, the superiority of the A.I. progeny was less pronounced; however, the differences were in favor of the A.I. progeny. The estimated unbiased difference was 83.2 pounds of milk and 5.8 pounds of butterfat for the Guernsey breed. In the Jersey breed, the superiority of the A.I. progeny was 135.8 pounds of milk and 11.1 pounds of butterfat. However, these differences were not statistically significant.

Results of the analysis involving all available lactation records showed that for the Holstein breed superiority in milk the production increased from 420.8 to 452.2 pounds, and the superiority of fat production decreased from 18.7 to 17.7 pounds while the superiority increased from 83.2 to 266.8 pounds of milk and 5.8 to 12.2 pounds of butterfat in the Guernsey breed. Although an increase of this amount would not be expected, it may have resulted from an increase in the number of A.I. progeny from 137 to 154 and an increase in the number of non-A.I. herd-mates from 170 to 176. The extreme variation in the superiority of the Jersey A.I. progeny from the first lactation estimates can not be completely explained. However, the extreme variation may be due to the few herds and small numbers of animals involved in this study. Since the bias from selection appeared to be small, in the comparison of the Holstein A.I. progeny and non-A.I. herd-mates, all lactations were used for the remainder of the study.

Although the estimated unbiased difference was not highly significant, the superiority of the Holstein A.I. progeny in this study exceeded that reported in the eight previous studies (4, 8, 10, 26, 29, 31, 33, 34). The four studies (4, 8, 30, 31) that reported a significant difference found the superiority of the A.I. progeny varied from 147 to 355 pounds of milk and from 9 to 17.8 pounds of butterfat. Three of these studies involved several thousand animals.

In the Guernsey breed, the superiority of the A.I. progeny generally agrees with that reported in the seven previous studies (4, 8, 10, 28, 30, 31, 33). However, the non-significant difference in this study is not in complete agreement with Tucker et al. (30) and Van Vleck (31). The small, but positive, milk production differences involving Guernseys are not in complete agreement with the negative differences reported by Cordey et al. (4) and Guderyon et al. (8). The small superiority of the Jersey A.I. progeny is in general agreement with that reported by Hahn (10) and Tucker et al. (30).

Comparison of A.I. Progeny and Non-A.I. Herd-mates Out of Tested Dams

In order to determine if selection of dams had occurred to an extent which could influence the results in favor of either of the A.I. progeny or the non-A.I. herd-mates, a comparison was made of the A.I. progeny and non-A.I. herd-mates out of dams with available records. A comparison of the records of the dams of A.I. and non-A.I. progeny was also needed. The results of these comparisons are shown in Tables III and IV for milk and butterfat production, respectively. The Holstein A.I. progeny showed a superiority of 243.3 pounds of milk and 14.4 pounds of butterfat. In the Guernsey breed, the superiority of the A.I. progeny was 117.1 pounds of milk and 6.4 pounds of butterfat, and the superiority of the Jersey A.I. progeny was 168.7 pounds of milk and 11.0 pounds of butterfat.

A possible explanation for the decrease in the superiority of the Holstein and Guernsey A.I. progeny from tested dams is that a majority of these comparisons were for registered herds. This would indicate that dairymen with registered herds have been more successful in selecting herd sires than the average dairyman. In the Jersey breed,

TABLE III

COMPARISON OF MILK PRODUCTION BETWEEN A.I. PROGENY AND NON-A.I. HERD-MATES FROM TESTED DAM AND A COMPARISON OF DAMS OF A.I. PROGENY WITH THE DAMS OF NON-A.I. DAUGHTERS

Breed	Herds	Type Individuals		Average Milk Production**		Estimated Unbiased Difference*
		A.I.	Non-A.I.	A.I.	Non-A.I.	
Daughters	-------------(no)---------------			-------------------(lb)-------------------		
Holsteins	17	253	205	12,027	11,599	243.5
Guernseys	13	101	123	8,057	8,188	117.1
Jerseys	4	26	19	7,783	7,873	168.7
Dams						
Holsteins	17	253	205	12,084	11,373	267.7
Guernseys	13	101	123	7,860	7,830	297.1
Jerseys	4	26	19	7,477	7,814	17.6

*Positive differences are in favor of A.I. progeny and negative differences are in favor of non-A.I. herd-mates.

