ESTIMATE OF DAILY MILK YIELD
IN HEREFORD AND ANGUS DAMS

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CHAPTER I

INTRODUCTION

Beef cattle producers have long recognized the importance of milk production in their cow herds. The preweaning growth of the calf as measured by its gain from birth to weaning reflects to a certain extent the amount of milk that the calf received from its dam. The cow not only provides the nutritional environment but also half of the calf's genes. It is this combination of maternal and direct genetic effects that determines the preweaning performance of the calf.

The existence of a high correlation between preweaning gain from birth to weaning with milk production of the dam is well known. Pope et al. (1963) noted that this correlation was higher early in the life of the calf up to three months of age after which it began to decline as the calf depended less and less on the dam's milk and more on other nutritional sources. Few studies have attempted to isolate the various sources of variation affecting the daily milk yield in beef cows. Environmental sources other than the nutritional levels are important and have been observed to cause differences in lactation yield. However, the real issue is not the ability of the cow to produce milk rather the response of the calf to the maternal influence, namely the ability of the calf to consume the milk produced and convert it into gain.

Milk yield estimates, however, are difficult to obtain because of the cumbersome procedures involved. With the calf suckling technique the calf has to be weighed both before and after suckling to obtain an indirect estimate of the dam's milk yield. This technique is tedious, especially when monthly measurements have to be taken twice a day for a large number of cow-calf pairs that are being kept in large pastures of native range. Also, using the calf weight change as the estimate of milk yield may not reflect the actual milk producing capability of the dam, rather it measures the amount of milk the calf can consume during one suckling. Since the correlation between calf weight gain and the dam's milk yield is high, predicting the daily milk yield from preweaning performance of the calf could possibly eliminate some of the steps in the milk measuring routine and improve the efficiency in the milk measuring technique.

Excessive increases in the amount of milk produced by the dam may not be entirely desirable. In some instances increased milk production due to too liberal feeding has been observed to lower the reproductive performance of the cow. Therefore the amount of milk necessary or even desirable in beef cattle operations may not be the maximum possible. In addition calves that are slow growing due to lack of milk can compensate in accelerated growth and efficiency of growth during the postweaning period. Thus milk is essential only to produce an adequate amount of growth from birth to weaning in the most efficient manner.

A study was conducted from 1967 to 1972 at the Fort Reno Livestock Experiment Station to study the milk producing ability of two lines of Herefore and four lines of Angus cows. The objectives of the present study were:

(1) to examine the various sources of variation affecting the milk production of the cows,

(2) to predict the daily milk yield of the dam using growth performance of her calf as well as her own weight and condition changes during the lactation period, and

(3) to examine the extent to which milk yield could be adequately estimated using fewer actual measures of daily milk yield.

CHAPTER II

REVIEW OF LITERATURE

Maternal Effects

Growth during the suckling period is affected by at least two factors, offspring growth and a maternal effect contribution by a dam. Wilham (1972) defined a maternal effect as a phenotypic value of a dam measurable only as a component part of her offspring's phenotypic value. The most obvious feature of the maternal effect for gain from birth to weaning is the milk supplied by the cow and the way the cow cares for her calf, such as protecting and nourishing it at the proper time. Differences in the milking ability would seem to be the most important element in maternal environment, since milk is the major source of nutrients for the calf during the early months of growth.

Koch and Clark (1955) suggested that possibly there exists a negative correlation between the maternal environment from birth to weaning with gain and score. A correlation of -.01 between weaning score of the dam and preweaning gain of her calf was reported. The maternal gain from birth to weaning was also found to be lowly correlated with the calf's weaning gain ($r = 0.04$).

Mangus and Brinks (1971) found a correlation of -.02 between the most probable producing ability (MPPA) of the dam and her weaning score. Improvement of weaning weights of beef calves was suggested to be primarily dependent upon increased preweaning growth potential of calves and mothering ability of their dams. Heifers that were fed a high level of nutrition during their preweaning growth had their lifetime milk production slightly depressed. This was indicated by a partial regression coefficient of MPPA of the heifer upon her weaning weight of 0.03.

However, Boston, Whiteman and Frahm (1973) and Boston, Frahm and Whiteman (1973) in their study involving 680 Angus and 183 Hereford cows found that the regression coefficient for the change in calves' weights per pound change in a cow's own weaning weight was 0.23 for Herefords and 0.12 for Angus which indicated that if the heifer calves with heavier than average weights at weaning are saved as replacements they can be expected to produce heavier weaning calves than if the lighter heifers had been saved. The repeatability for Hereford cows indicated that Hereford cows were more consistent in their level of productivity as measured by calf weaning weights.

Hohenboken and Brinks (1971) found that the negative environmental covariance between a dam's own preweaning growth and her subsequent maternal ability inflated the genetic antagonism between direct and maternal effects on weaning weight when covariance of offspring and dam but not covariance of offspring and sire was used. Estimates of direct effects, maternal effects and combined effects on weaning weight were 0.23 - 0.27, 0.34 - 0.40 and 0.28 - 0.34, respectively, indicating that more of the variability in preweaning growth was associated with maternal effects than with direct effects. The genetic correlation of direct and maternal effects of -.28 was also reported.

These recent studies plus comprehensive reviews by Koch (1972) and Wilham (1972) provide substantial evidence that maternal effects account for a significant portion of the variance in most preweaning growth traits. Since the role of the dam is so important in beef cattle operation, it becomes readily apparent that the maternal influence of beef females must be evaluated in order to be able to manage production systems in the most efficient manner.

Factors Affecting Milk Yield

Prior to the study by Gifford in 1953 there is a paucity of information known about the milk yields produced by beef cows and their effects on growth of suckling beef calves. Also little information is available concerning the environmental influences on milk yields of beef females. Most of the results available are based on the estimates of milk production using the calf suckling technique. By this technique, the difference in weight before and after suckling is taken as the milk yield estimate.

Gifford (1953) in his study involving 28 Hereford, seven Angus and five Shorthorn cows found that the milk production of the Hereford cows increased till six years of age after which period the milk yield began to decline. There was more variability in the milk yield of the Angus and Shorthorn cows of different ages. Cows between the ages of two and three years produced less milk than cows of any other age studied. Maximum milk production on the average was attained during the first month of lactation. The lactation curve did not follow the norm reported for dairy cows. Gifford also suggested that the three limiting factors affecting high milk production in most beef herds are genetic influences, feeding and management and calf effects on the physiological processes of milk secretion, including the ability of the calf to consume the milk produced by the dam.

Neville (1962) studied the influence of dam's milk production on preweaning weights of 135 Hereford calves and found that the effects of year, nutritional treatment, birth order of calves, milk yield in different treatments and birth weight of calf were significant factors influencing 120-day weight. With regard to 240-day calf weight, sex was reported to have a significant influence, along with nutritional treatment, milk yield in different treatments and birth weight of the calf. Of the total variance in eight-month weight, 66% was due to differences in the amount of milk consumed by the calves.

Pope et al. (1963) collected milk production data for three years on more than 300 range beef cows and reported that the levels of winter feed did influence the milk production of the cows. Fall-calving cows fed poorly during the winter gave less milk than those fed more liberally. But too liberal feeding was observed to have an adverse effect on milk yield. Age of dam, calf birth date, sex of calf and calf birth weight were significant. The average milk production per day over the five-month lactation period for the two-year, three-year and four-year olds were 8.36, 9.88 and 10.28 lbs., respectively. Later calving cows were in a higher stage of lactation at the time of first measurement of milk production. Cows nursing male calves gave more milk than cows nursing females. The correlation between the calf birth weight and average milk production for the entire lactation period was 0.14, indicating heavier calves at birth tended to consume more milk. As much as 50% of the variation in calf gain from birth to weaning could be attributed to differences in the amount of milk produced by the dams.

A modified version of the calf suckling technique was used by Christian et al. (1965) to study the effect of the dam's milk and other preweaning influences on weaning weight of 88 Hereford calves that were creep-fed. Milk yield was estimated twice daily at four-week intervals by hand-milking two of the udder sections while the calf nursed the other half of the udder. Calves from three- and four-year old dams were heavier at birth, consumed more milk from their dams, utilized more creep feed and were heavier at weaning than calves from two-year old dams. Birth weight of calves was lowly correlated with milk production of the dam which indicated that greater birth weight did not increase milk production. Sex of calf was found to have no significant effect on the dam's milk yield. Dams suckled by male calves did not produce any more milk than dams of female calves.

Rutledge et al. (1972) found quite a different result with 279 Herefore cow-calf pairs. Dams nursing female calves gave significantly more milk than those nursing males as female calves consumed 2.53 lbs. more milk over the entire seven-month lactation period than male calves. A significant quadratic effect was found for age of dam on milk yield, whereas the linear effect was not significant. The linear regression of total milk yield on calf birth weight was 0.51, indicating that heavier calves at birth had a great capacity to consume milk and thus demanded more milk from their dams.

Neville et al. (1974) studied the age of dam effects on milk production in 1218 lactations of Hereford dams. Age of dam was found to have a significant influence on daily milk yield which suggests the importance of using age of dam correction factors for milk production in beef cows. Calf birth date significantly affected milk production, but sex of the calf did not.

Most of the results available were based on investigations involving the Hereford and the Angus, two of the most popular beef breeds in the country today. Thus, very few comparisons have been made between the milk yield estimates of the different beef breeds. However, Melton et al. (1967) reported a comparative study in the milk production, milk composition and calf gains of 15 Angus, 15 Charolais and 15 Hereford cows. The average estimated daily milk yields for the 175-day lactation period for the Angus, Charolais and Hereford cows were 9.86, 8.35 and 7.30 lbs., respectively. Age of dam was also found to have a significant effect on dam's milk yield; with older cows having the tendency to produce more milk. Cows nursing bull calves gave 1.28 lbs. more milk per day than cows nursing heifer calves; however, this difference was not statistically significant.

Auran (1973) studied the monthly milk yield records of dairy cattle in Norway. Age at calving did influence the monthly milk yield but the effect decreased with advancing age of the dam. About 41% of the variation in milk yield at the first month was attributed to this factor. Month of calving accounted for about 1.8% of the variation on the first test-day, but continued to increase as lactation progressed. The effect of herd accounted for quite a substantial portion of the variation in milk yield (between 25-45% of the variation).

These studies provide substantial evidence that variation in daily milk production of the beef cow was due to several environmental factors, namely age of dam, calf birth weight and breed of cow. On the other hand, calf birth date, sex of calf and sire of calf were variable in their effects on milk yield. Since age of dam is the most consistent factor affecting the milk yield of beef cows, it is important to use age of dam correction factors for beef milk production in order to make better genetic comparisons between beef cow productivity and calf weaning weights.

Calf Gain as an Indicator of Dam's Milk Production

The economic value of rapid gain especially from birth to weaning has long been realized by most beef producers. Most studies dealing with milk production of beef cows have attempted to correlate the amount of preweaning gain made by the calf with the dam's milk yield. In most of the research cited thus far, the choice of the method for measuring the milk yield was the calf suckling technique. This technique assumes that the gain made by the calf during the nursing period was due to the milk consumed and that this represents the milk yield capabilities of the cow.

About 60-66% of the variation in weaning weight has been reported to be due to milk consumption by the calf (Drewry et al, 1950; Neville, 1962 and Rutledge et al., 1972). Most of the results indicated a positive correlation between weight gain from birth to weaning and the amount of milk consumed by the calf. Knapp and Black (1941) reported a correlation of 0.52 between daily gain and the amount of milk produced.

Gifford (1953) reported that the average daily gain in weight each month from birth to weaning date for 28 Hereford calves ranged from 1.1 to 1.6 lbs., even though the average daily milk production of their dams ranged from 8.5 lbs. during the first month to 4.1 lbs. the eighth month. In fact the gain in weight was quite uniform during the eight-month period, with a slight trend toward larger gains with increased age, even though there was a gradual decline in milk and butterfat production. The correlations for the average daily milk production of the Hereford dams with the eight monthly gains from the first to the eighth month were 0.60, 0.71, 0.52, 0.35, 0.19, 0.24, 0.39 and 0.57, respectively.

Burris and Baugus (1955) estimated milk production of 23 Hampshire ewes by allowing the lambs to suckle their dams four times per day. Milk production was highly correlated with average daily gain of their lambs during the first four weeks (r = 0.90). The correlation decreased rapidly as the lambs grew older and the average daily gain of the lambs was no longer significantly correlated with milk consumption from 12 to 16 weeks of the test period. However, the total milk production was highly correlated with the average daily gain of the lambs (r = 0.83).

Drewry et al. (1959) studied the milk production of 48 Angus cows and reported a negative correlation of -.15 between the dam's milk production and total weight gain of the calf during the first month of lactation. But the correlation was positive for the subsequent months showing that the calf would gain more as milk consumption increased.

Lampkin and Lampkin (1960) studied the effect of dam's milk production and growth of their suckling calves in Zebu cattle in East Africa. Male calves gained more than females over the total suckling period. This possibly reflected a higher level of milk consumed by the male calves and a correlation between calf daily gain and dam's milk production.

Todd et al. (1969) found that the amount of variation in gain of the progeny due to the difference in dam's milk yield decreased as the lactation period progressed. This suggested that the dam's milk yield had progressively less influence on progeny gain as the calf approached weaning.

