EFFECTS OF COW SIZE AND MILK YIELD ON BEEF COW PRODUCTION EFFICIENCY

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ABSTRACT

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Data on 5 groups of cow and Angus-sired first-calf pairs representing year and season of calving subclasses were analysed within groups for effects of cow size and milk yield on 180-day weaning weight and efficiency of production. There were 15, 20, 22, 32 and 38 cow-calf pairs in groups 1 to 5 respectively. There were 3 criteria for size: height at withers, post-calving weight and length of cow. The milk criteria were 180-day milk yield and 180-day milk fat yield. Efficiency was estimated as the ratio of calf weaning weight to total TDN consumption of cow and calf during lactation. Interactions between the effects of milk and size were examined and the data were analysed for relationships between the various criteria for cow size and milk yield.

Milk yield was generally positively associated with the various measures of cow size. With regard to 180-day weaning weight, interactions between height at withers and total milk yield were significant in 2 of 4 groups. When efficiency was considered, interaction was significant in 1 of 4 groups. The effect of sex was generally non-significant. Regression coefficients of 180-day weaning weight on height at withers where cows were classified into low, medium and high classes within group ranged from -4.7 to 5.7 Kg/cm. The regression coefficients were generally positive and significant indicating an increase in

weaning weight associated with increased height at withers. When efficiency estimates were regressed on height at withers, the regression coefficients were very low and generally negative. Regression of 180-day weaning weight and efficiency on total milk yield for the different height classes showed that both 180-day weaning weight and efficiency increased with the amount of milk produced by the dam.

There was no interaction effect between total milk yield and post-calving weight of cow on 180-day weaning weight and efficiency in any of the 5 groups. Regressions of 180-day weaning weight on weight of cow were positive and significant in 4 of 5 groups indicating an increase in weaning weight associated with increased weight at calving. Regressions ranged from -0.1 to 0.4 Kg calf weight/Kg cow weight. None of the regressions of efficiency on post-calving weight was significant.

Interaction between total milk yield and length of cow was significant in 1 of 5 groups. When fat yield was considered, there was no interaction effect between yield of fat and the 3 size criteria in any of the 5 groups, but fat yield had a significant effect on both 180-day weaning weight and efficiency in 3 of 5 groups.

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I. INTRODUCTION

Weaning weight is one of the major factors influencing profit in a cow-calf operation; and milk production is one of the most important factors affecting the weaning weight of calves. Many studies have shown positive associations between milk production of cow and growth of calf at various stages.

Size of cow, usually measured by weight, is another factor that has been shown to affect the weaning weight of calves. Many studies have shown heavier cows to wean heavier calves.

Reports on the relationship between size of cow measurements and milk yield, however, are inconsistent, indicating that selection for body size would give little assurance of any associated increase in milk yield (Jeffery et al. 1971a).

Totusek (1974) stated that many beef cows produce too little milk and that the weaning weights of their calves could be profitably increased by infusing genes from animals of dairy breeding. He pointed out, however, that there is a point beyond which additional increases in weaning weight accomplished with higher levels of milk production do not increase profit. Thus efficiency estimates (which take into account weaning weight and total energy required to produce that weaning weight) of cows that vary in milk yield would aid in finding the most economical level of milk yield.

A few studies have been reported on efficiency of cows that varied in size (Carpenter et al. 1973, Kress et al. 1969), the usual criterion of size being weight of cow, and with production efficiency of cow being estimated as the ratio of calf weaning weight to total digestible nutrients (TDN) consumption of cow and calf during lactation.

Small cows were found to be more efficient than large cows in weaning weight produced per unit of TDN. There is evidence that other size criteria, for example, height at withers also affect efficiency of production; Kress et al. (1969) found cows with greater heights at withers to be more efficient than those with smaller heights at withers. Such information on efficiency of cows of different sizes in a cow-calf operation is not well documented, and efficiency estimates of cows that vary in both milk yield and size measurements are completely lacking.

The present study investigates the relationship between milk yield and cow size and the effects of milk yield and cow size on weaning weight and cow production efficiency with interaction between milk and size assumed and using various criteria for milk and size.

II. LITERATURE REVIEW

1. Cow milk production and progeny performance

Totusek et al. (1970) stated that where attainment of high weaning weight within a cow-calf enterprise has priority, adequate milk production becomes paramount. They reported that within the limits of milk produced by beef cows, each additional 10 pounds of milk produces approximately an additional pound of weaned calf weight. A wide individual difference in milk production among cows was observed by Pope et al. (1963). Estimates of milk production on more than 300 range beef cows, representing both spring and fall-calving herds, were analysed to determine some of the factors that influence milk production. Milk production was found to be highly correlated with daily gain of calves, accounting for 50 to 80% of the variation observed in calf gains to three months of age.

Jeffery and Berg (1971) using 2 years data involving 176 and 201 cows from the University of Alberta beef breeding herd reported that of all factors studied, milk yield had the most influence on pre-weaning performance of calf. The correlations of milk yield with ADG to weaning were 0.76 and 0.78 for 1966 and 1967 respectively. Milk yield explained 56 to 59% of total variation in ADG to weaning and 42 to 57% of total variation in weaning weight. An increase of 1 Kg per day in milk yield resulted in an increase of 11.3 to 14.6 Kg in weaning weight. Neville (1962) reported correlations between milk production in 135 Hereford cows and weights of their calves to 60 days ($r = 0.74$); 120 days ($r = 0.63$); 180 days ($r = 0.59$); and 240 days ($r = 0.66$). Correlations were calculated within years, sex of calf and nutrition groups. There was a considerable range of 8-month milk yields, from about 180 Kg to

1,900 Kg in response to 3 dietary treatments. Partial regressions of weights at 120 and 240 days were of the order of 7 Kg weight/100 Kg milk produced. The regression of calf weight at 240 days on cow weight was 7 Kg/100 Kg, but was not significantly different from zero.

Drewry et al. (1959) obtained data on 48 Aberdeen-Angus cows and calves during the spring calving seasons of 1957 and 1958 to study the relationships among certain factors related to mothering ability in beef cattle. They reported that calves suckling heavier producing cows made larger total gains from birth to 6 months, but required more milk per pound of live weight gain. Neville (1962) working with Hereford calves, found that the relationship of milk to calf weight gains was greatest during the first 60-day period of the calf's life and declined slightly by weaning. 68% of the variation in 8-month's weight was due to differences in milk consumption of calves.

Furr and Nelson (1964) reported that the correlations between milk production of cows and ADG of calves from fall-calving Hereford beef cows ranged from 0.75 to 0.91 and the correlations were significant in six of nine groups. Melton et al. (1967a) found calf gain to be highly correlated with milk yield in Hereford and Charolais cows. A correlation coefficient of 0.46 between calf gain and Kg milk was reported by Wilson et al. (1968). Christian et al. (1965b) working with Hereford cows, found simple correlations between milk yield and ADG from birth to 60 days to be 0.48; and from 60 to 240 days the correlation with milk yield was 0.50. These values were highly significant.

Gleddie and Berg (1968) estimated milk yield in lactating range beef cows. Milk yield as measured in 4 test months was highly correlated with calf ADG from birth to weaning ($r = 0.73$ to 0.83). The average of 4 milk yield estimates had a similar correlation with calf ADG ($r = 0.84$).

Knapp et al. (1941) obtained a highly significant correlation of .517 between the daily gain of calves and the quality of milk produced by their dams. They stated that since these calves were allowed grain and hay in addition to milk and were not weaned until they reached 245 or 252 days of age, it is likely that with calves that do not receive as much supplementary feed or which are weaned at younger ages, there would be an even more marked effect on the amount of milk given by the cows on the growth of their calves.

Klett et al. (1965) obtained milk data from 15 Angus and 15 Hereford range cows in the Texas A&M University herd during a complete lactation period. Significant ($P < .01$) correlations ranging from 0.67 to 0.81 were found when milk yield was correlated with calf weight at various milking dates in the Angus herd. Non-significant correlations were found in the Hereford herd and this indicated that the Angus were providing a greater proportion of nutrients to their calves in the form of milk than the Hereford cows. Percent composition of the milk had little, if any, effect on calf weight as indicated by non-significant correlations.

The reports on the relationships between cow milk production and progeny performance generally indicate that milk yield is positively related to calf weight at various stages of growth.

2. Cow size and progeny performance

Jeffery and Berg (1972) stated that the association of cow size with performance of progeny has important economic implications to the cow-calf operation. Different kinds of association between cow size and progeny performance are reported in the literature.

Jeffery et al. (1971b) reported a low positive association between cow body weight and pre-weaning performance of calf. They suggested that a 10 Kg increase in post-calving weight of dam would result in about .7 Kg increase in weaning weight of calf.

The regression of calf weaning weight on dam weight as reported by Miquel et al. (1972) was significant for male and female progeny of 4-5 year old dams and for 10+ dams. Although regressions were not consistently significant, they were generally positive indicating that heavier dams had slightly heavier calves. Gregory et al. (1950) also reported a significant influence of the weight of dam on the birthweight of her calf. The correlation between the weaning weight of the calf and the weight of the cow at weaning was significant at the .05 level for one set of data but was negative and non-significant for another set of data. Hohenboken et al. (1973) reported small positive correlations between cow size at parturition and calf size at birth and weaning.

Vacarro and Dillard (1966) analysed 409 records to study the relationship between dam's changes in weight during the last third of gestation and the first 6 months of lactation with calf's birth weight and gain in different periods from birth to 180 days. They found that heavier cows 90 days before calving tended to produce heavier calves at birth and throughout the suckling period.

Simple correlation between post-calving weight (PCW) and average daily gain (ADG) of calf to weaning as reported by Jeffery and Berg

(1972) ranged from 0.29 to 0.38. This association, however, included interrelations among PCW, cow age and milk yield and hence did not represent a direct influence of PCW on ADG of calf to weaning. Jeffery et al. (1971b) compared weight of cow at weaning time of calf with PCW in respect to association with ADG of calf. Simple correlations between weight of cow at weaning (WCW) and ADG to weaning were 0.29 and 0.35 for 1966 and 1967 respectively.

McDonald and Turner (1969) reported that a 100 Kg increase of dam's weight resulted in 11.77 Kg additional weaning weight; Ewing et al. (1967) reported a 9.78 Kg increase in weaning weight per 100 Kg increase in dam's weight; Fitzhugh (1965) reported the average increase in weaning weight to range from .33 Kg to 5.22 Kg for every 45.5 Kg increment in PCW of dam; Tanner et al. (1965) reported weaning weight increments of 3.86 Kg and 2.22 Kg for Angus and Hereford dams respectively for each 45.5 Kg increment in body weight; and Neville (1962) reported a 3.18 Kg increase in weaning weight per 45.5 Kg increase in body weight of dam.

Other workers have found very little association between body weight of cow and pre-weaning performance of calves. Hawkins et al. (1965) analysed data on 214 Hereford cows with 919 calving records collected during a 12-year period. Some of the measures of cow productivity studied were calf birth weight, ADG from birth to weaning, weaning type score, and weaning condition score. They reported that cows that weighed less at weaning time weaned more calves and more total pounds of calf. Yearling weight and average cow weight did not have any significant effect on the measures of cow productivity.

Singh et al. (1970) working with 619 calves reported that cow weight at parturition significantly ($P < .01$) influenced birth weight (corr = .26). However, cow weight did not significantly influence pre-weaning ADG or weaning weight. Cows weighing 385 to 430 Kg produced the lightest calves at birth; those weighing 589 to 610 Kg at parturition produced the heaviest calves at birth. Cow weight change during suckling significantly ($P < .01$) influenced pre-weaning ADG and weaning weight. Each percent loss in a cow's weight between parturition and weaning added 0.14 to 1.09 Kg to her calf's weaning weight.

Carpenter et al. (1973) reported that mature size (weight) of cows individually fed to maintain equal fatness did not have a significant effect on calf birth weight, pre-weaning gain, pre-weaning feed consumption or 205-day weight of 144 Herefords, but did significantly affect gain and weight of 59 Charolais calves. The trend was for calves from smaller mature cows to have larger birth weights, pre-weaning gains, pre-weaning feed consumption and 205-day weights. Cows giving birth to larger calves had a slight tendency to gain less weight during the following lactation period probably because much of the feed energy is converted to milk energy. Calves tended to grow less rapidly and have lighter weaning weights if their dams gained more weight during the lactation period.

Lindsey et al. (1970) working with a small number (67) of Angus, Hereford and Shorthorn cows, found that after fitting effects of breeds, sex, cow condition and weight to hook ratio, the lighter cows (409-454 Kg) had weaned in the previous pregnancy 31 Kg heavier calves on average than the heavy cows (545-614 Kg). The hook measurement in this study was not specified. Wilson et al. (1969) found that cow body size did not significantly affect performance traits. Melton et al. (1967a) working with 26 Hereford and 14 Charolais cows studied the efficiency of calf gain as related to body size and breed of dam and calf from birth to 210 days of age. Size was determined as the product of measurements of chest depth, width at hooks and length from a point between the first and second palpable thoracic vertebral process to the pin bones. Cows were chosen to include the smallest and largest available in each breed. They reported that intra-breed and sex of calf correlation between cow size and calf gain and other measurements like cow feed and milk yield were either very low or negative.

The reports as found in the literature seem to indicate a general positive relationship between cow size and calf weight at various stages (Jeffery et al. 1971b, Miquel et al. 1972, Hohenboken et al. 1973, Vacarro and Dillard 1966, McDonald and Turner 1969, Fitzhugh 1965, Tanner et al. 1965, Neville 1962). However, negative relationships were also reported (Carpenter 1973, Lindsey et al. 1970). Other workers found little or no effect of cow weight on calf weight at weaning (Hawkins et al. 1965, Singh et al. 1970, Carpenter 1973, Wilson et al. 1969, Melton et al. 1967a).

3. Relationships between cow size and milk yield

The relationship between cow size and milk yield was investigated by Pope et al. (1963) by studying the correlations obtained from milk production estimates on 49 four-year old cows on comparable feed levels, using several indices of body size. Correlation between height at withers and average milk production was +0.09. Correlation between average milk production and the product of wither height and width at hooks was slightly negative (-.13). To better express body size and weight relationship an index was calculated which took into account body weight, volume per unit of body tissues, height at withers, and length of body. This index was believed to be a better reflection of both body weight and surface area than either weight or height alone. Since many experiments have shown that the maintenance requirements of beef cattle for energy (TDN) are proportional to a function of body weight ($W^{.73}$), this factor was calculated for each of the 49 cows, using an average of spring and summer weights. When correlated with average milk production for the summer, the values of r obtained were from -.16 to -.39. Correlation between fall body weight and average milk production during the previous summer was -.29, and this reflects loss in condition associated with milk yield. It was apparent from the data that regardless of the means of expressing body size or weight, there appeared to be little or no relationship between size at 4 years of age and milk production. They concluded that among cows that are well-developed for their age, there seemed to be little association between body size and milk yield.

Mason et al. (1957) found little correlation between body weight and milk yield, but reported a small positive correlation between wither height and milk yield in dairy cattle.

Jeffery and Berg (1971) found simple correlations between PCW and milk yield to be 0.28 and 0.38 for 1966 and 1967 data respectively. Part of the relationship between PCW and milk yield was associated with cow age, the correlation between cow age and PCW being 0.73 for 1966 and 0.76 for 1967 data. After removing the effect of cow age, PCW of cow had little effect on milk yield for 1966 data. However, for 1967, the regression coefficient was significant ($P < .01$), suggesting that an increase of 10 Kg in PCW would result in a 0.1 Kg increase in daily milk yield.

Clark and Touchberry (1962) working with Holsteins reported a 400 lb (181 Kg) increase in 180-day milk production for each 100 lb (45 Kg) increase in body weight with age of cow held constant. A small negative genetic correlation between body weight and milk yield was reported ($rg = -0.12 \pm 0.33$).

Carpenter et al. (1973) determined the relationships between the performance and mature size of beef cows within the Hereford and Charolais breeds. The cows were individually fed in dry lot along with their calves. Mean 24-hour milk yields were 4.9 Kg for Herefords and 6.0 Kg per day for Charolais. Mature cow size did not have a significant effect on milk yield within breeds, but small mature cows tended to produce more milk than larger cows. Due to the sex differences in size and growth rate of calves, it was expected that milk yield would be affected by sex of calf. However, it had no significant effect on the data.

Wilson et al. (1969) analysed data on 24 Angus-Holstein crossbred cows and their calves. The cows were measured for body depth at withers, width at hooks and length from shoulder point to pins. The products of the three measurements were used to express body size instead of actual weight or $W^{0.75}$ since the correlations with condition score were 0.22, 0.64 and 0.65 respectively. They found that cow body size did not significantly affect milk or performance traits although large cows tended to produce less total quantities of milk and milk energy.

Wilk et al. (1963) found very small phenotypic correlations between body weight and milk yield. Touchberry (1951) and Blackmore et al. (1958) using milk records statistically adjusted for differences in age at freshening, reported a very small and non-significant correlation between milk yield and body weight.

The literature reports on the relationships between cow size and milk yield are clearly inconsistent. Pope et al. (1963) and Mason et al. (1957) found a small positive correlation between wither height and milk production. Clark and Touchberry (1962) and Wilk et al. (1963) found positive associations between body weight and milk yield, and Jeffery and Berg (1971) found a positive association for 1967 data. Negative associations were reported by Carpenter et al. (1973) and Wilson et al. (1969). Touchberry (1951) and Blackmore et al. (1958) found little correlation between body size and milk yield, and Jeffery and Berg (1971) found cow weight to have little effect on milk yield for 1966 data.

4. On cow size

Most of the studies that have utilized cow size have generally taken weight of cow per se to classify cows into small, medium or large sizes. The question then arises as to whether weight of cow is a reliable measure of cow size. Jeffery and Berg (1972) reported that body weight varies with condition and hence does not necessarily reflect physiological size. Arnett et al. (1971) studied some effects of obesity in beef females by comparing sets of twin beef females with the second member of each set fed additional energy to induce and maintain a high degree of body fatness. Obese cows averaged 133 Kg heavier than normal cows at first mating. Arnett et al. (1971) concluded that much of the difference in weight was fat. Jeffery and Berg (1972) stated that where body weight is to be used as a criterion for comparing body size among animals, the population should either be uniform in condition or mathematically adjusted to a common base. They argued that the accuracy of either approach is open to question: the chance of a population of animals being uniform in condition is unlikely and measurements of condition often being subjective are vulnerable to experimental error.

Davis et al. (1937) reported that skeletal development unlike body weight is relatively independent of environmental influence and at maturity is essentially a constant reflecting heritable size of skeleton. Guilbert and Gregory (1952) indicated the allometric nature of bone development within and between bones. They indicated proportionately faster bone growth in length than width, growth in circumference continuing after growth in length has ceased. Length and width of cannon bone at birth are 85 and 55% mature respectively; wither height is about 50% mature at birth and skeletal growth has completely ceased at 30 to 40 months. Brody et al. (1937) reported that width and body circumference measurements tend to reflect condition, but height of animal measurements tend to reflect skeletal size. Eckles and Swett (1918) found height a satisfactory method of expressing skeletal development. Jeffery and Berg (1972) concluded that body height measurements are good indicators of skeletal size for any particular age of animal.

5. Cow size and production efficiency

The question of optimum size for beef cattle has been with beef cattle breeders for several years. Klosterman (1972) stated that since feed costs represent by far the major expense in beef cattle production, efficiency of feed use has usually been one of the major goals. Numerous reports have shown a high correlation between rate of gain and efficiency of gain. Unfortunately rate of gain is also positively related to mature size. Therefore selection for increased rate of gain at any age up to maturity tends to increase mature size to the extent of the genetic correlation between the gain character selected and mature size (Cartwright 1974).

Since a very high proportion of the total feed going into the beef enterprise is required for maintenance, the larger the animal becomes, the greater the amount of feed that must be provided for its maintenance needs. Klosterman (1972) reported that as a result of this beef cattle breeders have been faced with the problem of maximising efficiency of gain of feedlot cattle while at the same time minimising the maintenance costs of breeding herds. He mentioned Cartwright (1970) who outlined a system whereby distinct dam and sire lines would be developed and mated for the production of slaughter cattle. In this system, cow lines would be relatively small in body size, early maturing, fertile, and produce a desired amount of milk. Sire lines would be selected for rate and efficiency of gain and desirable carcass traits. Such a system would tend to solve the problem by maintaining cows small in size but producing efficient feeder cattle, and it would also utilize the advantages of heterosis.

