Correlated responses in body weight and measurements to milk production

by

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I. INTRODUCTION

Body weight and measurements have been used in attempts to describe the shape of dairy cows and other specific details of conformation or physical appearance. If any body weight or measurements were found with a high enough correlation to production, they could be used along with pedigree as a basis for selection. It would be essential for such characteristics to be correlated with production and have nonzero heritabilities; of course, the larger these parameters, the more useful these measurements would be. Then, selection for production would be more accurate than if pedigree alone were used.

Accurate measurement and assessment of individual cow performance becomes more important as the number of dairy cows declines. Milk production is the most important trait and should be measured on all cows. Measurements of additional traits also are important. The relations between additional traits and milk production classify the criteria of measurement. Traits negatively correlated genetically with milk production may reach undesired levels if selection continues for increased milk production without regard to correlated responses. Positively correlated traits could reach undesired levels also, but this is not anticipated to occur first. Traits independent of milk production and traits with unknown relations to milk production need to be monitored to determine or indicate changes in the relations.

The objectives of this study were to estimate the results of the difference of body weight and measurements between daughters of high sires vs average sires, and high dams vs low dams which were evaluated as correlated responses to selection for milk production.

II. LITERATURE REVIEW

Body weight and measurements of the dairy cow have been important to breeders for many years. The researchers indicate that performance was the major guide for selection in early breeding programs. The emphasis, however, which body size, as measured by weight and measurements, should receive in dairy cattle selection and management programs, and how it should be used have not been definitely ascertained.

Previously, reports have shown that body weight and measurements as correlated responses to milk production are not adequate indicators for selection. Furthermore, much of the body weight and measurements data reported have been obtained shortly before or subsequent to first calving, mostly from university experiment stations. Obtaining body weight and measurements under commercial conditions in large numbers of herds does not seem economically feasible. This puts major emphasis on how feed efficiency is likely to change as correlated to another trait or type conformation. Dickinson et al. (1968) indicated that the more weight the cow gained within each breed, the more rapidly did their feed efficiency decline. If selection for greater size and scale is practiced without accompanying selection for higher production, the results in future generations may very well be larger, less feed efficiency, and less profitable dairy cows. Freeman (1967) pointed out that if selection results in larger cows that are not proportionately higher producers, they will be less efficiency. Touchberry (1951) reported that body weight and measurements will depend to a high degree on the accuracy of the measurements taken. The accuracy of measurements will vary with many things including the method used, the instrument used, the temperament of the animal being measured, the man taking the measurement, and the nature of the measurement itself. However, body weight and measurements are accurate enough for practical purposes in dairy research.

A. Relationships of Measurements

Wilk et al. (1963) used data from the University of Minnesota Experiment Station herds, obtained during the years 1949 through 1961, to study the genetic and phenotypic relationships between body measurements at various ages and milk production. Information on body weight, wither height, chest depth, body length, heart girth and paunch girth were obtained at 3 months, 6 months, 12 months, 18 months of age and at 3 months following first calving. These traits were correlated with milk production in the first lactation, on a 305 day, 2x, mature-equivalent basis. Daughters of 71 sires were represented in the paternal half sister analysis and complete information was available for 157 daughter-dam pairs.

Estimates of the phenotypic (Wilk et al., 1963) correlation among all pairs of traits were obtained from paternal half sister analysis on a within-herd-year basis. Phenotypic correlations between milk production and measurement traits were low, and in some cases, slightly negative. Chest depth at 3 months of age showed a significant correlation of 0.295 with milk production while all other phenotypic correlations with milk production were nonsignificant and fell within the range of -0.1 to 0.1. Height at withers and paunch girth showed negative or near zero correlations with milk production at all ages investigated.

Genetic correlations were calculated (Wilk et al., 1963) from both paternal half sister analysis and daughter-dam correlations. The genetic correlations of major interest were those which involved milk production, and the estimates from the two methods were pooled to give combined estimates. The combined estimates of the genetic correlations between milk production and measurement traits were small but mostly positive. Body weight showed the most consistently high genetic correlation with milk production; however, body weight at 12 months of age gave the highest genetic correlation of 0.43 with milk production, and was the only significant correlation obtained. Other genetic correlations with milk production ranged from -0.07 to 0.37 and their standard errors ranged from 0.16 to 0.30.

Body measurements at 6 to 12 months of age appear to be of more value in selection than measurements taken at a postpartum period. Selection for body weight would appear to be as effective in improving milk production as selection for any other measure of body size. However, selection on the basis of measures of body size does not appear to be an effective method for the improvement of milk production.

Touchberry and Lush (1949) used data from the Iowa State College Holstein herd from 1931 to 1946 to study the accuracy of linear body measurement of dairy cattle. These cows were measured by 3 different workers at each of seven ages: 6 months, 1, 2, 3, 4, 5 and 7 years. They found the accuracies of the measurement were high. Paunch girth was the most accurate for single measurements (one man made one measurement of a trait on each animal at each age), while the corresponding figure for heart girth was the second most accurate, followed by wither height, chest depth, and body length, respectively. Measurement of body length was considerably less accurate than the other measurements. The reason was perhaps due to consistent changes in the temperament and position of the cow and possibly differences in the way the men located the point of the shoulder.

Blackmore et al. (1958) reported on the relationships between body measurements, meat conformation and milk production in a Holstein herd. The data were milk production and various measures of size at birth, 6 months, 1 year and 2 years of age. Negative genetic association between milk production and all measures of size except wither height were found. Thus, selection for milk production alone would eventually lead to animals with some decrease in chest depth, body length, and paunch girth, with an even more drastic reduction in chest girth but with an increase at wither height and practically no change in weight, at least through the ages concerned here. These associations indicate that any effort to select both for milk production and for a confirmation indicating good production of meat would require considerable compromise in both. Since the correlation between milk production and weight for age is practically zero (Blackmore et al., 1958), it seems possible to make some simultaneous progress in these two characteristics. The correlation between dam's production and daughter's size was consistently larger than the reciprocal correlations between dam's size and daughter's production. This excess was not evident at birth but was as strong at 2 years as it was at 6 months. It was concluded that this extra relationship was due to some maternal effect and not to contemporary environment affecting the characteristic similarly.

Clark and Touchberry (1962) used 1,344 lactations of Holstein cows, including records of lactation one through eight, and determined the independent influences of age and weight on production. A multiple regression analysis of first lactation data indicated that for a constant age, milk production increased 134 lbs and fat 7.8 lbs for each 100 lbs increase in body weight. For a constant weight, each increase of one month of age was accompanied by an increase of 46 lbs of milk and 1.2 lbs of fat. When all lactations were combined and the number of the lactation ignored, milk production increased by 400 lbs and fat production by 14.4 lbs for each 100 lbs increase in weight. For a constant weight, each month increase in age was accompanied by an increase of 28.4 lbs of milk and 0.9 lbs of fat.

Miller and McGilliard (1959) used the records for 4,677 Holstein, 1,001 Guernseys and 501 Jerseys to study the relations between weight at first calving and milk production during the first lactation. This was done by fitting least squares constants for the independent influences of age and weight on production in the first lactation. These effects indicated that delaying calving of heifers is not economically advantageous and that heavier heifers have little or no advantage over lighter heifers of similar age.

Table 1 presents the phenotypic correlation (Miller and McGilliard, 1959) on both an overall and intraherd basis.

Table 1. Phenotypic correlations between age, weight, milk, and fat

Trait	Level	Weight	Milk	Fat
<u>Holstein</u>				
Age	Overall	0.34	0.15	0.16
	Intraherd	0.36	0.23	0.24
Weight	Overall	—	0.31	0.31
	Intraherd	—	0.21	0.21
<u>Guernsey</u>				
Age	Overall	0.28	0.10	0.11
	Intraherd	0.43	0.30	0.31
Weight	Overall	—	0.30	0.32
	Intraherd	—	0.25	0.26
<u>Jersey</u>				
Age	Overall	0.25	0.08	0.04
	Intraherd	0.28	0.24	0.24
Weight	Overall	—	0.28	0.18
	Intraherd	—	0.22	0.21

The phenotypic correlation between age and weight appears to be slightly larger within herds than over a group of many herds. On the other hand, the correlation between weight and production within the herd is less than on an overall basis, the association within herds being of the order of 0.2. The correlation of age and production is distinctly larger when the differences between herds are removed. The intraherd correlation is of the order of 0.2 to 0.3, whereas the correlation between age and production is only about 0.1 on an overall basis.

Dickinson (1973), in using USDA-DHIA Sire Summary Information in Herd Management report, summarized the goals of a profitable breeding program in dairy:

1. produce large quantities of milk,
2. produce milk of a desirable composition,
3. produce at the lowest possible production costs,
4. cows of sound conformation and good health,
5. cows that will remain as profitable productive units as long as the dairyman wants them.

Dickinson (1973) suggested that body size appears to be related to feed utilization and profitability of cows within breeds; however, there is a complex relationship between body size and efficiency. There is strong evidence that even though larger cows in a breed give more milk, they also do it less efficiently and less profitably. Therefore, in planning matings, care should be exerted to raise production of the offspring without unduly increasing the size. Selection for higher production should automatically increase the size of future animals. Selection directly for large size, however, may result in animals which are less profitable even though they may be slightly higher producers. Speed of feeding is a trait that is probably part of the yield, body size and efficiency complex. There is a high positive genetic correlation of close to 1.0 between first lactation feeding speed and lifetime milk yield (Norman and Van Vleck, 1972). Therefore, it actually may be most advantageous to ignore body size and select for high yielders which are rapid feeders.

Johnson (1954) determined the change due to growth for the following twelve physical characteristics of 3 breeds (Holstein, Jersey and Guernsey): body weight, wither height, depth of forechest, circumference of forechest, length wither to pin bones, circumference of muzzle, depth of paunch, circumference of paunch, height of back, height of hips, width of hips, and circumference of chinbone, at 6, 12, 18, 30, and 36 months of age. The curve for percentage or instantaneous gain was similar for the three breeds for most characteristics studied, the main exception being body weight. The Jersey and Guernsey increased in percentage gain during the period 30 to 36 months, while the Holstein decreased in percentage gain. Since body weight is affected by lactation and this period includes a substantial portion of the lactation period for the three breeds, indications are differences in percentage gain may be due to a lactation effect.

Johnson (1954) used 66 dam-daughter pairs, 32 Holstein, 16 Guernsey and 18 Jersey, to study the heritability, genetic and phenotypic correlations of five body measurements: wither height, depth of forechest, circumference of forechest, length withers to pin bones and body weight at 30 months of age. Results of this study indicate the six body characteristics studied are correlated to one another both genetically and phenotypically. It is apparent that the genetic value of the five body measurements and body weight are associate and show much dependence on each other. There is strong evidence of the manifold effects of genes which affect size in general. On the basis of the data from this study, it appears that milk production is genetically independent of the body measurements studied and of body weight.