**Has not been adjusted for year-season difference and disproportional numbers.

TABLE IV

COMPARISON OF BUTTERFAT PRODUCTION BETWEEN A.I. PROGENY AND NON-A.I. HERD-MATES FROM TESTED DAMS AND A COMPARISON OF THE DAMS OF A.I. PROGENY AND NON-A.I. DAUGHTERS

Breed	Herds	Type Individuals		Average Butterfat Production**		Estimated Unbiased Difference*
		A.I.	Non-A.I.	A.I.	Non-A.I.	
Daughters	(no)			(lb)		
Holsteins	17	253	205	449	421	14.4
Guernseys	13	101	123	400	405	6.4
Jerseys	3	26	19	390	388	11.0
Dams						
Holsteins	17	254	205	438	406	13.7
Guernseys	13	101	123	371	378	7.2
Jerseys	3	26	19	348	399	33.1

*Positive differences are in favor of A.I. progeny and negative differences are in favor of non-A.I. herd-mates.

**Has not been adjusted for year-season difference and disproportional numbers.

the increase in superiority of the A.I. progeny out of dams with records could be due to over 90 per cent of the animals represented only two herds.

Comparison of the Dams of A.I. Progeny with the Dams of Non-A.I. Herd-Mates

The results of the comparisons of the dams of A.I. progeny with the dams of the non-A.I. herd-mates are shown in Tables III and IV for milk and butterfat production, respectively. Even though no significant differences were found, the positive difference in favor of the A.I. dams indicates that better dams were selected to breed artificially. The dams of Holstein A.I. progeny had a superiority of 267.7 pounds of milk and 13.7 pounds of butterfat above the dams of non-A.I. progeny. For the Guernsey breed the superiority was 297.1 pounds of milk and 7.2 pounds of butterfat for the dams of A.I. progeny. In the Jersey breed the dams of A.I. progeny were 17.6 pounds superior in milk but were 33.1 pounds of butterfat inferior.

Although the positive difference in favor of the dams of A.I. progeny indicates some selection of dams was practiced, the bias in favor of the A.I. progeny would be small. Since the heritability of milk production is widely accepted as being at the 20 to 30 per cent level as computed by Lush (17) and Rice et al. (23), this would mean that 10 to 15 per cent of the dams' superiority would be inherited by the daughters. Therefore, the portion of the A.I. daughters' superiority which could be attributable to dams' superiority, would only be 27 to 40 pounds of milk for Holsteins, 30 to 45 pounds of milk for Guernseys, and 2 to 3 pounds for Jerseys.

The results reported by Tucker et al. (31), and Beal and Madden (2) did not show any significant difference between the dams of A.I. progeny and the dams of non-A.I. herd-mates. However, the results reported by Tucker et al. (29) showed a superiority of 149 pounds of milk and 17.7 pounds of butterfat favoring the non-A.I. animals.

Implications of A.I. Superiority over Non-A.I.

This study indicates that more progress has been made in the upper East Tennessee area in the Holstein breed with artificial insemination than has been made during the same years by the non-A.I. herd sires used in natural service. The 420.8 pounds of milk and 18.7 pounds of butterfat superiority of the Holstein A.I. progeny represents a genetic gain of 0.7 per cent per year more than was obtained with non-A.I. sires, if a generation length of five years is assumed. Even though the estimated genetic gain appears rather small, it represents a substantial gain when compared to natural service results. Robertson and Rendel (22) estimated the genetic progress in a closed herd was only 0.7 per cent for a three year generation length, which indicates that rather intense selection was practiced. Also, the genetic gain estimated by Plum and Rumery (21) was only 1.3 pounds of butterfat per year in a 40-year breeding study using natural breeding and selection. Dillon et al. (5) reported no real genetic progress was found in a study covering 53 years of natural breeding and selection in the University of Illinois dairy herd. If these studies are used to estimate the genetic progress under natural service, then the rate of genetic progress from A.I. sires in this study is 2 to 3 times as great as the annual genetic improvement that would be expected from the use of natural service sires. This is in general agreement with Bayley's (1) estimate of the genetic progress that had been realized from the use of A.I. reported in six previous studies (4, 10, 28, 30, 31, 33).

