A STUDY OF SOME PRODUCTION TRAITS IN AN INBRED HERD OF SHORTHORN CATTLE

by

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INTRODUCTION

The making of our present beef cattle began several centuries ago, in fact, since domestication. The early livestock man exercised his influence by retaining in his herd animals that were more tractable and, aided by the selective forces of the environment, he was able to mold them to better satisfy his needs. At some point in the development process, man became aware of the fact that offspring tended to resemble their parents. But his beliefs and assumptions, some of them partly true, most of them falacious, such as the influence of maternal impressions, the injurious effects of mating close relatives, telegony, which accentuated his lack of understanding of the inheritance phenomena he had observed, were sources of confusion which undoubtedly impeded his progress.

The pattern of modern animal improvement plans began in England in the early eighteenth century. Stockmen began to breed for improvement within their own herds, presumably when they failed to obtain outside stock which were superior or otherwise free of faults. A notable pioneer in that endeavor was Robert Bakewell (1726-1795), who found that he could most effectively fix desired types and produce refinements by practicing inbreeding accompanied by careful selection. His breeding work was with the old Longhorn cattle, Leicester sheep and Shire horses. Because of the outstanding results he obtained in terms of uniformity of type and superiority of performance, his method was widely copied by the Collin Brothers, Thomas Booth, Thomas Bates, and others in several regions of England, with appreciable success, which marked the origin of the modern British breeds of cattle and an epoch in livestock improvement.

Selection of parents has been primarily by visual appraisal based on intuition and personal experience. Highly unpredictable and inefficient, success depended on the individual's accuracy of judgement and "stock sense". While the procedure may have had considerable value in the formative years of the breeds of cattle when color markings and comformation were important criteria considered, it became inadequate as a basis for the improvement of economic traits.

With the rediscovery of Mendel's experimental results and its wide applicability to several characters in plants and animals, animal breeding took on a distinctly scientific outlook, in contrast to the somewhat artistic scheme of the previous era. Because of the mode of inheritance of economic traits, and the role of the environment in their phenotypic expression, early Mendelian heredity was not immediately applicable to animal breeding plans. This had to await the introduction of the concept of quantitative inheritance, and the development and use of proper methods of measurement of traits and standards of comparison, for objective selection procedures such as progeny testing and index selection, which were both predictable and repeatable.

Major factors known to be important in the development of desirable beef animal are preweaning and postweaning rate of growth, efficiency of feed utilization, carcass composition and quality and reproductive rate. Several breeding methods and selection plans have been suggested towards the development of such an animal. The concept that heterosis may be important in beef cattle performance has been investigated in recent years. Earlier applied in the improvement of the domestic fowl, corn, and to a limited extent, swine, it involves continuous inbreeding to establish inbred lines, followed by crossing of the inbred lines. Although, more information is needed for more conclusive evaluation, there has been suggestions that the plan may not be appreciably valuable in beef cattle improvement, in view of the relatively high heritabilities of most economic traits in that class of farm livestock.

In addition to the complications of gene actions and interactions in phenotypic expression of traits, an underlying factor is that each trait is an attribute of the animal which is itself an indivisible economic unit as a potential parent. Thus each animal has to be selected or discarded on the basis of aggregate merit, the effectiveness of which depends on the accuracy of selection criteria. Until man is able to by-pass normal sexual process, and effect direct duplication of the individual through nuclear transplantation, and incubation, or some such procedure, the need for increased accuracy of selection methods will continue to be a focal point in animal husbandry research.

REVIEW OF LITERATURE

Inbreeding, Outcrossing and Heterosis

Inbreeding has been a significant force both in the improvement of livestock as well as in the development of lines and breeds within the different species of farm livestock. Following the development of methods of estimating inbreeding and relationship coefficients (Sewall Wright, 1922), investigations to determine the role of inbreeding in the development and maintenance of breeds were made. McPhee and Wright, (1925), observed that intensive inbreeding had occured early in the formation of the Shorthorn breed, and estimated that by 1920 the coefficient of inbreeding was about 26%. Willham (1937) found the inbreeding in Herefords to average 8.1% as of 1930, and Stonaker (1943) reported an average of 11.0% by 1939 for Aberdeen Angus. It was concluded (Warwick, 1958) that a large part of the inbreeding in the three breeds occured during the formative years, with successive increases averaging less than 1.0% per generation interval.