Farthing (1958) studied the relative influence of live weight and age on production in Holstein and Jersey cows. He developed a method of utilizing live weight as an aid to selection. These data indicated that age was more effective than weight in accounting for variation in production. In the Jersey data, there was no relationship between mature equivalent (M.E.) production and live weight. In the Holstein data, increases of 390 lbs in M.E. milk and 16 lbs in M.E. fat were associated with an average increase of 100 lbs in live weight. Estimates of the heritability of M.E. production in Holstein were increased when production was corrected for weight. The greatest expected genetic improvement in M.E. milk was obtained when weight corrected M.E. milk was used as the basis for selection.

Shanks and Spahr (1981) used data from the University of Illinois Holstein herd from 1966 to 1980 to study relationships among udder depth, hip height, hip width, and daily milk production. Single measurements per cow-lactation were taken within 16 weeks postpartum for records distributed as 523 first, 409 second, and 266 third lactations. Fifty-one sires had two or more progeny represented in each lactation. Udder depth, hip height, and hip width were measured to the nearest cm. Udder depth was measured from the cleft between the rear teats to the ground. Daily milk production was measured to the nearest half kg and was the average daily milk production for the week in which other measurements were taken. The result of this study in potential selection response per generation for increased daily milk production was 0.6 kg. Correlated responses were 0.12 cm, 0.19 cm, and 0.24 cm for udder depth, hip height, and hip width. Hip height was positively phenotypically correlated with hip width and udder depth in all lactations. Taller cows were broader in the rump, as measured at the hips.

Four to six percent of the variation in udder depth was accounted for by hip height. Greater than average daily milk production in early lactation was associated with taller hip height, broader hip width, and deeper than average udders.

B. Pedigree Selection for Milk Production

Freeman (1980) summarized the heifer's production of the dairy cattle that were purchased, as foundation cows for a selection experiment, based on their pedigree; the heifers were purchased before breeding in multiples of two from Iowa breeders. One heifer was pedigree selected for high milk and one for low milk production. These heifers were brought to the Ankeny, Iowa experimental herd, bred and calved. The results comparing the expected response from pedigree selection and the realized response are in Table 2. These are unadjusted values. The difference in mature equivalent production was 2,035 lbs between the average of pedigree high and low groups versus an expected 1,800 lbs, 235 lbs more than expected. After adjusting for year-seasons, he found the difference between the average of the adjusted high and low groups was 34 lbs of milk greater than expected.

C. Sire Selection for Milk Production

Freeman (1980) reported that the pedigree selected high foundation heifers were mated equally and at random to high and average sires; the pedigree selected low foundation heifers were mated equally and at random to high and average sires. In all future generations, progeny

Table 2. Expected and realized performance of heifers selected on pedigree for high and low milk production

First lactation	Estimated breed value at purchase	M.E. milk	M.E. fat	% fat	% SNF	Days in milk	Days carried calf
Pedigree high	1,373	16,652	633	3.88	8.96	302	190
Pedigree low	-427	14,627	570	3.98	9.09	299	189
Difference	1,800	+2,035	+63	-0.10	-0.13	+3	+1

of high sires are mated at random to the next selection of high sires and low cows to average sires. So, any effects generated by the selection will be perpetuated. Freeman (1980) used the data across all sire groups; there were 233, 152, 163 and 548 lactation for first, second, third or greater, and all lactation to study the difference between the high sires versus the average sires. Table 3 shows the results of his study.

The differences between high and average sires were large and significant, except sires progeny group for days carried calf in all generations. Selection for milk production was clearly effective and the correlated responses in pounds of fat and solids-not-fat were also larger for progeny of high sires. The correlated responses in percentages of fat and solids-not-fat were lower in progeny of sires selected for high milk production.

Table 3. Performance of daughters of high versus average sires by generations and lactations

	First lactation			Second lactation		
	High versus ave. sire			High versus ave. sire		
	Average	G_1	G_2	Average	G_1	G_2
Days carried calf	149.40	-13.00	6.20	149.40	-0.90	6.40
% SNF	9.11	-0.20[1]	-0.23[1]	8.94	-0.19[1]	-1.16
% fat	3.79	-0.11[5]	-0.15[1]	3.77	-0.08	-0.10
M.E. milk (lbs)	15,778.00	2,809.00[1]	2,313.00[1]	15,901.00	2,885.00[1]	1,759.00[1]
M.E. fat (lbs)	588.00	86.00[1]	59.20[1]	589.00	96.50[1]	49.50
Solid-not-fat (lbs)	1,436.00	219.00[1]	175.00[1]	1,420.00	229.00[1]	134.00

	Third lactation			All lactations		
	High versus ave. sire			High versus ave. sire		
	Average	G_1	G_2	Average	G_1	G_2
Days carried calf	127.80	19.10	34.90	149.90	1.40	11.40
% SNF	8.95	-0.22[1]	-0.24[5]	9.04	-0.20[1]	-0.23[1]
% fat	3.83	-0.16[1]	-0.02	3.81	-0.12[1]	-0.12[5]
M.E. milk (lbs)	15,646.00	2,608.00[5]	2,318.00[5]	15,830.00	2,755.00[5]	2,202.00[1]
M.E. fat (lbs)	594.00	73.10[5]	82.50[5]	593.00	83.60[5]	61.60[1]
Solid-not-fat (lbs)	1,389.00	200.00[5]	168.00	1,430.00	215.00[5]	163.00[1]

1 = P(< 0.01).

5 = P(< 0.05).

D. Health, Income over Feed Cost and Health Cost

Freeman (1980) reported that there were no significant differences for reproductive or digestive disorders between high or low genetic groups for either the foundation cow or their first generation progeny. For the foundation cows, there were significantly more problems in pedigree selected high cows for: digestive problems (milk fever and displaced abomasum), feet and leg problems (foot trimming), skeleton problems, edema, and mastitis incidences.

Shanks (1979) recommended the major technique to maximize profits was to select for increased milk production. Reducing health cost was a secondary technique to increase profits. In general, phenotypic correlations indicated that a rapid rate of decline in milk production was associated with reduced health costs.

Shanks et al. (1978) studied the effect of selection for milk production on reproductive and general health of the dairy cow. They used 43 pairs of open heifers purchased as foundation animals to evaluate direct response to selection for milk production and correlated responses of reproduction, digestion, respiration, skin or skeleton, and mammary disorders. One heifer of each pair was selected for high genetic potential, and the other was selected for low potential on pedigree evaluations for milk production. High pedigree cows produced more milk, but they also had 9% more digestive disorders, 5% more foot rot, 14% more skin or skeletal disorders, 11% more cases of udder edema, and 2% more lactations affected by mastitis. High pedigree cows even with the $12.46 more health costs netted $45.80 more per lactation than did low pedigree cows calving in the same year. These cows were the foundation generation animals in the selection experiment described by Freeman (1980). The high pedigree cows had an estimated breeding value for milk production of +640 kg, and the low pedigree cows had an estimated breeding value of -120 kg. To form the first generation, the foundation females were bred randomly to high or average predicted difference milk sires. The seven high sires of nonzero generation animals had a mean predicted difference milk of +626 kg when chosen. The seven average sires of nonzero generation animals had a mean predicted difference milk of +16 kg when chosen. The repeatability of every sire was greater than 70%. Daughters of high sires produced more milk, had 8% fewer systemic uterine treatment, 3% fewer mammary cuts, more joint or leg injuries, 13% more skin or skeletal disorders, and 19% more causes of udder edema than did daughters of average sires. Daughters of sires with high predicted difference milk netted $77.64 more per lactation than did daughters of breed average sires.

Whitemore et al. (1974) studied the effects of early postpartum breeding in Holstein cattle. The design of the experiment was a 2 x 2 x 2 factorial with two levels of genetic ability for milk production, two levels of concentrate feeding, and two different times of first breeding after parturition. In preparation for the experiment, each female in the herd was evaluated as to genetic ability for milk production. Cows and heifers were ranked from highest to lowest on the basis of an index of their estimated breeding values. The index was based on performance of close female relatives plus the cow's own individual performance. The whole herd was divided at the median into two groups, one designated as genetically high and the other genetically low for production of milk. Females in the high milk production group and their descendants were bred with semen obtained from proven sires whose AI daughters were high producers of milk (approximately 450 kg milk above contemporary herdmates), while the low milk production females and their descendants were bred with semen obtained from proven sires whose AI daughters were approximately equal to contemporary herdmates. The present experiment utilized all female descendants of the cows and heifers in the original herd. All cows were started on the experiment at the time of their first calving and every 6 months thereafter, all pregnant heifers that were due to calve during the following 6 months were assigned randomly to a nutrition and breeding subgroup. However, once an animal was assigned to a particular subgroup, she remained in the subgroup throughout her successive calving intervals until removed from the herd.

A major objective of this study was to determine if early postpartum breeding of dairy cows is detrimental to the animal's future reproductive performance. A total of 393 calving intervals of 168 Holstein cows was used in an experiment of factorial design to compare the effects of breeding at the first postpartum estrus versus breeding at 74 days postpartum. Also of interest was how these effects might be modified by two different levels of nutrition and two genetic levels for milk production. How first postpartum ovulation occurred can be characterized as: of the 386 first ovulation studied, 165 (43%) occurred without observed estrous behavior (quiet ovulation), 47 (12%) occurred with nonstanding estrous, and 174 (45%) occurred with standing estrous. A high incidence of quiet ovulation was shown by the high nutrition group compared to the average nutrition group (49% of 195 versus 36% of 191, $P < 0.01$). The interval to first postpartum estrous when judged by rectal palpation, of genetically high-producing cows were longer, on the average, from calving to first ovulation and to first estrous ($P < 0.05$) than were those of low-producing cows (31 versus 29, and 42 versus 36, respectively), and longer for cows on high nutrition compared to average nutrition (32 versus 28, and 42 versus 35, respectively). Fertility at first insemination was lower in cows bred at the first estrous following calving compared to those bred at a later estrous. There was no indication that early breeding had a cumulative detrimental effect on fertility. The average fertility at second, third and fourth inseminations was similar for the two breeding groups. The first estrous breeding group had fewer days open than the later estrous breeding group but required more inseminations per pregnancy. Cows on high nutrition had more retained placentas than those on average nutrition and similarly had a higher incidence of metritis. Genetically high-producing cows also had more retained placentas than low producers.

Shanks (1977) found that cows that gave more milk, had fewer conception rates and shorter conception intervals, primarily because they were healthier than less-fertile cows. Cows with poor 30 days uterine involution grades had 81 days longer conception intervals, 42% lower conception rates and 880 lbs less milk than those with good 30 days uterine involution grades.

Britt (1974) found that as calving interval increased, milk yield per day decreased, and maximum production per year was achieved when the calving interval was less than 365 days. Cows with a calving interval of 365 days or less produced an average of 4.9 calves during the 5 years compared with 3.8 calves for cows with a calving interval of more than 426 days. Breeding can normally begin at about 40 days postpartum with an acceptable rate of reproductive performance.