In the Guernsey and Jersey breeds, the difference was not approaching significance; therefore, no attempt was made to estimate the per cent genetic gains, since this difference could be due to chance alone. Even though these differences did not approach significance, it should be noted that there were positive differences in favor of the A.I. progeny.

A.I. Daughter Average and Daughter-Dam Comparison

Since production records were available for 977 additional A.I. progeny, representing 49 herds which had used all A.I. services, the daughter average and daughter-dam comparisons were computed using all available lactation records from the 87 dairy herds in the upper East Tennessee area. Although the precision of such a comparison is not as great as the first analysis, the increase in amount of information was sufficient to warrant this analysis. The results are shown in Tables V, VI, and VII for the Holsteins, Guernseys, and Jerseys, respectively.

The average production of the 1,055 Holstein A.I. progeny was 12,436 pounds of milk and 464 pounds of butterfat. This was 438 pounds of milk and 57 pounds of butterfat above the average production of the 369 A.I. progeny involved in the contemporary comparison. Also, this production level exceeded the national DHIA Holstein average production by 361 pounds of milk and 22 pounds of butterfat.

TABLE V

MATURE EQUIVALENT HOLSTEIN A.I. DAUGHTER AVERAGE AND DAUGHTER-DAM COMPARISONS USING ALL LACTATION RECORDS

					Mean Deviation From Year-Season Average*	
Animals	Records	Milk	Test	Fat	Milk	Fat
(no)	(no)	(lb)	(%)	(lb)	(lb)	(lb)
1,055 Daughters	2,810	12,456	3.73	464	-82	- .2
631 Daughters with Dams	1,716	12,528	3.73	468	-19	+1.9
631 Dams	2,772	12,327	3.63	447	+75	+1.2
Differences*		+201	+.10	+20	-94	+ .6

*Positive differences are in favor of A.I. daughters and negative differences are in favor of A.I. dams.

TABLE VI

MATURE EQUIVALENT GUERNSEY A.I. DAUGHTER AVERAGE AND DAUGHTER-DAM COMPARISONS
USING ALL LACTATION RECORDS

					Mean Deviation From Year-Season Average*	
Animals	Records	Milk	Test	Fat	Milk	Fat
(no)	(no)	(lb)	(%)	(lb)	(lb)	(lb)
258 Daughters	575	8,178	4.96	406	-131	-1.1
161 Daughters with Dams	350	8,261	5.00	413	-152	+ .3
161 Dams	691	8,114	4.72	383	23	4.8
Difference*		+147	+.28	+30	-175	+5.1

*Positive differences are in favor of A.I. daughters and negative differences are in favor of A.I. dams.

TABLE VII

MATURE EQUIVALENT JERSEY A.I. DAUGHTER AVERAGE AND DAUGHTER-DAM COMPARISONS USING ALL LACTATION RECORDS

Animals	Records	Milk	Test	Fat	Mean Deviation From Year-Season Average* Milk	Mean Deviation From Year-Season Average* Fat
(no)	(no)	(lb)	(%)	(lb)	(lb)	(lb)
228 Daughters	597	7,622	5.10	389	- 95	-1.2
102 Daughters with Dams	278	7,342	5.13	377	-153	-2.5
102 Dams	427	7,252	4.91	356	-105	-9.5
Differences*		+90	+.22	+21	- 48	+7.1

*Positive differences are in favor of A.I. daughters and negative differences are in favor of A.I. dams.

The same pattern was observed for the 259 Guernsey A.I. progeny. The average production was 8,178 pounds of milk and 406 pounds of butterfat. This was 19 pounds of milk and 1 pound of butterfat higher than the production of the 154 A.I. progeny involved in the contemporary comparisons. The Guernseys, however, were 189 pounds of milk below the national DHIA average, but the butterfat production was 4 pounds above the national DHIA average. In the Jersey breed the overall results were not quite so favorable. The average production of the 228 A.I. progeny was 7622 pounds of milk and 389 pounds of butterfat. This represents a decrease of 22 pounds of milk and 67 pounds of butterfat from the average of the 51 A.I. progeny involved in the contemporary comparison. The Jersey A.I. progeny were 246 pounds of milk and 21 pounds of butterfat below the national DHIA average production.