Research results in the efficiency of gain from beef milk production were quite variable. Drewry et al. (1959) estimated that Angus calves required 12.5, 10.8 and 6.3 lbs. of milk to produce a pound of gain in the first, third and sixth months of lactation, respectively. Calves that suckled higher producing dams made the least gain from a pound of milk, probably due to the higher maintenance requirements of the heavier calves. Melton et al. (1968) compared Angus, Charolais and Hereford dams for milk production and found that on the average the calves required 5.2 lbs. of milk to produce one pound of gain over all breeds. Hereford was most efficient requiring only 4.7 lbs. of milk per pound of gain, whereas Angus and Charolais needed 5.7 and 5.2 lbs. of milk, respectively, for every pound of gain.

Wistrand and Riggs (1968) studied 10 to 20 Santa Gertrudis calves and found that they needed slightly more milk to produce a pound of gain than those reported by Melton et al. (1968). Todd et al. (1969) found that Brahman and their crosses and Angus-Hereford-Brahman crosses required more milk per pound of gain than Herefords. Herefords were the most efficient among all the groups, requiring only 4.53 lbs. of milk per pound of gain.

Most studies reviewed thus far agreed that a high correlation existed between preweaning gain of the calf and the dam's daily milk production. This was the basis for taking the calf weight gain as a measure of the milk yield of the dam in the calf suckling technique. This relationship was prominent and seemed to increase till up the middle of the lactational period after which it started to decline.

Results in the efficiency of gain from milk of the various beef breeds were variable and on the average most beef calves required about 12 lbs. of milk to produce a pound of gain.

Sampling Procedure and the Milk Measuring Technique

Estimating the milk yield of beef cows has not received the same kind of interest and attention as that which has occurred in dairy cattle. Among the reasons for the probable causes of this lack of enthusiasm are firstly, the beef cow is not historically known to have been selected and bred for milk production; secondly, it is difficult to obtain an accurate estimate of the milk yield in beef cows, especially under range condition; and thirdly, since beef milk production could be estimated from a calf weight gain, the actual measurement of her milk yield did not seem very necessary or economical.

Dickinson and McDaniel (1970) stated that there are two types of problems associated with any sampling plan, bias and random variation. Random variation is inherent to any sampling procedure. However, bias is not necessarily present in sampling and in most cases bias hopefully is absent. On the other hand, the goal of any sampling procedure is to minimize both bias and random variation and yet still be practical and economical to operate.

Porzio (1953) proposed that monthly testing based on only one milking be used as an alternate form of milk yield recording. The morning milking would be weighed one month and the night milking the alternative month. No bias in the result was found in the 150 dairy lactations studied.

McDaniel (1969) reviewed the literature currently available on the accuracy of sampling procedures for estimating lactation yields in dairy cows. A single day's yield at a monthly test period has become more and more accepted as the standard to estimate the lactation yield in the United States and in Europe. Monthly sampling procedure has been assumed to give rather accurate estimates of lactation yields.

When lactation yield estimated from bimonthly testing with the same record based on monthly tests were compared, Alexander and Yapp (1930), Bifford (1930) and Bayley et al. (1952) found that the bimonthly tests could give unbiased estimates of the lactation yields. In general, bimonthly records are certainly sufficient for purposes such as herd averages, sire evaluation and group averages. They are also satisfactory for ranking cows within herds. But these estimates are not acceptable for inclusion in the national dairy herd improvement program.

However, there is a lack of information on the accuracy of sampling procedures used in milk production studies in beef cows. Most studies reported so far have involved the monthly milk recording to estimate the milk production of the dam (Gifford, 1953; Neville, 1962; Melton et al., 1967 and Rutledge et al., 1972). One probable reason why most researchers were not concerned about the accuracy of this sampling procedure was that it is not the total milk production of the cow that is of utmost importance, rather it is how much milk could the calf consume and convert to gain.

Several methods have been developed in trying to estimate the milk production in beef cows. Most of these milk yield measuring techniques do not exactly measure the actual milk producing ability of the cows;

instead they are measuring other traits which have some relationship with the dam's milk producing ability.

Calf suckling technique was widely used in a number of studies in beef milk production (Knapp and Black, 1941; Drewry et al., 1959; Dawson et al., 1960; Lampkin and Lampkin, 1960; Neville, 1962; Van Cottem, 1962; Pope et al., 1963; Gleddie and Berg, 1968; Rutledge et al., 1972; Dickey, 1972 and Neville et al., 1974). By this method the difference in weight before and after the calf has suckled its dam is taken as a measure of the milk yield estimate of the dam.

Jara-Almonte and White (1973) used this technique to measure the milk yield of mice. The young mice were allowed to suckle their dams for a period of 1.5 hours. The difference in individual weight before and after suckling was taken as the milk intake of the youngs.

Lams et al. (1969) compared three techniques for estimating milk production, namely a six-hour oxytocin test which was actually a measure of the rate of milk secretion, a 24-hour calf suckling method which estimated the daily milk intake and an overnight calf suckling together with oxytocin injection which was really an estimate of the udder capacity. The first two methods gave similar estimates while the latter gave a significantly higher estimate, 23% higher than the other two estimates.

Lamond et al. (1969) suggested that one reason for the use of oxytocin injection was to evacuate the udder in order to eliminate variation due to residual milk since the volume of residual milk varied from day to day, particularly when the cow was stressed.

Nursing technique has an advantage over milking the cows by hand or with a machine in that it takes advantage of any ability of the calf to encourage the cow to give milk. But this method is limited by the amount of milk a calf can consume and the estimate obtained may not give the true lactation yield. Use of oxytocin injection in milk evaluation technique is primarily for the purpose of stimulating milk letdown. Milk yield estimates were commonly sampled at monthly intervals in most of the studies cited.

Summary of Literature Review

Milk constitutes the major source of nutrients early in a calf's life. Some differences in the maternal effect could be accounted for by differences in the milking ability of the cows. The existence of a possible negative genetic correlation between the direct and maternal effects would indicate that rapidly gain heifers would tend to have a lower production in the future. Certain environmental factors have been reported to influence the milk production of the dams. Age of dam effects were highly significant with older cows giving more milk than younger cows. Sex of calf was variable in its effects on milk production with the majority of the reports indicating nonsignificance in the sex of calf effects. Calf birth date and sire of calves were also variable in their effects on the lactational performance of the dams. Preweaning gain in weight from birth to weaning was highly correlated with the milk yield of the dam. On the average about 12 lbs. of milk was needed to produce a pound of calf gain but this varies with breed of calf. The calf nursing technique was the most common method used in most beef milk production studies. By this technique the calf was weighed before and after suckling and the difference in the two pre- and post-nursing weights was taken as the estimate of the 12-hour period. Two estimates were commonly obtained daily at monthly intervals to estimate the daily milk production of the dam. Other methods of measuring the milk yield are hand milking with the use of oxytocin injection and hand milking one half of the udder and calf suckling the other half.

CHAPTER III

MATERIALS AND METHODS

General Procedure

This study involves the lactational performance of 459 beef cows, 144 Herefords and 315 Angus. The data comes from a long-term beef cattle selection project being conducted at the Oklahoma Agricultural Experiment Station. The overall objectives for this selection study located at the Ft. Reno Livestock Research Station are (1) to measure direct and correlated genetic response to selection for increased body weight at 205 and 365 days of age, (2) to measure genetic relationship between body weight at 205 and 365 days of age and (3) to compare realized genetic response from selection based on individual performance with selection based on a combination of individual and progeny test performance for increased body weight at 205 days of age.

The design of the selection experiment is presented in Table I. The general procedure is to measure direct and correlated selection responses for weaning (205-day) and yearling (365-day) weight in two Hereford lines, 5 and 6, and two Angus lines, 7 and 8. An additional Angus line, 9, is maintained as a control line to aid in the evaluation of selection progress. A fourth Angus line is maintained to evaluate the effectiveness of progeny testing for increasing weaning weight. Selection is based on individual performance of lines 5, 6, 7 and 8. Line 9 is a random mating line in which the breeding stock are as near to the herd

TABLE I

DESIGN OF THE BEEF CATTLE SELECTION EXPERIMENT

	Line Number					
	5	6	7	8	9	10
Breed[a]	H	H	A	A	A	A
Trait Selected: Wt. at Specified Age	205	365	205	365	RMC[b]	205
Selection Criteria[c]	I	I	I	I		I/P
Number of Males Selected per Year	2	2	2	2	2	5/2[d]
Number of Years Selected Males Used	2	2	2	2	2	2
Number of Females per Year	10	10	10	10	10	10

[a]H = Hereford, A = Angus.

[b]Random mating control line. Replacement breeding stock are as near herd average in 205-day wt. and 365-day wt. as possible.

[c]I = Individual, P = Progeny.

[d]Five sires initially selected for progeny testing on the basis of their 205-day wt. The top two bulls are selected for use in the line based on progeny 205-day wt.

average for 205-day and 365-day weight as possible. A combined selection criterion of individual performance and progeny testing is used in line 10. Two bulls are selected in a line each year except for line 10 where five sires are initially selected for progeny testing on the basis of their 205-day weight and the two top bulls are selected for use in the line based on the average 205-day weight of their progeny. The two selected sires are used in two successive years. Every year 10 females are selected in each line as replacements for the 50 cows maintained in each line.

The cows from the six selection lines were managed generally as one herd except during the 90-day breeding season from May 1 to July 31 when they were run in their respective breeding groups. The breeding season was reduced to 60 days by 1971 and has been continued at that length to the present. During the late fall and winter, the cows were run on wheat pasture when available, otherwise, they were pastured on native range throughout the year and supplemented with prairie hay and alfalfa as needed. The nursing calves were allowed to run with their dams on the native pasture without creep feed until weaning at an average age of 205 days.

Estimates of daily milk yield of the dams were obtained at monthly intervals from April to September for each year studied. The number of cow-calf pairs sampled each year is presented in Table II.

Estimates of Daily Milk Yield of the Dams

In this study the calf suckling technique was used to estimate the daily milk yield of the dam and was similar to that described by Pope et

TABLE II

NUMBER OF COWS SAMPLED FOR ESTIMATING DAILY MILK YIELD BY SELECTION LINE AND YEAR

Year	Line	5	6	7	8	9	10
	Breed[a]	H	H	A	A	A	A
1967		34	33				
1968				35	41		
1969						34	39
1970		39	38				
1971				21	20	18	17
1972				22	24	22	22
Total		73	71	78	85	74	78

[a]H = Hereford, A = Angus.

al. (1963) and Hendrix (1971). This procedure is based on using the difference in the weight of the calf before and after suckling as the estimate of the milk consumed.

In the present study, the suckling technique consisted of separating the calves from their dams at approximately 10:00 a.m. the day prior to the test. The calves remained separated until 6:00 p.m. when they were allowed to nurse their dams. This is simply a pretest milkout in order to place the cows and the calves on an equal basis relative to udder fill and hunger, respectively. After nursing, the calves were immediately separated. At 6:00 a.m. on the test day, the calves were weighed before nursing, allowed to nurse their dams and reweighed immediately after nursing. Although the actual time interval from nursing varied from group to group, it generally was in the range of 18 to 30 minutes. The difference in the pre- and post-nursing weights was taken as the milk production of the dam for the 12-hour overnight period. The calves were kept separated from their dams until 6:00 p.m., at which time the weighing and nursing procedure was again repeated. The sum of the two 12-hour estimates of milk production were used as an estimate of the milk production by the dam for a 24-hour period. Milk yield was measured on one half of the cow-calf pairs from each line involved in milk production measurement in a given year on a Tuesday near mid-month and the remaining one half were measured on Thursday of the same week. This was necessary because the facilities were not adequate to accomodate all the cattle at the same time.

Statistical Treatment of the Data

The analysis was carried out in three phases, each phase was aimed at answering one of the objectives of this study. Phase I dealt with the identification of various factors affecting daily milk production of the dam. Phase II of the analysis was concerned with the prediction of daily milk yield using the performance data of the calf and its dam. Phase III was concerned with estimating daily milk yield based on various sub-sets of the milk production data to see if the sampling techniques for measuring milk yield could be simplified without seriously affecting the accuracy of the estimate.

A computer program (SAS) developed by Barr and Goodnight (1972) was used to carry out the analysis. Only data from cow-calf pairs in which all six monthly milk yield measurements as well as complete performance data to weaning on the calf were included in the analysis.

The grouping of the cow-calf pairs into each phase of the analysis is presented in Table III. In Phase I, the two Hereford lines, 5 and 6, were grouped together for the two years in which they were sampled. Similarly, the four Angus lines were divided into two groups, lines 7 and 8 into one group and lines 9 and 10 into another group for the three years in which each group was sampled. The division of the cow-calf pairs into the three groups was necessary in order to facilitate the computation of the desired statistics using the SAS program. For purposes of analyzing Phase II and III, the cow-calf pairs were divided by breed group with the Hereford lines (5 and 6) in one group and the Angus lines (7, 8, 9 and 10) in another.