Slama et al. (1976) studied the various factors affecting calving interval within breeds. Fertility of bulls differed within breeds. Analysis, by fitting constants, revealed that intervals from calving to first service, from first service to conception and services per conception were major factors affecting calving intervals. Depending on breed combinations, unit changes (the services required per conception by one unit can change the calving interval from 7 to 14 days) in these variables would account for the greatest overall reduction in length of calving interval. Month of calving, month of conception, year of calving, age of calving, and peak milk had no significant effect on changing the average calving interval.

Rindsig (1973) studied the results of an experiment designed to measure genotype by environment interaction and the effects of contemporaneity upon growth and production in Holstein twins. This experiment was conducted by Iowa State University at the Ankeny location. Two feeding regimes were used. They differed only in the amount of grain fed. The high grain ration was approximately 110 percent of Morrison's standard while the low grain ration was approximately 90% of Morrison's standard. The experimental design used four pairs of twins as a replicate. The first pair of each replicate was placed on the high ration. The second and the third pair were split with one member on the high and the other member on the low ration. Both members of the fourth pair were placed on the low ration.

The high grain ration animals received up to 6 lbs of grain per day until calving. After calving, they received 1 lb of grain per 2 lbs of milk for all milk over 10 lbs per day. A maximum of 20 lbs of grain per day was allowed. They received 6 lbs of grain per day during dry periods.

The low grain ration animals received up to 6 lbs of grain per day up to 9 months of age. No grain was fed to the low group between 9 months of age and calving. After calving, they received 1 lb of grain for each 6 lbs of milk for all milk over 10 lbs per day. A maximum of 20 lbs of grain per day was allowed. Low ration animals received no grain during dry periods.

Results (Rindsig, 1973) of analyzing the twin data from Ankeny showed that the environmental differences created in this experiment were moderate and estimates of ration by pair and ration interaction were close to zero for the production traits and growth traits at young ages. F-tests for ration by pair interaction indicated that wither height has a genotype by environment interaction at older ages. Weighted least squares analysis also showed large estimates for ration by additive genetic variance for lactation associated growth measurements of wither height and chest depth. Overall, analysis of production and growth traits for monozygous and dizygous dairy cattle twins has shown that ration by pair and ration interaction are negligible and, thus, unimportant in dairy cattle evaluation for these levels of difference in rations. Contemporaneity is of great importance in accounting for variation in growth traits at young ages and decreases as twins grow older, reaching a minimum at about 15 to 21 months. By the time twins are in production, the effects of contemporaneity are small for yields of milk, SNF, and total solids but from 10 to 28 percent for fat, protein, fat percent, protein percent, and SNF percent.

Thomson (1966) used data which were collected over 35 years to study inbreeding and selection in a closed Holstein-Friesian herd at Iowa State University. An investigation was made of the effects of inbreeding on production, type, percentage white color, and the measurement of weight, wither height, chest depth, body length, heart girth, and paunch girth.

Inbreeding in this herd ranged from zero to 47%, with an average of 10.2%. All of the analyses of the effects of inbreeding on weight and measurements show the same general trend. At the earlier age, inbreeding had more of a depressing effect than was observed at the later ages. From the results of the study of measurements, a two-year-old cow, inbred to 10%, would be expected to weigh 31 lbs less, 1/2 cm shallower in chest depth, 1/2 cm lower at the withers, and 1 cm shorter in body length than a noninbred, heart girth 2 cm and paunch girth 3 cm less. The analyses of first lactation, milk yield decreased 50 lbs for each one percent increase in the inbreeding coefficient.

III. DESCRIPTION OF DATA

An experimental design for selection studies in dairy cattle (Hickman and Freeman, 1968; Freeman, 1980) is being conducted at Iowa State University Ankeny Dairy Farm. The selection criteria are for milk production. This experiment allows the relations among body weight and measurements to be studied as correlated responses to milk production. Open heifers were purchased in pairs, one had a high genetic potential and the other heifer had a low genetic potential for milk production. These open heifers were used as the zero generation. The high pedigree zero generation heifers were randomly bred to a high or average sire group. The low pedigree zero generation heifers were, also, randomly bred to a high or average sire group. The choice of the high or breed average sires mated to each cow will not change, but the specific sire used within each level will be random. Any resulting female offspring from such mating will be assigned the same high or average sire group from which dam were bred. Thus, two levels of sires are used, the highest available, and breed average sires. Currently, 12 sires are in use. Six each of the high (H) and breed average (BA) sire levels. A 2^2 factorial design was formed of high and low heifers and high and average sires.

		Sires: High PD	Sires: Average PD
Dams	High EATA	H x H	BA x H
	Low EATA	H x L	BA x L

Iowa State Breeding Plan

A. Body Weight and Measurements

Body weight and measurement data collected on 1,511 Holstein-Friesian cows from May 1977 to January 1981 were utilized in this study. Actual body weight was taken in pounds and the body measurements consisted of heart girth, paunch girth, wither height, chest depth, pelvic length, pelvic width and body length measured in centimeters when these heifers were 12 months and at each parity after calving between 30 to 55 days from postpartum.

The seven body measurements taken were:

1. Heart girth — the smallest circumference just behind the forelegs with the cow standing square on her legs and holding her head up.

2. Paunch girth — the largest circumference about the barrel.

3. Wither height — the distance from the ground to the highest point of the withers.

4. Chest depth — the vertical distance from the back to the floor of the chest at the shallowest part of the chest.

5. Pelvic length — the horizontal distance from in front of the hook bone to the back of the pin bone on the left side.

6. Pelvic width — the distance from the outside of the left hook bone to the outside of the right hook bone.

7. Body length — the horizontal distance from the front point of the shoulder to the end of the pin bones on the left side.

Care was taken each time to have the animal in a natural position standing rather squarely on all four legs. Each measurement was taken two times so that one man would make only one measurement of a characteristic on each animal. At the same time, another person recorded these in the record book as the first measurements. The cow was moved to a new position and the measurements were repeated. The name of the person who took each measurement was recorded so that the effect of possible differences in the way various men used the measuring instruments could be considered. Each measurement used in this study was the average of two independent estimates.

B. Definitions

The code names for this study are given below:

Code name	Definition
Cell S_1	Cell code of sire for high sires
Cell S_2	Cell code of sire for average sires
Cell D_1	Cell code of dam for pedigree high
Cell D_2	Cell code of dam for pedigree low
Cell D_1 vs Cell D_2	The total difference between pedigree high cows minus low cows for generation zero
Cell S (Gen)	Cell code of sire (1 or 2) within generation
Cell D (Gen)	Cell code of dam (1 or 2) within generation
High sire vs ave. sire	The total difference between pedigree high sires minus average sires for all generations
11 vs 21	The difference between pedigree high sires minus average sires within generation one

Code name	Definition
12 vs 22	The difference between pedigree high sires minus average sires within generation two
13 vs 23	The difference between pedigree high sires minus average sires within generation three
14 vs 24	The difference between pedigree high sires minus average sires within generation four
High dam vs low dam	The total difference between pedigree high cows minus low cows in generations greater than zero
11 vs 21	The difference between pedigree high cows minus low cows within generation one
12 vs 22	The difference between pedigree high cows minus low cows within generation two
13 vs 23	The difference between pedigree high cows minus low cows within generation three
14 vs 24	The difference between pedigree high cows minus low cows within generation four

IV. METHODS OF ANALYSES

To describe the factors affecting evaluation of any body weight and measurements, a model was chosen which included the effects, year, generation, cell code of sire, cell code of dam, and cell code of sire and cell code of dam within generations. All analyses of body weight and measurements were estimated using a General Linear Model (Helwig, 1979) and Statistical Methods (Snedecor and Cochran, 1978).

A. Foundation Cows in Generation Zero

An observation on cows bred for high and low genetic potential for milk production was represented by the following model (Model 1):

$$y_{ijk} = \mu + yr_i + c_j + e_{ijk}$$

y_{ijk} = an observation on weight or measurements of the kth cow in the jth cell code and started in the ith year

μ = an underlying mean

yr_i = a fixed effect of all records started in the ith birth year

c_j = a fixed effect of the cell code of females (1 and 2).

e_{ijk} = the residual random error associated with each observation.

B. Cows in Generations Greater than Zero

Model 2 was used to describe body weight and measurements between high sires vs average sires and high dams vs low dams:

$$y_{ijklm} = \mu + yr_i + G_j + \text{cell } S_k{:}G_j + \text{Cell } D_l{:}G_j + e_{ijklm}$$

y_{ijklm} = an observation on weight or measurements of the mth cow in the lth cell code of dam and kth cell code of sire in the jth generation and ith year

μ = an underlying mean

yr_i = a fixed effect of all observations started in the ith birth year

G_j = a fixed effect of all observations in the jth generation

Cell $S_k{:}G_j$ = a fixed effect of all observations in the kth cell code of sire within the jth generation

Cell $D_l{:}G_j$ = a fixed effect of all observations in the lth cell code of dam within the jth generation

e_{ijklm} = the residual random error associated with each observation.

Both Models 1 and 2 were fit separately for each age and parity.

V. RESULTS AND DISCUSSION

Body weight and measurements are the data used in these analyses. Models have been fit by least squares to enable estimation of body weight and measurement differences between high dams vs low dams for generation zero, high sires vs average sires and high dams vs low dams for generations greater than zero, means and least squares means for each trait have been put in Tables 4 to 28.

There are basically 2 sets of data that were analyzed: generation zero and generation greater than zero for each trait. The results will be discussed for each set of data by trait within ages and/or parities.

A. Foundation Females in Generation Zero — Model 1

Cell code of dam, birth year effects, linear contrasts, raw means, least squares means for pedigree high cows vs low cows at 12 months of age, parity one, two, three, and greater than or equal to four for body weight and measurements are in Tables 4 to 13.

1. Cell code of dam

Results from analyses between high and low foundation females for body weight and measurements (Cell D_1 vs Cell D_2) are in Tables 4, 6, 8, 10, and 12 and linear contrasts are in Tables 5, 7, 9, 11, and 13 for animals in each age and/or parity.

a. Body weight   Linear contrast between high and low dams for body weight and measurements were all negative, pedigree selected high cows were lighter than pedigree selected low cows, for all ages and

Table 4. Difference between high and low foundation heifers for weight and measurements at 12 months of age

Source	DF	MS	F	PR >F	MS	F	PR >F
		Weight			Heart girth		
Cell dam	1	8,266.40	0.91	0.35	328.81	5.83	0.02[5]
Birth year	5	14,761.58	1.63	0.17	77.04	1.37	0.26
Residual	41	9,074.82	—	—	56.39	—	—
		Paunch girth			Wither height		
Cell dam	1	37.21	0.41	0.53	55.34	4.04	0.05[5]
Birth year	5	257.67	2.85	0.03[5]	16.51	1.20	0.32
Residual	41	90.54	—	—	13.70	—	—
		Chest depth			Pelvic length		
Cell dam	1	24.65	5.13	0.03[5]	14.28	2.91	0.10[10]
Birth year	5	9.88	2.05	0.09[10]	4.77	0.97	0.45
Residual	41	4.81	—	—	4.90	—	—
		Pelvic width			Body length		
Cell dam	1	14.37	2.13	0.15	108.34	2.38	0.13
Birth year	5	13.19	1.96	0.11	97.25	2.14	0.08[10]
Residual	41	6.74	—	—	45.49	—	—

5 = P (< 0.05).