In the daughter-dam comparisons all breeds showed the same general pattern. In each breed, the A.I. progeny were superior to their dams in the normal daughter-dam comparison. However, the mean deviation from the year-season average production showed a difference in milk production favoring the dams, but the difference in butterfat production was in favor of the A.I. daughters.

It is probable that a small bias favoring the dams exists when one compares unselected progeny with older herd-mates which have been selected. Although the daughters showed an increase in milk production over their dams, the expression of records as a deviation from the year-season average of herd-mates (which should remove time trends) indicates that this improvement was non-genetic. In the Holstein breed, the dams exceeded the daughters by 94 pounds of milk but the daughters were 0.6 pounds of butterfat above their dams when the comparison was based on the deviation from the year-season. The Guernsey A.I. daughters had a minus 175 pounds of milk and a plus 5.1 pounds of butterfat when based on the mean deviation from the year-season. Whereas, in the Jersey breed, the comparison based upon mean deviation from the year-season average was a minus 48 pounds of milk and a plus 7.1 pound of butterfat.

Any selection bias that existed would appear to be in favor of the dams. This occurs because unselected A.I. daughters were compared with herd-mates, some of which were older and had survived varying degrees of herd culling. Therefore, this bias would be against the unselected daughters and in favor of the dams. Although it is difficult to determine the amount of this bias in this study, an estimate can be derived from the 1963 U.S.D.A. sire summaries for all A.I. proved sires. In these comparisons one would assume that sires which have survived some selection should at least sire daughters equal to their herd-mates. Since the daughters in these summaries average 50 to 100 pounds less milk than their herd-mates, one could assume that this constitutes an estimate of this bias.

The analysis comparing A.I. progeny with the non-A.I. herd-mates indicated that the sires in artificial insemination sired offsprings which were superior in production traits to offsprings of non-A.I. sires. Whereas the portion of this study which compares the production levels of the A.I. progeny with their dams production indicates that these A.I. progeny are about equal to their dams. Therefore, if one relates these two studies, one would conclude that the A.I. sires are superior to the non-A.I. sires although they are siring daughters approximately equal in merit to their dams. Since many of the dams were also A.I. progeny and the other dams were somewhat selected, these A.I. sires were providing some progress. Since the A.I. progeny were superior to the non-A.I. herd-mates, it would seem logical to conclude that the non-A.I. sires have not improved production but probably have had a negative influence.

Since the milk and fat production records available for this study only included DHIA herds where identification records had been kept up to date, these dairymen would place more emphasis on the selection of herd sires than would be expected of dairymen not on DHIA tests. The superiority of A.I. progeny found in DHIA tested herds should represent the lower limits of that found for all herds in the upper East Tennessee area. Therefore, the small but positive estimated unbiased difference has considerable economic importance to dairymen in the upper East Tennessee area. When we consider the 420.8 pounds superiority of the Holstein A.I. progeny, which was approaching significance at the five per cent level, this would represent several thousand dollars more income each year. In addition, 10 to 15 per cent of this superiority would be expected to be inherited by the daughters of these A.I. progeny.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study consisted of an analysis of 7,330 mature equivalent milk and butterfat production records to evaluate the influence of sires used in artificial insemination on dairy cattle production traits in the upper East Tennessee dairy herds. In the first part of the study, three comparisons of the production records of 1,095 A.I. progeny and non-A.I. herd-mates were used to compare the effectiveness of A.I. sires as compared to natural service sires, while the second part of the study included the daughter average and daughter-dam comparisons.

The first lactation comparison of the A.I. progeny and non-A.I. herd-mates revealed that the difference between the two groups was in favor of the A.I. progeny. The superiority of the Holstein A.I. progeny was the largest found (420.8 pounds of milk and 18.7 pounds of butterfat). The difference in milk production was approaching statistical significance at the five per cent level; whereas, in the Guernsey and Jersey breeds, the difference did not approach statistical significance (83.2, 135.8 pounds of milk and 5.8, 11.1 pounds of butterfat, respectively). Therefore, these results indicate that the advantage in annual genetic improvement in the Holstein breed has been approximately 0.7 per cent per year more with A.I. sires than occurred with non-A.I. sires.

In the Holstein breed, the comparison using all lactation records shows the same general trend as shown by first lactation comparisons. The estimated unbiased difference was 452.2 pounds of milk and 17.7

pounds of butterfat. Since the difference varied only 31.4 pounds of milk and 1.1 pounds of butterfat from the first lactation comparisons, it was concluded that the selection bias was small. However, greater variation in the Guernsey and Jersey breeds was probably due to the smaller number of animals involved in the study.