TABLE III

DIVISION OF COW-CALF PAIRS INTO PHASE I, II AND III OF THE ANALYSIS

Year	Line	5	6	7	8	9	10
	Breed[a]	H	H	A	A	A	A
1967		33	34				
1968				35	41		
1969						34	39
1970		39	39				
1971				21	20	18	17
1972				22	24	22	21
Sub-total		73	71	78	85	74	78
Sub-total for Phase I		144 Group I		163 Group II		152 Group III	
		PHASE I					
Sub-total for Phase II and III		144		315			
		PHASE II AND III					

[a]H = Hereford, A = Angus.

Sources of Variation in Average Daily Milk Yield

Variation in milk yield was examined in 144 and 315 lactations of Herefore and Angus cows, respectively. The dependent variable was the average daily milk yield which was the average of the six monthly 24-hour measures of milk yield. The model assumed for this within each analysis group was:

$$
\begin{aligned}
Y_{ijklmno} = \mu &+ L_i + Y_j + S_k + a_{\ell(i,j)} \\
&+ A_m + C_n + (LY)_{ij} + (LS)_{ik} \\
&+ (LA)_{im} + (YS)_{jk} + (YA)_{jm} \\
&+ (SA)_{km} + b_1(BW - \overline{BW}) + b_2(ACW - \overline{ACW}) \\
&+ b_3(FCCS - \overline{FCCS}) + b_4(CCWT - \overline{CCWT}) \\
&+ e_{ijklmno}
\end{aligned}
$$

where

$Y_{ijklmno}$ is the average daily milk yield of the dam;

μ is the overall mean common to all dams;

L_i is the effect of i-th line ($i = 1, 2$);

Y_j is the effect of the j-th year ($j = 1, 2$ or $1, 2, 3$, for Group I or Groups II and III, respectively);

S_k is the effect of the k-th sex of calf ($k = 1, 2$);

$a_{\ell(i,j)}$ is the effect of the ℓ-th sire of the calf within the i-th line and the j-th year ($\ell = 1, 2, \ldots, 16$ or 22 or 23, for Groups I or II or III, respectively);

A_m is the effect of m-th age of dam (m = 1, 2, ..., 4);

C_n is the effect of n-th birth date of calf (n = 1, 2, ..., 5);

$(LY)_{ij}$ is the line by year interaction;

$(LS)_{ik}$ is the line by sex of calf interaction;

$(LA)_{im}$ is the line by age of dam interaction;

$(YS)_{jk}$ is the year by sex of calf interaction;

$(YA)_{jm}$ is the year by age of dam interaction;

$(SA)_{km}$ is the sex of calf by age of dam interaction;

$b_1(BW - \overline{BW})$ is the partial regression coefficient on birth weight of calf;

$b_2(ACW - \overline{ACW})$ is the partial regression coefficient on average cow weight which was the average of the cow fall and spring weights;

$b_3(FCCS - \overline{FCCS})$ is the partial regression coefficient on fall cow condition score;

$b_4(CCWT - \overline{CCWT})$ is the partial regression coefficient on change in cow weight which was taken as the difference between the spring and fall cow weight; and

$e_{ijklmno}$ is the random variable assumed to be normally distributed with mean 0 and variance σ^2.

Line, year, sex of calf, sire of calf, age of dam and calf birth date were considered as fixed effects. Sex of calf was classified into two categories, 1 and 2, for the bull and heifer calves, respectively. There were four age of dam classifications, namely two year old (less than 30 months), three year old (between 31 and 42 months), four year old (between 43 and 54 months) and five year old (greater than 55 months). Calf birth date was classified into five groups, with groups 1, 2, 3, 4 and 5 for those calves that were born before February 14, between February 15-28, between March 1-14, March 15-28 and after March 29 in the year studied, respectively.

The partial regression coefficients included in the model would place the average daily milk production on the same basis as if the cows all had average cow weight, fall cow condition score and change in cow weight and had calves of average birth weight. The fall condition of a cow was scored on a scale of 1 to 9 with 1 being very thin and 9 being very fat.

Predicting the Average Daily Milk Yield (ADMY)

To predict the ADMY of the dam required the identification of the related variables that were more highly correlated with the trait. A correlation study was performed between ADMY and all possible variables of the dam's and her calf's performance to identify the variables that were highly correlated with ADMY. All possible one-factor, two-factor, three-factor, four-factor and five-factor regression models were developed from the five variables that were found to have the highest correlations with milk yield. These five variables were the calf's average daily gain, the calf's weaning weight, the calf's weaning condition score, the fall cow condition score and the change in cow weight.

The prediction models assumed for the trait ADMY were:

(i) one-factor model

$$Y_i = B_0 + B_1X + e_i$$

(ii) two-factor model

$$Y_i = B_0 + B_1X_1 + B_2X_2 + e_i$$

(iii) three-factor model

$$Y_i = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + e_i$$

(iv) four-factor model

$$Y_i = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + e_i$$

(v) five-factor model

$$Y_i = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 + e_i$$

where

Y_i is the predicted average daily milk yield;

B_0 is the overall mean;

B_i is the partial regression coefficient of the independent variable, X_i for each of the five respective models;

The independent variables considered were the average daily gain of calf, weaning weight of calf, calf weaning condition score, fall cow condition score and change in cow weight; and

e_i is the random element normally distributed with mean 0 and variance σ^2.

The analysis for this phase of the study was done by breed groups since preliminary examination of the coefficients of determination indicated that there were large differences in the amount of variation that could be accounted for by the same model in the two breed groups.

Improving the Sampling Procedure and the Milk Measuring Technique

The analysis for Phase III was done by breed groups similar to Phase II, namely Hereford lines 5 and 6 in one group and Angus lines 7, 8, 9 and 10 in another group. Correlations between the six monthly milk measures and between ADMY based on the first and second 12-hour estimates and ADMY based on two 12-hour estimates were examined as well as correlations between subsets of the six monthly milk measures ADMY.

CHAPTER IV

RESULTS AND DISCUSSION

Lactational Performance of Hereford and Angus Cows

The means and standard deviations for various milk yields and calf growth traits by breed groups are presented in Table IV. No direct comparisons of milk yield are possible between the two breeds because the estimates of the daily milk yields from the two breeds were not obtained in the same years. Milk yields in the Hereford dams were measured in only two years, 1967 and 1970, while the Angus milk yield estimates were sampled from four years, 1968, 1969, 1971 and 1972. However, averaging the milk yield of each breed over the respective years each were sampled provides some indication that Angus dams produced more milk per day than Hereford dams for each of the six months sampled and over the entire lactation period. The average daily milk yield over the six-month periods were 9.88 and 14.93 lbs. for the Hereford and the Angus dams, respectively. These were higher than the estimates of the average milk yields for a 175-day period reported by Melton et al. (1967) which were 7.31 and 8.36 lbs. for the Hereford and the Angus dams, respectively. Todd et al. (1969) reported a lower daily milk yield of 7.3 pounds for the Hereford dams. The first 12-hour milk yield over the entire lactation period was higher than the second 12-hour milk yield for both the Herefords and the Angus. All calf growth traits examined were higher in

TABLE IV

MEANS AND STANDARD DEVIATIONS FOR VARIOUS MILK YIELDS AND GROWTH TRAITS BY BREEDS POOLED WITHIN YEAR AND LINE[d]

	Hereford		Angus	
	Mean	S.D.	Mean	S.D.
Number of Cow-calf Pairs	144		315	
April ADMY,[a] Lbs.	11.57	3.79	15.43	4.46
May ADMY, Lbs.	10.67	3.28	17.10	4.53
June ADMY, Lbs.	10.95	3.40	17.45	4.78
July ADMY, Lbs.	9.94	3.44	14.58	4.42
August ADMY, Lbs.	8.35	4.02	14.19	5.05
September ADMY, Lbs.	7.60	3.44	11.10	3.83
First 12-Hr. Milk Yield (6 Mons.), Lbs.	5.28	1.41	7.69	1.54
Second 12-Hr. Milk Yield (6 Mons.), Lbs.	4.61	1.24	7.26	1.52
Six Mons. ADMY (April to September), Lbs.	9.88	2.46	14.93	2.78
Calf ADG[b] (Birth to Weaning), Lbs.	1.66	0.24	1.81	0.25
205-Day Age of Dam Adjusted W. Wt.,[c] Lbs.	428.23	48.29	459.77	54.19
Calf Weaning Condition Score	4.04	0.69	4.57	0.75
Fall Cow Weight, Lbs.	1007.43	116.38	980.35	120.66
Fall Cow Condition Score	5.64	1.01	5.79	1.32

[a]Average Daily Milk Yield.

[b]Average Daily Gain.

[c]Weaning Weight.

[d]Means are calculated from a six-year period with the Hereford dams sampled in 1967 and 1970 and the Angus dams sampled in 1968, 1969, 1971 and 1972.

the Angus than in the Herefords, except for the fall cow weight which was higher in the Herefords than in the Angus. Further critical comparison between these two breed means for all of the traits studied should be cautioned because the traits measured in the two breeds were recorded in different years. There were quite a great deal of fluctuations in the monthly milk yield estimates of the Hereford and the Angus dams of different lines in different years (Appendix Tables XIX, XX, XXI and XXII).

The lactational pattern of the Hereford dams in the two years sampled is given in Figure 1. Generally the trend in the lactational performance of the two lines, 5 and 6, was more alike when examined by the year when the estimates of the daily milk yields were taken. The estimate for the first month was the highest in the entire six months lactation period for the two lines in 1967, but not in 1970. There was a gradual decline in the average daily milk yield estimates of line 6 dams in 1967 following the first month of milk measurement. Milk yield estimates of line 5 dams fluctuated over the entire lactation period in 1967, but the lactational performance of line 5 dams in 1970 showed a gradual decline as the lactation progressed. It should be noted that dams selected for weaning weight (line 5 Herefords) showed a consistent higher level of milk yield than line 6 Hereford dams, which were selected for yearling weight.

The lactational pattern of the Angus dams in the four years (1968, 1969, 1971 and 1972) sampled is presented in Figures 2, 3 and 4. The dairy milk yield estimates in lines 7 and 8 in 1968 showed sharp increases after the first month of milk measurement and then began to decline after the second month of sampling. The lactational pattern of

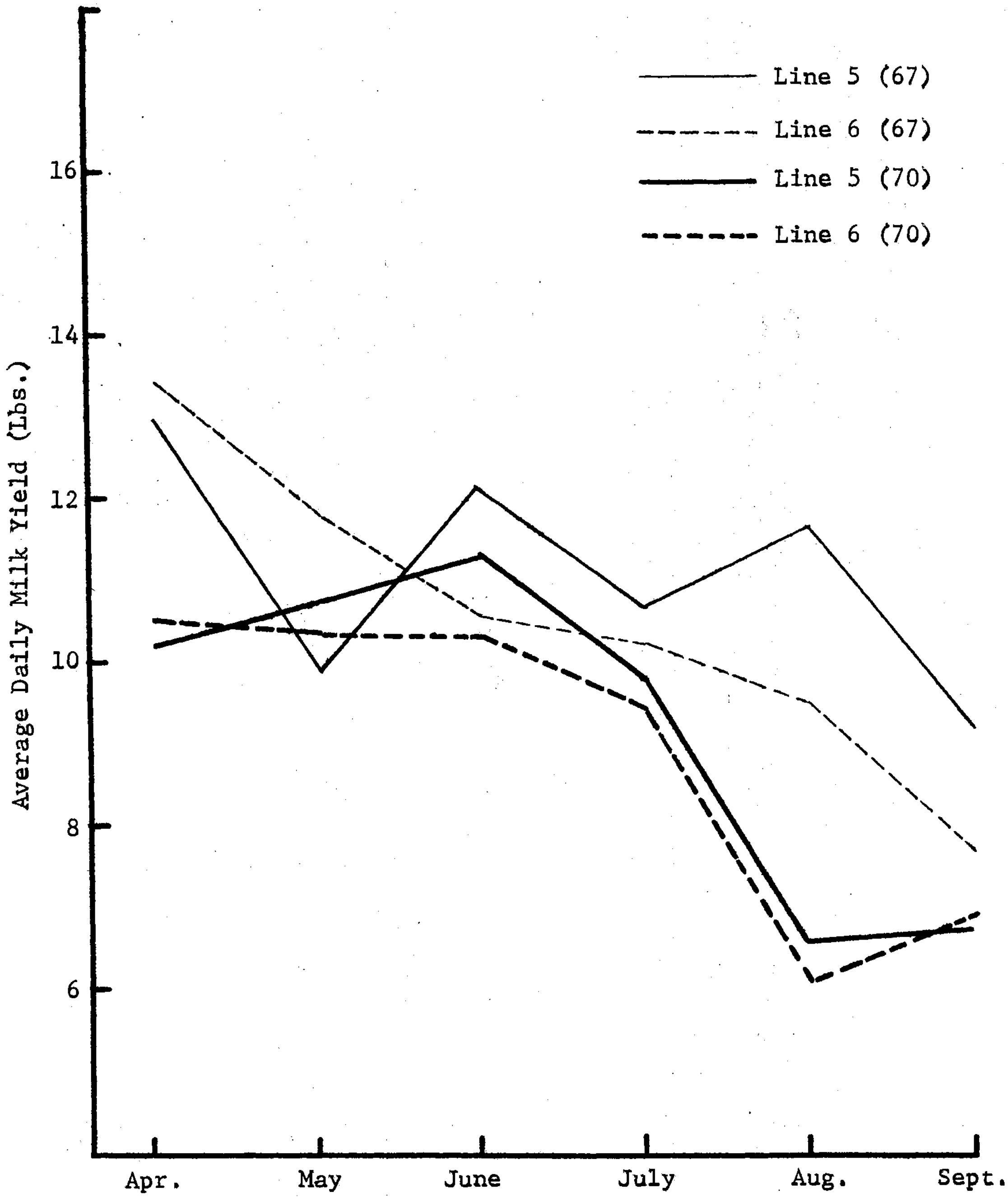

Figure 1. Average Daily Milk Yield Over Entire Lactation Period for Hereford Dams by Line and Year