Klosterman (1972) pointed out that the development of distinct *cow and sire lines is not without its problems since it would require some form of integration within the industry. Someone would need to maintain the breeds used in the development of the lines, make the selections, crosses, etc. to produce cows small in size and fast gaining sires which are likely to be large in size, but the incidence of calving problems was not discussed.*

Long and Fitzhugh (1970) reported a related experiment. They estimated beef produced per unit of TDN and compared 3 breeding programs:

Purebred

Rotational Crossing

Specialized Sire and Dam Lines

The TDN required each year for the various functions was totalled and cumulated over a nine-year period during which progeny were sold at weaning and at 12 months. They found that the purebred system was considerably more efficient in the early years than either of the cross systems. This purebred advantage was attributed to increased TDN costs of rapid replacement of purebred cows with cross-bred heifers. The extra TDN required to grow and develop cross-bred heifers did not immediately yield comparable increases in beef production. In later years the ranking of the breeding systems for efficiency of production changed in favour of the specialised cross. Long and Fitzhugh (1970) concluded that the rotational system which utilized the heaviest cows produced the most beef, required the most TDN and was more efficient than the purebred system, but was less efficient than the special cross which utilized the smallest cows. In this study the advantages of heterosis were disregarded and the differences in efficiency of pro-

duction were attributed to the differences in size of the breeding females in each system and the inherent growth potential of their progeny.

Carpenter et al. (1973) measured cow production efficiency as the ratio of calf weaning weight to total feed consumption of cow and calf during lactation. They found that, on this basis, mature cow size did not significantly affect efficiency of production, but there was a trend for smaller cows to be more efficient. Production efficiency was also positively associated with milk yield and negatively associated with feed efficiency.

The effect of cow size and breed on net efficiency was investigated by Klosterman et al. (1972). There were three weight classes of cows which averaged 389, 465 and 548 Kg. Least squares means adjusted for differences among breed and age of cows and sex of calf were used to compare the three weight classes. The larger cows had greater weight to height ratios and weaned significantly heavier calves. They required more total feed and their calves ate more prior to weaning, but the differences among weight classes in total TDN per unit of weaning weight were small.

Long et al. (1975) reported that genetic differences among herds for mature size affect efficiency, among other ways by differences in nutrient requirements for growth and maintenance of heifers and cows and for finishing calves. They analysed data on Angus, Charolais, Hereford and Jersey cows and their progeny from Texas A&M University Agricultural Research Centre at McGregor. Three basic genotypes for mature size were compared: small cattle intermediate in size to the Angus and Jersey, medium cattle similar in size to the

Hereford and large cattle similar in size to the Charolais. The model included nutritional costs, fixed costs, cow size and correlated progeny growth, attrition rates, milk yield from cows of different ages, and other considerations. Comparisons of the different genotypes for size were made under two different managerial and nutritional regimes. One, designated drylot, emulated an intensive, drylot program in which all nutrients for cows were supplied from harvested feed. The second, designated pasture, corresponded to a pasture grazing program for cows. Comparisons were made among size genotypes using each nutritional regime to independently calculate and satisfy nutritional requirements. This study brought out several important points associated with beef cattle production.

1) When nutritional resources are limited and progeny are slaughtered at a constant proportion of mature weight, larger cow size must result in fewer cows per herd.

2) Comparisons of liveweight sold for the three classes of sale cattle indicated that straightbred systems employing smaller cows produced greater weights of all classes of sale cattle, but since slaughter progeny from small cows were marketed at lighter weights, this was obviously the result of increased numbers of cattle sold.

3) While performance levels of calves of similar breeding were identical in both nutritional regimes, the economic efficiency of calf performance relative to dam size was determined by costs and returns associated with the reproductive and the growing phases of beef production of which nutritional costs for different classes of cattle were the primary sources of differences between regimes.

4) The differences in efficiency of the production systems were net

results of all effects of which the effects on cow numbers and nutrient allocations appeared to be of more importance in the drylot regime.

It was apparent that cow size which essentially determined nutrient costs per cow, number of cows maintained and relative nutrient costs for the breeding herd versus slaughter cattle had more effect on net income and returns on investment in the drylot regime than in the pasture regime. Long et al. (1975) stated that a point often cited in favour of large cows is their increased salvage value, but their study showed that when nutrient resources are limiting, returns from salvage of cull cows were very similar for each straight breeding system regardless of cow size.

Morris and Wilton (1975) used linear programming techniques to investigate the influence of mature cow weight on economic efficiency in beef cattle production. Four other factors were considered: farm size, herd size, beef and feed prices and marketing option i.e. the facility to feed home-grown crops or to feed and sell home-grown crops.

The model described straightbred production, and was integrated in the sense that it included a cow-calf operation with replacements bred on the farm, a beef feedlot for steers and surplus heifers, cropping, and the labour and capital required for livestock and cropping. Farm gross margins was considered the most relevant criterion for the farmer and was used to compare 450 combinations of factors. Comparisons of five different cow sizes were made within farm sizes. In general the larger cows produced larger farm gross margins. Comparisons of the efficiency of different cow sizes in the beef production systems reported here generally seem to favour small cows even when salvage weight of the cow was considered (Long and Fitzhugh 1970, Carpenter et al. 1973, Long et al. 1975, Morris and Wilton 1975); and Klosterman et al. (1972) found differences among weight classes in efficiency to be small. However, Morris and Wilton (1975) concluded that there was no definitive statement that could be made about the economic merits of different cow sizes.

Kress, Hauser and Chapman (1969) stated that even though height at withers is a good criterion for measuring skeletal size, it is recognized that selection for wither height may not realize the objective of muscular development. They reported an experiment that throws more light on the question. They carried out an extensive survey on the relationship between efficiency of production and several measures of cow size, and other traits of the cow and calf. The first estimate of the efficiency of production, E_1, was calculated for 3 cumulative periods according to cow age, using information collected between 240 days of age (weaning) and at the end of each chronological period. Period I was from birth to 1058 days of age. Period II was from birth to 1411 days of age, and Period III was from birth to 1764 days of age. The second measure of efficiency of production (E_2) was based on data for 3 periods according to physiological states. The first period was from birth to the end of the first lactation, the second from birth to the end of the second lactation, and the third from birth to the end of the third lactation. The formulas for estimating E_1 and E_2 included factors of variable cost such as the feed consumed by the cow and her calves and factors of variable production such as the weaning weights of the calves and in the case of E_1, the cow's salvage weight. The means and standard deviations of the traits of the cows and calves for each lactation are shown in Table 1. The records of the cows at 240 days and 15 months of age indicated that those which completed 2 or 3 lactations were not unlike those with only one lactation in their weights and measurements at these ages. It was also found that the correlations of the efficiency estimates during Period I with the same kind of efficiency estimate for Periods II and III were positive for each of the 2 kinds of efficiency estimates.

The regressions of efficiency during Periods II and III on efficiency during Period I were also positive. When averaged over E_1 and E_2, the correlations ranged from 0.50 to 0.85, and the regressions ranged from 0.60 to 0.90. These results indicate that efficiency during later periods can be predicted with a reasonable degree of accuracy from efficiency during earlier periods.

It was also found that efficiency was related to cow size. The standard partial regressions of the 2 estimates of efficiency on age at calving, height at withers at calving, and the ratio of weight at calving to height at withers are presented in Table 2. Age at calving was included in the multiple regression equations so that the regressions on the measures of size could be estimated with this age held constant.

In model 1, the partial regressions of E_1 on weight were small and non-significant. However, the partial regressions of E_1 on weight were consistently negative and significant for the first lactation.

TABLE 1[a]

Means and standard deviations of traits of the dams and their progeny classified by lactation.

Trait	Lactation no. 1 Mean	1 S.D.	2 Mean	2 S.D.	3 Mean	3 S.D.
Cow						
Wt. calving, Kg	442	44.8	485	53.5	488	47.0
Withers ht. calving, cm	116.1	3.82	118.1	3.63	118.4	3.51
TDN consumed during lactation, Kg	1190	87.0	1283	121.7	1285	99.5
Milk production, Kg	866	170.0	983	205.0	1031	258.5
Butterfat production, Kg	30.4	6.83	34.5	9.01	36.3	8.46
Efficiency estimates, E_1	0.101	0.0186	0.102	0.0136	0.112	0.0056
E_2	0.051	0.0076	0.067	0.0080	0.081	0.0049
Calf						
Wt. birth, Kg	30.4	3.64	32.2	4.84	33.6	4.26
Wt. 240 days, Kg	225	24.5	236	25.6	233	29.3
TDN consumed 60-240 days	333	48.0	362	56.0	366	47.5
Wt. gain, birth to 240 days, Kg	195	22.2	203	24.0	200	26.4

a From Kress, Hauser and Chapman (1969).

TABLE 2[a]

Standard partial regressions of efficiency on various independent variables for different models.

Independent variables	Lactation no. and period no.					
	1		2		3	
	E_1	E_2	E_1	E_2	E_1	E_2
Model 1						
Age calving	-.89**	-.67**	-.94**	-.77**	-.55**	-.07
Wt. calving	-.03	-.22*	.09	-.12	.30	-.02
R^2	.80	.61	.84	.67	.33	.01
Model 2						
Age calving	-.96**	-.77**	-.95**	-.77**	-.56*	-.08
Wt. calving	-.17*	-.41**	.04	-.23*	.26	-.07
Withers ht. calving	.29**	.40**	.09	.18	.27	.35
R^2	.86	.70	.84	.69	.41	.13
Model 3						
Age calving	-.86**	-.67**	-.94**	-.76**	-.52*	-.07
Wt./withers ht. calving	-.14	-.32**	.07	-.13	.25	-.02
R^2	.82	.66	.84	.67	.31	.01

a From Kress, Hauser and Chapman (1969).
* $P < .05$
** $P < .01$

It was concluded therefore that when salvage weight of the cow was not considered and when age at calving was held constant the lighter cows tended to be more efficient. This result was reported to be in agreement with the results of Lindholm and Stonaker (1957) where a phenotypic correlation of -.32 of 18-month weight of the dam with net income per unit of finished steer was reported. But working with Hereford calves, Melton et al. (1967) reported that cow size did not appear to influence the amount of TDN required per unit gain from birth to 210 days of age.

When height at withers at calving was added to age and weight at calving as an independent variable (Model 2) the increase in the R^2 value ranged from 0.00 to 0.12. The partial regressions on height at withers were consistently positive and significant ($P < .01$) for the first lactation. This indicated that when age and weight at calving are held constant, the cows with the greater heights at withers tended to be more efficient.

The ratio of weight at calving to height at withers at calving (W/T) may be regarded as a measure of the degree of fatness. Klosterman, Sanford and Parker (1968) reported a highly significant correlation of 0.89 between condition score and the ratio of weight to height at hooks in beef cattle. When age and W/T were the independent variables (Model 3), the partial regressions of E_1 and E_2 on W/T were negative and significant ($P < .01$) for the first lactation, but were non-significant for the second and third lactation. It was concluded that cows with smaller values of W/T (i.e. thinner cows) may be more efficient, suggesting that efficiency is negatively related to fatness.

Phenotypic correlations of the 2 estimates of efficiency with traits of the cow and calf were computed. It was found that few of the correlations with the early traits of the cow were significant and none of the correlations suggested that efficiency could readily be selected for at an early age. E_1 and E_2 did not appear to be significantly related to 15 month weights. Hawkins et al. (1965) reported that yearling weight did not have a significant effect on measures of cow productivity. In any case the study reported by Kress et al. (1969) brought out the following points:

1) Efficiency during later periods could be predicted with a reasonable degree of accuracy from efficiency during earlier periods.

2) When salvage weight of the cow was not considered and when age at calving was held constant, lighter cows tended to be more efficient.

3) When age and weight at calving were held constant, cows with greater heights at withers tended to be more efficient.

III. MATERIALS AND METHODS

1. Data

Data utilized for this study came from records on five groups of cow and Angus-sired first calf pairs of the Elora cross-breeding project. The number of cow-calf pairs in each group, the year and season of calving are given in Table 1. The breed groups of the cows are shown in Table 2.

2. Procedures

(a) Cow feeding

Cows post-calving were fed rations to provide a 12% protein level. Cows in groups 1, 2 and 5 were individually fed and cows in groups 3 and 4 were group fed but this was purely a management procedure dictated by facilities. Cows that were about the same in size were put together for group feeding. The rations given the cows differed in some cases between groups but within groups the same rations were fed to all cows. The ingredients used to formulate the rations and their total digestible nutrients (TDN) percent on a dry matter (DM) basis are given in Appendix Table 1. Appendix Table 2 shows the actual rations fed and the calculated TDN percent of each ration as fed.

Feed intake from calving to time of weaning the calf was recorded for each cow; and TDN intakes were calculated on the basis of actual feed intakes and tabular NRC feed composition data. The computation of TDN content of rations is shown in Appendix Table 3.

TABLE 1

Number and group of cow-calf pairs in experiment

Group	Year of calving	Season of calving	No. of cow-calf pairs
1	1972	fall	15
2	1973	spring	20
3	1973	fall	22
4	1974	spring	32
5	1974	fall	38

TABLE 2

Cow Breed Groups

Breed group	Cow group				
	1	2	3	4	5
British[1] x British	2	2	2	6	3
Burwash[2] x British	1	0	4	10	6
Ayrshire x British	2	2	1	2	2
Jersey x British	2	1	1	3	1
Charolais x British	4	6	9	4	11
Simmental x British	0	1	0	0	0
Holstein x British	4	3	4	0	6
Holstein x Burwash	0	0	0	0	5
Holstein	0	5	1	4	2
Maine Anjou x Holstein	0	0	0	2	0
Charolais x Holstein	0	0	0	1	2
	15	20	22	32	38

1 The British breeds referred to here are Hereford, Angus or Shorthorn.

2 Burwash is a synthetic line that is approximately ½ Charolais, ¼ Hereford, ¼ Shorthorn.

(b) Calf feeding

Calves were allowed to suckle cows. In groups 3, 4 and 5, calves received creep feed in addition to milk. Appendix Table 4 gives the ingredients used in the creep rations and Appendix Table 5 shows the actual creep rations and their calculated TDN content.

(c) Cow measurements

Weights: Cows were weighed one week post-calving.

Ultrasonic measurements: Average of 3 subcutaneous fat measurements along the longitudinal axis of the *Longissimus dorsi* muscle at the 11th and 12th rib junction was obtained one week post-calving by an ultrasonic Beta scan.

(d) Size measurements

Height at withers, length from shoulder to hooks and from hooks to pins were taken one week post-calving and at weaning (of calf) in the manner described by Johnston (1972).

Height at withers of each cow was calculated as the average of calving and weaning measurements.

Length of cow was calculated as the sum of average length from shoulder to hooks and average length from hooks to pins.

(e) Milk yield measurements

Milk yields were measured by both calf nursing and machine milking measurements taken at 6 weeks, 14 weeks and 22 weeks post-calving.

Calf weighing method: Six-hour milk yields were measured by weighing calves before and after nursing, after calves had been separated from cows for 6 hours. This was repeated on two consecutive days.

Machine milking method: On the third consecutive day of taking calf nursing measurements, calves were separated from cows. Cows were milked after being injected with 3 cc oxytocin intramuscularly. They were kept separated from calves for 6 hours. Oxytocin injections and milking were repeated and milk yield was weighed. Samples of milk were taken for fat, protein and lactose content.

(f) Estimation of total milk yield

Daily milk yield (Kg) was calculated from average 6-hour yields by multiplying 6 hour yields by 4; and 180-day milk yield was obtained by averaging daily yields at 6 weeks, 14 weeks, and 22 weeks and multiplying by 180.

(g) Classification of cows

For each criterion of milk and size, the range was found for each group. The interval between the lowest and highest measurement was divided into 3 and, on this basis, cows were classified into low, medium or high in milk production and size.

(h) Calf measurements

Calves were weighed at one week and at 180 days plus or minus 2 weeks.

(i) 180-day adjusted weaning weights

180-day weaning weights were calculated using the following formula:

$$\text{180-day WW} = \left[\left(\frac{WW - BW}{AGEW}\right) \times 180 \right] + BW$$

where:

WW = Weaning weight (Kg)

BW = Birth weight (Kg)

AGEW = Age at weaning in days.

(j) Production efficiency calculation

Cow production efficiency was calculated by the following formula:

$$\text{Efficiency} = \frac{\text{Actual WW (Kg)}}{\text{TDN cow (Kg)} + \text{TDN calf (Kg)}}$$

where:

WW = Weaning weight

TDN cow = Total Kg TDN fed to cow

TDN calf = Total Kg TDN fed to calf in creep.

If the calf received no creep, then cow production efficiency was calculated by the formula:

$$\text{Efficiency} = \frac{\text{Actual WW (Kg)}}{\text{TDN cow (Kg)}}$$

It is important to emphasize that the estimates calculated give a measure of cow first-lactation production efficiency alone, or a measure of the efficiency with which the cow weans her first calf. Other efficiency estimates for the same cow could be calculated. For example, cow production efficiency could be computed for the first, second and subsequent lactations. Life cycle production efficiencies could also be computed, which would take into account total TDN fed to the cow and her calves from the time the first calf is conceived to the time the last calf is weaned. The present study concerns itself with cow first lactation production efficiency alone.

It is also recognized that the TDN system which was used in this study overestimates the true energy contents of roughages and that the efficiencies with which feeds are utilized vary with the quality of the feed given. Thus a more precise measure of cow production efficiency would be a ratio of Mcal of calf empty body energy at weaning to total Mcal of metabolisable energy consumed by the cow-calf pair expressed as a percentage (Schake and Riggs 1975). However, for the nature of the data involved in the study, the TDN system was considered adequate.

3. Statistical analysis

Two assumptions made were:

1) Interaction of breeds with milk and size levels is not important. That is, the economics of size and milk apply to breeds in the same way. This allows the different categories of milk and size to be of different breeds and is necessary in making statements regarding the economics of beef cattle in general.

2) Non-linearity of and interaction between the effects of size and milk is possible.

The correlations between the various measures of size and milk were computed within each group.

The data were subjected to least-squares analyses using the model:

$$Y_{ijklm} = \mu + \alpha_{ik} + \beta_{jk} + \alpha\beta_{ijk} + S_l + E_{ijklm}$$

where:

Y_{ijklm} is the 180-day adjusted weaning weight of the calf, and the efficiency estimate for the cow,

μ is the population mean representing a constant contribution common to all observations,

α_{ik} is a fixed effect due to the i^{th} milk production level within the k^{th} group (i = 1, 2, 3),

β_{jk} is a fixed effect due to the j^{th} size of cow within the k^{th} group (j = 1, 2, 3),

$\alpha\beta_{ijk}$ is a joint effect contributed by the interaction between the i^{th} level of milk yield and j^{th} size of cow within the k^{th} group,

S_l is a fixed effect due to the l^{th} sex of calf, and

E_{ijklm} is a random variation peculiar to the m^{th} calf of the i^{th} milk production level of cow, j^{th} size of cow and l^{th} sex of calf.

The main effects of milk and size i.e. milk yield or milk fat yield and height at withers, post-calving weight or length of cow, and sex as well as interaction between the main effects of milk and size were tested for significance using the F-statistic. Analyses of variance were computed separately for each group and for each milk and size criteria.

When interactions were significant the following simple linear regressions were computed separately for each group:

1) Regressions of 180-day weaning weight and efficiency on height at withers for low, medium and high milk producers.

2) *Regressions of 180-day weaning weight and efficiency on total milk yield for low, medium and high heights at withers.*

When interactions were non-significant the simple linear regressions of 180-day weaning weight and efficiency on post-calving weight were calculated for each group.

IV. RESULTS AND DISCUSSION

1. Table 1 shows means and standard deviations of milk and size measurements of cows in groups 1 to 5. The standard deviations in 180-day milk yield in all the groups indicated the wide variation in milk yield observed within the groups. Standard deviations in post-calving weight ranged from about 43 Kg in group 3 to 58 Kg in group 4. Mean wither heights for all groups were fairly close ranging from 119.63 to 123.33 cm. Average length of cow ranged from 152.75 cm in group 5 to 156.72 cm in group 3. The standard deviations were large for all traits.