In the Holstein and Guernsey breeds, the estimated unbiased difference was less for the comparison of A.I. progeny and non-A.I. herd-mates out of dams with records than for the overall comparison. Since most of these animals were in registered herds, a logical conclusion would be that these dairymen have been more successful in the selection of herd sires than the average dairymen on DHIA tests.

The comparison of the dams of A.I. progeny and non-A.I. herd-mates showed that some selection of A.I. dams in favor of the A.I. progeny may have been practiced. The dams of A.I. progeny showed a slight superiority over the dams of the non-A.I. herd-mates. However, none of these differences approached significance. Even though these differences may have favored the A.I. progeny, the bias would be very small. Assuming that 10 to 15 per cent of this difference would be inherited by the A.I. progeny, the bias would be from 2 to 40 pounds of milk in favor of the A.I. progeny.

In the second part of this study, the A.I. daughter average was shown to compare very favorably with the national DHIA average production. The 1,055 Holstein A.I. daughter average was 361 pounds of milk and 22 pounds of butterfat above the national Holstein DHIA average production. The 258 Guernsey A.I. daughter average was a minus 189 pounds of milk and a plus 4 pounds of butterfat as compared to the Guernsey national DHIA average production, while the 102 Jersey A.I. daughters' average was 175 pounds of milk and 48 pounds of butterfat below the national Jersey DHIA average production.

In the daughter-dam comparison the A.I. progeny were superior to their dams in each breed. The Holsteins A.I. showed an increase of 201 pounds of milk and 20 pounds of butterfat above their dams. In the Guernsey breed, the A.I. progeny were 147 pounds of milk and 30 pounds of butterfat above their dams, and the Jersey A.I. daughters were 90 pounds of milk and 21 pounds of butterfat above their dams. Even though all breeds showed an increase over their dams, most of this increase in milk production was probably due to improvements in management practices, since the mean deviation from the year-season average of the herd-mates was a minus 94, minus 175, and minus 48 pounds of milk for the Holsteins, Guernseys, and Jerseys, respectively.

Considering the results of the two analysis jointly, one would conclude that the A.I. sires were superior to the non-A.I. sires. The daughter-dam analysis, however, indicates that the A.I. progeny were about equal to the dams merit. This would indicate non-A.I. sires were not improving production but rather were having a negative influence.

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APPENDICES

TABLE VIII

ANALYSIS OF VARIANCE COMPARISON OF MILK PRODUCTION BETWEEN HOLSTEIN A.I. PROGENY AND NON-A.I. HERD-MATES

	D.F.	Sums Squares	Mean Square	F. Value
		First Lactation		
Total	637	3,017,466,236	4,736,996	
Among Classes	21	146,886,883	6,994,613	1.50
Within Classes	616	2,870,579,353	4,660,031	
		All Lactations		
Total	653	2,602,798,301	4,992,022	
Among Classes	21	87,843,089	4,183,004	1.05
Within Classes	632	2,514,955,212	3,979,356	
		All Lactations Out of Dams With Records		
Total	440	1,798,063,855	4,086,509	
Among Classes	17	48,157,261	2,832,780	0.68
Within Classes	432	1,749,906,594	4,136,895	
		All Lactations A.I. Dams and Non-A.I. Dams		
Total	439	1,866,137,855	4,250,883	
Among Classes	17	75,638,594	4,449,329	1.04
Within Classes	422	1,790,499,261	4,242,889	

TABLE IX

ANALYSIS OF VARIANCE COMPARISON OF MILK PRODUCTION BETWEEN GUERNSEY A.I. PROGENY AND NON-A.I. HERD-MATES

	D.F.	Sums Squares	Mean Square	F. Value
		First Lactation		
Total	299	789,626,991	2,640,893	
Among Classes	13	26,350,271	2,026,944	0.76
Within Classes	286	763,276	2,668,800	
		All Lactations		
Total	317	725,267,375	2,287,910	
Among Classes	13	34,905,346	2,688,719	1.18
Within Classes	304	690,362,029	2,270,928	
		All Lactations Out of Dams With Records		
Total	211	501,287,660	2,375,771	
Among Classes	13	27,838,053	2,141,389	0.89
Within Classes	198	473,449,607	2,391,160	
		All Lactations A.I. Dam and Non-A.I. Dams		
Total	219	496,530,115	2,267,261	
Among Classes	13	23,732,227	1,825,556	0.76
Within Classes	206	472,797,888	2,392,223	