The effect of inbreeding on size, type and other performance traits have been extensively investigated both in farm and laboratory animals. Wright (1922) observed loss of vigor and marked reduction in size of inbred guinea pigs during the first few generations of inbreeding. Margolin and Bartlett (1945) in comparisons of growth characters of outbred animals, and inbreds which were rigidly selected at New Jersey Agricultural Experiment Station, concluded that Holstein-Fresian dairy cattle could be inbred without a risk of size or weight depression. They observed that females with 20.0% or more coefficient of inbreeding showed abnormal development after first calving.

Sutherland and Lush (1962) used data obtained from 25 years of mild inbreeding (2½% per generation interval) to estimate the effect of inbreeding on size and type in the Holstein-Fresian cattle. They found that birth weight decreased by 0.2 lb. for each one per cent increase in inbreeding, and 1 year-old calves which were 12½% inbred were 22 lbs lighter than their non-inbred counterparts. A negative correlation was found between weight and coefficient of inbreeding at all ages. They also observed that inbred animals generally grew more slowly than outbreds up to three years of age, tending to grow more rapidly thereafter.

Dickerson (1940) reported that calves with 16.0% inbreeding coefficient weighed 10 lbs lighter at birth, than controls. Rollins, et al (1949) in studies of effect of inbreeding on growth found that inbred Jersey cattle grew more slowly than outbreds up to six months of age but comparatively less slowly thereafter. Woodward and Graves (1946) reported that inbreeding effects became pronounced at inbreeding levels of 25.0%; calves with 50.0% or more inbreeding averaged 65.9 lbs at birth compared with 81.5 lbs for outcrossed calves.

Bartlet, et al (1942) estimated the influence of inbreeding on birth weight, growth rate and type. They found that there were no significant differences in birth weight, rate of growth and type between inbred and outbred dairy heifers at 5, 12, and 16 months, although inbred heifers weighed 21 lbs less than outbred at 10 months of age. In studies by Burgess, et al (1954) in which they measured effect of inbreeding as deviations from the weaning weight they found that there was a decrease of 1.75 lbs for each 1.0% inbreeding of calf and a decrease of 1.15 for each 1.0% inbreeding of dam.

Craft (1953) summarized the results of the regional swine breeding laboratory in which 100 inbred lines were established. He observed that inbreeding resulted in a general decline in litter size and growth rate.

Several studies with sheep indicated that inbreeding had depressing effect on production. Brown, et al (1961) reported that all inbred lambs on test showed a decline in weight to 120 days; the effect of the inbreeding of dam was found to be less than that of the lamb. Doney (1957) found that inbreeding Peppin Merinos without selection led to reduction in body size. On treating inbred lambs with crude pituitary extracts, he observed increase in growth rate to ten weeks of age compared to untreated inbreds. He suggested that the effect of inbreeding was due, in part, to a reduction in pituitary activity rather than to the effect of some deleterious genes per se. In another report Doney (1961) also stated that production levels of crosses between inbred lines was similar to that of random-bred controls.

Carter (1962) estimated that inbreeding coefficient in the Hampshire sheep in the United States increased at an average of 0.4-0.5% per generation interval of 7.6 years. He suggested that the level of inbreeding and average increase would not cause a loss of vigor if the breed was considered as a single population, but that individual flocks would probably suffer loss of performance since they were likely to be more highly inbred than average of the breed.

Amstein (1957) in analysis of NC-1 data collected at Kansas State University Experiment Station (1950-55 data), found that inbreeding was significantly negatively correlated with initial weight, was not correlated with rate of gain, and not significantly but consistently negatively correlated with feed efficiency. Analysis by Gottlieb (1962) indicated that weaning weight decreased as the coefficient of inbreeding increased.

In summaries of the results from NC-1 regional projects Gregory (1961) pointed out that level of performance mothering ability, and fertility showed the greatest decline with increased inbreeding. He noted that bulls from production selected inbred lines performed as well as outbred bulls on top-cross tests. He suggested that the decline in fertility and other traits resulting from inbreeding might indicate that heterosis is important in performance but the high heritability estimates (additive genetic variance) obtained for those traits in beef cattle seem to indicate the contrary.