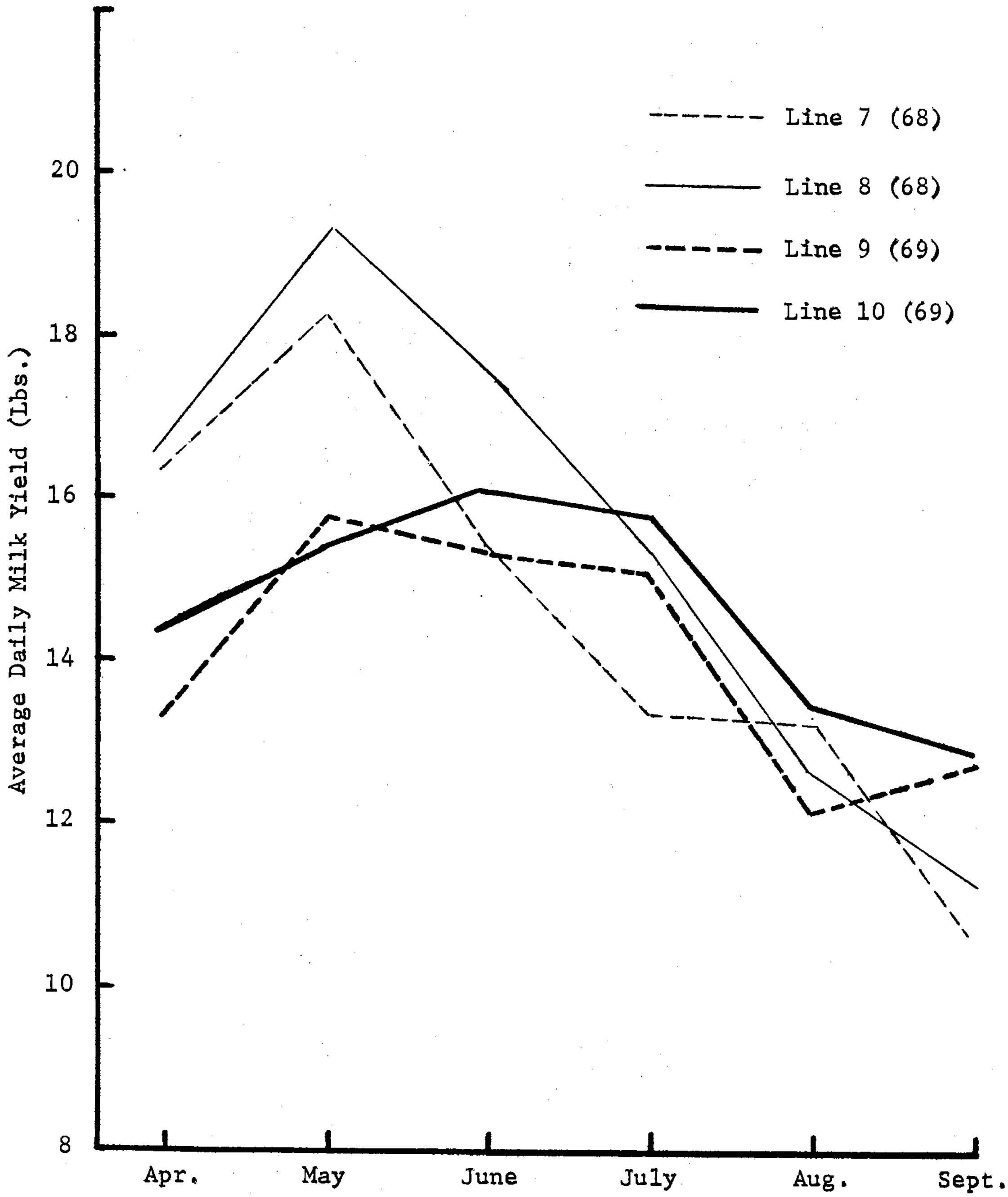

Figure 2. Average Daily Milk Yield Over Entire Lactation Period for Angus Dams by Line and Year

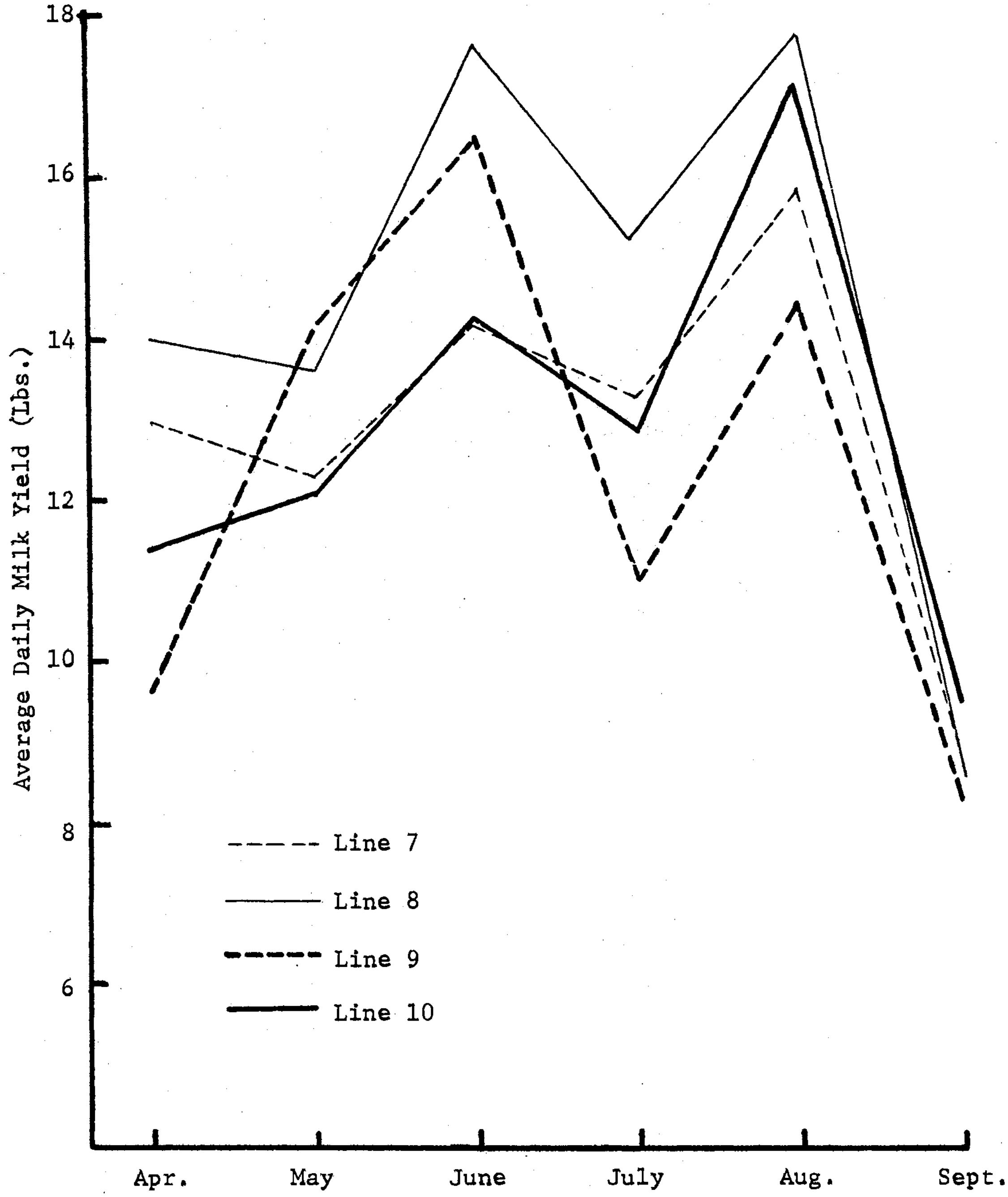

Figure 3. Average Daily Milk Yield Over Entire Lactation Period for Angus Dams in 1971 by Lines

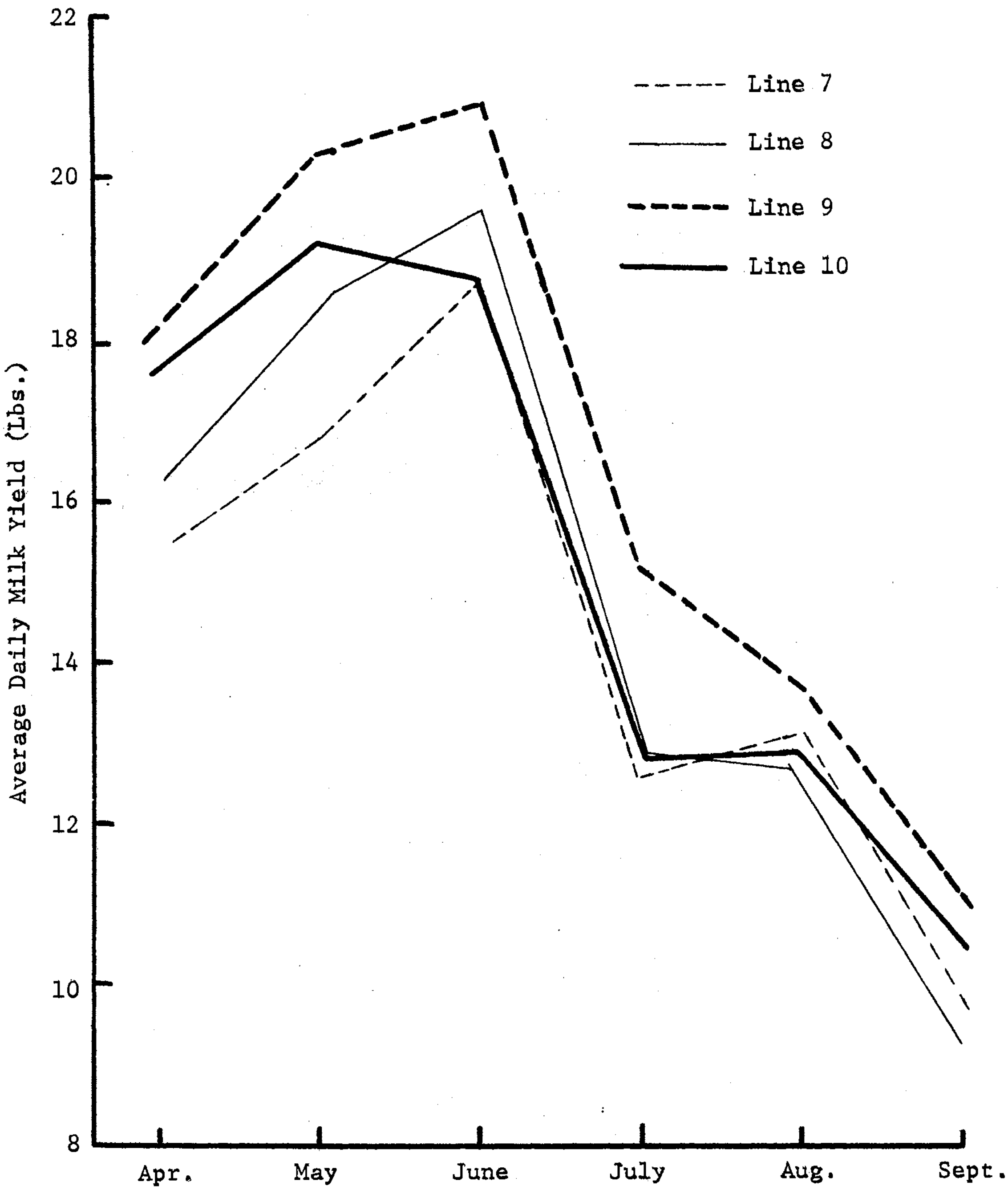

Figure 4. Average Daily Milk Yield for Entire Lactation Period for Angus Dams for 1972 by Lines

lines 9 and 10 conformed more closely to the lactational curves normally seen in the dairy cows, showing a gradual increase following the first month of milking and stayed at a relatively high level during the middle of the lactational period which coincided with the lush growth of the summer pasture. Following that, the estimates decreased gradually towards the end of the lactational period. There was a relatively large fluctuation in the lactational yields of the Angus dams in 1971 with a sharp decline during fourth month of sampling (Figure 3). Generally, the lactational performance in 1972 followed that observed in 1968, but with a much longer high peak level after the first milk measurement (Figure 4).

The lactational pattern for the two breeds averaged over all years and lines is presented in Figure 5. On the average the lactational pattern of the Angus dams was nearly alike that of the dairy cows showing a gradual increase in milk yield following the first month of milking and then began to decline after reaching its peak during the third month of the lactation period. The Hereford dams exhibited a similar lactational pattern to that of the Angus but at a lower level.