TABLE X

ANALYSIS OF VARIANCE COMPARISON OF MILK PRODUCTION
BETWEEN JERSEY A.I. PROGENY AND NON-A.I. HERD-MATES

	D.F.	Sums Squares	Mean Square	F. Value
		First Lactation		
Total	79	160,582,241	2,032,687	
Among Classes	4	6,678,906	1,669,727	0.90
Within Classes	83	153,903,335	1,854,257	
		All Lactations		
Total	96	194,783,647	2,028,996	
Among Classes	4	6,613,777	1,653,444	0.81
Within Classes	92	188,169,870	2,045,325	
		All Lactations Out of Dams With Records		
Total	42	82,046,685	1,953,493	
Among Classes	3	3,856,475	1,285,492	0.64
Within Classes	39	78,190,210	2,004,877	
		All Lactations A.I. Dams and Non-A.I. Dams		
Total	42	35,302,185	840,528	
Among Classes	3	1,651,059	550,353	1.14
Within Classes	39	18,791,595	481,835	

TABLE XI

ANALYSIS OF VARIANCE COMPARISON OF BUTTERFAT PRODUCTION BETWEEN HOLSTEIN A.I. PROGENY AND NON-A.I. HERD-MATES

	D.F.	Sums Squares	Mean Square	F. Value
		First Lactation		
Total	637	3,546,274	5,567	
Among Classes	21	145,670	6,937	1.29
Within Classes	630	3,400,604	5,398	
		All Lactations		
Total	653	3,172,837	4,859	
Among Classes	21	105,238	5,011	1.07
Within Classes	632	3,067,599	4,698	
		All Lactations Out of Dams With Records		
Total	440	2,284,383	5,192	
Among Classes	17	88,595	5,211	1.00
Within Classes	423	2,195,788	5,191	
		All Lactations A.I. Dams and Non-A.I. Dams		
Total	439	2,440,485	5,559	
Among Classes	17	83,608	4,918	0.88
Within Classes	422	2,356,877	5,585	

TABLE XII

ANALYSIS OF VARIANCE COMPARISON OF BUTTERFAT PRODUCTION BETWEEN GUERNSEY A.I. PROGENY AND NON-A.I. HERD-MATES

	D.F.	Sums Squares	Mean Square	F. Value
		First Lactation		
Total	299	1,823,250	6,098	
Among Classes	13	88,855	6,835	1.13
Within Classes	286	1,734,395	6,064	
		All Lactations		
Total	317	1,584,334	4,998	
Among Classes	13	91,473	7,036	1.43
Within Classes	304	1,492,861	4,911	
		All Lactations Out of Dams with Records		
Total	211	1,090,171	5,167	
Among Classes	13	76,211	5,862	1.14
Within Classes	198	1,013,959	5,121	
		All Lactations A. I. Dams and Non-A. I. Dams		
Total	219	909,987	4,155	
Among Classes	13	58,339	2,949	0.64
Within Classes	206	851,648	4,620	

TABLE XIII

ANALYSIS OF VARIANCE COMPARISON OF BUTTERFAT PRODUCTION BETWEEN JERSEY A.I. PROGENY AND NON-A.I. HERD-MATES

	D.F.	Sums Squares	Mean Square	F Value
		First Lactation		
Total	83	304,675	3,671	
Among Classes	4	14,522	3,631	0.99
Within Classes	79	290,153	3,673	
		All Lactations		
Total	96	430,562	4,485	
Among Classes	4	7,574	1,894	0.40
Within Classes	92	430,562	4,680	
		All Lactations Out of Dam With Records		
Total	42	137,738	3,279	
Among Classes	3	2,086	695	0.20
Within Classes	39	135,652	3,478	
		All Lactations A.I. Dams and Non-A.I. Dams		
Total	42	159,144	3,789	
Among Classes	3	58,729	19,576	7.60
Within Classes	39	100,415	2,575	