Vogt, et al (1967) used data from 471 straight bred, twobreed, threebreed and backcross steers and heifers to estimate the effect of heterosis on postweaning gain and grade. Data were adjusted for effects of mating types, year of birth and age on weight. Using least squares analysis, least squares means, mid-parent values and deviations of the cross bred least squares means from corresponding mid-parent values were calculated for each trait, and compared between the mating systems. They observed that heterosis in postweaning growth rate amounting to 2.1% to 5.2% could be expected, up to 18 months of age; and that any significant superiority thereafter, could be attributed to a headstart enjoyed by the cross breds. They suggested that observed significant differences in slaughter grades in favor of the crossbreds were due to their heavier slaughter weights and higher condition.

Weaning Weight and Initial Weight

Brown and Gaucula (1964) studied some economic traits of beef cattle using 20 performance tested sires and 201 progenies produced between 1951 and 1962 at Arkansas Agricultural

Experiment Station. Estimates of heritability based on regression of offspring on sire record were 0.27 for initial test weight and 0.19 for 120-day weight. They observed that heritability of initial weight was comparable to that of weaning weight. Pierce, et al (1952) reported heritability estimate of 0.23 for weaning weight. In summaries of data reported before 1958, Warwick (1958) calculated a mean estimate of 0.31. The average heritability estimate from several studies including those made under the NC-1 project summarized by Gregory (1961) was 0.40.

In studies at Beltsville, Black and Knapp (1936) reported that weaning weight was correlated -0.62 to per cent of fat in carcass and 0.66 to lbs of carcass produced per 100 lbs. TDN consumed. Thus the heavier weaners put on the least fat, and were the most economical. They also observed that weaning gain was highly correlated to pound of milk taken. They suggested that weaning weight in addition to certain other conditions must be held constant in a record-of-performance tests, particularly since correlations indicated that weaning weight accounted for 40% and 44% respectively of the variations in amount of fat and economy of gain in subsequent feeding period.

Swiger, et al (1962) found that weaning weight was genetically correlated -0.31 to feed consumed from weaning to 1,000 lbs. live body weight. The correlation coefficients indicated that there would be simultaneous selection of heavier weights through selection for feed and days. From indexes derived, it was concluded that selecting for weaning weight alone would be relatively ineffective for bringing about genetic improvement. Christian, et al (1965) evaluated the relationships between preweaning and postweaning traits in cattle. They reported that birth weight was correlated 0.62 to weaning weight, 0.40 to days to slaughter, 0.43 to height at withers, 0.55 to weight at slaughter, 0.52 to loin eye area, and 0.60 to trimmed lean cuts. These indicated that selection for heavier weaning weights would result in genetic selection for cattle that are fast gaining, heavier weaning and heavier finishing.

In analysis of data on 46 individually fed and 160 group-fed grade Hereford calves, Pierce, et al (1954) found that weight at start of test showed a significant negative partial regression coefficient on gain on test (-0.014), indicating that calves which were 10.0 lbs heavier at start of test gained 0.14 lbs less per day.

In his studies of factors affecting weaning weight, Gottlieb (1962) classified the principal ones as (1) those considered to be primarily genetic--degree of inbreeding of dam and calf, sex of calf, sire; (2) those considered to be primarily environmental--age of dam, age of calf, year of birth; and (3) one that is both genetic and environmental, namely the lactating ability of the dam.

Weaning weight has been indicated as a valuable criterion for evaluation of breeding value of mothers in terms of its repeatability in their offspring. Gregory (1961) stated that weaning weight was 30.0-50.0% repeatable thus selection for mothering ability would be expected to increase weaning weight. Data obtained at U.S. Range Livestock Experiment Station, Miles City, over the period 1929-51, were analyzed for correlations among paternal and maternal half-sibs (Koch and Clark, 1955). They used data from 4,234 calves 1,231 dams and 137 sires. They reported that repeatability, measured as a permanent character of the cow, were 0.34 for weaning weight, 0.34 for gain from birth to weaning, 0.22 for weaning score and 0.20 for yearling weight. They concluded that weaning weight, gain from birth to weaning and weaning score were subject to considerable maternal environmental effect.

Rate of Growth

Growth rate, both preweaning and postweaning, is considered to be a major factor in selection for desirable beef cattle. It has been studied quite extensively not only because of its importance in practical production in terms of economies of time, labor and other reduction in cost that would result from the use of fast gaining animals, but also its genetic association with efficiency of feed utilization.