Sources of Variation in Daily Milk Yield

Separate analysis was performed on each of the three groups described in the experimental procedure. The three groups were Group 1 (Herefords, lines 5 and 6, measured in years 1967 and 1970), Group 2 (Angus, lines 7 and 8, measured in years 1968, 1971 and 1972) and Group 3 (Angus, lines 9 and 10, measured in years 1969, 1971 and 1972). The mean squares from the analysis of variance for average daily milk yield

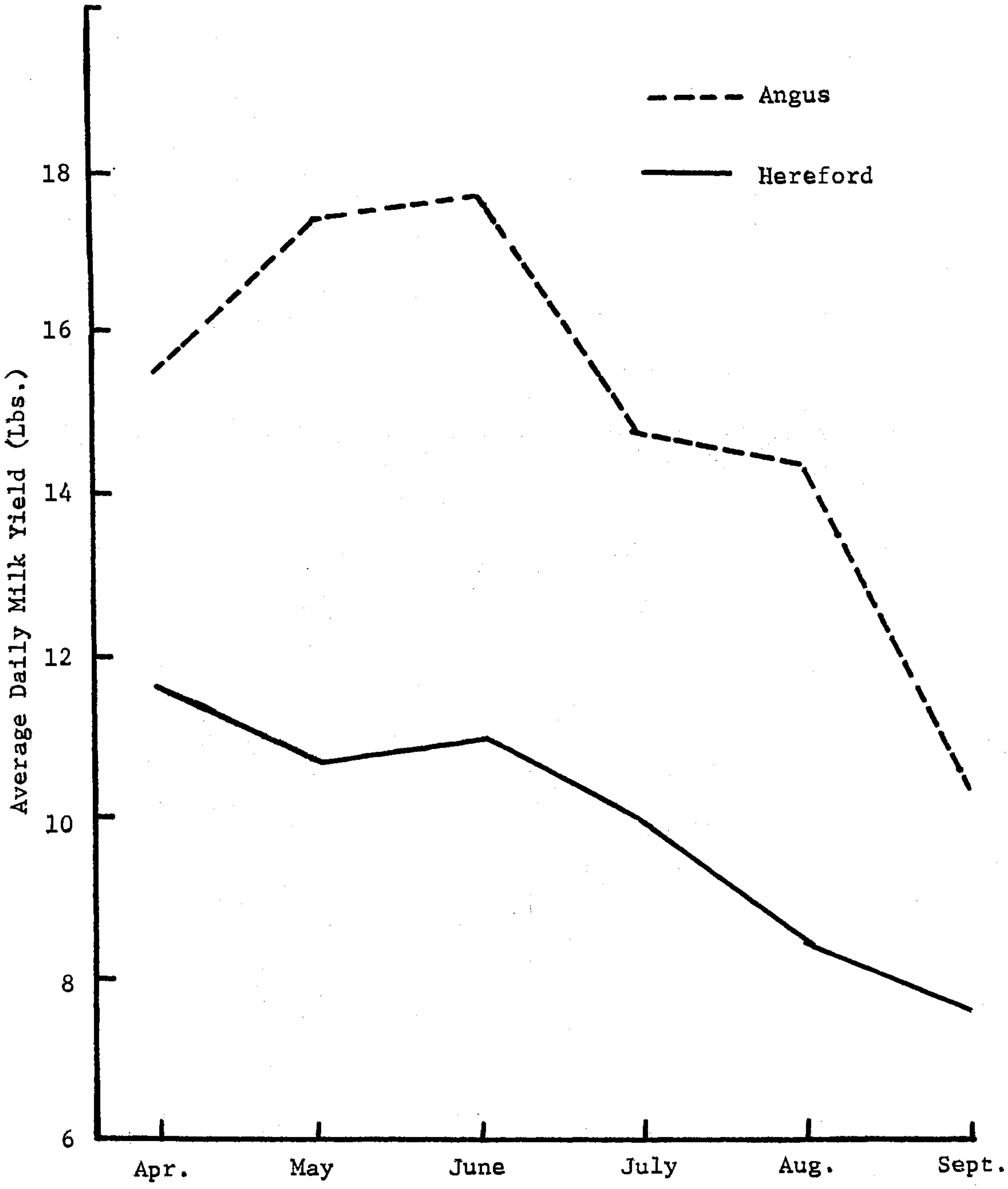

Figure 5. Average Daily Milk Yield Over Entire Lactation Period for Hereford and Angus Dams Over All Lines and Years

for each of the three groups are presented in Table V. Table VI presents the least square constants for three fixed effects that were important in influencing daily milk yield included in the regression model and the standard partial regression coefficients for the four covariables, namely calf birth weight, average cow weight, fall cow condition score and change in cow weight which was defined as the difference between the fall and spring cow weights are presented in Table VII. The least square constants for the other fixed effects are shown in Appendix Table XXIII.

Line effects were significant in Groups 1 and 2. Line 5 Hereford dams produced 0.40 lb. more milk per day than Hereford dams of line 6. Angus cows in line 7 gave 0.66 lb. less milk to their calves than line 8 dams. Although line effects were not significant in Group 3, the average daily milk yield of line 10 dams was 0.18 lb. higher than that of line 9 dams. The effects of years were highly significant ($p < .01$) only in Group 2 as the estimates of the daily milk yields of the Angus dams sampled in 1968 were higher than the estimates obtained in 1971 and 1972 (1.04 lbs. for 1968 vs. -.16 and -.87 lb. for 1971 and 1972, respectively). Year effects were not significant in Groups 1 and 3. Rutledge et al. (1972) reported significant year effects on total milk yield as the estimates of the total milk yields of the Hereford dams sampled in 1969 were 2.80 lbs. higher than those sampled in 1968.

Although sex of calf was not significant in any of the groups studied, male calves consumed 0.20, 0.07 and 0.73 lbs. more milk per day than female calves in Groups 1, 2 and 3, respectively. This result is in agreement with those reported by Christian et al., 1965; Melton et al., 1967, and Neville et al., 1974, who found that sex of calf was not

TABLE V

MEAN SQUARES AND TESTS OF SIGNIFICANCE FOR AVERAGE DAILY MILK YIELDS OF GROUP 1 (LINES 5 AND 6), GROUP 2 (LINES 7 AND 8) AND GROUP 3 (LINES 9 AND 10)

Source	Herefords Group 1		Angus Group 2		Angus Group 3	
	df	MS	df	MS	df	MS
Fixed Effects:						
Line (L)	1	15.123*	1	43.119**	1	2.303
Year (Y)	1	7.645	2	21.675**	2	6.920
Sex (S)	1	3.438	1	0.310	1	0.695
Sires/Line × Year	12	4.905	18	6.722*	19	4.162
Age of Dam (A)	3	30.357**	3	34.946**	3	28.151**
Calf Birth Date	4	1.740	4	4.192	4	3.633
LXY	1	0.076	2	0.685	2	3.126
LXS	1	24.377**	1	0.277	1	9.590
LXA	3	2.723	3	4.389	3	3.433
YXS	1	4.091	2	1.240	2	6.143
YXA	3	5.387	6	18.525**	6	5.911
SXA	3	5.725	3	14.950*	3	5.757
Covariables:						
Calf Birth Weight	1	0.095	1	10.739	1	5.382
Average Cow Weight	1	6.277	1	3.484	1	1.582
Fall Cow Condition Score	1	2.175	1	11.614	1	2.389
Change in Cow Weight	1	14.892*	1	0.031	1	1.408
Random Effect:						
Error	104	2.833	112	3.794	100	5.629
Total	142		162		151	
Coefficient of Determination (R^2)		0.653		0.661		.521

*$p < .05$.

**$p < .01$.

TABLE VI

LEAST SQUARE CONSTANTS AND STANDARD ERRORS FOR LINE, SEX OF CALF AND AGE OF DAM FROM THE ANALYSES OF VARIANCE FOR GROUPS 1, 2 AND 3[a]

Fixed Effects	Least Square Constants ± Std. Errors		
	Group 1	Group 2	Group 3
Line[b]	0.403 ± .174 (5)	- .661 ± .196 (7)	- .179 ± .280 (9)
	- .403 ± .205 (6)	0.661 ± .184 (8)	0.179 ± .284 (10)
Sex of Calf			
Male	0.197 ± .179	0.065 ± .227	0.093 ± .263
Female	- .197 ± .199	- .065 ± .227	- .093 ± .264
Age of Dam			
≤ 2 Yr. Old	-1.448 ± .445	-2.040 ± .409	-2.035 ± .609
3 Yr. Old	- .557 ± .366	0.286 ± .415	- .017 ± .511
4 Yr. Old	0.057 ± .317	0.671 ± .398	0.670 ± .494
≥ 5 Yr. Old	1.988 ± .318	1.183 ± .349	1.382 ± .459

[a]Group 1 (Herefords, lines 5 and 6), Group 2 (Angus, lines 7 and 8) and Group 3 (Angus, lines 9 and 10).

[b]Line nos. in parenthesis after std. error.

TABLE VII

STANDARD PARTIAL REGRESSION COEFFICIENTS AND STANDARD ERRORS FOR THE FOUR COVARIABLES FROM THE ANALYSES OF VARIANCE FOR GROUPS 1, 2 AND 3[a]

Covariables	Std. Partial Regression Coef. ± S.E.		
	Group 1	Group 2	Group 3
Calf Birth Weight	0.004 ± .024	0.043 ± .025	0.032 ± .033
Average Cow Weight	- .004 ± .002	0.002 ± .002	0.001 ± .004
Fall Cow Condition Score	0.173 ± .198	- .314 ± .180	- .138 ± .212
Change in Cow Weight	0.009 ± .004	0.000 ± .004	- .003 ± .006

[a]Group 1 (Herefords, lines 5 and 6), Group 2 (Angus, lines 7 and 8) and Group 3 (Angus, lines 9 and 10).

significantly associated with milk production of the cow. In contrast, Pope et al. (1965) reported that dams nursing male calves produced more milk than those nursing females, while Rutledge et al. (1972) found the advantage for dams nursing female calves.

Sire effects were significant ($p < .05$) only among the Angus sires in Group 2 but not among Hereford sires in Group 1 and Angus sires in Group 3. Rutledge et al. (1972) found no significant sire effects on total milk yield. Age of dam effects were highly significant ($p < .01$), as older cows produced more milk per day than younger cows. This was indicated by the least square constants for the dams of various ages. Dams of two years of age or younger produced 1.45, 2.04 and 2.04 lbs. less milk per day than the herd average for the Hereford dams in Group 1, Angus dams in Group 2 and Angus dams in Group 3, respectively. Three year old dams produced 0.56 and 0.02 lbs. less milk per day in Groups 1 and 3, respectively, but Angus dams of Group 2 of this age category gave 0.29 lb. more milk per day. Four year old, five year old and older dams produced more milk per day in each of the three groups as four year old and five year old or older dams produced 0.06 and 1.99 lbs. per day in Group 1, 0.67 and 1.18 lbs. per day in Group 2 and 0.67 and 1.38 lbs. per day in Group 3, respectively. The lower milk yields observed in younger cows is in agreement with the standard practice of adjusting weaning weights upwards on two, three and four year old cows. Rutledge et al. (1972) found a significant quadratic effect for age of dam but not a linear effect. Neville et al. (1974) reported a highly significant effect for age of dam and suggested a set of multiplicative correlation factors of 1.33, 1.20, 1.09 and 1.00 for adjusting daily milk yields of three, four, five year and older cows in one of the herds in

Georgia. Calf birth date was not significant in any of the groups. Similar result was reported by Rutledge et al. (1972) with non-significance linear calf birth date effects on total milk yield.

For the two-factor interactions, only line × sex of calf was significant in Group 1 and year × age of dam and sex of calf × age of dam were significant in Group 2. In Group 1, the estimates of the average daily milk yield of line 5 dams were different from those of line 6 for dams suckled by either heifer or bull calves. While in Group 2 the daily milk estimates for dams of different ages were not the same either in the different years when the estimates were taken or when the dams were suckled by either male or female calves. All other interactions in the three groups, 1, 2 and 3, were not significant.

Among the four covariables included in the model in Group 1, only change in cow weight was significant. The standard partial regression coefficient for change in cow weight was 0.01, indicating that cows which gained the most weight between their spring and fall weights tended to produce more milk. The magnitude of the standard partial regression coefficients for the four covariables in the three groups suggests that these effects are not the major factors affecting daily milk yield.

Predicting the Average Daily Milk Yield

To identify the appropriate variables to be included in the prediction equations, a correlation study was run on several growth traits of the dams and their calves. These correlations are presented by year group in Appendix Table XIX for Hereford dams of lines 5 and 6, Appendix Tables XX, XXI, XXII and XXIII for Angus dams of lines 7, 8, 9 and 10, respectively. The correlations averaged over all line and year groups for the two breeds are presented in Table VIII. For the Herefords, average daily gain of the calf from birth to weaning (ADG), calf's weaning weight (WW) and calf's weaning condition score (CCS) were significantly correlated ($p < .01$) with ADMY. The correlation coefficients ranged from 0.76 to 0.81, 0.77 to 0.79 and 0.56 to 0.65 for ADG, WW and CCS, respectively. Most of the components of gain from birth to weaning were also highly significant, except for the average daily gain during the last month (August to September). The cow's growth traits were not consistent in the magnitude of their correlations with ADMY.