10 = P (< 0.10).

Table 5. Linear contrasts between high and low foundation heifers for weight and measurements at 12 months of age

Linear contrasts		Weight (lbs)	Heart girth (cm)	Paunch girth (cm)	Wither height (cm)
Difference					
Cell D_1 vs Cell D_2		-27.86	-5.56[5]	-1.87	-2.28[5]
Mean		711.67	157.42	193.51	117.67
L.S. means	Cell D_1	663.04	152.71	187.81	115.53
	Cell D_2	690.90	158.27	189.68	117.81

Linear contrasts		Chest depth (cm)	Pelvic length (cm)	Pelvic width (cm)	Body length (cm)
Difference					
Cell D_1 vs Cell D_2		-1.52[5]	-1.16[10]	-1.16	-3.19
Mean		59.76	43.63	41.05	130.63
L.S. means	Cell D_1	58.07	42.50	39.73	127.10
	Cell D_2	59.59	43.66	40.90	130.29

5 = ($P < 0.05$).

10 = ($P < 0.10$).

Table 6. Difference between high and low foundation cows for weight and measurements in generation zero and parity one

Source	DF	MS	F	PR >F	MS	F	PR >F
		Weight			Heart girth		
Cell dam	1	5,104.13	0.26	0.61	148.37	2.31	0.13
Birth year	5	31,323,20	1.58	0.18	35.23	0.55	0.74
Residual	74	19,877.01	–	–	64.33	–	–
		Paunch girth			Wither height		
Cell dam	1	0.25	0.00	0.97	46.15	3.04	0.09[10]
Birth year	5	415.01	3.09	0.01[1]	12.27	0.81	0.55
Residual	74	134.35	–	–	15.18	–	–
		Chest depth			Pelvic length		
Cell dam	1	25.38	4.03	0.05[5]	9.57	1.90	0.17
Birth year	5	6.40	1.02	0.42	3.38	0.67	0.65
Residual	74	6.30	–	–	5.03	–	–
		Pelvic width			Body length		
Cell dam	1	0.21	0.03	0.86	44.85	1.75	0.19
Birth year	5	6.96	1.06	0.39	34.83	1.36	0.25
Residual	74	6.54	–	–	25.70	–	–

1 = P (< 0.01).

5 = P (< 0.05).

10 = P (< 0.10).

Table 7. Linear contrasts between high and low foundation cows for weight and measurements in generation zero and parity one

Linear contrasts		Weight (lbs)	Heart girth (cm)	Paunch girth (cm)	Wither height (cm)
Difference					
Cell D_1 vs Cell D_2		-16.07	-2.74	-0.11	-1.53[10]
Mean		1,169.73	191.84	226.87	133.08
L.S. means	Cell D_1	1,134.29	188.92	223.47	131.40
	Cell D_2	1,150.36	191.66	223.59	132.93

Linear contrasts		Chest depth (cm)	Pelvic length (cm)	Pelvic width (cm)	Body length (cm)
Difference					
Cell D_1 vs Cell D_2		-1.13[5]	-0.70	-0.10	-1.51
Mean		72.86	52.97	52.83	155.26
L.S. means	Cell D_1	71.47	52.37	52.10	153.26
	Cell D_2	72.60	53.06	52.20	154.76

5 = ($P < 0.05$).

10 = ($P < 0.10$).

Table 8. Difference between high and low foundation cows for weight and measurements in generation zero and parity two

Source	DF	MS	F	PR >F	MS	F	PR >F
		Weight			Heart girth		
Cell dam	1	82,421.49	4.20	0.04[5]	110.82	1.81	0.18
Birth year	5	33,621.43	1.71	0.14	102.96	1.68	0.15
Residual	63	19,637.23	–	–	61.34	–	–
		Paunch girth			Wither height		
Cell dam	1	131.38	1.06	0.31	19.95	1.32	0.26
Birth year	5	321.94	2.60	0.03[5]	13.82	0.91	0.48
Residual	63	123.79	–	–	15.17	–	–
		Chest depth			Pelvic length		
Cell dam	1	14.70	2.20	0.14	22.95	4.79	0.03[5]
Birth year	5	15.41	2.31	0.05[5]	9.62	2.01	0.09[10]
Residual	63	6.67	–	–	4.79	–	–
		Pelvic width			Body length		
Cell dam	1	4.80	0.71	0.40	125.31	3.62	0.06[10]
Birth year	5	13.00	1.91	0.10[10]	70.92	2.05	0.08[10]
Residual	63	6.80	–	–	34.58	–	–

5 = ($P < 0.05$).

10 = ($P < 0.10$).

Table 9. Linear contrasts between high and low foundation cows for weight and measurements in generation zero and parity two

Linear contrasts		Weight (lbs)	Heart girth (cm)	Paunch girth (cm)	Wither height (cm)
Difference					
Cell D_1 vs Cell D_2		-69.68[5]	-2.56	-2.78	-1.08
Mean		1,320.39	199.14	239.19	136.13
L.S. means	Cell D_1	1,235.74	194.60	232.71	134.73
	Cell D_2	1,305.42	197.16	235.49	135.81

Linear contrasts		Chest depth (cm)	Pelvic length (cm)	Pelvic width (cm)	Body length (cm)
Difference					
Cell D_1 vs Cell D_2		-0.93	-1.16[5]	-0.53	-2.72[10]
Mean		75.16	54.94	56.54	161.41
L.S. means	Cell D_1	73.56	53.42	55.15	157.38
	Cell D_2	74.49	54.58	55.68	160.10

5 = ($P < 0.05$).

10 = ($P < 0.10$).

Table 10. Difference between high and low foundation cows for weight and measurements in generation zero and parity three

Source	DF	MS	F	PR >F	MS	F	PR >F
		Weight			Heart girth		
Cell dam	1	126,378.33	7.68	0.01[1]	6.70	0.03	0.87
Birth year	5	40,335.86	2.45	0.05[5]	53.45	0.21	0.96
Residual	47	16,456.56	—	—	254.74	—	—
		Paunch girth			Wither height		
Cell dam	1	168.61	1.35	0.25	209.83	0.50	0.48
Birth year	5	516.52	4.14	0.01[1]	181.42	0.43	0.82
Residual	47	124.76	—	—	419.49	—	—
		Chest depth			Pelvic length		
Cell dam	1	26.52	3.87	0.06[10]	27.31	5.53	0.02[5]
Birth year	5	13.08	1.91	0.11	6.67	1.35	0.26
Residual	47	6.86	—	—	4.94	—	—
		Pelvic width			Body length		
Cell dam	1	19.72	2.63	0.11	107.66	3.01	0.09[10]
Birth year	5	12.70	1.69	0.16	70.72	1.98	0.10[10]
Residual	47	7.51	—	—	35.72	—	—

1 = P (< 0.01).

5 = P (< 0.05).

10 = P (< 0.10).

Table 11. Linear contrasts between high and low foundation cows for weight and measurements in generation zero and parity three

Linear contrasts		Weight (lbs)	Heart girth (cm)	Paunch girth (cm)	Wither height (cm)
Difference					
Cell D_1 vs Cell D_2		-98.67[1]	-0.72	-3.60	4.02
Mean		1,388.13	202.79	243.98	140.18
L.S. means	Cell D_1	1,280.82	200.61	234.81	139.41
	Cell D_2	1,379.49	201.33	238.41	135.39

Linear contrasts		Chest depth (cm)	Pelvic length (cm)	Pelvic width (cm)	Body length (cm)
Difference					
Cell D_1 vs Cell D_2		-1.43[10]	-1.45[5]	-1.23	-2.88[10]
Mean		76.82	56.18	58.34	163.90
L.S. means	Cell D_1	74.98	54.60	56.45	160.22
	Cell D_2	76.41	56.05	57.68	163.10

1 = P (< 0.01).

5 = P (< 0.05).

10 = P (< 0.10).

Table 12. Difference between high and low foundation cows for weight and measurements in generation zero and parity ≥ 4

Source	DF	MS	F	PR >F	MS	F	PR >F
		Weight			Heart girth		
Cell dam	1	27,371.46	1.29	0.26	47.43	0.75	0.39
Birth year	5	21,373.44	1.01	0.42	69.32	1.10	0.37
Residual	89	21,224.66	–	–	62.96	–	–
		Paunch girth			Wither height		
Cell dam	1	504.74	4.28	0.04[5]	34.40	2.16	0.15
Birth year	5	52.62	0.45	0.82	33.55	2.11	0.07[10]
Residual	89	118.02	–	–	15.92	–	–
		Chest depth			Pelvic length		
Cell dam	1	18.45	3.87	0.05[5]	8.88	1.73	0.19
Birth year	5	12.97	2.72	0.02[5]	26.58	5.17	0.01[1]
Residual	89	4.77	–	–	5.14	–	–
		Pelvic width			Body length		
Cell dam	1	3.18	0.53	0.47	81.43	2.82	0.10[10]
Birth year	5	23.91	4.01	0.01[1]	212.14	7.35	0.01[1]
Residual	89	5.96	–	–	28.85	–	–

1 = P (< 0.01).

5 = P (< 0.05).

10 = P (< 0.10).

Table 13. Linear contrasts between high and low foundation cows for weight and measurements in generation zero and parity ≥ 4

Linear contrasts		Weight (lbs)	Heart girth (cm)	Paunch girth (cm)	Wither height (cm)
Difference					
Cell D_1 vs Cell D_2		-36.56	-1.52	-4.96[5]	-1.30
Mean		1,421.17	204.78	247.30	138.52
L.S. means	Cell D_1	1,384.19	202.43	243.88	136.95
	Cell D_2	1,420.74	203.95	248.84	138.24

Linear contrasts		Chest depth (cm)	Pelvic length (cm)	Pelvic width (cm)	Body length (cm)
Difference					
Cell D_1 vs Cell D_2		-0.95[5]	-0.66	-0.39	-1.99[10]
Mean		77.58	56.23	58.98	164.69
L.S. means	Cell D_1	76.41	55.03	57.49	161.06
	Cell D_2	77.36	55.69	57.88	163.06

5 = P (< 0.05).

10 = P (< 0.10).

parities, -27.86 lbs (nonsignificant) at 12 months of age in Table 5, -16.07 lbs (nonsignificant) in parity one (Table 7), -69.68 lbs (significant $P < 0.05$) in parity two (Table 9), -98.67 lbs (significant $P < 0.01$) in parity three (Table 11), and -36.56 lbs (nonsignificant) in parity greater than or equal to four (Table 13). Negative contrasts of body weight in parities two and three were significant as contrasted to no significance in parity one, which could be due to high-producing cows during these ages. Perhaps high milking cows in these parities may lose body weight from the previous late lactation and then they could not completely replenish their body weight for the next lactation.