Rate of gain has a high coefficient of heritability. Estimates by Brown and Gacula (1964) from data on performance-tested sires and progeny of three breeds of beef cattle (Herefords, Angus, and Shorthorns) was 0.93. Warwick and Cartwright (1955) estimated heritability of rate of gain using data collected from gain-evaluation tests on 853 head of cattle. They analyzed on the basis of gain ratio (individual record divided by average of sex, breed, year and ration group). Estimates from half-sib analyses were between 0.33 and 0.51; and regression of parents on average of offspring, which they considered the most reliable estimate, was 0.54. The authors stated that even though estimates from gain ratio were not true heritabilities, they would be of immense value in practical selection since differences due to sex, ration and year were adequately eliminated.

Heritability estimate for average daily gain computed by Knapp and Clark (1950), was 0.60. Kholi, <u>et al</u> (1952) using data collected from 157 purebred milking Shorthorn steers between 1932 and 1949, obtained 0.63 for average daily gain from 500 lbs to 900 lbs. Estimate for days from birth to 900 lbs was 0.03. Heritabilities computed on intra-year and line basis using paternal half-sib analysis was 0.60 for gain on feedlot and 0.84 for final weight at end of feedlot period, Shelby, <u>et al</u> (1955). Mean estimates from NC-1 studies and others summarized by Gregory (1961) were

0.45 for feedlot gain, 0.30 for pasture gain, and 0.60 for final feedlot gain. Cundiff, et al (1964) used a unique measure, carcass weight per day of age, as an indicator of rate of growth. They obtained heritability coefficient of 0.39.

These estimates indicate that selection for rate of gain would be effective. The large differences also underscore the fact that there are variations which might depend on such factors as the methods of analyses used, the amount of selection previously practiced, and the effect of various environmental conditions.

Correlation coefficients between rate and gain and other economic traits were reported by Black and Knapp (1936). These were 0.88 for average daily gain and economy of gain (weaning to slaughter), 0.89 for average daily gain and economy of gain (birth to slaughter), -0.36 for average daily gain, birth to weaning and average daily gain weaning to slaughter. These indicate that average daily gain and economy of gain are highly positively correlated, not only for the period from weaning to slaughter but also for the period from birth to slaughter. The negative correlation for rate of gain between two periods, birth to weaning and weaning to slaughter, suggests that calves that gained faster on milk would tend to gain more slowly after weaning. The data used were a complete record of 14 beef Shorthorn calves, 20 Hereford calves, 32 Milking Shorthorns, and 6 dairy calves, weaned at constant age of 252 days and slaughtered at a constant weight of 900 lbs.

Correlation coefficients of 0.81 between net profit and average daily gain, and 0.71 between efficiency quotient and daily gain, Winters (1936) indicates that cattle average daily feedlot gains would serve as a satisfactory indicator of feed efficiency. Further, multiple correlations of daily gains and value per 100 lbs with net profit was 0.914, with only an insignificant increase of 0.002 when the efficiency quotient was included in the computation. He suggested a record of performance program which combined rate of growth and body score as an index for evaluation of animals.

Swiger, et al (1962) defined net merit in terms of the cost of producing a 1,000-lb beef animal. They compared the relative accuracy of (1) combining the three traits, weaning weight, post-weaning gains and postweaning feed consumption (2) using two traits, weaning weight and postweaning rate of gains and (3) using each trait separately as basis of selection. They found that selecting for weaning weight and postweaning gains would result in 0.73 as much genetic change in net merit as when the third trait (individual feed consumption) was included in the index. They concluded that although selection for feed consumption alone would be as accurate as selecting for all three traits, the use of weaning weight and postweaning rate of gain would be satisfactory in view of the high cost involved in individual feeding.

Knapp, et al (1941) reported a low correlation of 0.44 between rate of growth and efficiency of feed utilization. In studies with 60 steers having initial weights ranging from 289 to 492 lbs, Knapp and Nordskog (1944) found that 0.49 correlation coefficient between observed rate and efficiency of gain would result in a high error if selection for efficiency were based on rate of gain. But after the observed efficiency were computed on a weight constant basis (700 lbs) correlation between rate and efficiency of gain increased to 0.83. They concluded that average daily gain might be used to predict efficiency of gain at comparable weights, and suggested that in time-constant tests selection should be made for rate rather than efficiency of gain.