2. Adjustment of post-calving weight for backfat

It was necessary to consider whether weight of cow at calving should be adjusted for backfat because of the fact that body weight can vary with condition. Means and standard deviations of post-calving weight and backfat in the experimental cows are presented in Table 2. Table 3 shows regression coefficients and their standard errors for post-calving weight on backfat. Correlation coefficients between the two traits in the 5 groups of cows are also shown. In group 1 the regression and correlation coefficients were small and positive, but the standard error was large. In group 5, the coefficients were small and negative, and in groups 2, 3 and 4, they were comparatively large but negative. The negative correlations were rather surprising. Arnett et al. (1971) and Swanson and Hinton (1964) indicated much of the difference in weight between twin normal and obese cows to be due to fat. But it is important to note that these results were obtained across various cow breeds within the groups and the differences in weight observed in the experimental cows may therefore be attributed to actual differences

TABLE 1

Means and standard deviations of milk and size measurements of experimental cows

Trait/Group	1	2	3	4	5
Total 180-day milk yield (Kg)	1557.96	1809.90	1255.36	1449.96	1239.30
S.D.	470.10	516.93	402.78	548.94	352.67
Total 180-day milk fat yield (Kg)	48.71	51.31	46.39	42.87	43.90
S.D.	18.45	15.97	16.33	16.20	15.52
Weighted fat %	3.08	2.88	3.77	3.00	3.57
S.D.	0.59	0.52	1.01	0.60	0.81
Weighted lactose %	4.89	5.12	5.06	5.10	5.03
S.D.	0.42	0.28	0.25	0.23	0.30
Weighted protein %	3.84	3.48	3.80	3.00	3.26
S.D.	0.31	0.38	0.37	0.37	0.35
Average withers height (cm)	123.33	122.24	119.81	119.63	122.95
S.D.	3.69	8.82	5.63	8.38	7.31
Post-calving weight (Kg)	496.00	419.00	455.00	491.00	463.00
S.D.	46.81	51.53	42.64	57.59	55.81
Average length (cm)	154.06	155.69	156.72	154.68	152.75
S.D.	4.99	8.94	5.75	9.33	9.22

TABLE 2

Means and standard deviations of post-calving weight and backfat

Group	Post-calving weight (Kg)	n	Range	S.D.	Backfat (cm)	Range	S.D.
1	496	15	425-575	47	1.02	0.58-1.63	0.32
2	419	20	314-523	52	0.32	0.00-0.69	0.20
3	455	22	350-538	43	0.60	0.25-0.97	0.19
4	491	32	390-604	58	0.94	0.25-1.78	0.35
5	463	38	322-574	56	0.60	0.15-0.17	0.26

TABLE 3

Regression of post-calving weight on backfat, standard errors and correlation coefficients

Group	b (Kg/cm)	std. error	r
1	+7.1	40.2	+0.05
2	-120.7*	54.0	-0.47
3	-60.4	48.9	-0.27
4	-60.1*	27.7	-0.37
5	-3.7	36.4	-0.02

* $P < .05$

in skeletal size. In this case the skeletally heavier cows tended to put on less fat than skeletally lighter cows. The regressions could not therefore be used as a basis to adjust weight of cow for fat cover, and the cows were classified within groups into low, medium or high size on the basis of unadjusted weight at calving.

3. Milk production

Figs. 1 to 5 show average daily milk (Kg) produced at 6, 14 and 22 weeks for low, medium and high producers in groups 1 to 5.

In group 1, milk production at 22 weeks for both high and low producers was higher than production at 6 and 14 weeks. In group 2, high and low producers produced more milk at 22 weeks than at 6 or 14 weeks, but medium producers showed decreased milk production at 22 weeks. In group 3, milk production was again highest at 22 weeks for medium producers with low producers showing decreased milk production at 22 weeks. Low, medium and high producers in group 4 showed an upward trend. Milk production increased from 6 weeks, through 14 weeks with peak production at 22 weeks. Group 5 cows showed a different pattern. Milk production was highest at 6 weeks, and decreased through 14 and 22 weeks.

Fig. 6 shows lactation curves presented by Arnett et al. (1971) in normal twin beef females made up of Angus, Hereford, Shorthorn and Hereford x Angus, Hereford x Brahman, Hereford x Santa Gertrudis and Hereford x Shorthorn. Total milk production was determined by weighing the calves immediately before and after nursing 6 days each week during the entire lactation. On the 7th day of each week, milk was drawn from one side of the udder while the calf nursed the opposite

Fig. 1 | Daily Milk Production (kg) of Low and High producers in group 1.

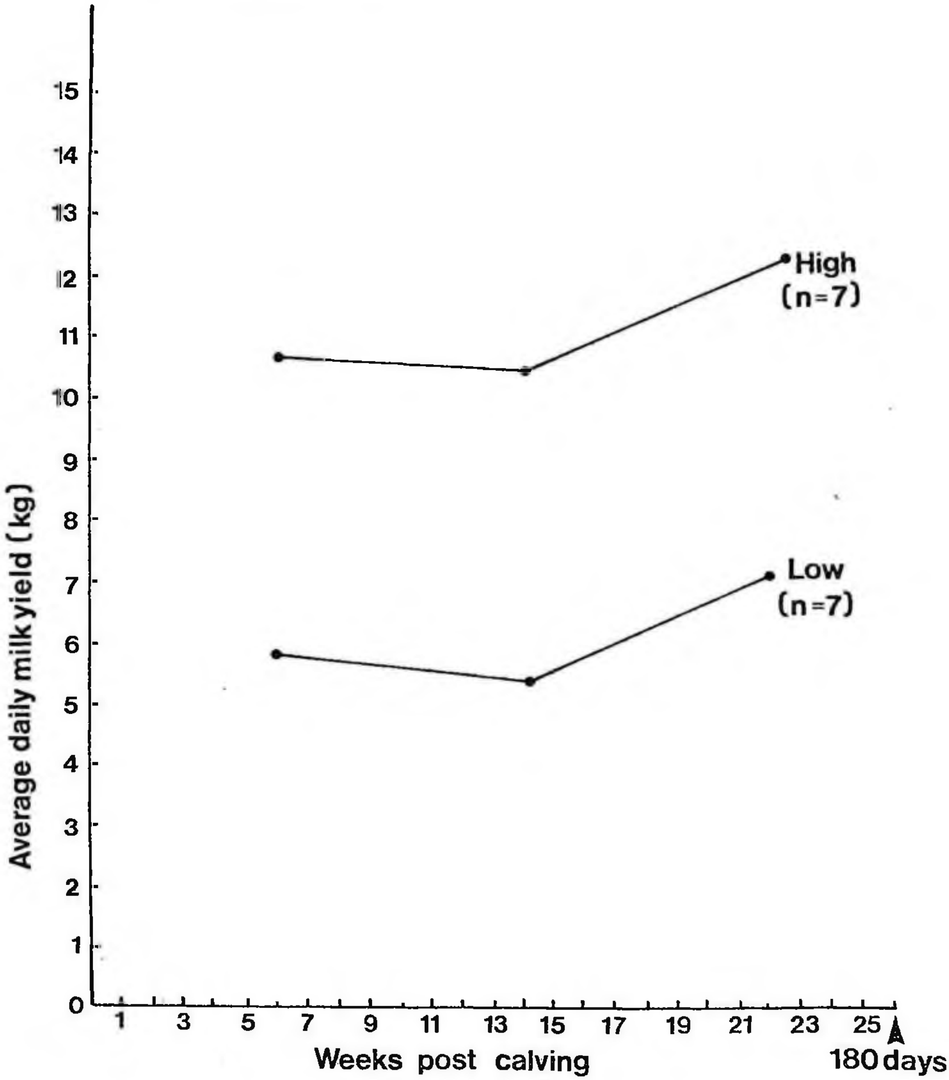


Fig. 2. Daily Milk Production (kg) of Low, Medium and High producers in group 2.

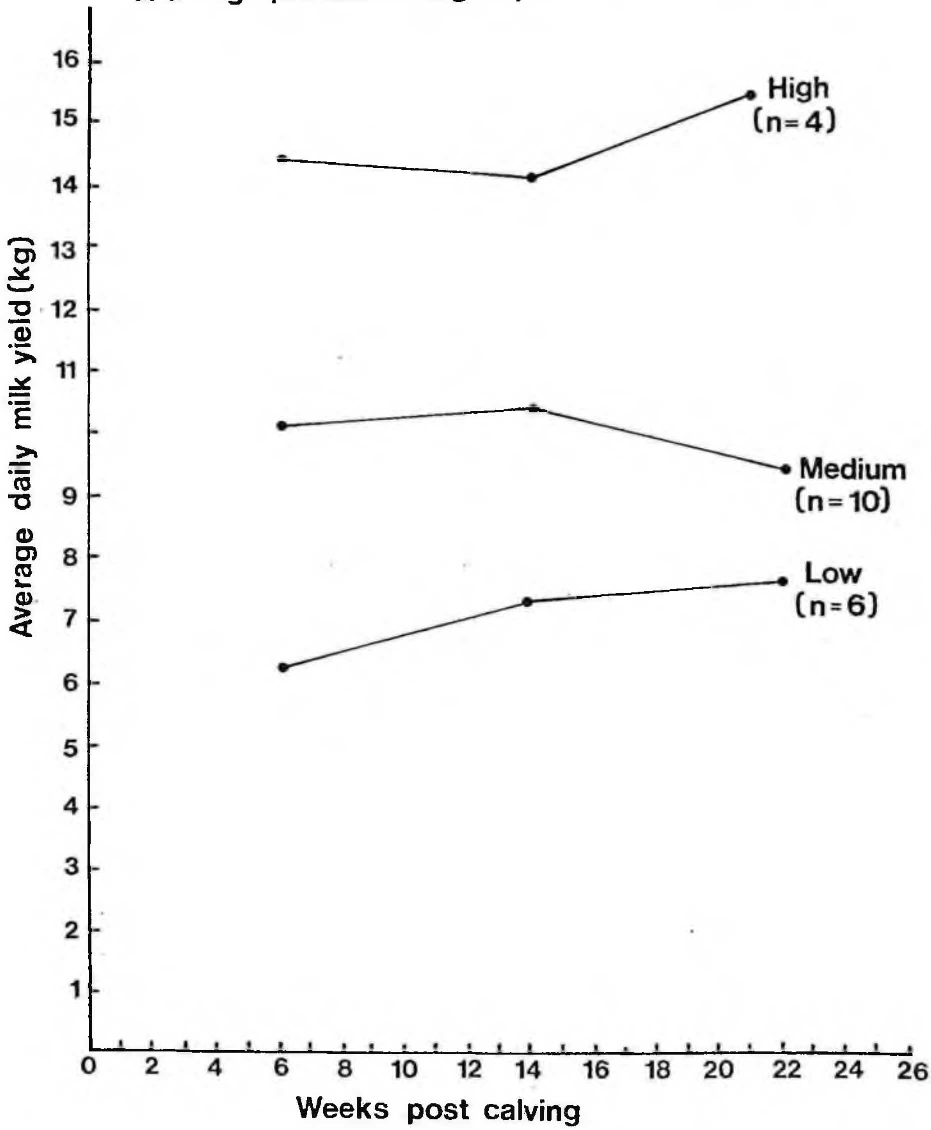


Fig. 3 Daily Milk Production (kg) of Low, Medium and High producers in group 3.

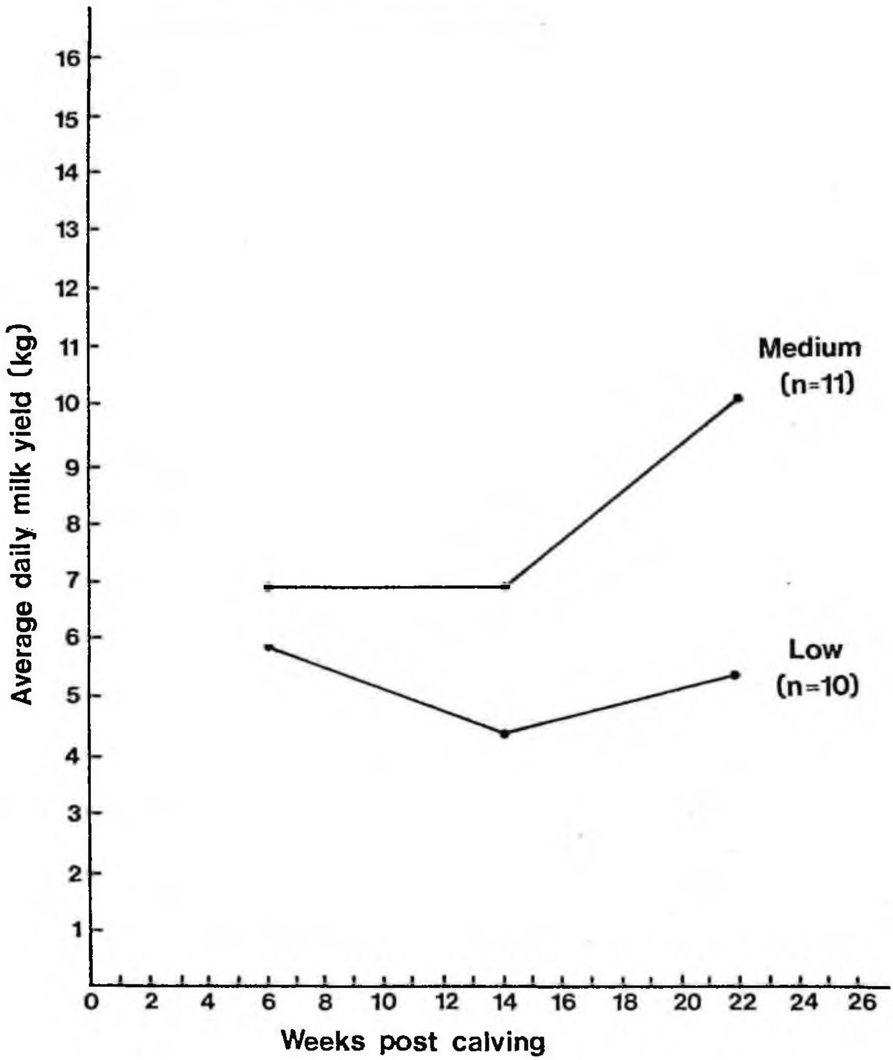


Fig. 4. Daily Milk Production (kg) of Low, Medium and High producers in group 4.

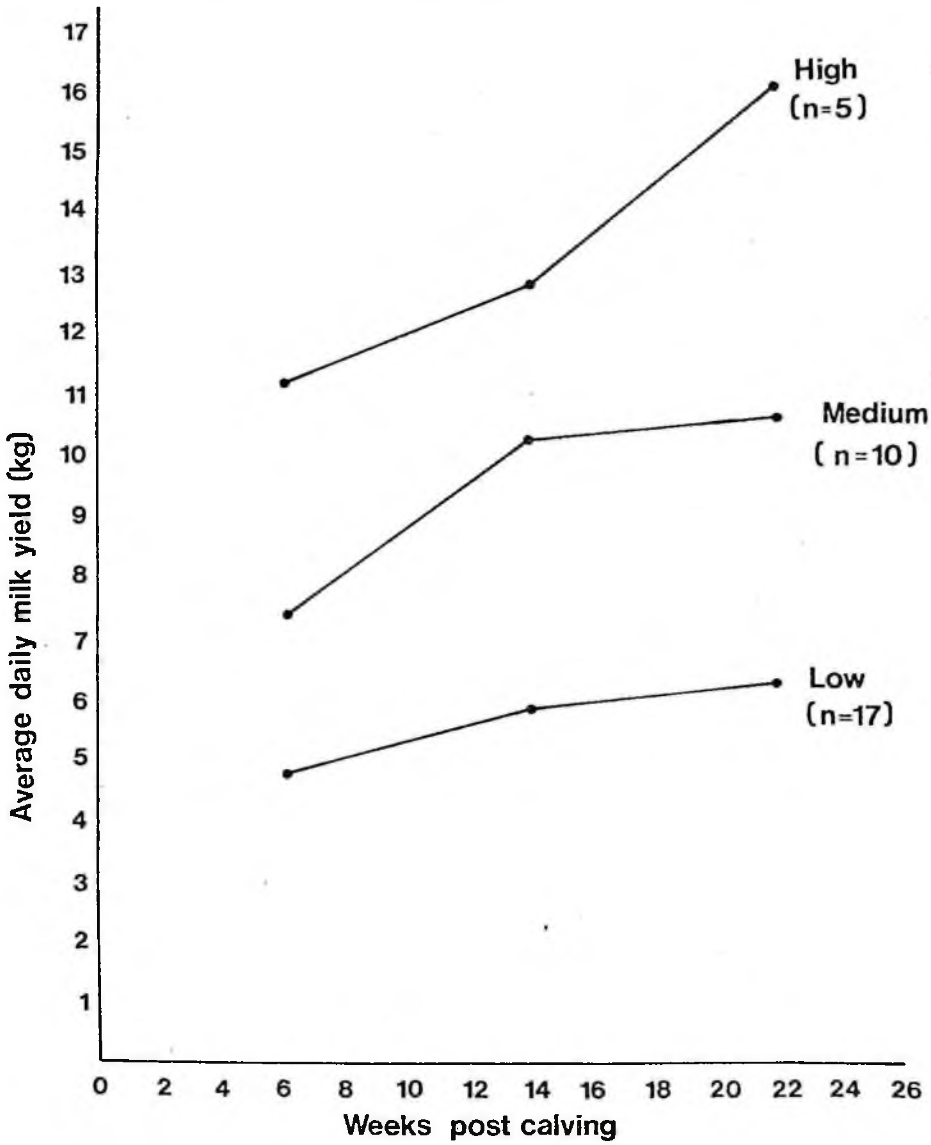


Fig. 5. Daily Milk Production (kg) of Low, Medium, and High producers in group 5.