Contrast between dam groups in parity greater than or equal to four in Table 13 was not significant; one explanation was that cows of fourth parity and older could have differed in body weight, but when compared as one group, these differences could have cancelled. In general, foundation cows producing more milk were lighter in body weight than the heavier cows that produced less milk.

b. Heart girth The linear contrast between high-producing and low-producing females were all negative; pedigree selected high cows were smaller in heart girth than pedigree selected low cows, for all ages and parities: -5.56 cm (significant $P < 0.05$) at 12 months of age in Table 5, -2.74 cm (nonsignificant) in parity one (Table 7), -2.56 cm (nonsignificant) in parity two (Table 9), -0.72 cm (nonsignificant) in parity three (Table 11), and -1.52 cm (nonsignificant) in parity greater than or equal to four (Table 13). All these differences were small, particularly for the parity groups. The only significant difference was between high and low heifers at 12 months of age in generation zero ($P < 0.05$). Heifers for low milk production at younger ages seems to develop heart girths larger than heifers pedigree selected for high milk production. Heart girth was defined by Touchberry (1951) as a flesh factor which is strongly influenced by the degree of fatness. Touchberry (1951) and Blackmore (1954) have shown that fleshiness is antagonistic to milk production, and these results are corroborated in this study with all negative constrasts between high cows vs low cows. Rindsig (1973) pointed out that heart girth was influenced by ration (high and low nutrition) between split monozygous twins. Therefore, high-producing cows had smaller heart girth than low-producing cows, as would be expected from their genetic potential.

c. Paunch girth Linear contrast between high and low dams for body weight and measurements were: -1.87 cm (nonsignificant) at 12 months of age in Table 5, -0.11 cm (nonsignificant) in parity one (Table 7), -2.78 cm (nonsignificant) in parity two (Table 9), -3.60 cm (nonsignificant) in parity three (Table 11), and -4.96 cm (significant $P < 0.05$) in parity greater than or equal to four (Table 13). All of these results were nonsignificant except parity greater than or equal to four. Reasons for this could be that paunch girth is measured from the largest circumference for the body or posterior to the last rib and is generally indicative of "fill" or food ingested. Large errors in paunch girth may be due to problems in obtaining accurate measures such as temperament and respiration of the cows. As mentioned earlier, grouping cows together in parities four and greater could have resulted in difference at these later parities counterbalancing each other with the result that genetic differences are not significant for this parity grouping.

d. Wither height Pedigree high cows had a shorter wither height than low cows with the results: -2.28 cm (significant $P < 0.05$) for animals at 12 months of age (Table 5), -1.53 cm (significant $P < 0.10$) in parity one (Table 7), -1.08 cm (nonsignificant) in parity two (Table 9), 4.02 cm (nonsignificant) in parity three (Table 7), and -1.30 cm (nonsignificant) in parity greater than or equal to four (Table 13). Negative contrast between high and low cows decreased from heifers at 12 months of age through first parity, second parity, changed to positive contrast in parity three, and again decreased to negative contrasts in parity greater than or equal to four; though the latter two groups were not significantly different. Most of the growth potential is expressed by second parities. So it is not surprising that differences in parities three and greater are not significant.

e. Chest depth Cows that had high milk production potential were smaller than those with low milk production, and the differences for the linear contrasts for females at 12 months of age were: -1.52 cm (significant $P < 0.05$) (Table 5); in first parity, - 1.13 cm (significant $P < 0.05$) (Table 7); in second parity, -0.93 cm (nonsignificant) (Table 9); in third parity, -1.43 cm (significant $P < 0.10$) (Table 11); and parity greater than or equal to four, -0.95 cm (significant $P < 0.05$) (Table 13). Negative linear contrasts between high and low cows in generation zero decreased from -1.52 cm for heifers at 12 months of age through -1.13 cm in first parity and -0.93 cm in second parity, and increased negative contrast -1.43 cm in third parity, and again decreased to -0.95 cm in parity greater than or equal to four. These results were similar for heart girth and wither height as parity changed, except for parity three. These results indicate that heart girth, wither height and chest depth for high-producing cows at 12 months of age, first parity and second parity would be related to milk production. Therefore, effective changing for any one of them would lead to change in the same direction in each of the others.

f. Pelvic length Cows with high milk production had shorter pelvic length than low-producing cows in generation zero, with the differences: -1.16 cm (significant $P < 0.10$) at 12 months of age in Table 5, -0.70 cm (nonsignificant) for first parity in Table 7, - 1.16 cm (significant $P < 0.05$) for second parity in Table 9, -1.45 cm (significant $P < 0.05$) for third parity in Table 11, and -0.66 cm (nonsignificant) for parity greater than or equal to four in Table 13. It seems the trend in pelvic length is generally the same; higher-producing cows were shorter in pelvic length as in the other traits, though the differences were not as consistent. All of the differences in pelvic length were small.

g. Pelvic width Linear contrasts between high and low cows in generation zero were all negative and nonsignificant. These results were -1.16 cm at 12 months of age in Table 5, -0.10 cm in parity one (Table 7), -0.53 cm in parity two (Table 9), -1.23 cm in parity three (Table 11), and -0.39 cm in parity greater than or equal to four (Table 13).

h. Body length Body length for high-producing cows were shorter than low-producing cows with the differences: -3.19 cm (nonsignificant) at 12 months of age (Table 5), -1.51 cm (nonsignificant) in parity one (Table 7), -2.72 cm (significant $P < 0.10$) in parity two (Table 9), -2.88 cm (significant $P < 0.10$) in parity three (Table 11), and -1.99 cm (significant $P < 0.10$) in parity greater than or equal to four (Table 13). The result of the differences on measures of body length reached a negative maximum at 12 months of age, decreased in first parity, increased in parity two and three, and again decreased in parity greater than or equal to four. Rindsig (1973) pointed out that a large amount of error might be expected in this measurement since it is the longest one and may be difficult to take based on how the animals would stand. Females at 12 months of age had negative contrast (nonsignificant) larger than females in second parity (significant). Perhaps heifers at 12 months of age are less quiet and more difficult to handle than animals at older ages resulting in greater measurement error. Another reason for this is that the number of observations in parity two are larger than for females at 12 months of age.

2. Birth year

There were significant differences ($P < 0.05$) for paunch girth of the heifers at 12 months of age (Table 4), paunch girth and chest depth in parity two (Table 8), body weight in parity three (Table 10), chest depth in parity greater than or equal to four (Table 12). Birth year effects were also significant ($P < 0.01$) for paunch girth in parity one (Table 6) and parity three (Table 10), pelvic length, pelvic width and body length in parity greater than or equal to four (Table 12). Differences were all significant ($P < 0.10$) for chest depth and body length of the heifers at 12 months of age (Table 4), pelvic length, pelvic width and body length in parity two (Table 8), body length in parity three (Table 10), and wither height in parity greater than or equal to four (Table 12).

The effect of birth year was intended as an adjustment for enviromnental differences and this effect may result from many factors that influence the performance of cattle that are peculiar to the particular year in which they were born and reared. Most commonly cited reasons for yearly variation are the effects of feed supply, temperature, humidity, rainfall, management, diseases and other seasonal variation which differs from one birth year to the next. It is not surprising, then, to find birth year differences for many traits.

B. Cows in Generations Greater than Zero — Model 2

Birth year, generation, cell code of sire within generation, and cell code of dam within generation were fit in the model. Linear contrasts were computed for generation, high sires vs average sires and high dams vs low dams within generations greater than zero. These analyses were computed separately for heifers at 12 months of age and all parity groups. The results plus raw means and least square means are shown in Tables 14 to 28.

Table 14. Difference between high and average sires, and high and low dams for weight and measurements of heifers in generations greater than zero at 12 months of age

Source	DF	MS	F	PR > F
		Weight		
Birth year	12	60,306.44	9.98	0.01[1]
Generation	3	4,988.73	0.83	0.48
Cell S (Gen)	4	6,864.82	1.14	0.34
Cell D (Gen)	4	2,040.19	0.34	0.85
Residual	334*	6,039.99	—	—
	338**	—	—	—
		Chest depth		
Birth year	12	29.32	6.47	0.01[1]
Generation	3	0.87	0.19	0.90
Cell S (Gen)	4	3.12	0.69	0.60
Cell D (Gen)	4	5.41	1.19	0.31
Residual	338	4.53	—	—

*Residual DF for weight.

**Residual DF for heart girth, paunch girth, and wither height.

1 = P (< 0.01).

5 = P (< 0.05).

10 = P (< 0.10).

MS	F	PR > F	MS	F	PR > F	MS	F	PR > F
Heart girth			Paunch girth			Wither height		
319.05	11.37	0.01[1]	839.65	8.92	0.01[1]	66.05	2.98	0.01[1]
6.17	0.22	0.88	17.87	0.19	0.90	16.23	0.73	0.54
57.48	2.05	0.08[10]	96.10	1.02	0.40	13.16	0.59	0.67
42.90	1.53	0.19	21.71	0.23	0.92	31.42	1.42	0.23
–	–	–	–	–	–	–	–	–
28.05	–	–	94.16	–	–	22.18	–	–
Pelvic length			Pelvic width			Body length		
24.17	6.90	0.01[1]	48.76	4.46	0.01[1]	147.77	1.79	0.05[5]
2.86	0.82	0.49	5.64	0.52	0.68	54.30	0.66	0.58
2.23	0.64	0.64	6.54	0.60	0.66	54.28	0.66	0.62
2.23	0.64	0.64	2.64	0.24	0.91	47.94	0.58	0.68
3.50	–	–	10.94	–	–	82.41	–	–

Table 15. Linear contrasts between high and average sires, and high and low dams for weight and measurements of heifers in generations greater than zero at 12 months of age

Linear contrasts	Weight (lbs)
Difference Cell S (Gen)	
High sire vs ave. sire	32.42
11 vs 21	-16.44
12 vs 22	19.70
13 vs 23	19.22
14 vs 24	9.94
Difference Cell D (Gen)	
High dam vs low dam	15.62
11 vs 21	-14.36
12 vs 22	3.60
13 vs 23	3.13
14 vs 24	23.24
Generation linear	-37.40

Linear contrasts	Chest depth (cm)
Difference Cell S (Gen)	
High sire vs ave. sire	0.54
11 vs 21	- 0.34
12 vs 22	0.33
13 vs 23	0.54
14 vs 24	0.01
Difference Cell D (Gen)	
High dam vs low dam	- 1.00
11 vs 21	- 0.93[5]
12 vs 22	0.02
13 vs 23	0.25
14 vs 24	- 0.35
Generation linear	0.54

1 = P (< 0.01).

5 = P (< 0.05).

10 = P (< 0.10).