In the Angus, the traits that were highly correlated with ADMY were similar to those found in the Herefords, but those correlations calculated for 1971 and 1972 were highly variable in magnitude.

On the average, ADG, WW and CCS were moderately to highly correlated with ADMY. The correlation coefficients for ADG, WW and CCS with ADMY were 0.78, 0.77 and 0.59 in the Herefords and 0.44, 0.46 and 0.35 in the Angus, respectively. Two other variables were selected to be included in the prediction equations, change in cow weight (CHGCWT) and fall cow condition score (FCCS), because they were easily available traits measurable on the cow.

CHGCWT was moderately correlated (0.31) with ADMY in the Herefords, but was negatively correlated (-.04) with ADMY in the Angus. As CHGCWT was defined as the difference in the fall and spring cow weight, then Hereford cows that gained the most would tend to produce more milk per day while Angus cows that lost the most amount of weight would produce more milk.

FCCS was lowly correlated with ADMY in both the Herefords and the Angus (0.06 and -.04, respectively). The fatter the cow during the fall

TABLE VIII

CORRELATIONS OF VARIOUS TRAITS WITH AVERAGE DAILY MILK YIELD OF HEREFORD AND ANGUS DAMS AVERAGED OVER YEARS AND LINES

Correlated Traits	Hereford	Angus
Birth Date	.099	.037
Birth Weight	.245	.244
Average Daily Gain (Birth to Weaning)	.782[b]	.443[a]
Weaning Weight	.765[b]	.455[a]
Calf Weaning Condition Score	.592[b]	.348[a]
Spring Cow Weight	.367[a]	.242
Spring Cow Condition Score	.286	.009
Fall Cow Weight	.256	.245
Fall Cow Condition Score	.062	-.043
Average Daily Gain		
Birth to April	.480[b]	.296
April to May	.643[b]	.502[b]
May to June	.483[b]	.225
June to July	.467[b]	.262
July to August	.482[b]	-.055
August to September	.238	.333
Change in Cow Condition Score	.268	.025
Average Cow Weight	.318	.251
Change in Cow Weight	.309	-.041

[a] $p < .05$.

[b] $p < .01$.

period would indicate that she had produced less amount of milk in the previous summer. The other three variables of the calf were also easily obtained since weights were taken at birth and together with condition score at weaning for each calf.

These five factors, ADG, WW, CCS, CHGCWT and FCCS, were included in all possible one-factor, two-factor, three-factor, four-factor and five-factor models. Those models with the highest coefficients of determination were selected as the prediction equations with the most reliability and accuracy in predicting the ADMY.

The coefficients of determination for the various regression models for the Herefords and Angus are presented in Table IX. The amount of variability in ADMY accounted for by the regression models was higher in the Herefords than in the Angus. The linear regression variables; average daily gain of calf (ADG), calf's weaning weight (WW), calf's weaning condition score (CCS), fall cow's condition score (FCCS) and change in cow weight (CHGCWT) were pooled within breed in the Herefords since there were no substantial differences in the coefficients of determination (R^2) when pooled within line and year. However, in the Angus the amount of variation explained by the models varied a great deal when the variables were pooled within line and year. A regression equation developed for each line and year would not be of much utility for future prediction of ADMY of the cows in these herds since a prediction equation should have a wider scope of application irrespective of line and year. As such, the regression models were examined within each breed separately. Among the one-factor models, the equation with either ADG or WW as the only predictor variable had the highest coefficient of determination in both breeds. The amount of variation explained by the

TABLE IX

COEFFICIENTS OF DETERMINATION (R^2) FOR VARIOUS REGRESSION MODELS FOR DEPENDENT VARIABLE ADMY POOLED WITHIN LINE AND YEAR

Model	Hereford	Angus
One-Factor		
FCCS[a]	.012	.000
CHGCWT[b]	.192	.002
CCS[c]	.208	.117
ADG[d]	.538	.269
WW[e]	.531	.277
Two-Factor		
CHGCWT FCCS	.204	.003
CCS FCCS	.248	.120
CCS CHGCWT	.365	.122
ADG FCCS	.557	.269
ADG CHGCWT	.595	.272
WW FCCS	.543	.277
ADG WW	.541	.277
ADG CCS	.547	.278
WW CHGCWT	.587	.279
WW CCS	.532	.289
Three-Factor		
CCS CHGCWT FCCS	.365	.126
ADG CHGCWT FCCS	.596	.272
ADG WW FCCS	.558	.277
ADG CCS FCCS	.561	.279
WW CHGCWT FCCS	.587	.279
ADG WW CHGCWT	.597	.279
ADG CCS CHGCWT	.599	.284
WW CCS FCCS	.543	.290
ADG WW CCS	.549	.291
WW CCS CHGCWT	.588	.295
Four-Factor		
ADG WW CHGCWT FCCS	.597	.279
ADG CCS CHGCWT FCCS	.599	.285
ADG WW CCS FCCS	.562	.291
WW CCS CHGCWT FCCS	.588	.296
ADG WW CCS CHGCWT	.600	.297
Five-Factor		
ADG WW CCS CHGCWT FCCS	.600	.298

[a]Fall cow condition score.

[b]Change in cow weight.

[c]Calf weaning condition score.

[d]Average daily gain of calf.

[e]Weaning weight of calf.

model was improved when a second variable was included in the model containing either ADG or WW. The R^2 for the three best two-factor models in the Hereford groups were 0.557 (ADG FCCS), 0.587 (WW CHGCWT) and 0.595 (ADG CHGCWT). Among the two-factor models in the Angus, the models with the three highest R^2 values were those with ADG and CCS, WW and CHGCWT, and WW and CCS as their predictor variables (R^2 = 0.278, 0.279 and 0.289, respectively). Adding the third or fourth variable into the three best two-factor models did not increase the R^2 substantially. The five-factor models in the two breeds differed from the four-factor models only in their third decimal place in the magnitude of their coefficients of determination (R^2 = .600 and .298 in the Herefords and Angus, respectively).

The two best models in each category (one- to four-factor model) were selected based on their capabilities to account for as much of the variation in daily milk as they possibly could and were examined further. In addition the five-factor model was also included for comparison. These nine prediction equations are presented in Tables X and XI for the Herefords and Angus, respectively.

Among the Hereford models, weaning weight of calf (WW), average daily gain of calf (ADG) and change in cow weight (CHGCWT) were important variables influencing ADMY since they consistently were significant in all models except for equation 5 where ADG and WW were not significant and for equations 8 and 9 in which WW was not a significant factor in affecting ADMY. About 53% of the variability in ADMY could be explained by the models using only WW or ADG as the independent variables. If no other measures of the dam's or her calf's performance were

TABLE X

BEST REGRESSION MODELS FOR PREDICTING AVERAGE DAILY MILK YIELD USING THE FIVE SELECTED VARIABLES FOR HEREFORD DAMS[a]

Prediction Equations	R^2 [c]	S.E.E.[d]
Std. Deviation for ADMY = 2.460		
1. $\hat{Y}$[b] = − 3.55 + .33 WW**	.531	1.688
2. $\hat{Y}$ = − 2.16 + .75 ADG**	.538	1.674
3. $\hat{Y}$ = − .99 + .03 WW** + .01 CHGCWT**	.587	1.588
4. $\hat{Y}$ = .24 + 6.74 ADG** + .01 CHGCWT**	.595	1.573
5. $\hat{Y}$ = − .28 + 4.68 ADG + .01 WW + .01 CHGCWT**	.597	1.574
6. $\hat{Y}$ = 2.73 + 7.37 ADG** − .29 CCS + .01 CHGCWT**	.599	1.572
7. $\hat{Y}$ = 2.75 + 7.37 ADG** − .29 CCS + .01 CHGCWT** − .03 FCCS	.599	1.577
8. $\hat{Y}$ = 2.05 + 5.64 ADG** + .01 WW − .26 CCS + .01 CHGCWT**	.600	1.575
9. $\hat{Y}$ = 2.07 + 5.67 ADG** + .01 WW − .26 CCS + .01 CHGCWT** − .02 FCCS	.600	1.581

[a]WW = weaning weight of calf, ADG = average daily gain of calf, CHGCWT = change in cow weight, CCS = calf weaning condition score and FCCS = fall cow condition score.

[b]Predicted average daily milk yield.

[c]Coefficient of determination

[d]Standard error of estimate.

*$p < .05$.

**$p < .01$.

TABLE XI

BEST REGRESSION MODELS FOR PREDICTING AVERAGE DAILY MILK YIELD USING THE FIVE SELECTED VARIABLES FOR ANGUS DAMS[a]

Prediction Equations	R^2 [c]	S.E.E.[d]
Std. Deviation for ADMY = 2.784		
1. $\hat{Y}$[b] = 4.47 + 5.79 ADG**	.270	2.383
2. $\hat{Y}$ = 3.36 + .03 WW**	.277	2.371
3. $\hat{Y}$ = .70 + 5.20 ADG** + .38 CCS	.278	2.374
4. $\hat{Y}$ = 3.02 + .03 WW** - .00 CHGCWT	.279	2.372
5. $\hat{Y}$ = - 1.08 + .02 WW** + .49 CCS* - .06 FCCS	.290	2.358
6. $\hat{Y}$ = - 2.20 - 3.12 ADG + .04 WW* + .52 CCS*	.291	2.356
7. $\hat{Y}$ = - 3.71 - 2.89 ADG + .04 WW* + .61 CCS** - .00 CHGCWT	.296	2.351
8. $\hat{Y}$ = - 2.76 + .02 WW** + .59 CCS** - .00 CHGCWT - .07 FCCS	.296	2.351
9. $\hat{Y}$ = - 3.72 - 2.87 ADG + .04WW** + .65 CCS** - .00 CHGCWT - .07 FCCS	.298	2.353

[a]WW = weaning weight of calf, ADG = average daily gain of calf, CHGCWT = change in cow weight, CCS = calf weaning condition score and FCCS = fall cow condition score.

[b]Predicted average daily milk yield.

[c]Coefficient of determination.

[d]Standard error of estimate.

*$p < .05$.

**$p < .01$.

available, either WW or ADG is adequate to account for slightly more than one-half of the variation in ADMY of the dam.

Including the WW and CHGCWT in a single model increased the R^2 to 58.7%, an increase of only 5% over the model that included only WW. Although CHGCWT improved the R^2 by only a small percentage, both of the variables, CHGCWT and WW, singificantly affected ADMY.

There were little differences in the amount of variation that could be explained by equations 4, 5, 6, 7, 8 and 9; they only differed in the third decimal place of the R^2 and accounted only for about 60% of the variability in ADMY. It was interesting to note that using only ADG and CHGCWT as the independent variables as in equation 4 was as good as using any other three-factor or four-factor or five-factor equation. Both ADG and CHGCWT were highly significant in the model although there was no substantial difference in the R^2 between equations 4 and 5; ADG was no longer significant in equation 5; only CHGCWT was significant in affecting ADMY in the model. ADG and CHGCWT were the only two variables that were significant in equations 6, 7, 8 and 9. All four of these models were similar in their ability to account for the variability in ADMY. Since a three-factor model could explain for the same amount of variation in ADMY as a four-factor or five-factor model, equation 6 should be the choice because it only used three variables to predict ADMY, while other models required four or five variables to account for about the same amount of variability in ADMY. Considering all equations examined, equations 4 and 6 had greater efficiency and advantage than any other models since they included only two and three variables in their models, respectively, while explaining approximately the same amount of variation as a five-factor model.

The amount of variation that could be explained by the models in the Angus was generally lower than those in the Herefords. The R^2 ranged from 0.270 in the one-factor model to 0.298 in the five-factor model. ADG and WW were highly significant in models with one or two or three variables. There was little difference in the R^2 in equations 5, 6, 7, 8 and 9. Only about 29% of the variability in ADMY could be accounted by each of these five equations. Among the reasons for this low R^2 value were (1) there were large differences in the R^2 between models developed from the dam's and her calf performance sampled either in 1968 or 1969, and models developed from data taken either in 1971 or 1972, (2) the low R^2 obtained in models constructed from data obtained in the last two years, 1971 and 1972, could not be clearly understood, and (3) the standard error of estimate for each of the regression models was generally larger than that found in the Hereford's model. This could mean that due to a greater variation in the ADMY in the Angus, predicting the ADMY using the five variables was not as accurate or reliable. Very little of the variability in ADMY could be explained by the models. Possibly some other combination of different variables associated with ADMY could produce a model with a higher coefficient of determination. Unless such a model were found, the prediction of ADMY using the five variables is not recommended in the Angus lines in this particular herd. Estimate of ADMY should then be obtained through monthly milk measures.

There was little similarity in the prediction equations developed by Rutledge et al. (1972) with the one shown here. In that report, alternate month measures of milk yield were used as the predictor variables.

Improving the Milk Measuring Technique and the Sampling Procedure

The correlations for the six monthly milk measures with ADMY for Hereford and Angus cows are reported in Tables XII and XIII, respectively. All correlations were highly significant ($p < .01$) in the Herefords and Angus with the exception of the correlation between ADMY and April second 12-hour ADMY estimate which was significant only at 5% level in the Herefords. Monthly estimates of ADMY were highly correlated with the total ADMY with the highest correlations corresponding to the middle of the lactation period, namely from June to August.