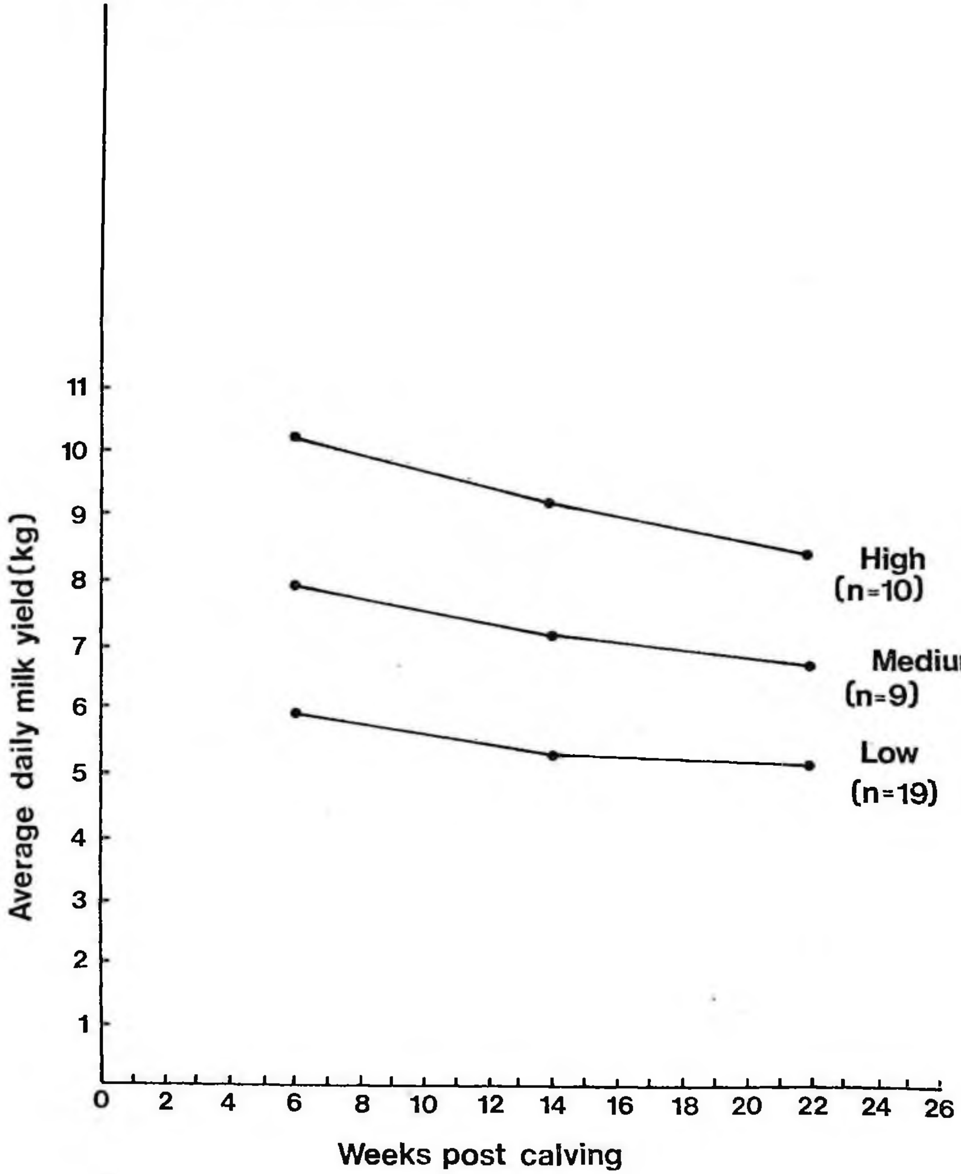
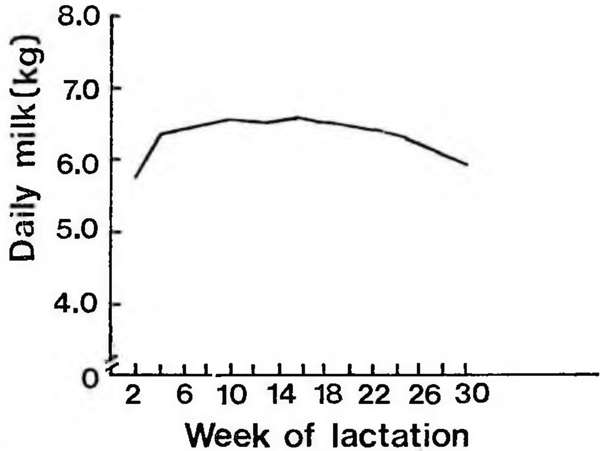
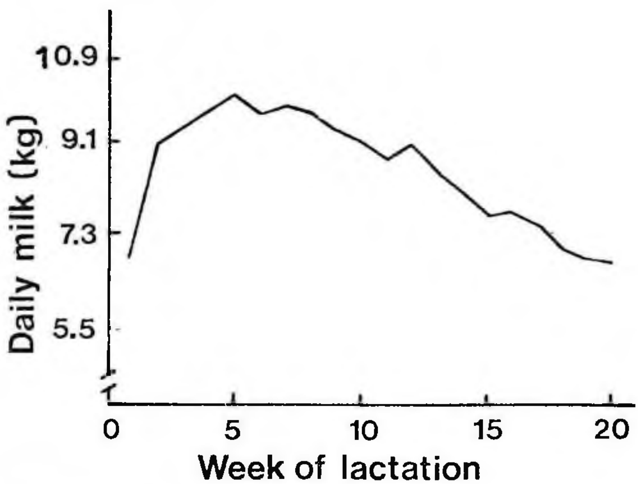


Fig. 6. Average daily milk production of normal twin beef females.[1]



[1]Arnett et al (1971)

Fig. 7. Average first lactation curve of normal twin females.[2]



[2]Swanson and Hinton (1964)

side. It is seen that milk yield peaked at 9 weeks and remained relatively constant until 16 weeks. By 22 weeks milk yield was on the decline. Fig. 7 represents the average first lactation curve of normal twin females presented by Swanson and Hinton (1964). Daily milk production peaked at 5 weeks and declined toward the end of lactation.

In the experimental cows the general trend in groups 1 to 4 was increasing milk production from 6 weeks to 22 weeks, with the highest daily yields measured at 22 weeks. It seems that longer lactation periods are possible with these cows. Milk production patterns in group 5 approximated the lactation curves presented by Arnett et al. (1971) and Swanson and Hinton (1964), with milk production reaching a peak earlier in lactation and steadily declining toward the end of lactation.

The general inconsistency of the pattern of milk production observed in the experimental cows may be a result of certain factors operating both within and across the groups:-

(a) Sample sizes for low, medium and high producers: With the small numbers used in computing the means, one or two very outstanding individuals would tend to have a marked effect on the average, thus giving a false picture of the true situation both within and across the groups.

(b) Effect of breed group of cow: Milk yield and production patterns may be different for various straight and cross-bred beef cows and this may explain the different patterns shown between different milk classes within and across groups.

(c) The effect of different rations: Favorable or unfavorable effects of rations being fed at the times milk measurements were taken in the different groups may be one source of the variation observed across the groups.

A more accurate pattern of milk production could be obtained if milk measurements were taken more frequently (at least once monthly) in a larger number of cows that varied less in breed group; with rations and methods of feeding (individual, group, and creep feeding) controlled.

4. Associations between cow size and milk yield

Simple correlations between milk yield and size measurements are presented in Table 4. The correlation between average height at withers and milk production ranged from 0.03 in group 1 to 0.70 in group 3. This positive association indicates increases in milk yield were associated with increases in height at withers. Pope et al. (1963) reported a small positive correlation of 0.09 between height at withers and milk production in 4-year old cows on comparable feed levels. Correlations between weight at calving and subsequent milk production also indicate increases in milk yield were associated with increased weight at calving. The correlations between milk yield and average length of cow were also positive for groups 2 to 5 and low but negative for group 1.

Pope et al. (1963) reported that among cows that are well developed for their age there seemed to be little association between body size and milk yield.

The results obtained for the experimental cows can perhaps be explained on the basis of the breeds included in the groups. In group 1 where there were no straight and very few crossbred Holsteins the correlations between milk yield and the various criteria for size were

TABLE 4

Within group correlations between milk and size measurements

Traits/Group	1	2	3	4	5
Milk yield/fat yield	0.92**	0.81**	0.62**	0.89**	0.75**
Milk yield/height	0.03	0.48*	0.70**	0.63*	0.41*
Milk yield/calving wt.	0.00	0.55*	0.70**	0.32	0.07
Milk yield/length	-0.04	0.43	0.59**	0.49**	0.16
Fat yield/height	0.27	0.27	0.48*	0.66**	0.40*
Fat yield/calving wt.	-0.17	0.34	0.68**	0.32	0.19
Fat yield/length	0.02	0.16	0.65**	0.45**	0.22
Height/calving wt.	0.72**	0.92**	0.75**	0.63**	0.68**
Height/length	0.83**	0.85**	0.76**	0.86**	0.81**
Length/calving wt.	0.83**	0.78**	0.71**	0.73**	0.73**

* $P < .05$
** $P < .01$

very low and sometimes negative. In groups 2 to 5 which included straight and crossbred Holsteins it is not surprising that the correlations between milk yield and size measurements were all positive and sometimes quite high. Small positive phenotypic correlations between body weight and milk yield in dairy cattle have been reported by Wilk et al. (1963), Touchberry (1951) and Blackmore et al. (1958). Mason et al. (1957) have also reported small positive correlations between wither height and milk yield in dairy cattle.

As expected fat yield was highly correlated with milk yield and the correlations between the various size measurements were also high.

5. Mean weaning weights and efficiency estimates

Average weaning weights of calves and efficiency estimates of the experimental cows are presented in Table 5. The ranges in weaning weight and efficiency in each group are also given. Across groups, mean 180-day weaning weights ranged from 155 Kg in group 5 to 183 Kg in group 4. Average efficiency estimates of cows ranged from 0.142 Kg ww/Kg TDN to 0.189 Kg ww/Kg TDN. First lactation efficiency estimates of cows calculated similarly are not well documented in the literature, but Kress et al. (1969) using two formulae that calculated the units of weaning weight produced per Kg TDN, reported estimates that agree with the results obtained in the present study. They reported cow first lactation production efficiency estimates of 0.101 and 0.051 Kg ww/Kg TDN in beef cattle for E_1 and E_2 respectively.

TABLE 5

Means and standard deviations of calf weaning weights and efficiency estimates of cows

Group	Mean weaning weight (Kg)	n	Range	S.D.	Mean efficiency Kg ww/Kg TDN	Range	S.D.
1	171	15	104-217	34	0.164	0.103-0.214	0.029
2	180	20	126-239	26	0.176	0.120-0.226	0.024
3	170	22	122-241	28	0.189	0.136-0.258	0.032
4	183	32	116-248	36	0.151	0.077-0.207	0.026
5	155	38	104-211	26	0.142	0.095-0.193	0.022

6. Effect of milk and size measurements on 180-day weaning weight and efficiency

Least squares analysis of variance tables showing the effects of each criterion of milk and size on 180-day weaning weight and efficiency are presented in Appendix Tables 6 to 63.

(a) Effects of total milk yield and average height at withers of cow

Tables 6 and 7 show the sources of variation and the effect of total milk yield and average height at withers on 180-day weaning weight and efficiency in groups 1 and 2, and 4 and 5. Group 3 was deleted because there were no degrees of freedom to test for interaction.

180-day weaning weight

Interaction effects between milk yield and height at withers were significant ($P < .05$) in group 1 and highly significant ($P < .01$) in group 4 (Table 6). In the remaining groups, interaction was not significant. Height at withers had a highly significant ($P < .01$) effect on 180-day weaning weight in group 4 alone, and milk yield had a significant ($P < .05$) effect in groups 1, 4 and 5. With interaction significant, the main effects of milk and height cannot be estimated since the effect of one depends on the level of the other. It is rather surprising that the effect of sex of calf was not significant in any of the 5 groups.

Efficiency

Interaction between milk yield and height at withers was again highly significant ($P < .01$) in group 4 but not in the other groups. Also, in group 4, the effect of milk yield was significant ($P < .05$),

TABLE 6

Effects of total milk yield and average height at withers on 180-day weaning weight

Source/Group	Mean squares (Kg^2)			
	1	2	4	5
Sex of calf	484	1422	1038	1021
Milk yield	1656*	626	1619*	1281*
Height	179	704	4350**	1002
Milk x height	1110	140	3258**	81
Error	212	410	362	334

* Significant $P < .05$
** Significant $P < .01$

TABLE 7

Effects of total milk yield and average height at withers on efficiency

Source/Group	Mean squares $(Kg\ calf/Kg\ TDN)^2 \times 100$			
	1	2	4	5
Sex of calf	.039	.161	.031	.099
Milk yield	.122	.074	.145*	.039
Height	.031	.001	.212*	.026
Milk x height	.076	.007	.282**	.001
Error	.027	.038	.028	.046

* Significant $P < .05$
** Significant $P < .01$

and the effect of height at withers was highly significant ($P < .01$). None of the main effects of sex, milk yield and height at withers had any significant effect on efficiency in the other four groups.

(b) Effects of total milk yield and post-calving weight of cow

Tables 8 and 9 show the effects of total milk yield and post-calving weight of cow on 180-day weaning weight and efficiency in groups 1 to 5.

180-day weaning weight

There was no significant interaction between total milk yield and post-calving weight of cow in all 5 groups. The effect of milk yield on weaning weight was significant ($P < .05$) in group 1, and highly significant ($P < .01$) in groups 4 and 5. Post-calving weight of cow and sex of calf had no significant effects on weaning weight in all 5 groups.

Efficiency

Interaction between total milk yield and post-calving weight of cow was not significant in any of the 5 groups. Milk yield was the only main effect that had a significant ($P < .05$) effect on efficiency in groups 1 and 4.

(c) Effects of total milk yield and average length of cow

Effects of total milk yield and average length of cow on 180-day weaning weight and efficiency are presented in Tables 10 and 11.

180-day weaning weight

Interaction between total milk yield and length of cow was significant ($P < .05$) in group 4, and non-significant in groups 1,

TABLE 8

Effects of total milk yield and post-calving weight of cow on weaning weight

Source/Group	Mean squares (Kg^2)				
	1	2	3	4	5
Sex of calf	160	1748	1789	127	803
Milk yield	2608*	1338	1431	8678**	3874**
Post-calving weight	527	311	11	1395	466
Milk x weight	309	151	517	984	142
Error	334	497	744	655	342

* Significant $P < .05$
** Significant $P < .01$

TABLE 9

Effects of total milk yield and post-calving weight on efficiency

Source/Group	Mean squares $(Kg\ calf/Kg\ TDN)^2 \times 100$				
	1	2	3	4	5
Sex of calf	.007	.135	.395	.000	.063
Milk yield	.195*	.104	.070	.272*	.077
Post-calving weight	.049	.001	.009	.033	.004
Milk x weight	.035	.009	.007	.043	.016
Error	.032	.036	.091	.056	.047

* Significant $P < .05$

TABLE 10

Effects of total milk yield and average length of cow on weaning weight

Source/Group	Mean squares (Kg^2)				
	1	2	3	4	5
Sex of calf	120	981	311	1754*	685
Milk yield	1113	649	1965	843	3691**
Length of cow	200*	1269	326	4423**	1629*
Milk x length	678	308	1301	1951*	31
Error	308	405	530	404	332

* Significant P < .05
** Significant P < .01

TABLE 11

Effect of total milk yield and average length of cow on efficiency

Source/Group	Mean squares $(Kg\ calf/Kg\ TDN)^2 \times 100$				
	1	2	3	4	5
Sex of calf	.013	.154	.284	.070	.107
Milk yield	.077	.096	.071	.051	.043
Length of cow	.022	.000	.003	.236**	.037
Milk x length	.036	.005	.035	.138*	.053
Error	.038	.040	.094	.038	.042

* Significant P < .05
** Significant P < .01

2, 3 and 5. The effect of milk yield was highly significant ($P < .01$) in group 5 alone. Length of cow had a significant ($P < .05$) effect on weaning weight in groups 1 and 5, and a highly significant ($P < .01$) effect in group 4. Sex of calf had a significant ($P < .05$) effect on weaning weight in group 4, but the sex effect was not significant in the other groups.

Efficiency

Interaction between milk yield and length of cow had a significant ($P < .05$) effect on efficiency in group 4 alone. Length of cow effect was also highly significant ($P < .01$) in group 4, but the effect cannot be simply explained because of the significant interaction. Milk yield and sex of calf had no significant effects in any of the groups.

(d) Effect of total milk fat yield and average height at withers of cow

Tables 12 and 13 show the effects of total fat (Kg) and average height at withers (cm) on weaning weight and efficiency in groups 1 to 5.

180-day weaning weight

In all 5 groups, interaction between total fat and height at withers was not significant. Effects of fat yield and sex of calf were not significant in all groups, but height at withers had a significant ($P < .05$) effect on weaning weight in groups 2, 3 and 5.

Efficiency

There was no significant interaction between total fat and average height at withers in all groups, but height at withers had a significant effect ($P < .05$) on efficiency in group 3. In the remaining 4 groups, none of the main effects of fat yield, height at withers

TABLE 12

Effects of total milk fat yield and average height at withers on weaning weight

Source/Group	Mean squares (Kg^2)				
	1	2	3	4	5
Sex of calf	1152	1319	1583	1000	239
Fat yield	1070	869	504	468	1193
Height	415	2560*	3460*	599	1389*
Fat x height	879	165	623	1704	288
Error	319	396	576	570	395

* Significant $P < .05$

TABLE 13

Effects of total milk fat yield and average height at withers on efficiency

Source/Group	Mean squares $(Kg\ calf/Kg\ TDN)^2 \times 100$				
	1	2	3	4	5
Sex of calf	.063	.174	.285	.058	.051
Fat yield	.124	.086	.105	.059	.116
Height	.057	.016	.272*	.118	.036
Fat x height	.120	.047	.080	.129	.021
Error	.026	.041	.072	.039	.040

* Significant $P < .05$

and sex of calf were significant at the 5% level.

(e) Effect of total milk fat yield and post-calving weight of cow

The sources of variation and effects of total fat and post-calving weight of cow on weaning weight and efficiency in groups 1 to 5 are presented in Tables 14 and 15.

180-day weaning weight

In all 5 groups interaction between total fat and post-calving weight of cow had no significant effect on weaning weight. The effect of fat yield, however, was significant ($P < .05$) in group 1, and highly significant ($P < .01$) in groups 4 and 5. Post-calving weight of cow was highly significant ($P < .01$) in group 5, but non-significant in the other groups. Sex of calf had no significant effect in all 5 groups.

Efficiency

Interaction effects were not significant in all groups, but fat yield had a significant ($P < .05$) effect on efficiency in groups 1, 4 and 5. The effects of sex of calf and post-calving weight of cow on efficiency were not significant at the 5% level of probability in any of the groups.

(f) Effect of total milk fat yield and average length of cow

Tables 16 and 17 show the sources of variation and effects of total kilogram milk fat yield and average length of cow on weaning weight and efficiency in groups 1 to 5.

180-day weaning weight and efficiency

In all groups, interaction between total fat and average length of cow had no significant effect on both 180-day weaning weight and

TABLE 14

Effects of total milk fat yield and post-calving weight of cow on weaning weight

Source/Group	Mean squares (Kg^2)				
	1	2	3	4	5
Sex of calf	1322	1509	3116	306	241
Fat yield	2402*	929	1090	8211**	3566**
Weight of cow	385	1958	813	1999	2704**
Fat x weight	685	326	545	1002	248
Error	319	555	894	717	346

* Significant P < .05
** Significant P < .01

TABLE 15

Effects of total milk fat yield and post-calving weight on efficiency

Source/Group	Mean squares $(Kg\ calf/Kg\ TDN)^2 \times 100$				
	1	2	3	4	5
Sex of calf	.075	.144	.330	.000	.039
Fat yield	.168*	.145	.043	.226*	.147*
Weight of cow	.052	.019	.052	.036	.043
Fat x weight	.071	.059	.044	.021	.013
Error	.028	.039	.210	.065	.041

* Significant P < .05

TABLE 16

Effects of total milk fat yield and average length of cow on weaning weight

Source/Group	Mean squares[1] (Kg^2)				
	1	2	3	4	5
Sex of calf	1671	1163	495	1742	0
Fat yield	563	1039	703	703	534
Length of cow	269	1391	1262	1040	988
Fat x length	228	102	181	806	429
Error	400	508	753	556	494

1 None of the mean squares was significant

TABLE 17

Effects of total milk fat yield and average length of cow on efficiency

Source/Group	Mean squares[1] ($(Kg\ calf/Kg\ TDN)^2 \times 100$)				
	1	2	3	4	5
Sex of calf	.132	.181	.213	.111	.015
Fat yield	.065	.083	.020	.040	.084
Length of cow	.040	.000	.014	.056	.029
Fat x length	.038	.023	.001	.051	.053
Error	.037	.049	.112	.051	.038

1 None of the mean squares was significant

efficiency and none of the main effects of fat yield, length of cow and sex of calf had any significant effect on weaning weight and efficiency.

7. Investigation of interaction

Looking at the results for all groups, and for all the criteria for milk and size, the following characteristics of the data became apparent:

(a) With regard to 180-day weaning weight and efficiency, there was evidence of some interaction between total milk yield and height at withers, and between total milk yield and length of cow. There was no interaction between total milk yield and weight of cow at calving.

(b) Milk yield, fat yield, height at withers and length of cow all had significant effects on 180-day weaning weight and efficiency in at least one group. Post-calving weight of cow significantly affected 180-day weaning weight but not efficiency.

(c) Sex of calf generally did not significantly affect 180-day weaning weight or efficiency.

The significant interaction effect between height at withers and milk yield on both 180-day weaning weight and cow production efficiency indicates that the magnitude of one of the effects depended upon the level of the other factor. There were no comparisons available from the literature. As a result of the significant interactions, regression coefficients of 180-day weaning weight and efficiency on height at withers were computed for the different milk classes in order to determine the direction and magnitude of response. The results are presented in Tables

18 and 19. The number of cow-calf pairs associated with each regression coefficient is also shown. The numbers involved are very small. As a result, the magnitude of the regression coefficients, even though some of them are significant, may have little meaning. However, the regressions of 180-day weaning weight on height at withers for the different milk classes ranged from -4.7 to +5.7 Kg/cm height and were generally positive indicating an increase in 180-day weaning weight associated with increase in wither height of cow. Comparisons of the relationship between wither height of cow and 180-day weaning weight of calf as found in the present study are not directly available in the literature. However, the results are reasonable in the sense that height at withers was found to be positively and sometimes highly correlated with milk yield in 4 of the 5 groups; and high positive correlations between milk yield of dam and calf weaning weight are well documented.