Heart girth (cm)	Paunch girth (cm)	Wither height (cm)
-3.46	5.86	-2.63
-0.13	1.22	-1.44
2.33[1]	3.22[10]	-0.01
1.51	0.71	0.08
-0.24	0.71	-1.26
-0.24	2.37	-3.10
-2.38[5]	1.75	-2.17[5]
1.07	-0.56	0.41
0.39	0.41	-0.70
0.68	0.77	-0.63
-1.46	-4.41	1.87

Pelvic length (cm)	Pelvic width (cm)	Body length (cm)
0.78	2.56	4.37
-0.32	0.70	-1.01
0.32	0.30	2.05
0.28	-0.03	0.12
0.50	1.60	3.22
0.54	1.76	0.01
-0.41	0.36	-1.39
0.03	0.10	2.09
-0.05	0.28	-0.28
0.97	1.01	-0.40
0.51	0.94	5.71

Table 16. Means and least square means for cell code of sire and cell code of dam within generations greater than zero for weight and measurements of heifers at 12 months of age

			Weight (lbs)	Heart girth (cm)	Paunch girth (cm)	Wither height (cm)	Chest depth (cm)	Pelvic length (cm)	Pelvic width (cm)	Body length (cm)
Mean			653.52	155.54	185.49	116.03	59.70	43.47	39.84	129.17
L.S. Means Cell S (Gen)										
	Cell S	Gen								
	1	1	649.95	155.77	187.27	115.50	59.36	43.31	40.35	128.92
	1	2	661.01	156.35	187.11	115.40	59.63	43.41	39.71	129.40
	1	3	645.60	156.34	185.48	115.72	59.96	43.24	39.54	129.77
	1	4	655.74	155.09	185.66	116.12	59.64	43.94	41.11	132.50
	2	1	666.40	155.90	186.04	116.94	59.70	43.64	39.65	129.94
	2	2	641.31	154.02	183.89	115.41	59.30	43.08	39.42	127.35
	2	3	626.38	154.83	184.78	115.64	59.43	42.96	39.57	129.65
	2	4	645.79	155.33	184.95	117.38	59.63	43.44	39.51	129.28
L.S. Means Cell D (Gen)										
	Cell D	Gen								
	1	1	650.99	154.64	187.53	115.13	59.07	43.27	40.18	128.73
	1	2	652.96	155.72	185.22	115.61	59.47	43.26	39.61	129.42
	1	3	637.55	155.78	185.33	115.33	59.82	43.07	39.70	129.57
	1	4	662.39	155.55	185.69	116.44	59.46	44.18	40.82	130.69
	2	1	665.36	157.02	185.79	117.30	60.00	43.68	39.82	130.12
	2	2	649.36	154.65	185.77	115.20	59.45	43.23	39.51	127.33
	2	3	634.42	155.39	184.93	116.03	59.57	43.12	39.42	129.85
	2	4	639.14	154.87	184.92	117.07	59.81	43.21	39.81	131.09

Table 17. Difference between high and average sires, and high and low dams for weight and measurements of cows in generations greater than zero and parity one

Source	DF	MS	F	PR >R
		Weight		
Birth year	10	26,583.17	2.94	0.01[1]
Generation	2	2,398.90	0.27	0.77
Cell S (Gen)	3	2,091.53	0.23	0.87
Cell D (Gen)	3	312.87	0.03	0.99
Residual	267*	9,038.99	–	–
	269**	–	–	–
		Chest depth		
Birth year	10	13.35	2.45	0.01[1]
Generation	2	3.85	0.71	0.49
Cell S (Gen)	3	4.31	0.79	0.50
Cell D (Gen)	3	5.91	1.08	0.36
Residual	269	5.45	–	–

*Residual DF for weight.

**Residual DF for heart girth, paunch girth, wither height.

1 = P (< 0.01).

5 = P (< 0.05).

10 = P (< 0.10).

MS	F	PR >F	MS	F	PR >F	MS	F	PR >F
Heart girth			Paunch girth			Wither height		
164.79	4.26	0.01[1]	278.40	3.22	0.01[1]	12.73	1.00	0.45
11.74	0.30	0.74	49.00	0.57	0.57	1.40	0.11	0.90
57.05	1.48	0.22	44.26	0.51	0.68	14.78	1.16	0.33
10.95	0.27	0.85	58.13	0.67	0.57	14.69	1.15	0.33
–	–	–	86.34	–	–	12.76	–	–
38.64	–	–	–	–	–	–	–	–
Pelvic length			Pelvic width			Body length		
10.73	2.55	0.01[1]	10.37	1.94	0.04[5]	31.15	1.01	0.43
4.38	1.04	0.35	8.03	1.50	0.22	51.31	1.67	0.19
2.61	0.62	0.61	1.09	0.20	0.89	32.70	1.07	0.37
6.62	1.57	0.19	1.11	0.21	0.88	1.87	0.06	0.97
4.21	–	–	5.35	–	–	30.71	–	–

Table 18. Linear contrasts between high and average sires, and high and low dams for weight and measurements of cows in generations greater than zero and parity one

Linear contrasts	Weight (lbs)
Difference Cell S (Gen)	
High sire vs ave. sire	11.61
11 vs 21	- 8.78
12 vs 22	10.64
13 vs 23	9.75
Difference Cell D (Gen)	
High dam vs low dam	- 7.56
11 vs 21	0.23
12 vs 22	- 5.75
13 vs 23	- 2.04
Generation linear	-13.05

Linear contrasts	Chest depth (cm)
Difference Cell S (Gen)	
High sire vs ave. sire	0.10
11 vs 21	- 0.54
12 vs 22	0.00
13 vs 23	0.64
Difference Cell D (Gen)	
High dam vs low dam	- 0.99
11 vs 21	- 0.76
12 vs 22	0.19
13 vs 23	- 0.42
Generation linear	- 0.57

5 = P (< 0.05).

10 = P (< 0.10).

Heart girth (cm)	Paunch girth (cm)	Wither height (cm)
-1.86	0.02	-2.23
-2.41[5]	-1.75	-0.68
0.86	1.38	-1.06
-0.31	0.39	-0.49
0.34	1.09	-1.42
-0.74	0.19	-1.13
-0.03	-1.73	0.44
1.12	2.64	-0.73
-0.78	-1.63[10]	-0.33

Pelvic length (cm)	Pelvic width (cm)	Body length (cm)
0.69	0.62	-2.37
-0.13	0.02	-1.71
0.46	0.25	0.46
0.35	0.35	-1.12
-1.32[10]	-0.55	-0.71
-0.82[5]	-0.31	-0.43
-0.03	-0.18	-0.02
-0.47	-0.06	-0.26
-0.52	-0.85[10]	-1.96

Table 19. Means and least square means for cell code of sire, and cell code of dam within generations greater than zero for weight and measurements of cows in parity one

		Weight (lbs)	Heart girth (cm)	Paunch girth (cm)	Wither height (cm)	Chest depth (cm)	Pelvic length (cm)	Pelvic width (cm)	Body length (cm)
Mean		1,077.75	186.12	217.84	130.82	71.38	51.71	50.53	152.63
L.S. Means Cell S (Gen)									
Cell S	Gen								
1	1	1,086.09	185.74	218.79	131.05	71.48	51.86	51.21	152.69
1	2	1,094.98	187.48	218.72	130.61	71.64	52.17	51.12	153.58
1	3	1,082.31	186.01	218.23	130.82	71.50	51.58	50.53	151.02
2	1	1,094.87	188.15	220.54	131.74	72.02	51.99	51.19	154.40
2	2	1,084.35	186.61	217.34	131.67	71.64	51.71	50.88	153.12
2	3	1,072.56	186.32	217.84	131.31	70.86	51.23	50.18	152.15
L.S. Means Cell D (Gen)									
Cell D	Gen								
1	1	1,090.60	186.58	219.77	130.83	71.37	51.52	51.04	153.32
1	2	1,086.79	187.03	217.16	131.36	71.74	51.92	50.91	153.34
1	3	1,076.42	186.72	219.35	130.70	70.97	51.17	50.32	151.46
2	1	1,090.37	187.32	219.57	131.96	72.13	52.33	51.35	153.76
2	2	1,092.54	187.06	218.90	130.92	71.55	51.75	51.09	153.36
2	3	1,078.45	185.61	216.72	131.43	71.39	51.64	50.38	151.71

Table 20. Difference between high and average sires, and high and low dams for weight and measurements of cows in generations greater than zero and parity two

Source	DF	MS	F	PR >F
		Weight		
Birth year	10	33,666.14	3.59	0.01[1]
Generation	2	4,708.41	0.50	0.61
Cell S (Gen)	3	12,947.98	1.38	0.25
Cell D (Gen)	3	9,580.03	1.02	0.39
Residual	158*	9,387.82	–	–
	159**	–	–	–
		Chest depth		
Birth year	10	5.24	1.00	0.45
Generation	2	4.83	0.92	0.40
Cell S (Gen)	3	14.20	2.71	0.05[5]
Cell D (Gen)	3	10.15	1.94	0.12
Residual	159	5.25	–	–

*Residual DF for weight.

**Residual DF for heart girth, paunch girth, wither height.

1 = P (< 0.01).

5 = P (< 0.05).

10 = P (< 0.10).

MS	F	PR > F	MS	F	PR > F	MS	F	PR > F
Heart girth			Paunch girth			Wither height		
51.66	1.68	0.09[10]	138.20	1.74	0.08[10]	6.00	0.49	0.90
2.22	0.07	0.93	19.13	0.24	0.79	6.27	0.51	0.60
59.21	1.92	0.13	90.93	1.14	0.33	5.70	0.46	0.71
28.87	0.94	0.43	7.41	0.09	0.96	11.66	0.95	0.42
–	–	–	79.65	–	–	12.34	–	–
30.79	–	–	–	–	–	–	–	–
Pelvic length			Pelvic width			Body length		
11.22	2.95	0.01[1]	5.92	1.51	0.14	45.29	1.45	0.16
5.26	1.38	0.25	3.03	0.77	0.46	49.57	1.58	0.21
1.78	0.47	0.71	0.01	0.00	1.00	92.67	2.96	0.03[5]
10.05	2.65	0.05[5]	0.61	0.15	0.92	11.98	0.38	0.77
3.80	–	–	3.93	–	–	31.32	–	–

Table 21. Linear contrasts between high and average sires, and high and low dams for weight and measurements of cows in generations greater than zero and parity two

Linear contrasts	Weight (lbs)
Difference Cell S (Gen)	
High sire vs ave. sire	19.28
11 vs 21	-36.16[10]
12 vs 22	21.97
13 vs 23	33.47
Difference Cell D (Gen)	
High dam vs low dam	-14.67
11 vs 21	26.02
12 vs 22	14.11
13 vs 23	-54.79
Generation linear	14.30

Linear contrasts	Chest depth (cm)
Difference Cell S (Gen)	
High sire vs ave. sire	- 0.10
11 vs 21	- 1.26[1]
12 vs 22	- 0.21
13 vs 23	1.38
Difference Cell D (Gen)	
High dam vs low dam	0.68
11 vs 21	- 0.42
12 vs 22	1.36[5]
13 vs 23	- 0.26
Generation linear	- 0.74

1 = P (< 0.01).

5 = P (< 0.05).

10 = P (< 0.10).