The calf suckling technique adopted in this study required that the calf be weighed before and after suckling to obtain an estimate of the amount of milk produced for the first 12 hours. This was repeated in the late afternoon to obtain the second 12-hour estimate of milk yield. Any improvement in the calf suckling technique should involve the two 12-hour estimates of milk yield. The correlations between the first 12-hour estimate averaged over the six monthly milk measures with total ADMY were 0.933 and 0.882 in the Herefords and Angus, respectively. This suggests that the total ADMY could be estimated rather accurately from the first 12-hour estimate of milk yield. The correlation was higher in the Herefords than in the Angus. Thus, in both breeds the first 12-hour milk production was nearly as good an estimate of the total ADMY as the total of two successive 12-hour milk measures. The second 12-hour milk yield estimate was highly correlated too with the total ADMY but lower than the correlations for the first 12-hour estimate. The correlation coefficients for the second 12-hour estimate were 0.904 and 0.874 in the Herefords and Angus, respectively. Thus, the

TABLE XII

CORRELATIONS OF SIX MONTHLY MILK MEASURES AND OTHER TRAITS WITH AVERAGE DAILY MILK YIELD (ADMY) OF HEREFORD DAMS (LINES 5 AND 6)[a]

	ADMY
Number of Cow-Calf Pairs	144
April ADMY	.719
May ADMY	.654
June ADMY	.798
July ADMY	.709
August ADMY	.769
September ADMY	.598
First 12-hour estimate ADMY	.933
Second 12-hour estimate ADMY	.904
Alternate months ADMY (April, June, August)	.933
Mid-lactation ADMY (May to August)	.935
April First 12-hour ADMY	.567
April Second 12-hour ADMY	.697
May First 12-hour ADMY	.597
May Second 12-hour ADMY	.577
June First 12-hour ADMY	.748
June Second 12-hour ADMY	.655
July First 12-hour ADMY	.573
July Second 12-hour ADMY	.612
August First 12-hour ADMY	.725
August Second 12-hour ADMY	.610
September First 12-hour ADMY	.546
September Second 12-hour ADMY	.289

[a]All correlations are significant ($p < .01$).

TABLE XIII

CORRELATIONS OF SIX MONTHLY MILK MEASURES AND OTHER TRAITS WITH AVERAGE DAILY MILK YIELD (ADMY) FOR ANGUS DAMS[a]

	ADMY (Angus)		
	Lines 7 and 8	Lines 9 and 10	Combined All Lines
Number of Cow-Calf Pairs	163	152	315
April ADMY	.644	.618	.629
May ADMY	.585	.644	.614
June ADMY	.570	.666	.616
July ADMY	.716	.642	.676
August ADMY	.445	.632	.572
September ADMY	.458	.519	.480
First 12-hour estimate, ADMY	.874	.904	.882
Second 12-hour estimate, ADMY	.846	.914	.874
Alternate months ADMY (April, June, August)	.823	.896	.856
Mid-lactation ADMY (May to August)	.897	.928	.912
April First 12-hour ADMY	.599	.548	.567
April Second 12-hour ADMY	.482	.178[b]	.247[b]
May First 12-hour ADMY	.531	.571	.547
May Second 12-hour ADMY	.452	.525	.486
June First 12-hour ADMY	.495	.451	.475
June Second 12-hour ADMY	.470	.628	.543
July First 12-hour ADMY	.612	.508	.559
July Second 12-hour ADMY	.641	.579	.608
August First 12-hour ADMY	.424	.533	.474
August Second 12-hour ADMY	.357	.575	.448
September First 12-hour ADMY	.336	.525	.409
September Second 12-hour ADMY	.417	.370	.384

[a]All correlations are significant ($p < .01$) except for [b]($p < .05$).

first 12-hour milk yield estimate could be used to estimate the total ADMY rather accurately.

In this study, milk production was sampled in each of the six months from April to September. Under range conditions, monthly milk yield estimates are difficult to obtain. Therefore the extent of milk yield samplings is of great significance. In this study, estimates based on four months (May to August) or three months (April, June and August) were the most highly correlated with the total ADMY. The correlations between the mid-lactation estimate of ADMY and total ADMY were 0.933 and 0.912 in the Herefords and Angus, respectively. Using the alternate month sampling (April, June and August) did not improve the correlations with total ADMY. The correlation coefficients were 0.933 and 0.856 in the Herefords and Angus, respectively, which were lower than those reported for the correlations with the mid-lactation estimate of ADMY. To minimize the number of monthly milk yield samplings in the two breeds, estimating the total ADMY from the four monthly milk yield estimates (May to August) was adequate.

This suggests that ADMY could be adequately estimated from fewer milk samplings. Only the first 12-hour milk yield estimates taken for four months from May to August of the lactation period need be taken to accurately estimate the total ADMY. The high correlation between the alternate months milk yield estimate and total ADMY agreed with that reported by Rutledge et al. (1972) in which a correlation of 0.91 was reported between the predicted value using the first, third and fifth monthly milk measures as the predictor variables and total milk yield, while Neville (1962) suggested that only two or three milk samplings during the nursing period were needed to determine the relationship of milk consumption to calf gains. This study was also in general agreement with that reported by Totusek et al. (1973) where estimates based on four days (days 30, 70, 112, 210) or five days (days 30, 70, 112, 140, 210) were highly correlated with 210-day yield (r = 0.91 and 0.93, respectively).

CHAPTER V

SUMMARY

The objectives of this study were (1) to partition the various sources of variation affecting the milk production of cows on native range conditions, (2) to predict the daily milk yield of the dam using growth performance of her calf as well as her own weight and condition changes during the lactation period and (3) to examine the extent to which milk yield could be adequately estimated from using fewer actual measures of daily milk yield.

The data were collected in the summers of 1967 to 1972 on cows involved in a long term beef cattle selection study at the Oklahoma Agricultural Experiment Station. A total of 459 dams (144 Hereford and 315 Angus) were involved in this milk production study. Monthly milk measures were obtained from these dams from April to August each year for six years (1967 to 1972). The calf suckling technique was used to measure the milk yield where the difference in weight of the calf before and after suckling was taken as the estimate of milk yield. Two 12-hour estimates, one in the morning and the other in the late afternoon, were taken to estimate the 24-hour milk yield. Line effects were significant ($p < .05$) only among the Hereford lines (5 and 6) and among Angus lines (7 and 8 but not 9 and 10). Year and sire of calves effects were significant among lines 7 and 8 but not among the other lines. Age of dam effects were highly significant in influencing the ADMY in all lines.

This indicates that some of the differences in ADMY between lines may be the results of differences in the age of the dams. Sex of calf was not significant, but male calves consumed 0.197, 0.065 and 0.730 lbs. more milk per day in lines 5 and 6, 7 and 8, and 9 and 10, respectively. Date of calving was not significant in all lines. Among the regression effects, only change in cow weight was significant, only among lines 5 and 6, but not in the other lines.

Prediction equations were developed to predict the ADMY using the five variables: average daily gain of calf, weaning weight of calf, calf's weaning condition score, fall cow's condition score and change in cow weight. The coefficients of determination for all possible regression models for the Herefords were higher than for the Angus ($R^2 = 0.600$ and 0.298 for all five variable models, respectively). Among the Hereford models, the three-factor model (ADMY = 2.73 + 7.37 ADG - 0.29 CCS + 0.01 CHGCWT) could account for the same amount of variation in ADMY as the model involving all five variables. In Angus, daily milk yield could not be as accurately predicted as in Herefords (R^2 of 0.600 and 0.298 for five-factor models of Herefords and Angus, respectively).

All correlations between total ADMY and monthly milk measures were highly significant ($p < .01$), (0.72, 0.65, 0.80, 0.71, 0.77 and 0.60 and 0.63, 0.61, 0.62, 0.68, 0.57 and 0.48 for April, May, June, July, August and September milk measures for the Herefords and Angus, respectively). The first 12-hour milk measure was highly correlated to total ADMY (0.93 and 0.88 for the Herefords and Angus, respectively) which was higher than the correlation for the second 12-hour milk measure (0.90 and 0.87 for the Hereford and Angus, respectively). This suggests that the first 12-hour milk measure is as good an estimate of the total ADMY as using the two 12-hour measures commonly used in the calf-suckling technique. Sampling from only four months (May to August) was as good as sampling from all six months in estimating the ADMY. The correlations between the mid-lactation estimate of ADMY and total ADMY was 0.933 and 0.912 in the Herefords and Angus, respectively. Thus, ADMY could be accurately estimated by taking only the first 12-hour milk measure from the four months (May to August).

If the availability of labor to undertake the task of measuring the milk yield each month was scarce, then it would be economical to obtain the estimate of ADMY just from one measurement for each test day and reduce the number of monthly milk measures from six to four. However, if milk production were to be estimated for a large number of cow-calf pairs, then predicting the daily milk yield using the recommended prediction equations seem economical and accurate enough, but it would be better in terms of precision and accuracy of the estimates of ADMY to actually measure the daily milk yield using the calf-suckling technique or any other milk measuring technique.

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APPENDIX

TABLE XIV

MEANS AND STANDARD DEVIATIONS FOR SIX MONTHLY MILK MEASURES AND OTHER TRAITS OF HEREFORD DAMS BY YEAR AND LINE

Year	1967				1970			
Line	5		6		5		6	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Number of Calves	34		33		39		38	
April ADMY[a], Lbs.	12.82	4.30	13.27	4.17	10.15	2.67	10.42	3.02
May ADMY, Lbs.	9.88	3.00	11.83	3.66	10.64	2.96	10.39	3.35
June ADMY, Lbs.	12.06	4.06	11.06	3.29	10.41	3.13	10.39	2.95
July ADMY, Lbs.	10.59	4.26	10.21	3.64	9.72	3.01	9.34	2.83
August ADMY, Lbs.	11.57	5.00	9.50	3.58	6.79	2.52	6.08	1.98
September ADMY, Lbs.	9.12	5.14	7.76	3.36	6.77	2.21	6.97	2.06
First 12-Hr. Milk Yield (6 Mons.), Lbs.	6.23	1.32	5.95	1.61	4.57	0.89	4.58	0.93
Second 12-Hr. Milk Yield (6 Mons.), Lbs.	4.94	1.60	4.67	1.31	4.57	1.08	4.29	0.86
Six Month ADMY (April to September), Lbs.	11.19	2.76	10.63	2.81	9.09	1.86	8.87	1.54
Calf ADG[b] (Birth to Weaning), Lbs.	1.66	0.25	1.62	0.23	1.60	0.25	1.58	0.23
205-Day Age of Dam Adjusted W. Wt.[c], Lbs.	436.59	50.13	430.24	45.56	425.95	47.87	421.29	49.99
Calf Weaning Condition Score	4.10	0.62	3.73	0.65	4.24	0.75	4.06	0.65
Fall Cow Weight, Lbs.	1014.56	123.88	1015.91	126.77	1013.08	111.94	987.89	106.58
Fall Cow Condition Score	5.21	0.85	5.09	0.77	6.10	0.97	6.03	1.03

[a]Average Daily Milk Yield.

[b]Average Daily Gain.

[c]Weaning Weight.

TABLE XV

MEANS AND STANDARD DEVIATIONS FOR SIX MONTHLY MILK MEASURES AND OTHER TRAITS OF ANGUS DAMS FOR LINES 7 AND 8 (1968) AND LINES 9 AND 10 (1969)

Year	1968				1969			
Line	7		8		9		10	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Number of Calves	35		41		34		39	
April ADMY[a], Lbs.	16.27	4.27	16.61	4.35	13.29	4.33	14.46	4.42
May ADMY, Lbs.	18.23	3.93	19.31	4.74	15.79	4.25	15.44	4.62
June ADMY, Lbs.	15.38	4.93	17.76	4.84	15.18	4.54	16.00	4.45
July ADMY, Lbs.	13.23	3.99	15.44	5.30	14.94	5.01	15.74	4.90
August ADMY, Lbs.	13.11	3.70	12.46	4.15	12.06	3.66	13.31	4.01
September ADMY, Lbs.	10.51	4.41	11.12	4.66	12.53	4.24	12.64	3.84
First 12-Hr. Milk Yield (6 Mons.), Lbs.	7.87	1.70	8.53	1.89	6.95	1.57	7.66	1.69
Second 12-Hr. Milk Yield (6 Mons.), Lbs.	6.54	1.49	6.95	1.38	7.03	1.50	6.90	1.64
Six Month ADMY (April to September), Lbs.	14.39	2.95	15.48	2.99	13.99	2.95	14.57	3.08
Calf ADG[b] (Birth to Weaning), Lbs.	1.78	0.20	1.85	0.24	1.61	0.20	1.59	0.25
205-Day Age of Dam Adjusted W. Wt.[c], Lbs.	457.51	39.14	465.90	46.04	415.85	39.40	411.72	46.92
Calf Weaning Condition Score	3.99	0.55	4.08	0.62	4.05	0.43	3.85	0.50
Fall Cow Weight, Lbs.	974.29	132.31	965.85	117.20	873.68	67.98	919.87	130.41
Fall Cow Condition Score	5.51	1.15	5.54	1.19	5.44	1.24	5.21	1.63

[a]Average Daily Milk Yield.

[b]Average Daily Gain.

[c]Weaning Weight.