When efficiency was regressed on height at withers, the regression coefficients were very small ranging from -0.0039 to +0.0032 Kg ww/Kg TDN/cm height. None of the regressions was significant but they were generally positive for medium milk producers and generally negative for low and high milk producers. This would seem to indicate that for medium milk producers efficiency was positively related to height at withers while for low and high milk producers cows with smaller heights at withers tended to be more efficient. Kress et al. (1969) calculated standard partial regressions of efficiency (ww/Kg TDN) on various independent variables (age at calving, weight at calving, and withers height at calving). No interaction between milk yield and height at withers was assumed; and they reported cows with greater heights at withers to

TABLE 18

Regression coefficients (b) and standard errors (Sb) for 180-day weaning weight on height at withers (Kg weaned calf/cm height)

Group	Low milk			Medium milk			High milk		
	b	Sb	n	b	Sb	n	b	Sb	n
1	-4.7	2.3	7	-	-	1	+1.0	0.2	7
2	-0.4	1.6	6	+2.0*	0.8	10	+0.6	0.8	4
3	+5.7*	0.2	10	+0.1	1.3	11	-	-	1
4	+0.1	0.8	17	+2.9*	1.1	10	-4.1	2.1	5
5	+1.0	0.6	19	+1.4	1.1	9	+4.2*	1.0	10

* $P < .05$

TABLE 19

Regression coefficients (b) and standard errors (Sb) for efficiency on height at withers (Kg weaned calf/Kg TDN/cm height) x 100

Group	Low milk			Medium milk			High milk		
	b	Sb	n	b	Sb	n	b	Sb	n
1	-0.39	0.23	7	-	-	1	-0.04	0.22	7
2	-0.02	0.18	6	+0.06	0.08	10	-0.11	0.04	4
3	+0.32	0.30	10	-0.02	0.13	11	-	-	1
4	-0.13	0.08	17	+0.15	0.10	10	-0.18	0.19	5
5	-0.03	0.06	19	+0.16	0.18	9	+0.17	0.13	10

be more efficient in weaning weight produced per Kg TDN with age and weight at calving held constant. Although this agrees with the results obtained for medium milk producers, only simple regressions were calculated and weight of cow at calving was completely disregarded.

The nature of the interaction between milk yield and height at withers is rather difficult to explain from the results. The scatter diagrams and regression lines for 180-day weaning weight on height at withers of cow for low and medium milk yields in group 1 to 5 and for high milk yield in group 5 are presented in Figs. 8 to 17. The number of observations in each milk class was too small and the observations showed too much variation to justify a pooled regression coefficient. The results are therefore interpreted on the basis of general direction of response. The scatter diagrams and regression lines for efficiency on height at withers for the different milk classes are presented in Figs. 18 to 22. The data again showed too much variation to justify a pooled regression coefficient.

8. Correlations between weaning weight, efficiency and wither height of cow

Correlation coefficients for weaning weight and height at withers of cow are presented in Table 20. The correlations ranged from -0.76 for low milk producers in group 2 to 0.83 for high milk producers in group 5, and were generally positive. Direct comparisons are not available in the literature.

Table 21 shows correlations between efficiency and wither height of cow. Generally correlations were negative but the magnitudes were inconsistent. The negative correlations would indicate however that

Fig.8. Scatter diagram and regression line: Regression of 180-day weaning weight on wither height of cow (Group1, Low milk)

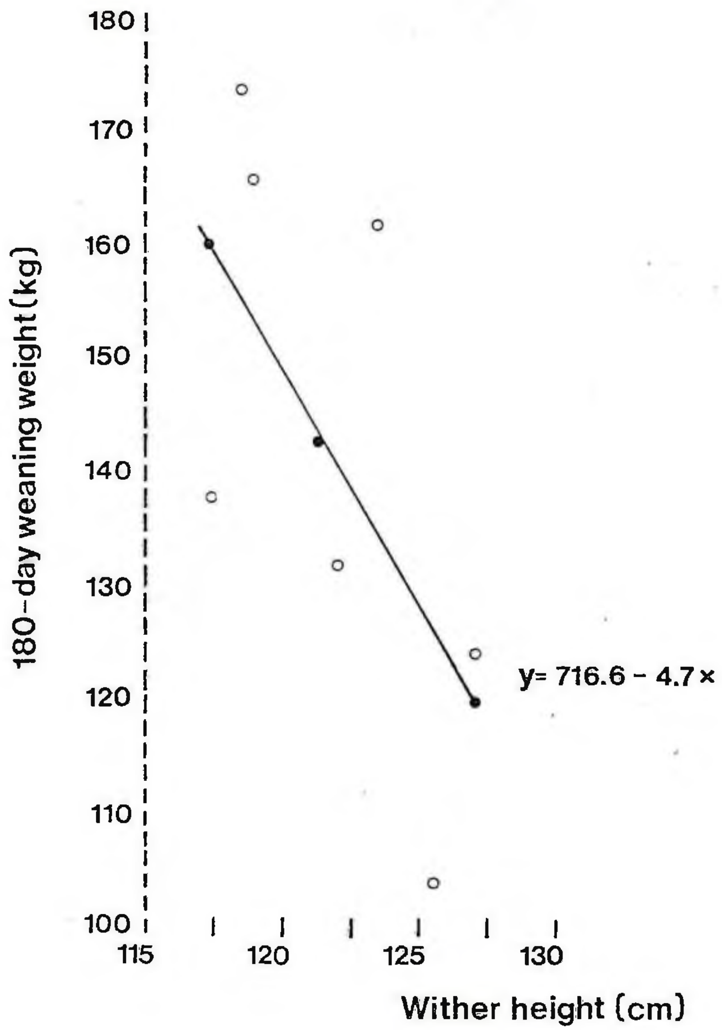


Fig.9. Scatter diagram and regression line: Regression of 180-day weaning weight on wither height of cow (Group 2, Low milk)

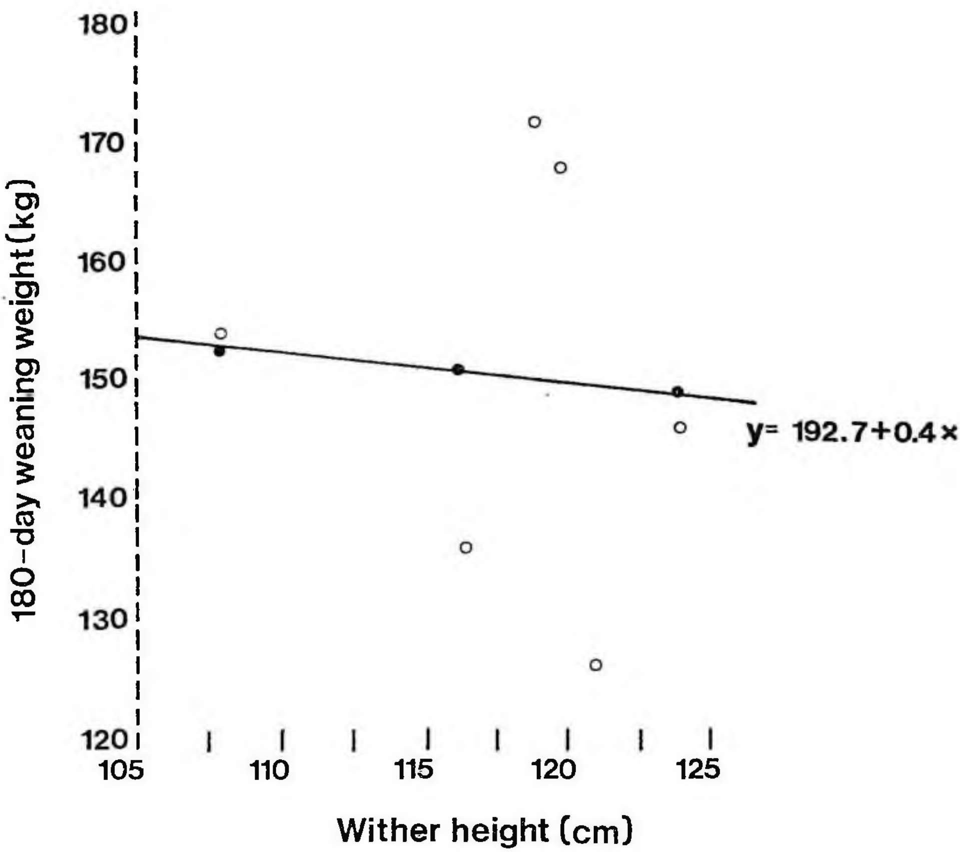


Fig.10. Scatter diagram and regression line: Regression of 180-day weaning weight on wither height of cow (Group 3, Low milk)

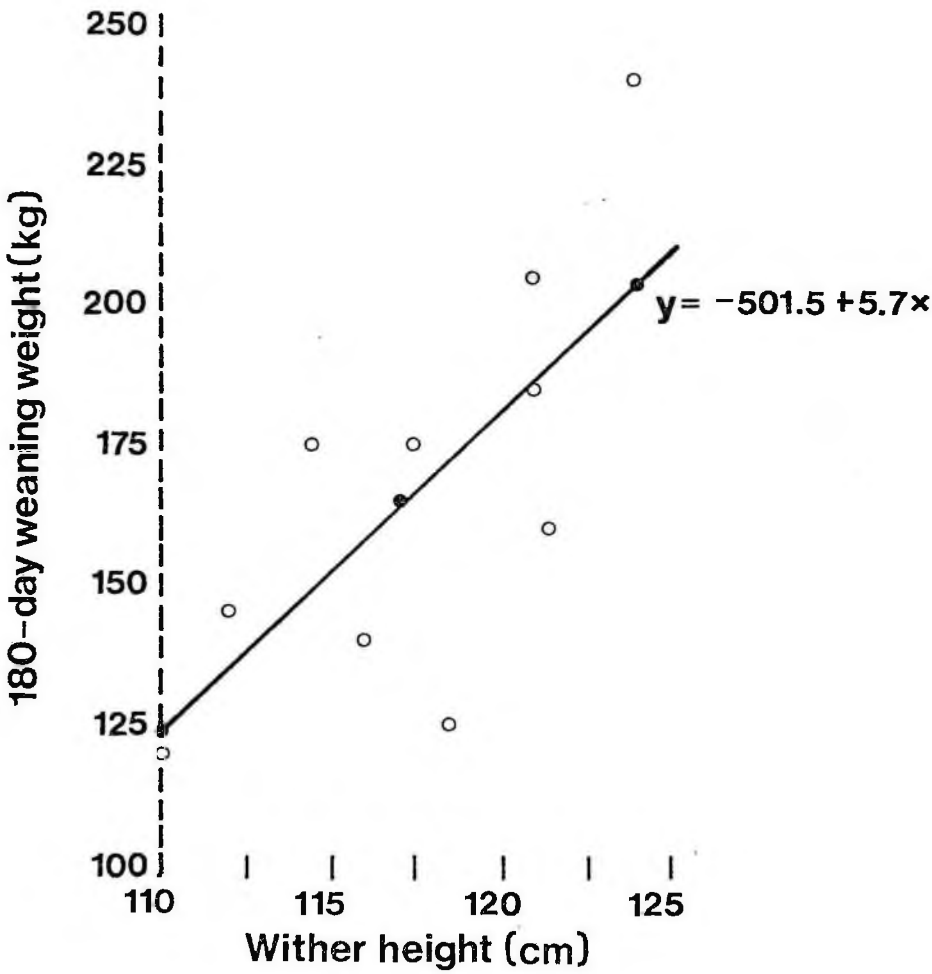


Fig.11. Scatter diagram and regression line: Regression of 180-day weaning weight on wither height of cow (Group 4, Low milk)

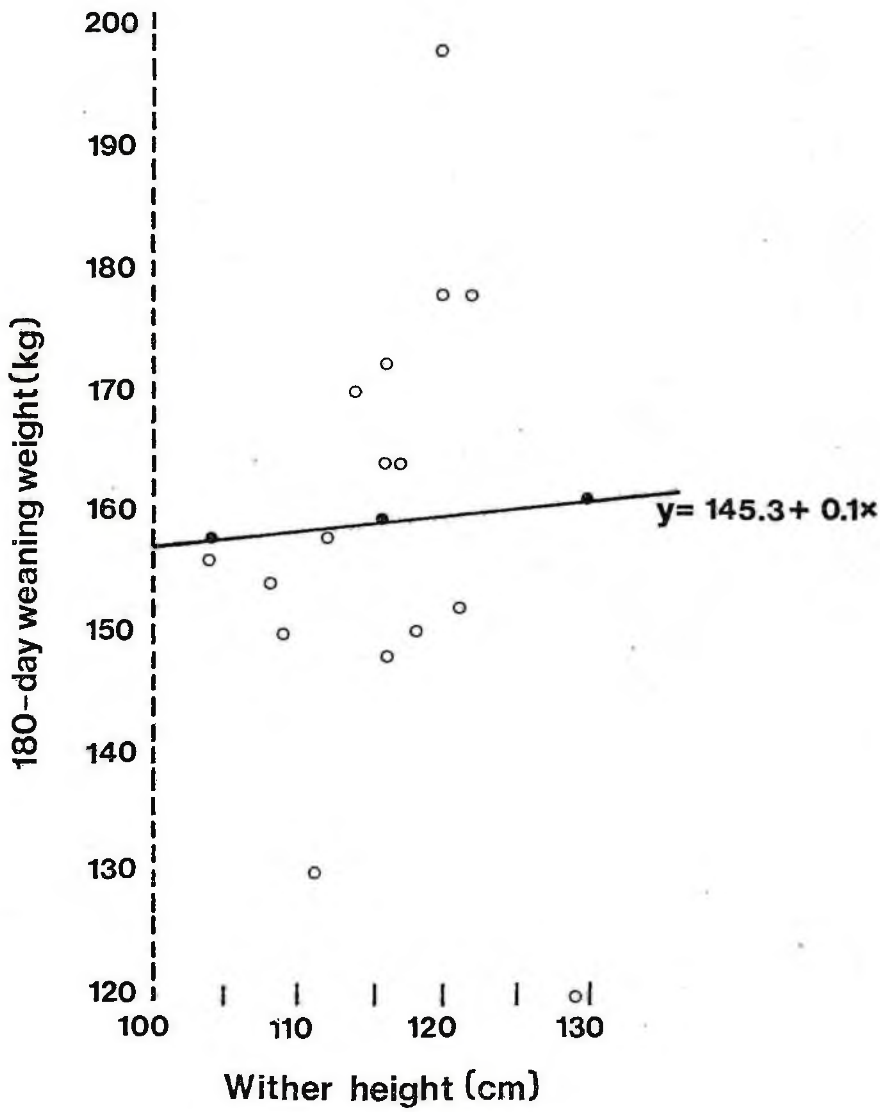


Fig.12. Scatter diagram and regression line: Regression of 180-day weaning weight on wither height of cow (Group5, Low milk)

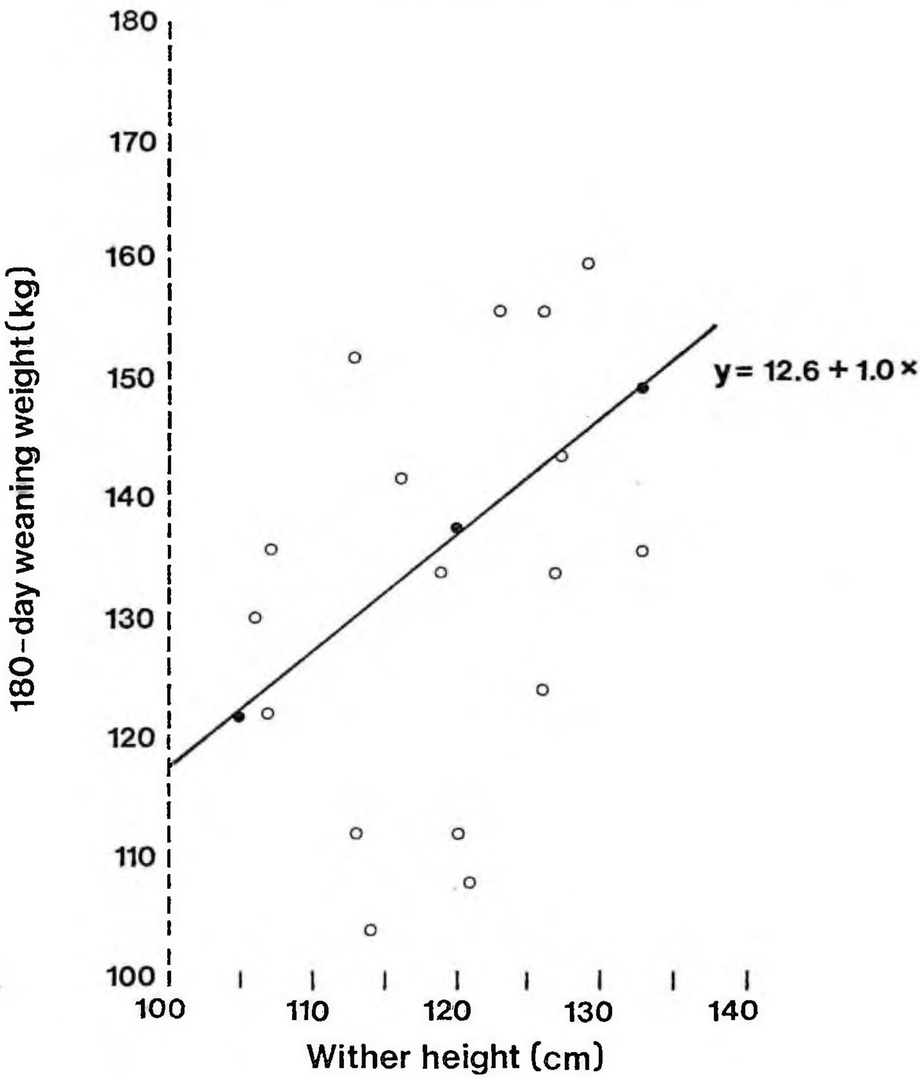


Fig.13. Scatter diagram and regression line:
Regression of 180-day weaning weight
on wither height of cow (Group 2, Medium milk)

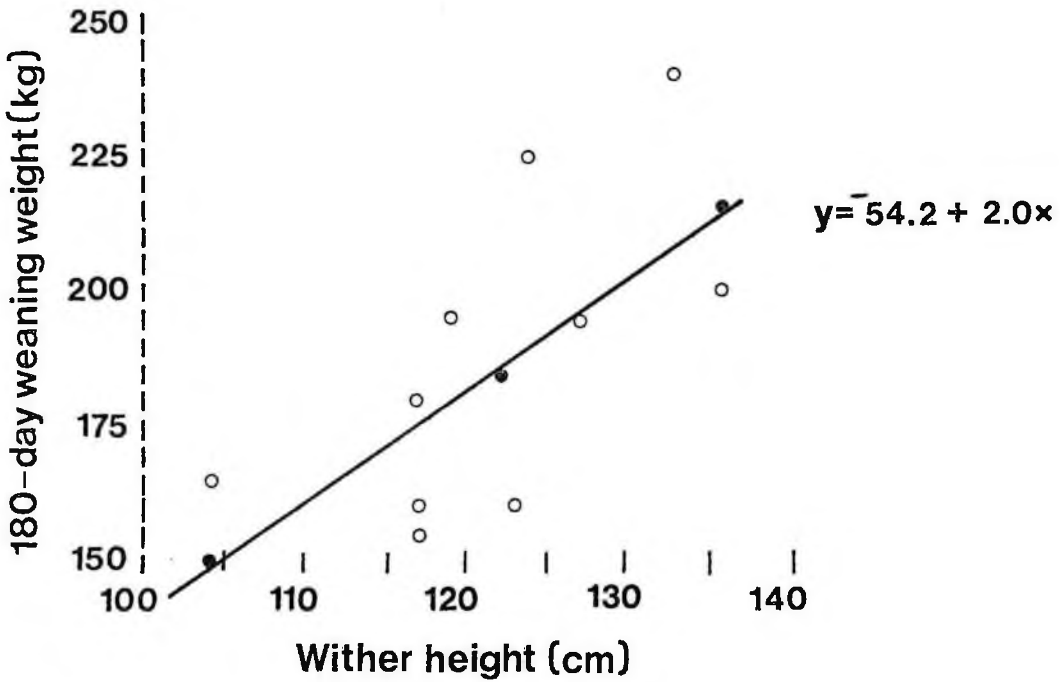


Fig.14. Scatter diagram and regression line: Regression of 180-day weaning weight on wither height of cow (Group3,Medium milk