Heart girth (cm)	Paunch girth (cm)	Wither height (cm)
-0.63	4.53	-1.48
-2.69[5]	-2.34	-0.81
1.24	2.10	-0.50
0.83	4.77	-0.17
-1.41	-0.59	-2.08
-1.01	0.87	-1.26
1.81	-0.45	-0.03
-2.21	-1.02	-0.78
0.52	1.09	-1.08

Pelvic length (cm)	Pelvic width (cm)	Body length (cm)
-1.21	-0.05	-6.24[10]
-0.38	-0.02	-2.74[5]
-0.10	0.03	-2.97[5]
-0.74	-0.06	-0.53
1.62	0.61	2.85
-0.41	0.06	0.27
1.31[1]	0.32	1.38
0.72	0.23	1.20
-0.05	-0.51	0.38

Table 22. Means and least square means for cell code of sire, and cell code of dam within generations greater than zero for weight and measurements of cows in parity two

		Weight (lbs)	Heart girth (cm)	Paunch girth (cm)	Wither height (cm)	Chest depth (cm)	Pelvic length (cm)	Pelvic width (cm)	Body length (cm)
Mean		1,212.04	194.15	228.93	135.52	74.61	54.11	54.34	159.13
L.S. Means Cell S (Gen)									
Cell S	Gen								
1	1	1,202.28	192.85	227.40	135.53	73.77	53.80	54.66	157.98
1	2	1,250.72	194.72	230.84	135.54	74.47	54.52	54.88	159.75
1	3	1,251.41	195.13	232.05	134.77	74.36	53.57	54.13	159.46
2	1	1,238.45	195.54	229.74	136.34	75.04	54.18	54.68	160.71
2	2	1,228.75	193.49	228.74	136.04	74.68	54.61	54.85	162.72
2	3	1,217.93	194.30	227.28	134.94	72.98	54.31	54.19	159.99
L.S. Means Cell D (Gen)									
Cell D	Gen								
1	1	1,233.37	193.69	229.01	135.31	74.20	53.79	54.70	159.48
1	2	1,246.79	195.01	229.56	135.77	75.26	55.22	55.02	161.92
1	3	1,207.27	193.61	229.16	134.47	73.54	54.30	54.27	160.32
2	1	1,207.36	194.70	228.14	136.57	74.62	54.20	54.64	159.21
2	2	1,232.68	193.20	230.01	135.81	73.89	53.91	54.71	160.54
2	3	1,262.07	195.82	230.17	135.25	73.80	53.58	54.04	159.12

Table 23. Difference between high and average sires, and high and low dams for weight and measurements of cows in generations greater than zero and parity three

Source	DF	MS	F	PR > F
		Weight		
Birth year	8	71,755.04	2.43	0.02[5]
Generation	1	54,916.61	3.19	0.08[10]
Cell S (Gen)	2	31,772.03	1.85	0.16
Cell D (Gen)	2	5,006.46	0.29	0.75
Residual	104	17,194.97	—	—
		Chest depth		
Birth year	8	11.22	2.05	0.05[5]
Generation	1	0.56	0.10	0.75
Cell S (Gen)	2	16.74	3.06	0.05[5]
Cell D (Gen)	2	9.90	1.81	0.17
Residual	104	5.47		

1 = P (< 0.01).

5 = P (< 0.05).

10 = P (< 0.10).

MS	F	PR > F	MS	F	PR > F	MS	F	PR > F
Heart girth			Paunch girth			Wither height		
102.84	2.00	0.05[5]	158.78	1.32	0.24	12.12	0.92	0.51
31.93	0.62	0.43	231.19	1.92	0.17	3.69	0.28	0.60
63.15	1.23	0.30	225.96	1.87	0.16	5.43	0.41	0.66
21.95	0.43	0.65	79.85	0.66	0.52	0.18	0.01	0.99
51.54	–	–	120.53	–	–	12.24	–	–
Pelvic length			Pelvic width			Body length		
14.12	3.30	0.01[1]	11.28	2.34	0.02[5]	47.71	1.61	0.13
0.81	0.19	0.66	1.64	0.34	0.56	0.34	0.01	0.92
8.67	2.02	0.14	0.36	0.07	0.93	42.33	1.43	0.24
5.88	1.37	0.26	0.82	0.17	0.85	67.60	2.29	0.11
4.28	–	–	4.83	–	–	29.56	–	–

Table 24. Linear contrasts between high and average sires, and high and low dams for weight and measurements of cows in generations greater than zero and parity three

Linear contrasts	Weight (lbs)	Heart girth (cm)	Paunch girth (cm)	Wither height (cm)
Difference Cell S (Gen)				
High sire vs ave. sire	-25.88	-0.76	1.82	-0.86
11 vs 21	-57.97[10]	-2.47	-3.28	-0.83
12 vs 22	32.09	1.70	5.10	-0.03
Difference Cell D (Gen)				
High dam vs low dam	38.14	1.83	1.66	0.13
11 vs 21	20.81	-0.15	3.06	-0.04
12 vs 22	17.33	1.98	-1.40	0.17
Generation linear	58.09[10]	1.40	3.77	0.48

Linear contrasts	Chest depth (cm)	Pelvic length (cm)	Pelvic width (cm)	Body length (cm)
Difference Cell S (Gen)				
High sire vs ave. sire	- 1.65[10]	-1.30	-0.01	-3.38
11 vs 21	- 1.45[5]	-1.03[5]	-0.17	-2.02
12 vs 22	- 0.20	-0.27	0.16	-1.36
Difference Cell D (Gen)				
High dam vs low dam	1.31	1.05	0.29	4.51[5]
11 vs 21	- 0.03	0.02	-0.08	1.60
12 vs 22	1.33[10]	1.03[10]	0.37	2.92[10]
Generation linear	0.19	0.22	0.32	0.14

5 = P (< 0.05).

10 = P (< 0.10).

Table 25. Means and least square means for cell code of sire, and cell code of dam within generations greater than zero for weight and measurements of cows in parity three

	Weight (lbs)	Heart girth (cm)	Paunch girth (cm)	Wither height (cm)	Chest depth (cm)	Pelvic length (cm)	Pelvic width (cm)	Body length (cm)
Mean	1,307.28	200.36	236.02	137.29	76.65	55.17	56.42	162.44
L.S. Means Cell S (Gen)								
Cell S Gen								
1 1	1,280.68	199.79	234.55	137.39	76.37	54.82	56.55	162.22
1 2	1,383.80	203.27	242.50	138.27	77.18	55.42	57.03	162.69
2 1	1,338.64	202.26	237.83	138.23	77.82	55.84	56.72	164.23
2 2	1,351.71	201.57	237.41	138.30	77.37	55.69	56.88	164.05
L.S. Means Cell D (Gen)								
Cell D Gen								
1 1	1,320.06	200.95	237.72	137.79	77.08	55.34	56.60	164.02
1 2	1,376.42	203.41	239.26	138.37	77.94	56.07	57.14	164.83
2 1	1,299.26	201.10	234.66	137.83	77.11	55.32	56.68	162.43
2 2	1,359.09	201.43	240.66	138.20	76.61	55.04	56.77	161.91

Table 26. Difference between high and average sires, and high and low dams for weight and measurements of cows in generations greater than zero and parity greater than or equal to four

Source	DF	MS	F	PR >F
		Weight		
Birth year	6	25,924.20	1.78	0.11
Generation	1	28,878.80	1.98	0.16
Cell S (Gen)	2	16,850.61	1.16	0.32
Cell D (Gen)	2	18,742.46	1.29	0.28
Residual	102*	14,563.22	–	–
	105**	–	–	–
		Chest depth		
Birth year	6	28.02	5.19	0.01[1]
Generation	1	0.55	0.10	0.75
Cell S (Gen)	2	1.28	0.24	0.79
Cell D (Gen)	2	22.48	4.16	0.02[5]
Residual	105	5.40	–	–

*Residual DF for weight.

**Residual DF for heart girth, paunch girth, wither height.

1 = P (< 0.01).

5 = P (< 0.05).

10 = P (< 0.10).

MS	F	PR > F	MS	F	PR > F	MS	F	PR > F
Heart girth			Paunch girth			Wither height		
180.27	4.73	0.01[1]	180.85	1.72	0.12	39.81	3.60	0.01[1]
87.84	2.30	0.13	367.60	3.49	0.06[10]	7.73	0.70	0.41
30.95	0.81	0.45	192.22	1.82	0.17	2.61	0.24	0.79
95.93	2.52	0.09[10]	217.67	2.07	0.13	2.65	0.24	0.79
–	–	–	105.35	–	–	11.07	–	–
38.13	–	–	–	–	–	–	–	–
Pelvic length			Pelvic width			Body length		
25.81	6.02	0.01[1]	15.50	4.10	0.01[1]	73.14	3.10	0.01[1]
0.18	0.04	0.84	2.42	0.64	0.43	61.23	2.59	0.11
16.37	3.82	0.03[5]	11.01	2.91	0.06[10]	49.44	2.09	0.13
12.23	2.85	0.06[10]	3.47	0.92	0.40	73.16	3.10	0.05[5]
4.28	–	–	3.78	–	–	23.62	–	–

Table 27. Linear contrasts between high and average sires, and high and low dams for weight and measurements of cows in generations greater than zero and parity greater than or equal to four

Linear contrasts	Weight (lbs)	Heart girth (cm)	Paunch girth (cm)	Wither height (cm)
Difference Cell S (Gen)				
High sire vs ave. sire	79.08	-3.63	-7.65	1.00
11 vs 21	-35.07	-0.58	-4.10[10]	0.42
12 vs 22	-44.01	-3.05	-3.55	0.58
Difference Cell D (Gen)				
High dam vs low dam	69.77	3.79	4.38	-0.29
11 vs 21	- 5.56	-1.25	-2.61	-0.54
12 vs 22	75.33	5.04[5]	7.00[10]	0.24
Generation linear	46.26	2.55	5.21[10]	0.76

Linear contrasts	Chest depth (cm)	Pelvic length (cm)	Pelvic width (cm)	Body length (cm)
Difference Cell S (Gen)				
High sire vs ave. sire	- 0.49	-1.64[10]	0.98	-2.02
11 vs 21	- 0.37	-1.32[1]	1.09[5]	-2.31[5]
12 vs 22	- 0.12	-0.31	-0.11	0.29
Difference Cell D (Gen)				
High dam vs low dam	2.53[5]	2.23[5]	0.78	4.75[5]
11 vs 21	- 0.09	0.42	-0.20	0.02
12 vs 22	2.62[1]	1.81[5]	0.98	4.74[1]
Generation linear	0.20	-0.12	0.42	-2.13

1 = P (< 0.01).

5 = P (< 0.05).

10 = P (< 0.10).