TABLE XVI

MEANS AND STANDARD DEVIATIONS FOR SIX MONTHLY MILK MEASURES AND OTHER TRAITS OF ANGUS DAMS FOR 1971 BY LINES

Year	1971							
Line	7		8		9		10	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Number of Calves	21		20		18		17	
April ADMY[a], Lbs.	14.90	3.81	16.00	3.16	11.78	3.73	13.47	4.24
May ADMY, Lbs.	14.33	3.35	15.45	4.08	16.06	3.75	14.06	3.36
June ADMY, Lbs.	16.05	3.75	19.65	6.39	18.33	5.41	16.06	5.12
July ADMY, Lbs.	14.86	4.00	17.00	3.21	12.89	4.35	15.65	3.08
August ADMY, Lbs.	19.05	7.47	19.70	5.15	16.11	5.27	17.76	6.56
September ADMY, Lbs.	11.29	3.36	10.55	3.97	10.17	2.98	10.65	3.26
First 12-Hr. Milk Yield (6 Mons.), Lbs.	7.39	1.19	8.45	1.11	6.89	1.56	7.05	1.29
Second 12-Hr. Milk Yield (6 Mons.), Lbs.	7.67	0.19	1.99	0.23	1.81	0.24	7.54	1.08
Six Month ADMY (April to September), Lbs.	14.69	2.78	16.36	2.13	14.26	2.74	14.58	1.97
Calf ADG[b] (Birth to Weaning), Lbs.	1.76	0.19	1.99	0.23	1.81	0.24	1.87	0.17
205-Day Age of Dam Adjusted W. Wt.[c], Lbs.	455.43	45.14	496.90	49.21	457.33	55.84	472.53	34.78
Calf Weaning Condition Score	5.28	0.27	5.34	0.24	5.38	0.53	5.37	0.34
Fall Cow Weight, Lbs.	1006.43	87.11	989.50	101.95	997.22	120.77	1054.12	108.57
Fall Cow Condition Score	6.05	0.97	5.55	1.23	6.44	0.78	6.47	0.87

[a]Average Daily Milk Yield.

[b]Average Daily Gain.

[c]Weaning Weight.

TABLE XVII

MEANS AND STANDARD DEVIATIONS FOR SIX MONTHLY MILK MEASURES AND OTHER TRAITS OF ANGUS DAMS FOR 1972 BY LINES

Year	1972							
Line	7		8		9		10	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Number of Calves	22		24		22		22	
April ADMY[a], Lbs.	15.32	4.73	16.33	4.41	18.14	2.83	17.86	5.00
May ADMY, Lbs.	16.86	4.17	18.38	4.45	20.41	3.81	19.05	4.21
June ADMY, Lbs.	18.68	4.25	19.75	3.03	20.91	2.26	18.64	3.46
July ADMY, Lbs.	12.59	4.03	13.03	3.78	15.18	3.26	13.68	4.08
August ADMY, Lbs.	13.09	4.05	12.83	3.51	13.73	3.49	13.05	3.66
September ADMY, Lbs.	10.18	3.05	10.83	3.69	11.55	2.04	9.27	3.01
First 12-Hr. Milk Yield (6 Mons.), Lbs.	7.27	1.26	7.70	1.00	8.06	0.95	7.84	1.28
Second 12-Hr. Milk Yield (6 Mons.), Lbs.	6.99	1.81	7.45	1.39	8.61	1.18	7.49	1.70
Six Month ADMY (April to September), Lbs.	14.26	2.83	15.15	2.25	16.69	1.66	15.33	2.80
Calf ADG[b] (Birth to Weaning), Lbs.	1.91	0.25	1.93	0.15	1.86	0.19	2.00	0.22
205-Day Age of Dam Adjusted W. Wt.[c], Lbs.	485.95	54.42	491.63	44.96	460.00	47.30	504.32	55.61
Calf Weaning Condition Score	4.77	0.60	2.70	0.52	4.92	0.40	4.95	0.40
Fall Cow Weight, Lbs.	1047.05	115.13	1035.12	110.10	1023.18	88.67	1015.45	104.45
Fall Cow Condition Score	6.23	1.66	5.96	1.20	6.32	1.43	6.05	1.33

[a]Average Daily Milk Yield.

[b]Average Daily Gain.

[c]Weaning Weight.

TABLE XVIII

LEAST SQUARE CONSTANTS AND STANDARD ERRORS FOR THE FIXED EFFECTS FOR GROUPS 1, 2 AND 3[a]

Fixed Effects	Least Square Constants ± Std. Errors		
	Group 1	Group 2	Group 3
Year[b]	0.471 ± .287 (67)	1.035 ± .196 (68)	- .067 ± .445 (68)
	- .471 ± .300 (70)	- .162 ± .337 (71)	0.730 ± .482 (71)
		- .873 ± .304 (72)	- .663 ± .454 (72)
Sires	0.369 ± .548	0.743 ± .791	0.907 ± 1.003
	- .027 ± .479	- .209 ± .951	- .005 ± 1.301
	0.144 ± .486	-1.699 ± .794	-1.689 ± 1.090
	- .190 ± .521	- .585 ± .761	- .612 ± .971
	1.869 ± .601	-1.115 ± .822	0.857 ± .984
	- .653 ± .592	1.174 ± .843	-1.041 ± .933
	0.095 ± .472	- .608 ± .674	0.312 ± .734
	- .136 ± .545	1.160 ± .705	0.109 ± .663
	0.428 ± .528	- .827 ± .612	0.125 ± .752
	0.270 ± .527	0.327 ± .873	- .538 ± 1.662
	0.228 ± .646	-1.899 ± .796	0.711 ± 1.578
	0.871 ± .567	1.384 ± .991	- .942 ± 1.579
	-3.268 ± .463	- .363 ± .890	- .798 ± 1.379
		- .449 ± .683	0.052 ± .902
		-1.380 ± .818	- .575 ± 1.251
		- .692 ± .599	0.787 ± 1.165
		1.023 ± .598	- .853 ± .748
		- .781 ± .573	1.465 ± .751
		4.796 ± .508	-1.125 ± .800
			2.853 ± .752
Calf Birth Date 1	- .365 ± .392	- .219 ± .530	0.454 ± .624
2	0.050 ± .297	0.198 ± .485	0.620 ± .604
3	- .297 ± .320	- .066 ± .515	1.056 ± .730
4	0.287 ± .346	1.268 ± .655	0.153 ± .779
5	0.325 ± .328	-1.181 ± .663	-2.283 ± .769

[a]Group 1 (Herefords, lines 5 and 6), Group 2 (Angus, lines 7 and 8) and Group 3 (Angus, lines 9 and 10).

[b]Year in parenthesis after std. error.

TABLE XIX

CORRELATIONS OF VARIOUS TRAITS WITH THE AVERAGE DAILY MILK YIELD OF HEREFORD DAMS BY LINE AND YEAR

Correlated Traits	Line	5		6	
	Year	1967	1970	1967	1970
Birth Date		.007	-.020	.225	.184
Birth Weight		.182	.460[b]	.052	.325[a]
Average Daily Gain (Birth to Weaning)		.764[b]	.772[b]	.811[b]	.782[b]
Weaning Weight		.738[b]	.785[b]	.770[b]	.766[b]
Calf Weaning Condition Score		.562[b]	.570[b]	.653[b]	.583[b]
Spring Cow Weight		.259	.463[b]	.296	.451[b]
Spring Cow Condition Score		-	.278	-	.293
Fall Cow Weight		.216	.389[a]	.212	.206
Fall Cow Condition Score		.277	.247	-.068	-.208
Average Daily gain Birth to April		.449[b]	.508[b]	.648[b]	.313
April to May		.728[b]	.559[b]	.626[b]	.659[b]
May to June		.593[b]	.178	.509[b]	.652[b]
June to July		.486[b]	.509[b]	.388[a]	.485[b]
July to August		.510[b]	.452[b]	.289	.676[b]
August to September		.327	-.059	.396[a]	.286
Change in Cow Condition Score		-.277	.073	.068	.404[b]
Average Cow Weight		.241	.432[b]	.259	.340[a]
Change in Cow Weight		.267	.281	.233	.456[b]

[a] $p < .05$.

[b] $p < .01$.

TABLE XX

CORRELATIONS OF VARIOUS TRAITS WITH AVERAGE DAILY MILK YIELD OF ANGUS DAMS OF LINE 7 BY YEAR

Correlated Traits	Line 7		
Year	1968	1971	1972
Birth Date	-.128	-.109	.054
Birth Weight	.678[b]	.198	.313
Average Daily Gain (Birth to Weaning)	.648[b]	.406	.464[a]
Weaning Weight	.721[b]	.390	.467[a]
Calf Weaning Condition Score	.510[b]	.266	.489[a]
Spring Cow Weight	.573[b]	-.008	.565[b]
Spring Cow Condition Score	.265	.009	.309
Fall Cow Weight	.438[b]	.124	.575[b]
Fall Cow Condition Score	-.121	-.533[b]	.244
Average Daily Gain Birth to April	.336[a]	.195	.149
April to May	.466[b]	.315	.573[b]
May to June	.626[b]	.126	.289
June to July	.278	.281	.215
July to August	.453[a]	-.523[b]	.032
August to September	.494[a]	.692[a]	.208
Change in Cow Condition Score	.295	.443[a]	-.061
Average Cow Weight	.515[b]	.058	.584[b]
Change in Cow Weight	.311	-.161	-.114

[a] $p < .05$.

[b] $p < .01$.

TABLE XXI

CORRELATIONS OF VARIOUS TRAITS WITH AVERAGE DAILY MILK YIELD OF ANGUS DAMS OF LINE 8 BY YEAR

Correlated Traits	Line 8		
Year	1968	1971	1972
Birth Date	-.087	.435[a]	.107
Birth Weight	.228	.530[b]	.329
Average Daily Gain (Birth to Weaning)	.729[b]	.233	.464[a]
Weaning Weight	.711[b]	.323	.484[a]
Calf Weaning Condition Score	.658[b]	-.094	.268
Spring Cow Weight	.409[b]	-.111	-.109
Spring Cow Condition Score	.249	-.290	.094
Fall Cow Weight	.316[a]	-.145	-.055
Fall Cow Condition Score	.152	-.382	-.172
Average Daily Gain Birth to April	.452[b]	-.012	.199
April to May	.554[b]	.555[b]	.681[b]
May to June	.365[a]	-.044	.001
June to July	.579[b]	.594[b]	-.128
July to August	.329[a]	-.606	.320
August to September	.592[b]	.554[b]	.002
Change in Cow Condition Score	.042	.091	.254
Average Cow Weight	.368[a]	-.130	-.086
Change in Cow Weight	.281	.058	-.157

[a] $p < .05$.

[b] $p < .01$.

TABLE XXII

CORRELATIONS OF VARIOUS TRAITS WITH AVERAGE DAILY MILK YIELD OF ANGUS DAMS OF LINE 9 BY YEAR

Correlated Traits	Year	Line 9		
		1969	1971	1972
Birth Date		-.044	.082	-.459
Birth Weight		.264	-.130	-.194
Average Daily Gain (Birth to Weaning)		.712[b]	.500[a]	-.234
Weaning Weight		.703[b]	.443	-.245
Calf Weaning Condition Score		.503[b]	.246	.668[b]
Spring Cow Weight		.461[b]	.148	.095
Spring Cow Condition Score		-.250	.193	-.096
Fall Cow Weight		.500[b]	.208	.050
Fall Cow Condition Score		.180	.152	.287
Average Daily Gain Birth to April		.331[a]	.071	.459[a]
April to May		.526[b]	.590[a]	.074
May to June		.450[b]	.043	.015
June to July		.019	.736[b]	-.039
July to August		.665[b]	-.423	-.470
August to September		.363[a]	.646[b]	-.234
Change in Cow Condition Score		-.263	.181	-.386
Average Cow Weight		.515[b]	.181	.076
Change in Cow Weight		-.208	-.176	.137

[a]$p < .05$.

[b]$p < .01$.

TABLE XXIII

CORRELATIONS OF VARIOUS TRAITS WITH AVERAGE DAILY MILK YIELD OF ANGUS DAMS OF LINE 10 BY YEAR

Correlated Traits	Line 10		
Year	1969	1971	1972
Birth Date	.113	-.199	-.206
Birth Weight	.413[b]	.167	.137
Average Daily Gain (Birth to Weaning)	.646[b]	.404	.354
Weaning Weight	.672[b]	.407	.389
Calf Weaning Condition Score	.519[b]	-.131	.277
Spring Cow Weight	.517[b]	.423	-.054
Spring Cow Condition Score	-.215	.092	-.317
Fall Cow Weight	.476[b]	.409	.041
Fall Cow Condition Score	.024	-.076	-.025
Average Daily Gain Birth to April	.370[a]	.344	.569[b]
April to May	.403[b]	.631[b]	.655[b]
May to June	.481[b]	.180	.169
June to July	.410[b]	-.084	.179
July to August	.174	-.546[a]	-.063
August to September	.259	.485[a]	-.060
Change in Cow Condition Score	-.177	.181	-.299
Average Cow Weight	.508[b]	.425	-.007
Change in Cow Weight	-.186	.043	-.320

[a] $p < .05$.

[b] $p < .01$.

VITA

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