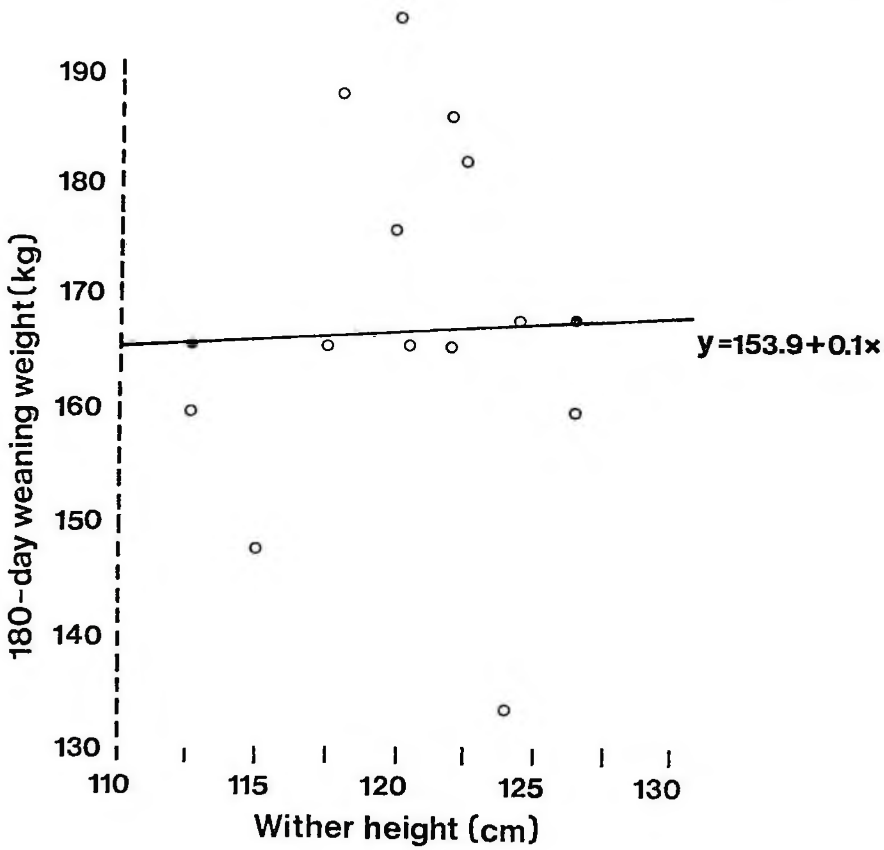


Fig.14. Scatter diagram and regression line: Regression of 180-day weaning weight on wither height of cow (Group3, Medium milk

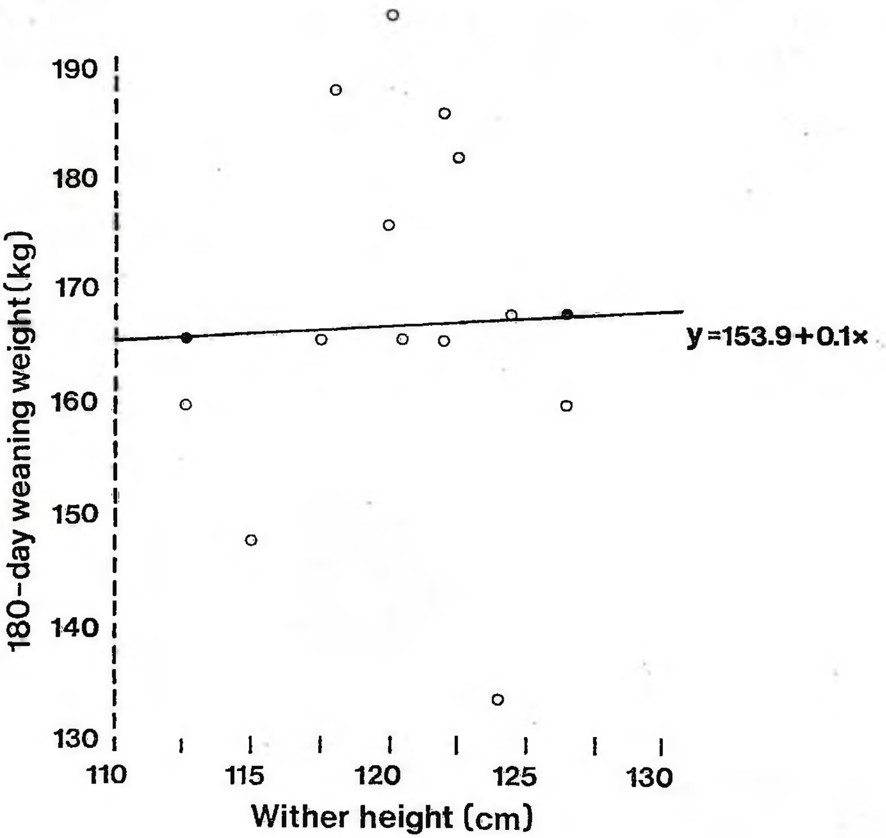


Fig.15. Scatter diagram and regression line: Regression of 180-day weaning weight on wither height of cow (Group4, Medium milk)

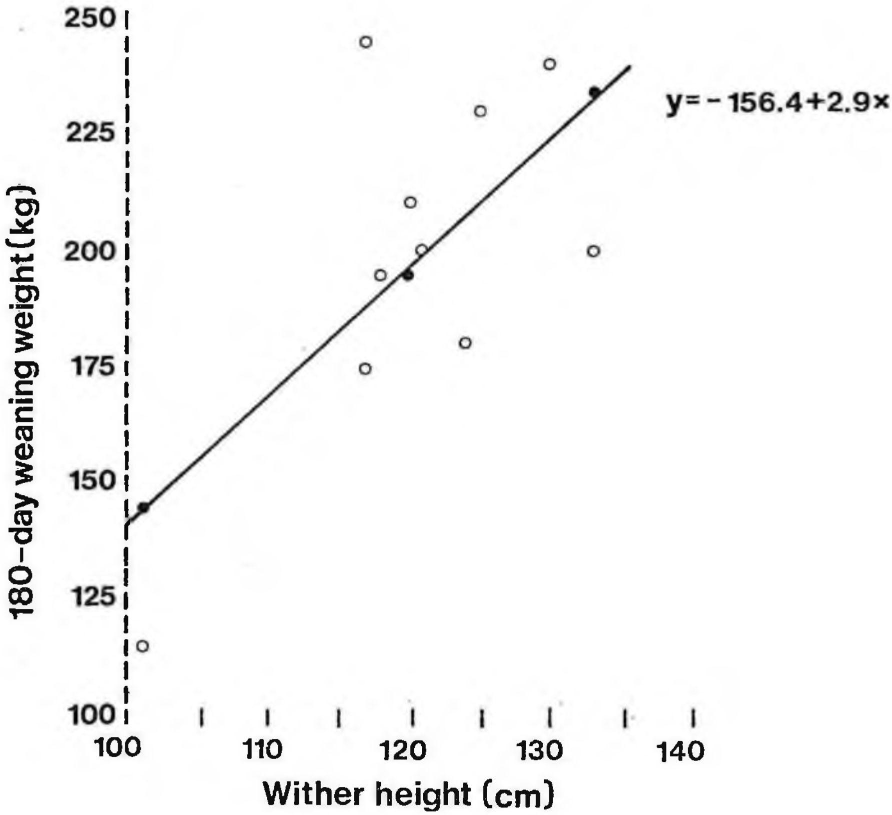


Fig.16. Scatter diagram and regression line: Regression of 180-day weaning weight on wither height of cow (Group 5, Medium milk)

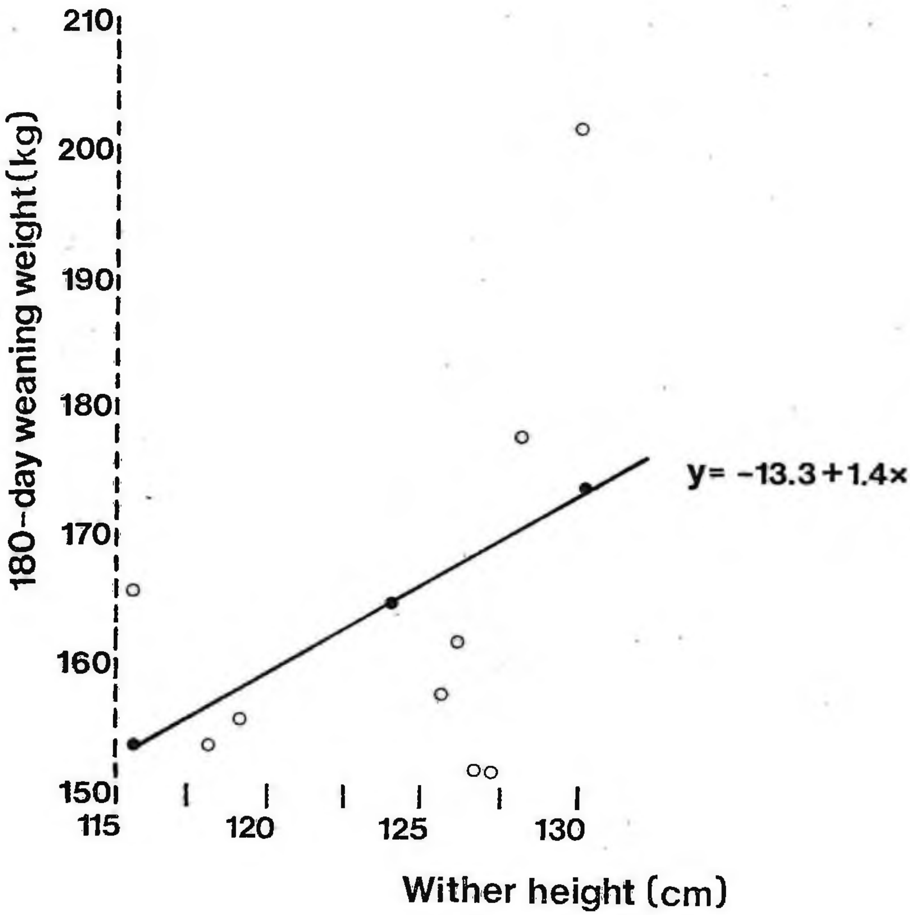


Fig.17. Scatter diagram and regression line: Regression of 180-day weaning weight on wither height of cow (Group 5, High milk)

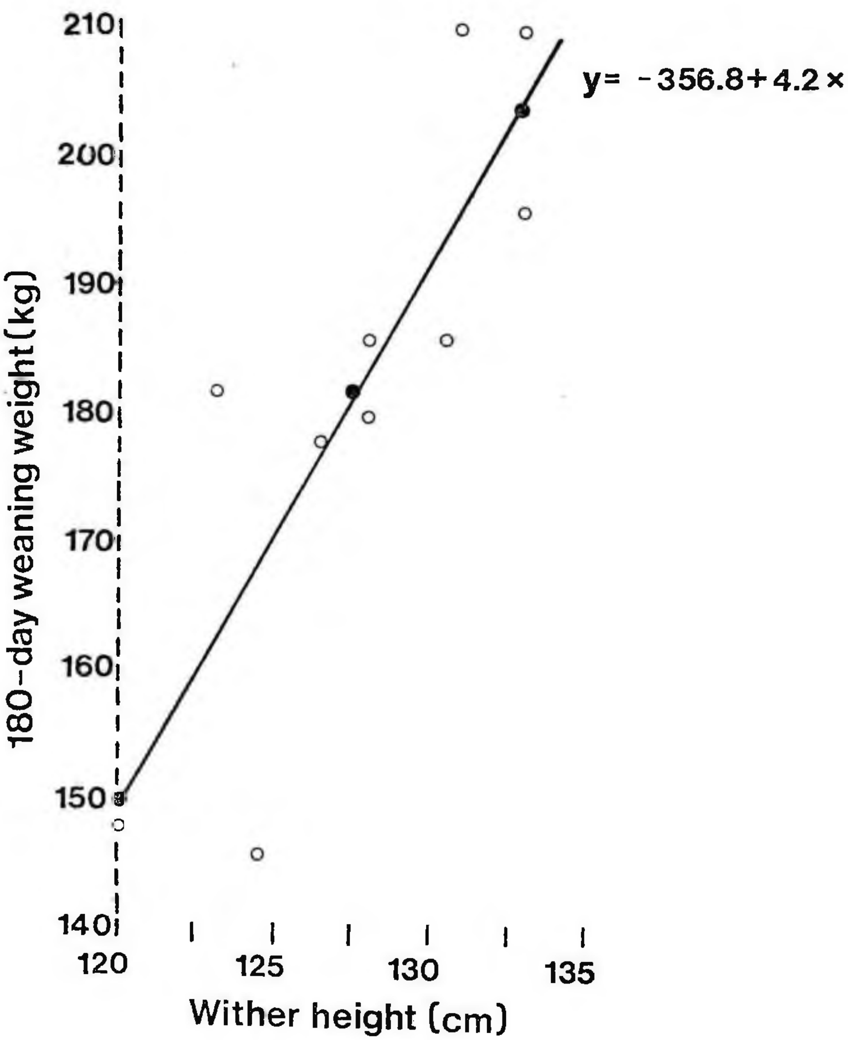


Fig. 18. Regression of efficiency on height at withers for low and high milk producers (group 1)

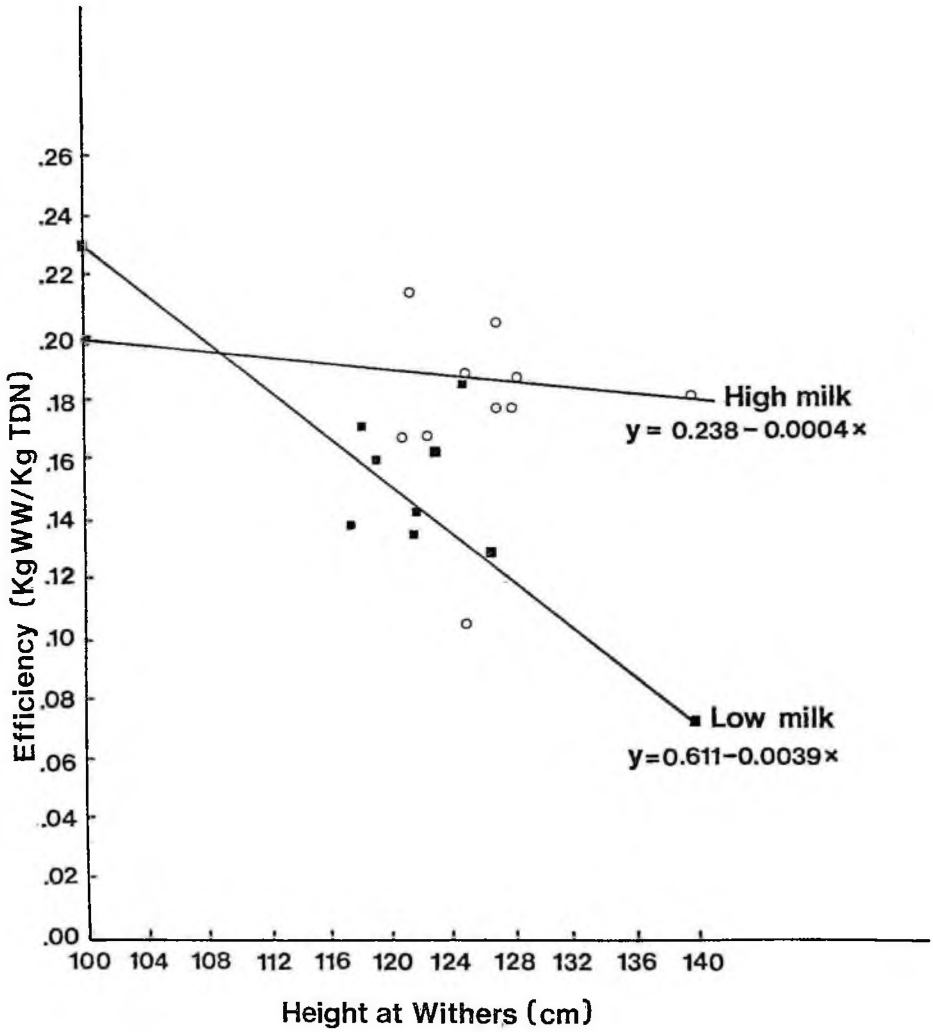


Fig. 19. Regression of efficiency on height at withers for low, medium, and high milk producers (group 2)

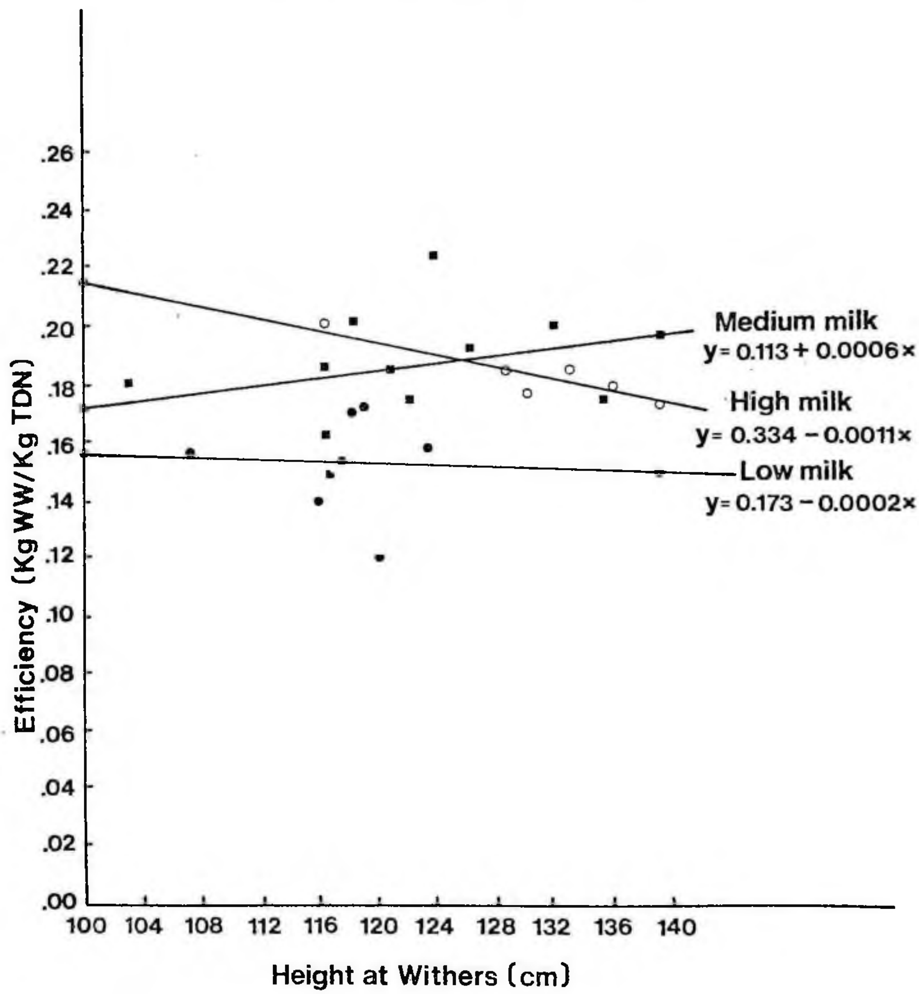


Fig. 20. Regression of efficiency on height at withers for low and medium milk producers (group 3)