Table 28. Means and least square means for cell code of sire, and cell code of dam within generations greater than zero for weight and measurements of cows in parity greater than or equal to four

			Weight (lbs)	Heart girth (cm)	Paunch girth (cm)	Wither height (cm)	Chest depth (cm)	Pelvic length (cm)	Pelvic width (cm)	Body length (cm)
Mean			1,361.20	203.02	240.92	137.76	77.52	55.05	56.85	163.52
L.S. Means Cell S (Gen)										
	Cell S	Gen								
	1	1	1,339.71	202.89	238.30	137.38	77.42	54.59	57.48	163.23
	1	2	1,381.50	204.20	243.79	138.22	77.74	54.98	57.30	162.41
	2	1	1,374.78	203.46	242.40	136.97	77.78	55.91	56.39	165.54
	2	2	1,425.51	207.25	247.34	137.64	77.86	55.30	57.41	162.11
L.S. Means Cell D (Gen)										
	Cell D	Gen								
	1	1	1,354.47	202.55	239.04	136.91	77.55	55.47	56.83	164.40
	1	2	1,441.17	208.24	249.06	138.05	79.11	56.04	57.85	164.63
	2	1	1,360.03	203.80	241.66	137.44	77.64	55.04	57.03	164.38
	2	2	1,365.84	203.21	242.07	137.81	76.49	54.23	56.87	159.89

1. Birth year

The effect of birth year was highly significant ($P < 0.01$) for most of the traits in this study, especially when the females were young at 12 months of age (Table 14), in first parity (Table 17) and old cows in parity greater than or equal to four (Table 26). These results might be expected from differences in feeding, diseases, weather, and moisture levels on the forage supply which were different in each year and affect the growth rate of the cattle. Shanks (1979) found that older cows had more total health cost than cows calving at younger ages.

2. Generation

Generation effect was nonsignificant for all traits except ($P < 0.10$) for body weight in parity three (Table 23) and paunch girth in parity greater than or equal to four (Table 26). For these traits, cows in generation two were heavier or measurements larger than cows in generation one. However, body weight and paunch girth are traits affected by increased body fat which are more environmental influenced than skeletal factors. With so many differences tested, some of these could be significant due to chance alone. This seems particularly suspect when there is no real biological trend evident to help interpret the significantly different effects. This is, in fact, a problem in interpreting all these data where only occasional differences are significant.

3. Cell code of sire within generation

F-ratios for cell code of sire were significant ($P < 0.10$) for heart girth of heifers at 12 months of age in generations greater than zero (Table 14), for pelvic width in parity greater than or equal to four (Table 26), significant ($P < 0.05$) for chest depth and body length in parity two (Table 20), for chest depth in parity three (Table 23), and pelvic length in parity greater than or equal to four (Table 26).

Differences due to cell code of sire in weight or measurements are correlated responses due to differences between high and average sires selected for milk production. Means of body weight and measurements for cows in each trait at any age and/or parity in generations greater than zero were smaller than cows in generation zero. These results indicated that the cell code of sire does have a sporatic effect on their progeny when selection was practiced to develop two biological types of dairy cows (high and low producers). Robertson and Rendel (1950) proposed that 76% of the total possible genetic improvement in populations of dairy cattle is contributed to by the selection of sires. Therefore, the cell code of sire effect did not only influence the different production between sires within generations but also the difference in sires affected the growth rate of the cows for some measurements in some parities.

4. Cell code of dam within generation

There were significant differences ($P < 0.05$) for pelvic length in parity two (Table 20), chest depth and body length in parity greater than or equal to four (Table 26), significant ($P < 0.10$) for heart girth and pelvic length in parity greater than or equal to four (Table 26). Considering the number of trait parities and generations, there are only a small number of significant differences between cell code of dam (1 and 2) within generations.

5. <u>High sire vs average sire contrasts in generations greater than zero</u>

Linear contrasts for body weight and measurements of high sires vs average sires in generations greater than zero were significant ($P < 0.10$) for body length, - 6.24 cm in second parity (Table 21), chest depth, -1.65 cm in third parity (Table 24), and pelvic length, -1.64 cm in parity greater than or equal to four (Table 27). These results were due to the superiority of the average sires in body measurements resulting from the breeding program.

a. <u>High sires vs average sires in generation one (11 vs 21)</u> Linear contrasts between high sires vs average sires in generation one were significant ($P < 0.01$) for chest depth, -1.26 cm in second parity (Table 21), and pelvic length, -1.32 cm in parity greater than or equal to four (Table 27), significant ($P < 0.05$) for heart girth, -2.41 cm in first parity (Table 18), heart girth, -2.69 cm and body length, -2.74 cm in second parity (Table 21), chest depth, -1.45 cm and pelvic length, -1.03 cm in third parity (Table 24), and body length, -2.31 cm in parity greater than or equal to four (Table 27), significant ($P < 0.10$) for body weight, -36.16 lbs in second parity (Table 21), body weight, -57.97 lbs in third parity (Table 24), and paunch girth, -4.10 cm in parity greater than or equal to four (Table 27). The greatest influence of the genetic effects was in daughters of average sires in generation one. The contrasts were almost all negative except paunch girth and pelvic width at 12 months of age in Table 15, pelvic width in parity one (Table 18), wither height and pelvic width in parity greater than or equal to four (Table 27). There were more significant differences in generation one for genetic effects of sires for body weight and measurements than high sires vs average sires in generations two, three, and four. Other results for daughters of high sires vs average sires in parity two and three in generation one were of negative sign and larger for all body weight and measurements than cows in parity one and heifers at 12 months of age. This could be from daughters in the high sire groups produced more milk in later lactation and a reduction in body deposits.

b. High sires vs average sires in generation two (12 vs 22) Sire differences in generation two were significant ($P < 0.01$) for heart girth with a difference of 2.33 cm, significant ($P < 0.10$) for paunch girth with a difference of 3.22 cm for heifers at 12 months of age in Table 15, significant ($P < 0.05$) for body length with a difference of -2.97 cm for cows in parity two (Table 21). Results of high sires vs average sires tended to be positive, especially for animals at 12 months of age and first parity. This represents a positive correlated response in body weight and measurements is the breeding scheme contributable to the genetic effect to the cows in the high sire groups over cows in the average sire groups. Only three of these contrasts were significant.

c. High sires vs average sires in generation three (13 vs 23) There were no significant differences at any age and/or parity between high sire vs average sire groups. The contrasts were not large, but there were more positive contrasts from the high sire groups over the average sire groups for females at 12 months of age in Table 15 and first parity in Table 18. Body weight, paunch girth and chest depth in the high sire groups were greater than the average sire groups for females at 12 months of age (Table 15), first parity (Table 18) and second parity (Table 21).

d. High sires vs average sires in generation four (14 vs 24) There were only females at 12 months of age in this group. No differences were significant for any trait (Table 15).

6. High dam vs low dam contrasts in generations greater than zero

The results of the linear contrast analyses for body weight and measurements of high dams vs low dams in generations greater than zero were significant ($P < 0.05$) for body length, 4.51 cm in third parity (Table 24), chest depth, 2.53 cm, pelvic length, 2.23 cm, and body length, 4.75 cm in parity greater than or equal to four (Table 27). All of these contrasts were positive. These positive values occurred, however, in later lactation, especially in parity three; all contrasts were positive between high dams vs low dams.

a. High dams vs low dams in generation one (11 vs 21) There were significant differences between the high and low dam group's offspring in generation one ($P < 0.05$) for heart girth, -2.38 cm, wither height, 2.17 cm for heifers at 12 months of age in Table 15, and pelvic length, -0.82 cm in first parity (Table 18). The results were calculated for cows and heifers (high and low producers) at different ages and/or parities within the breed of sire groups (high and average sires); these are the two groups (high and low producers) in four cells of the breeding plan. The contrasts between high and low cows in generation one at particular ages and parities were almost all negative. Low-producing cows in generation zero were larger for body weight and measurements than high-producing cows. This difference carries over to the genetic influence to their offspring in generation one but not in generation two.

b. High dams vs low dams in generation two (12 vs 22) Linear contrasts of the cows from high dams vs low dams in generation two were significant and positive for the following traits ($P < 0.01$): pelvic length, 1.31 cm in parity two (Table 21), chest depth, 2.62 cm, and body length, 4.74 cm in parity greater than or equal to four (Table 27); significant ($P < 0.05$) with the difference for chest depth, 1.36 cm in parity two (Table 21), heart girth, 5.04 cm, and pelvic length, 1.81 cm in parity greater than or equal to four (Table 27); significant ($P < 0.10$) with the difference for chest depth, 1.33 cm, pelvic length, 1.03 cm, and body length, 2.92 cm in parity three (Table 24); ($P < 0.10$) for paunch girth, 7.00 cm in parity greater than or equal to four (Table 27). Comparing the different results of the cows from high dams vs low dams in generation two, all of the significant contrasts were in older cows (parity two, three and parity greater than or equal to four). Cows from high dam groups tended to be larger for body weight and measurements over cows from their low dam groups in generation two at 12 months of age (Table 15), third parity (Table 24), and parity greater than or equal to four (Table 27).

c. <u>High dams vs low dams in generation three (13 vs 23)</u> Results from linear contrasts between high dams vs low dams in generation two were not significant at any ages and parities; however, the differences were more negative than positive but not large for each trait.

d. <u>High dams vs low dams in generation four (14 vs 24)</u> There were data in generation 4 only for females at 12 months of age. No contrasts were significant (Table 15).

VI. SUMMARY AND CONCLUSIONS

The dairy breeding research herd at Ankeny, Iowa was designed to develop two biological types of dairy cows (high milk and low milk production). Foundation heifers purchased by pedigree for high and low production were assigned to be bred to high and average sires in a 2^2 factorial design. Mating was random. The objectives were to study the effectiveness and limitations to selection for high milk production including correlated responses.

Linear contrasts between cell codes of dam were generally negative for cows in generation zero for body weight and measurements between high-milk vs low-milk producers. This was for all traits of females at 12 months of age, first parity, second parity, third parity and parity greater than or equal to four, except for wither height in parity three with positive contrast (nonsignificant). Differences were negative and significant for all of these traits: heart girth, wither height, chest depth, pelvic length of heifers at 12 months of age, wither height, chest depth in parity one; body weight, pelvic length, body length in parity two; body weight, chest depth, pelvic length, body length in parity three; paunch girth, chest depth, body length in parity greater than or equal to four. These were correlated responses to milk production for cows in generation zero.

Differences in body weight and measurements for cows from high sires vs average sires in generations greater than zero were mostly negative contrasts when cows were older in parity two, three and parity greater than or equal to four. Most of these differences were small.

The genetic influence of the high sires vs average sires on their progeny at 12 months and first parity with the body weight and measurements were small and perhaps slightly positive, but mostly nonsignificant. However, body weight and measurements of daughters of high sires in parity two, three and parity greater than or equal to four were generally smaller than cows from average sires; this could be due to genetic effect for high milk yield reducing body fat.

Correlated responses of body weight and measurements to milk production between high dams vs low dams in generations greater than zero tended to be positive in parity three and parity greater than or equal to four. This tends to be opposite in direction when compared to the results of high sires vs average sires. High dams vs low dams in generation one were mostly negative contrasts and decrease as the cows grow older reaching third parity. Contrasts from high dams vs low dams in generation two were mostly positive and increase as the animals grow older from age 12 months through parity greater than or equal to four. Again, most of these differences were small.

As a general conclusion, there is no consistent and clear trend in changes in body weight and measurements as correlated responses to selection for high and average milk production.

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