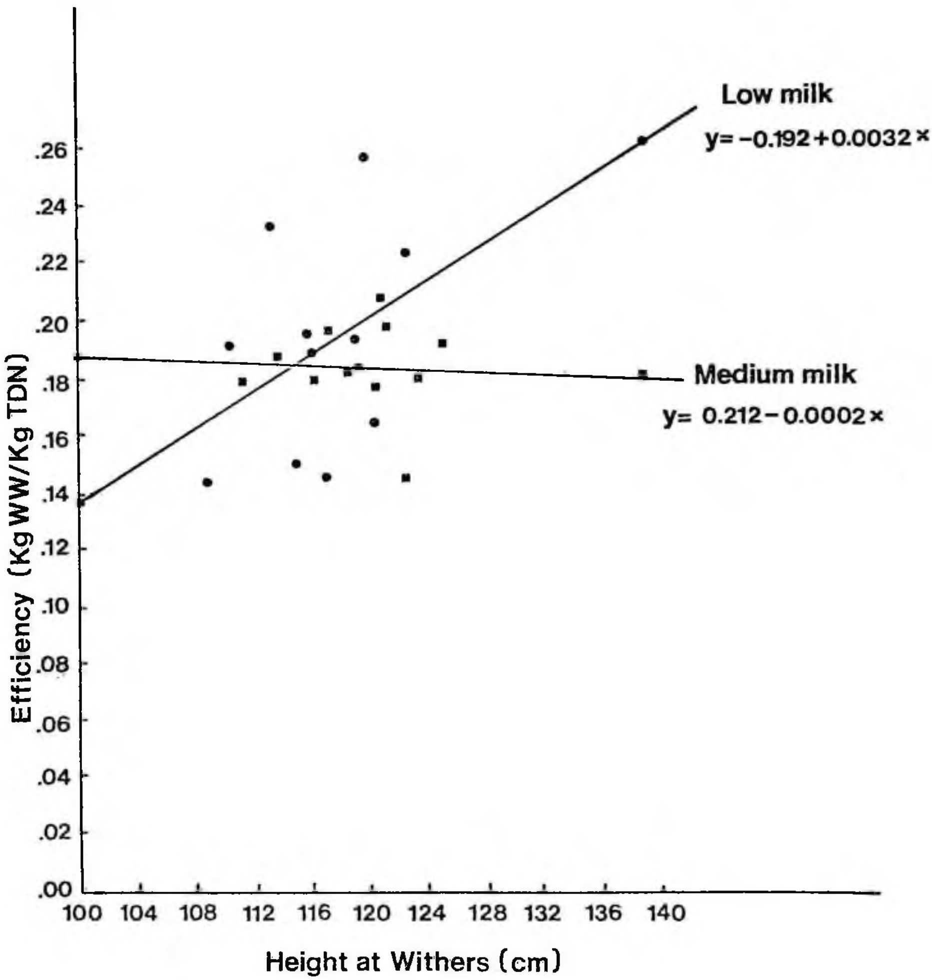


Fig.21 Regression of efficiency on height at withers for low and medium milk producers (group 4)

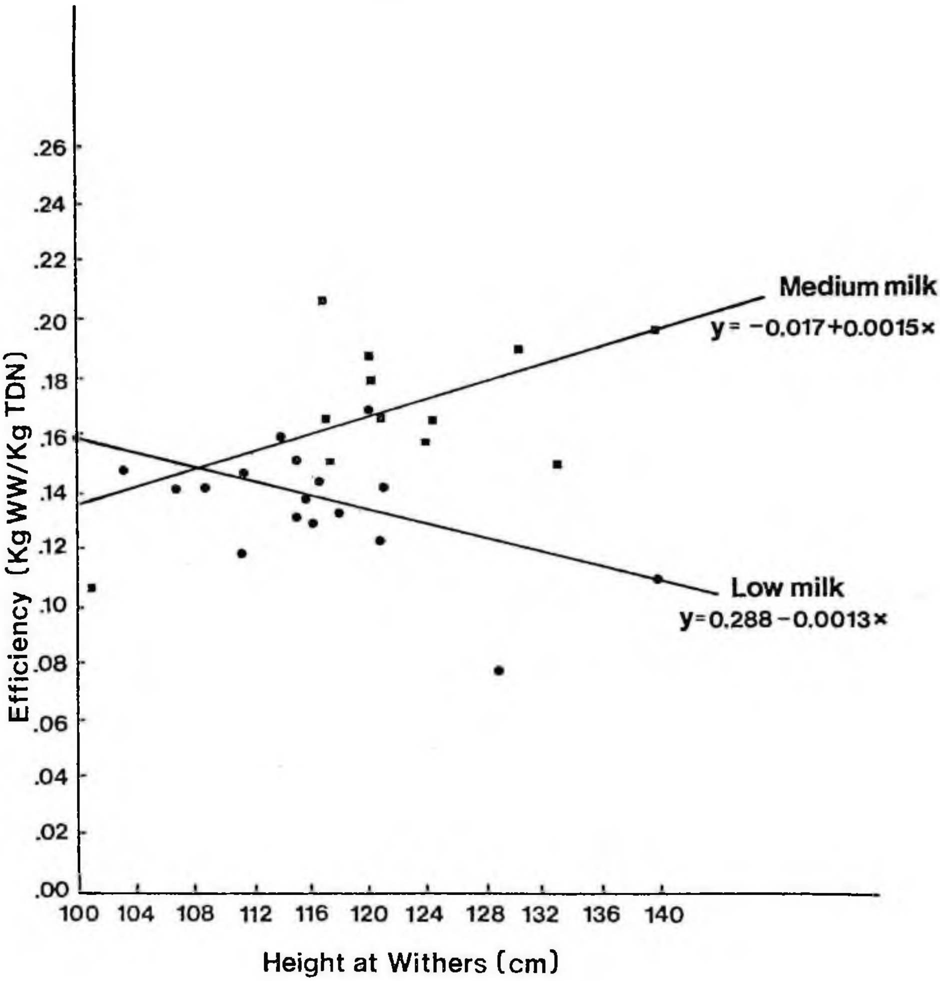


Fig. 22. Regression of efficiency on height at withers for low, medium, and high milk producers (group 5)

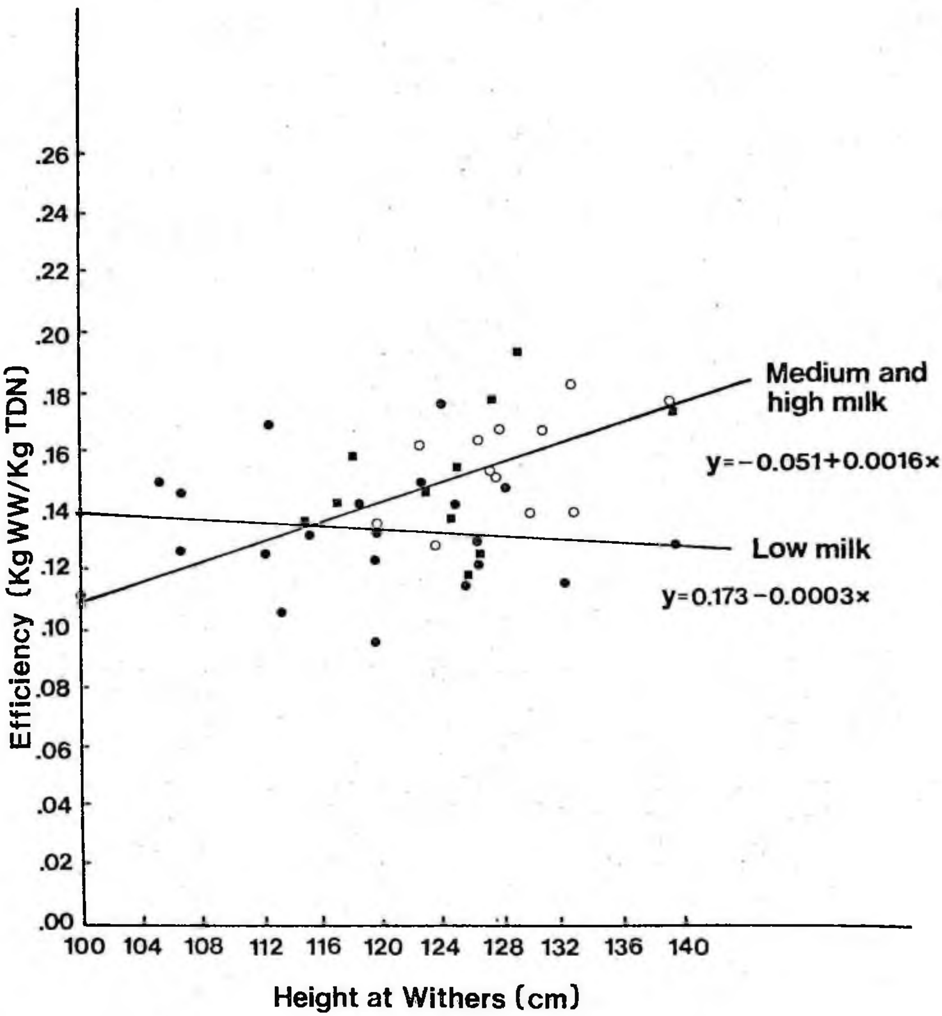


TABLE 20

Correlation coefficients for weaning weight and height at withers

Group	Milk yield		
	Low	Medium	High
1	-0.67	-	0.24
2	-0.11	0.65	0.51
3	0.70	0.03	-
4	0.04	0.68	-0.76
5	0.41	0.44	0.83

TABLE 21

Correlation coefficients for efficiency and height at withers

Group	Milk yield		
	Low	Medium	High
1	-0.60	-	-0.09
2	-0.05	0.25	-0.89
3	0.35	-0.06	-
4	-0.36	0.47	-0.49
5	-0.14	0.33	0.41

cows with smaller heights at withers were more efficient in weaning weight produced per Kg TDN. Even though regression coefficients for efficiency on wither height of cow were small and not significantly different from zero, the inconsistency of the correlation coefficients showed that there was no clear cut association between efficiency and wither height of cow. Reports in the literature are lacking in this kind of information.

9. 180-day weaning weight, efficiency and milk yield

Regressions of 180-day weaning weight on total milk yield for the different height classes are presented in Table 22. The regressions were generally low and positive, indicating that weaning weights increased with the amount of milk produced by the dam. Regressions of weaning weight on daily milk yield reported by Jeffery and Berg (1971) ranged from 11.3 to 14.6 Kg weight/Kg milk. With calves weaned between 167 to 180 days, an average of 173 days, these regressions would range from 0.06 to 0.08 Kg weight/Kg total milk. The regressions obtained in the present study (-0.05 to +0.08 Kg weaning weight/Kg total milk) were therefore comparable with the results obtained by Jeffery and Berg (1971). Partial regressions of weights at 120 and 240 days reported by Neville (1962) were of the order of 7 Kg weight/100 Kg milk produced. These are in agreement with the positive regressions obtained in the present study which ranged from 2 to 8 Kg weaning weight/ 100 Kg milk produced. Other workers reported correlations only.

When efficiency estimates were regressed on total milk yield for the different height classes (Table 23), the regression coefficients were generally small, ranging from -0.00005 to +0.00006 Kg weaned calf/ Kg TDN/Kg milk. They were, however, generally positive but not signi-

TABLE 22

Regression coefficients (b) and standard errors (Sb) for 180-day weaning weight on total milk yield (Kg weaned calf/Kg milk)

Group	Low height			Medium height			High height		
	b	Sb	n	b	Sb	n	b	Sb	n
1	+0.02	0.04	4	+0.06*	0.01	5	+0.08**	0.01	6
2	-	-	2	+0.04*	0.01	12	0.00	0.02	6
3	+0.03	0.02	10	-0.05	0.03	11	-	-	1
4	-0.03	0.02	6	+0.05**	0.02	18	+0.06**	0.01	8
5	-0.01	0.04	6	+0.03	0.02	10	+0.05**	0.01	22

* $P < .05$
** $P < .01$

TABLE 23

Regression coefficients (b) and standard errors (Sb) for efficiency on total milk yield (Kg weaned calf/Kg TDN/Kg milk) x 1000

Group	Low height			Medium height			High height		
	b	Sb	n	b	Sb	n	b	Sb	n
1	+0.01	0.03	4	+0.05*	0.01	5	+0.06**	0.01	6
2	-	-	2	+0.04*	0.01	12	-0.01	0.01	6
3	+0.01	0.03	10	-0.05	0.03	11	-	-	1
4	-0.03	0.02	6	+0.04	0.01	18	+0.05*	0.01	8
5	-0.01	0.05	6	+0.02	0.01	10	+0.03	0.01	22

* $P < .05$
** $P < .01$

ficantly different from zero. The positive regressions would indicate that efficiency increases with the amount of milk produced. This is in agreement with Carpenter et al. (1973) who found production efficiency to be positively associated with milk yield.

10. Correlations between weaning weight, efficiency and total milk yield

Correlation coefficients for weaning weight and total milk yield for the different height classes are presented in Table 24. Correlations ranged from -0.51 to 0.97. Although regression coefficients were small, the correlations were generally high and positive indicating a strong association between weaning weight and milk yield. This is in agreement with correlations reported by many research workers. Neville (1962) reported a correlation of 0.59 between milk production of dam and weight of calf to 180 days. Correlations obtained by Klett et al. (1965) ranged from 0.67 to 0.81. Furr and Nelson (1964), Gleddie and Berg (1968) and Wilson et al. (1968) reported correlations ranging from 0.46 to 0.83 between calf gain and milk yield of dam.

Correlation coefficients for efficiency and total milk yield for the different height classes are presented in Table 25. Correlations ranged from -0.59 to 0.92, and were generally positive and high. Thus even though regression coefficients were small, efficiency was strongly associated with milk yield. Similar correlations using the same criteria are not available in the literature.

11. 180-day weaning weight, efficiency and post-calving weight of cow

With regard to 180-day weaning weight and efficiency, there was no interaction detected between post-calving weight and milk yield.

TABLE 24

Correlation coefficients for weaning weight and total milk yield

Group	Height		
	Low	Medium	High
1	0.32	0.95	0.97
2	-	0.70	0.08
3	0.43	-0.45	-
4	-0.51	0.61	0.89
5	-0.11	0.48	0.65

TABLE 25

Correlation coefficients for efficiency and total milk yield

Group	Height		
	Low	Medium	High
1	0.29	0.92	0.92
2	-	0.70	-0.59
3	0.13	-0.43	-
4	-0.57	0.62	0.83
5	-0.11	0.38	0.37

Therefore, weight classes were ignored and regression coefficients for 180-day weaning weight and efficiency on post-calving weight of cow were calculated for the 5 groups. The results are presented in Tables 26 and 27. Except for group 1, the regressions of 180-day weaning weight on post-calving weight were all positive and significant. The positive regressions ranged from 0.2 to 0.4 Kg weaning weight/Kg cow weight. Thus across groups 2 to 5, weaning weight increased 2 to 4 Kg for every 10 Kg increase in cow weight. Jeffery et al. (1971b) reported a lower regression of 0.7 Kg increase in weaning weight of calf for every 10 Kg increase in post-calving weight of dam. Miquel et al. (1972) reported regressions of calf weaning weight on dam weight to be generally positive, indicating that heavier dams had slightly heavier calves. Correlations between cow size at parturition and calf size at birth and weaning as reported by Hohenboken et al. (1973) were small and positive. Vaccaro and Dillard (1966) found that heavier cows 90 days before calving tended to produce heavier calves at birth and throughout the suckling period.

Positive correlations obtained between weaning weight and post-calving weight of dam ranged from 0.35 to 0.59. Jeffery and Berg (1972) reported correlations of 0.29 and 0.38 between post-calving weight and average daily gain of calf to weaning.

Regressions of efficiency on post-calving weight of cow were generally positive but non-significant. However, the general positive regressions indicate that heavier cows tended to be more efficient. Carpenter et al. (1973) found smaller cows to be more efficient when efficiency was measured as the ratio of calf weaning weight to total feed consumption of cow and calf during lactation.

TABLE 26

Regression of 180-day weaning weight on post-calving weight of cow, standard errors and correlation coefficients

Group	b (Kg ww/Kg cow wt.)	Std. error	r
1	-0.1	0.2	-0.16
2	+0.4**	0.1	+0.59
3	+0.3*	0.1	+0.43
4	+0.2*	0.1	+0.35
5	+0.2*	0.1	+0.39

* Significant P < .05
** Significant P < .01

TABLE 27

Regression of efficiency on post-calving weight of cow, standard errors and correlation coefficients

Group	b (Kg ww/Kg TDN/Kg cow wt.) x 1000	Std. error	r
1	-0.14	0.17	-0.22
2	+0.11	0.11	+0.25
3	+0.11	0.16	+0.14
4	+0.03	0.08	+0.07
5	+0.08	0.06	+0.19

The generally positive correlations between efficiency and post-calving weight were low ranging from 0.07 to 0.25. It seems that when weaning weight alone was considered, heavier cows weaned heavier calves, but when the TDN cost of producing the weaned calf was taken into account, small and heavy cows were about equal in efficiency.

V. GENERAL SUMMARY AND CONCLUSIONS

Data on 5 groups of cow and Angus-sired first-calf pairs were analysed within groups for effects of cow size and milk yield on 180-day weaning weight and efficiency of production. There were 15 cows in group 1, 20 in group 2, 22 in group 3, 32 in group 4 and 38 in group 5. Groups represented year and season of calving subclasses. The first group calved in the fall of 1972, with the subsequent groups calving in the spring and fall of 1973 and 1974. A within group analysis was therefore considered appropriate. Interactions between the effects of milk and size were examined and the data were analysed for relationships between cow size and milk yield.

Efficiency was estimated as the ratio of calf weaning weight to total TDN consumption of cow and calf during lactation. The milk criteria were 180-day milk production measured by calf nursing and machine milking, and 180-day milk fat production. There were 3 criteria for size: average height at withers, post-calving weight of cow and average length of cow.

Average 180-day milk yields for groups 1 to 5 ranged from 1239 Kg to 1801 Kg; 180-day fat production ranged from 43 Kg to 53 Kg; the range in average wither height was 120 cm to 123 cm; average calving weight ranged from 419 to 496 Kg, and average length of cow ranged from 153 to 157 cm. Average daily milk production generally increased from 6 to 22 weeks with the highest daily yields measured at 22 weeks. Backfat was negatively related to weight at calving, indicating that heavier cows at calving tended to have less backfat.

Milk yield generally was positively associated with the various measures of cow size. With regard to 180-day weaning weight, analysis *by least squares showed that there was an indication of interaction between total milk yield and height at withers. Interaction was significant in 2 of 4 groups. When efficiency was considered interaction was significant in 1 of 4 groups. There was no interaction effect between total milk yield and weight at calving on 180-day weaning weight and efficiency in any of the 5 groups, but when length of cow was the criterion of size, interaction was significant in 1 of 5 groups. There was no interaction between fat yield and the 3 size criteria in any of the groups, but fat yield had a significant effect on both 180-day weaning weight and efficiency in 3 of the 5 groups.*

Milk yield, height at withers and length of cow all had significant effects on 180-day weaning weight and efficiency in at least one group. Post-calving weight of cow significantly affected 180-day weaning weight, but not efficiency; and sex of calf generally did not significantly affect 180-day weaning weight or efficiency.

As a result of significant interactions between milk yield and height at withers, regression coefficients of 180-day weaning weight and efficiency on height at withers for the different milk classes were computed. The numbers associated with the regression coefficients were, in general, small and the actual data showed too much variation to justify calculating pooled regression coefficients. However, the regressions of 180-day weaning weight on height at withers for the different milk classes were generally positive indicating an increase in weaning weight associated with an increase in height at withers; but when efficiency estimates were regressed on height at withers, the regression coefficients were generally negative.

Regressions of 180-day weaning weight and efficiency on total milk yield for the different height classes showed that both weaning weight and efficiency increased with the amount of milk produced by the dam, as was evident from general positive regressions. Although the regression coefficients were small and often non-significant, correlations between traits of the cow and calf showed that weaning weight was positively related to milk yield and height at withers. Efficiency was also positively related to milk yield but negatively related to height at withers.

When post-calving weight was the criterion of size, regressions of 180-day weaning weight on weight of cow were positive and significant in 4 of 5 groups, but when efficiency was regressed on post-calving weight none of the regressions was significant even though they were generally positive.

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APPENDIX TABLES

TABLE 1

Cow Ration Ingredients

Ingredient	Name	International Reference Number[1]	Percent dry matter	Percent TDN (DM basis)
Alfalfa-brome hay	Alfalfa hay, s-c, midbloom (1)	1-00-063	89.2	58
	Brome hay, s-c, (1)	1-00-890	89.7	44
Dry shelled corn	Corn, dent yellow (4)	4-02-931	89.0	91
Corn silage	Corn, aerial part, ensiled, mature, well eared, mx 30% dry matter	3-08-154	27.9	70
Protein supplement	Soybean, seeds, mech. extd, mx 7% fiber (5)	5-04-600	90	85
Haylage	Alfalfa-brome, smooth, aerial part, ensiled, mx 30% dry matter (3)	3-08-147	46.5	53
High moisture corn	-			64[2]
Coarse cracked corn	-			80[2]

1 NRC. 1970. Nutrient Requirements of Domestic Animals, No. 4, Nutrient Requirements of Beef Cattle. National Research Council, Washington, D.C.

2 Values of TDN percent 'as fed' (obtained from Dr. J.H. Burton, Dept. of Nutrition, University of Guelph, by personal communication).

TABLE 2

Cow Rations and Calculated TDN Percent

Ration	Ingredients	TDN Percent (As Fed)
1	100% alfalfa brome hay	45.62
2	100% dry shelled corn	80.99
3	98% corn silage 2% protein supplement	20.66
4	97.10% corn silage 2.64% protein supplement 0.26% dicalcium phosphate	20.97
5	100% haylage	24.64
6	90% haylage 10% high moisture corn	28.58
7	90% haylage 10% coarse cracked corn	30.18
8	50% haylage 50% corn silage	22.09
9	65% haylage 35% corn silage	22.86
10	49.87% haylage 49.87% corn silage 0.26% dicalcium phosphate	22.03
11	49.83% haylage 49.83% corn silage 0.35% mineral salt mix	22.01
12	48.99% haylage 48.99% corn silage 1.67% soybean meal 0.35% mineral salt mix	22.92
13	69.65% corn silage 30% haylage 0.35% mineral salt mix	20.99
14	49.79% corn silage 49.79% haylage 0.43% mineral salt-vitamin mix	21.99

TABLE 3

Calculation of TDN Content of Rations

Ration - 98% corn silage
2% protein supplement

Corn silage is tabulated as 27.9% dry matter and 70% TDN on a dry matter basis.

Protein supplement (soybean meal) is tabulated as 90% dry matter and 85% TDN on dry matter basis (Appendix Table 1).

Corn silage = .70 x 27.9 = 19.53% TDN as fed
Supplement = .90 x 85 = 76.5% TDN as fed

100 lb corn silage = 19.53% TDN as fed

Therefore 98 lb corn silage = $\frac{98}{100}$ x 19.53 = 19.13 lb TDN as fed

100 lb supplement = 76.5% TDN as fed

Therefore 2 lb supplement = $\frac{2}{100}$ x 76.5 = 1.53 lb TDN as fed

TDN % (as fed) of 98% corn silage + 2% protein supplement
= 19.13 + 1.53
= 20.66%

TABLE 4

Ingredients in Creep Feed

Ingredient	Percent TDN as Fed*
Cavalier Calf Starter	70.6
Aureomycin Crumbles	50.0
Rolled Oats	68.6

* TDN values were obtained by personal communication from Dr. J.H. Burton, Dept. of Nutrition, University of Guelph.

TABLE 5

Creep Rations

Ration	Ingredients	TDN Percent As Fed
1	100% Cavalier Calf Starter	70.6
2	100% Rolled Oats	68.6
3	90% Calf Starter 10% Aureomycin Crumbles	68.5
4	50% Calf Starter 50% Aureomycin Crumbles	60.3
5	75% Calf Starter 25% Aureomycin Crumbles	65.5
6	75% Oats 25% Aureomycin Crumbles	64.0

Effect of total milk yield and average height at withers on weaning weight

Analysis of Variance Tables

GROUP 1 - TABLE 6

Source	df	MS	F-value
Total	14		
Sex of calf	1	484.02	2.28
Milk yield	2	1656.42	7.81*
Height	2	178.51	0.84
Milk x height	2	1110.00	5.23*
Residual	7	212.18	

GROUP 2 - TABLE 7

Source	df	MS	F-value
Total	19		
Sex of calf	1	1422.36	3.47
Milk yield	2	626.41	1.53
Height	2	704.36	1.72
Milk x height	2	140.19	0.34
Residual	12	410.19	

GROUP 3

Source	df
Total	21
Sex of calf	1
Milk yield	2
Height	2
Milk x height	0
Residual	16

GROUP 4 - TABLE 8

Source	df	MS	F-value
Total	31		
Sex of calf	1	1037.81	2.86
Milk yield	2	1619.09	4.47*
Height	2	4349.86	12.01**
Milk x height	2	3258.08	8.99**
Residual	24	362.34	

GROUP 5 - TABLE 9

Source	df	MS	F-value
Total	37		
Sex of calf	1	1021.32	3.05
Milk yield	2	1281.10	3.83*
Height	2	1001.65	3.00
Milk x height	2	80.49	0.24
Residual	30	334.42	

* $P < .05$
** $P < .01$

Effect of total milk yield and average height at withers on efficiency

Analysis of Variance Tables

GROUP 1 - TABLE 10

Source	df	MS (x 100)	F-value
Total	14		
Sex of calf	1	.0390	1.45
Milk yield	2	.1216	4.51
Height	2	.0312	1.15
Milk x height	2	.0758	2.81
Residual	7	.0270	

GROUP 2 - TABLE 11

Source	df	MS (x 100)	F-value
Total	19		
Sex of calf	1	.1611	4.24
Milk yield	2	.0741	1.95
Height	2	.0013	0.03
Milk x height	2	.0074	0.19
Residual	12	.0380	

GROUP 3

Source	df
Total	21
Sex of calf	1
Milk yield	2
Height	2
Milk x height	0
Residual	16

GROUP 4 - TABLE 12

Source	df	MS (x 100)	F-value
Total	31		
Sex of calf	1	.0313	1.14
Milk yield	2	.1449	5.27*
Height	2	.2117	7.70**
Milk x height	2	.2821	10.26**
Residual	24	.0275	

GROUP 5 - TABLE 13

Source	df	MS (x 100)	F-value
Total	37		
Sex of calf	1	.0987	2.17
Milk yield	2	.0385	0.85
Height	2	.0260	0.57
Milk x height	2	.0007	0.016
Residual	30	.0455	

* $p < .05$

** $p < .01$

Effect of total milk yield and post-calving weight of cow on weaning weight

Analysis of Variance Tables

GROUP 1 - TABLE 14

Source	df	MS	F-value
Total	14		
Sex of calf	1	159.71	0.48
Milk yield	2	2607.82	7.80*
Weight of cow	2	526.87	1.58
Milk x weight	2	309.20	0.92
Residual	7	334.32	

GROUP 2 - TABLE 15

Source	df	MS	F-value
Total	19		
Sex of calf	1	1748.14	3.51
Milk yield	2	1337.63	2.69
Weight of cow	2	311.39	0.63
Milk x weight	2	150.99	0.30
Residual	12	497.44	

GROUP 3 - TABLE 16

Source	df	MS	F-value
Total	21		
Sex of calf	1	1789.31	2.41
Milk yield	2	1431.40	1.92
Weight of cow	2	11.31	0.02
Milk x weight	1	516.51	0.69
Residual	15	743.95	

GROUP 4 - TABLE 17

Source	df	MS	F-value
Total	31		
Sex of calf	1	126.58	0.19
Milk yield	2	8677.92	13.25**
Weight of cow	2	1395.16	2.13
Milk x weight	4	983.86	1.50
Residual	22	654.75	

GROUP 5 - TABLE 18

Source	df	MS	F-value
Total	37		
Sex of calf	1	803.29	2.35
Milk yield	2	3873.65	11.34**
Weight of cow	2	466.12	1.36
Milk x weight	3	141.62	0.41
Residual	29	341.56	

* $p < .05$
** $p < .01$

Effect of total milk yield and post-calving weight of cow on efficiency

Analysis of Variance Tables

GROUP 1 - TABLE 19

Source	df	MS (x 100)	F-value
Total	14		
Sex of calf	1	.0067	0.21
Milk yield	2	.1951	6.17*
Weight of cow	2	.0492	1.56
Milk x weight	2	.0345	1.09
Residual	7	.0316	

GROUP 2 - TABLE 20

Source	df	MS (x 100)	F-value
Total	19		
Sex of calf	1	.1351	3.71
Milk yield	2	.1042	2.86
Weight of cow	2	.0006	0.16
Milk x weight	2	.0088	0.24
Residual	12	.0364	

GROUP 3 - TABLE 21

Source	df	MS (x 100)	F-value
Total	21		
Sex of calf	1	.3953	4.34
Milk yield	1	.0696	0.76
Weight of cow	2	.0089	0.097
Milk x weight	1	.0069	0.076
Residual	15	.0911	

GROUP 4 - TABLE 22

Source	df	MS (x 100)	F-value
Total	31		
Sex of calf	1	.0003	0.006
Milk yield	2	.2715	4.81*
Weight of cow	2	.0325	0.58
Milk x weight	4	.0431	0.76
Residual	22	.0564	

GROUP 5 - TABLE 23

Source	df	MS (x 100)	F-value
Total	37		
Sex of calf	1	.0626	1.31
Milk yield	2	.0767	1.63
Weight of cow	2	.0044	0.09
Milk x weight	3	.0162	0.35
Residual	29	.0471	

* $P < .05$

Effect of total milk yield and average length of cow on weaning weight

Analysis of Variance Tables

GROUP 1 - TABLE 24

Source	df	MS	F-value
Total	14		
Sex of calf	1	119.70	0.39
Milk yield	2	1112.50	3.61
Length of cow	2	199.64	6.47*
Milk x length	2	678.01	2.20
Residual	7	308.34	

GROUP 2 - TABLE 25

Source	df	MS	F-value
Total	19		
Sex of calf	1	981.00	2.42
Milk yield	2	648.72	1.60
Length of cow	2	1268.81	3.13
Milk x length	2	307.87	0.76
Residual	12	405.06	

GROUP 3 - TABLE 26

Source	df	MS	F-value
Total	21		
Sex of calf	1	311.04	0.016
Milk yield	2	1964.85	0.20
Length of cow	2	326.23	0.033
Milk x length	2	1300.88	0.13
Residual	14	529.71	

GROUP 4 - TABLE 27

Source	df	MS	F-value
Total	31		
Sex of calf	1	1754.19	4.34*
Milk yield	2	842.83	2.09
Length of cow	2	4422.53	10.94**
Milk x length	2	1950.61	4.83*
Residual	24	404.20	

GROUP 5 - TABLE 28

Source	df	MS	F-value
Total	37		
Sex of calf	1	684.54	2.06
Milk yield	2	3690.86	11.12**
Length of cow	2	1629.46	4.91*
Milk x length	2	31.06	0.094
Residual	30	331.82	

* $P < .05$
** $P < .01$

Effect of total milk yield and average length of cow on efficiency

Analysis of Variance Tables

GROUP 1 - TABLE 29

Source	df	MS (x 100)	F-value
Total	14		
Sex of calf	1	.0133	0.35
Milk yield	2	.0769	2.03
Length of cow	2	.0222	0.59
Milk x length	2	.0326	0.86
Residual	7	.0378	

GROUP 2 - TABLE 30

Source	df	MS (x 100)	F-value
Total	19		
Sex of calf	1	.1542	3.87
Milk yield	2	.0956	2.40
Length of cow	2	.0001	0.002
Milk x length	2	.0050	0.13
Residual	12	.0398	

GROUP 3 - TABLE 31

Source	df	MS (x 100)	F-value
Total	21		
Sex of calf	1	.2842	3.02
Milk yield	2	.0714	0.76
Length of cow	2	.0029	0.03
Milk x length	2	.0349	0.37
Residual	14	.0940	

GROUP 4 - TABLE 32

Source	df	MS (x 100)	F-value
Total	31		
Sex of calf	1	.0698	1.84
Milk yield	2	.0514	1.36
Length of cow	2	.2360	6.23**
Milk x length	2	.1380	3.64*
Residual	24	.0379	

GROUP 5 - TABLE 33

Source	df	MS (x 100)	F-value
Total	37		
Sex of calf	1	.1065	2.56
Milk yield	2	.0426	1.02
Length of cow	2	.0366	0.88
Milk x length	2	.0530	1.28
Residual	30	.0416	

* $P < .05$

** $P < .01$

Effect of total fat yield and average height at withers on weaning weight

Analysis of Variance Tables

GROUP 1 - TABLE 34

Source	df	MS	F-value
Total	14		
Sex of calf	1	1151.70	3.61
Fat yield	2	1070.16	3.35
Height	2	415.26	1.30
Fat x height	2	878.74	2.75
Residual	7	319.05	

GROUP 2 - TABLE 35

Source	df	MS	F-value
Total	19		
Sex of calf	1	1319.37	3.33
Fat yield	2	868.89	2.19
Height	2	2559.71	6.46*
Fat x height	3	164.60	0.41
Residual	11	396.35	

GROUP 3 - TABLE 36

Source	df	MS	F-value
Total	21		
Sex of calf	1	1583.34	2.75
Fat yield	2	503.47	0.87
Height	2	3459.81	6.01*
Fat x height	2	623.11	1.08
Residual	14	575.68	

GROUP 4 - TABLE 37

Source	df	MS	F-value
Total	31		
Sex of calf	1	999.82	1.75
Fat yield	2	467.54	0.82
Height	2	598.76	1.05
Fat x height	3	1704.10	2.99
Residual	23	570.01	

GROUP 5 - TABLE 38

Source	df	MS	F-value
Total	37		
Sex of calf	1	238.64	0.60
Fat yield	2	1193.01	3.02
Height	2	1388.78	3.51*
Fat x height	3	288.37	0.73
Residual	29	395.24	

* $P < .05$

Effect of total fat yield and average height at withers on efficiency

Analysis of Variance Tables

GROUP 1 - TABLE 39

Source	df	MS (x 100)	F-value
Total	14		
Sex of calf	1	.0631	2.39
Fat yield	2	.1237	4.68
Height at withers	2	.0571	2.16
Fat x height	2	.1197	4.53
Residual	7	.0264	

GROUP 2 - TABLE 40

Source	df	MS (x 100)	F-value
Total	19		
Sex of calf	1	.1735	4.24
Fat yield	2	.0864	2.11
Height	2	.0162	0.40
Fat x height	3	.0474	1.16
Residual	11	.0410	

GROUP 3 - TABLE 41

Source	df	MS (x 100)	F-value
Total	21		
Sex of calf	1	.2850	3.94
Fat yield	2	.1051	1.45
Height	2	.2715	3.75*
Fat x height	2	.0802	1.11
Residual	14	.0723	

GROUP 4 - TABLE 42

Source	df	MS (x 100)	F-value
Total	31		
Sex of calf	1	.0583	1.51
Fat yield	2	.0590	1.53
Height	2	.1183	3.07
Fat x height	3	.1294	3.35
Residual	23	.0386	

GROUP 5 - TABLE 43

Source	df	MS (x 100)	F-value
Total	37		
Sex of calf	1	.0506	1.26
Fat yield	2	.1164	2.90
Height	2	.0355	0.88
Fat x height	3	.0205	0.51
Residual	29	.0402	

* $P < .05$

Effect of total fat yield and post-calving weight of cow on weaning weight

Analysis of Variance Tables

GROUP 1 - TABLE 44

Source	df	MS	F-value
Total	14		
Sex of calf	1	1321.64	4.14
Fat yield	2	2401.54	7.52*
Weight	2	384.89	1.21
Fat x weight	3	685.16	2.15
Residual	6	319.38	

GROUP 2 - TABLE 45

Source	df	MS	F-value
Total	19		
Sex of calf	1	1509.37	2.72
Fat yield	2	928.57	1.67
Weight	2	1958.18	3.53
Fat x weight	3	325.69	0.59
Residual	11	554.74	

GROUP 3 - TABLE 46

Source	df	MS	F-value
Total	21		
Sex of calf	1	3116.20	3.49
Fat yield	2	1090.14	1.22
Weight	2	812.59	0.91
Fat x weight	2	544.67	0.61
Residual	14	893.78	

GROUP 4 - TABLE 47

Source	df	MS	F-value
Total	31		
Sex of calf	1	306.18	0.43
Fat yield	2	8210.61	11.46**
Weight	2	1998.99	2.79
Fat x weight	4	1002.24	1.40
Residual	22	716.53	

GROUP 5 - TABLE 48

Source	df	MS	F-value
Total	37		
Sex of calf	1	240.84	0.70
Fat yield	2	3565.99	10.31**
Weight	2	2703.63	7.82**
Fat x weight	4	247.94	0.72
Residual	28	345.85	

* $p < .05$
** $p < .01$

Effect of total fat yield and post-calving weight of cow on efficiency

Analysis of Variance Tables

GROUP 1 - TABLE 49

Source	df	MS (x 100)	F-value
Total	14		
Sex of calf	1	.0749	2.67
Fat yield	2	.1681	5.99*
Weight	2	.0524	1.87
Fat x weight	3	.0711	2.54
Residual	6	.0281	

GROUP 2 - TABLE 50

Source	df	MS (x 100)	F-value
Total	19		
Sex of calf	1	.1436	3.65
Fat yield	2	.1148	2.92
Weight	2	.0194	0.49
Fat x weight	3	.0586	1.49
Residual	11	.0393	

GROUP 3 - TABLE 51

Source	df	MS (x 100)	F-value
Total	21		
Sex of calf	1	.3301	3.17
Fat yield	2	.0430	0.43
Weight	2	.0524	0.50
Fat x weight	2	.0444	0.43
Residual	14	.2104	

GROUP 4 - TABLE 52

Source	df	MS (x 100)	F-value
Total	31		
Sex of calf	1	.0001	.0014
Fat yield	2	.2264	3.51*
Weight	2	.0359	0.56
Fat x weight	4	.0206	0.32
Residual	22	.0646	

GROUP 5 - TABLE 53

Source	df	MS (x 100)	F-value
Total	37		
Sex of calf	1	.0390	0.94
Fat yield	2	.1472	3.56*
Weight	2	.0429	1.04
Fat x weight	4	.0125	0.30
Residual	28	.0414	

* $P < .05$

Effect of total fat yield and average length of cow on weaning weight

Analysis of Variance Tables

GROUP 1 - TABLE 54

Source	df	MS	F-value
Total	14		
Sex of calf	1	1670.76	4.17
Fat yield	2	563.21	1.41
Length	2	268.79	0.67
Fat x length	3	227.62	0.57
Residual	6	400.29	

GROUP 2 - TABLE 55

Source	df	MS	F-value
Total	19		
Sex of calf	1	1162.89	2.29
Fat yield	2	1038.95	2.04
Length	2	1390.79	2.74
Fat x length	2	102.03	0.20
Residual	12	508.44	

GROUP 3 - TABLE 56

Source	df	MS	F-value
Total	21		
Sex of calf	1	495.37	0.66
Fat yield	2	703.10	0.93
Length	2	1261.89	1.67
Fat x length	3	181.29	0.24
Residual	13	752.94	

GROUP 4 - TABLE 57

Source	df	MS	F-value
Total	31		
Sex of calf	1	1742.43	3.13
Fat yield	2	703.32	1.26
Length	2	1039.76	1.87
Fat x length	3	806.48	1.45
Residual	23	556.38	

GROUP 5 - TABLE 58

Source	df	MS	F-value
Total	37		
Sex of calf	1	0.335	.0007
Fat yield	2	533.83	1.08
Length	2	988.49	2.00
Fat x length	3	428.52	0.87
Residual	29	493.88	

Effect of total fat yield and average length of cow on efficiency

Analysis of Variance Tables

GROUP 1 - TABLE 59

Source	df	MS (x 100)	F-value
Total	14		
Sex of calf	1	.1315	3.53
Fat yield	2	.0652	1.75
Length	2	.0402	1.08
Fat x length	3	.0380	1.02
Residual	6	.0373	

GROUP 2 - TABLE 60

Source	df	MS (x 100)	F-value
Total	19		
Sex of calf	1	.1814	3.72
Fat yield	2	.0830	1.70
Length	2	.0001	0.002
Fat x length	2	.0227	0.47
Residual	12	.0487	

GROUP 3 - TABLE 61

Source	df	MS (x 100)	F-value
Total	21		
Sex of calf	1	.2133	1.91
Fat yield	2	.0204	0.18
Length	2	.0135	0.12
Fat x length	3	.0006	0.006
Residual	13	.1117	

GROUP 4 - TABLE 62

Source	df	MS (x 100)	F-value
Total	31		
Sex of calf	1	.1111	2.17
Fat yield	2	.0402	0.79
Length	2	.0564	1.10
Fat x length	3	.0511	1.00
Residual	23	.0511	

GROUP 5 - TABLE 63

Source	df	MS (x 100)	F-value
Total	37		
Sex of calf	1	.0151	0.40
Fat yield	2	.0841	2.22
Length	2	.0288	0.76
Fat x length	3	.0530	1.40
Residual	29	.0379	