Cundiff, et al (1964) used data on 47 sire progeny groups classified in five groups by herd and year of birth in studies of some growth and carcass traits. They reported genetic correlation of 0.66 between carcass weight per day of age and rib-eye area; and 0.15 between carcass weight per day of age and back fat thickness. These indicated that selection based on rate of growth would result in more muscular development and a slight increase in back fat thickness. The genetic, environmental and phenotypic correlations between rate of growth and rib eye area were 0.66, 0.27 and 0.46 respectively. The authors inferred that the phenotypic relationships observed were not always correct indicators of the genetic relationships between traits.

Hazel, et al (1943) evaluated the relative importance of genetic and environmental factors in growth rate of pigs. They computed the genetic, environmental and phenotypic correlations at three 56-day periods from birth to 168 days. The variance due to genetic causes was small, representing 15, 28 and 17 per cent for the first, second and third periods respectively, but was more highly correlated between periods than variations due to either environment or phenotype. The authors concluded that inherent ability had a amaller but more constant influence on rate of growth, and that selecting in the second 56-day period (56-112 days of age) would probably result in greater genetic improvement in growth rate of pigs.

Feed Efficiency

A major goal of beef cattle improvement programs is to combine in the same animal an efficient fast gainer, that yields quality carcass. Efficiency of feed utilization is closely associated with the economic value of an animal, particularly when considered in terms of the total feed requirement for growth and maintenance both preweaning and postweaning. Since feed efficiency is not usually included in record-of-performance tests because of the costs involved in its measurement, considerable amount of investigations have been made to determine the amount of variability that exists within species, the level of heritability, and its interrelationships with other more easily and cheaply measurable production traits.

Morris, et al (1933) developed two lines of rats one of which was 40.0% less efficient with regard to feed utilization. Winters (1936) fed steers individually for three years in studies of economy of production. He found that the least efficient animals in each of the three years cost 31.0%, 26.0% and 44.0% more per 100 lbs gain. He suggested that variation in feed efficiency was large enough to be of importance in livestock improvement and that lines of livestock which were more efficient and more uniform in performance could be developed through selection. In investigations with the domestic fowl, Hess and Jull (1948) also reported that observed differences in efficiency of feed utilization were hereditary.

Heritability of feed efficiency reported in literature represents a wide range of values. Shelby, et al (1955) reported 0.22 from paternal half-sib analysis. Summary by Warwick (1958) including some of the investigations reported before 1958 showed a mean of 0.39 with a range of 0.03 to 0.75. Carter and Kincard (1959) reported estimates ranging between 0.21 and 0.41 from parent-offspring regressions and half-sib correlations. Christian, et al (1965) used date on identical and fraternal twins. They reported heritabilty estimate of 0.69 and 0.92 for feed efficiencies from six to twelve months of age.

McDonald and Borgart (1955) studied the relationships between efficiency of gain and type in breeding cattle in an effort to evaluate the age-old practice of selection by visual appraisal, especially with regard to breeding animals. They found that correlation between TDN intake and days from 500 to 800 lbs was 0.68 but found no correlation between type score and any of the performance traits.

Results reported by Black and Knapp (1936) showed that economy of gain was correlated 0.56 to feeder grade, 0.49 to slaughter grade, and 0.85 to return above feed cost, while economy of gain birth to weaning was correlated 0.06 to postweaning economy of gain. These indicated that preweaning selection for postweaning economy of gain would be ineffective in causing genetic improvement, but economy of gain was a good indicator of feeder grade and economic worth. Multiple correlation of return above feed cost with economy of gain and slaughter grade was 0.969. Partial correlation was 0.91 with economy of gain (when slaughter grade was held constant) and 0.88 with slaughter grade (when economy of gain was held constant). It was further indicated that economy of gain and slaughter grade together accounted for 94.0% of the variations in return above feed cost; with economy of gain the slightly more important factor.

Nelms and Borgart (1955) studied the effect of age on test, gain on test, and birth weight on feed efficiency. The simple correlations of TDN per 100 lbs gain to each of the three variables (the figures after correction for maintenance are shown in parenthesis) were 0.81 (-0.56) with gain on test; 0.28 (0.49) with age on test; -0.12 (-0.23) with birth weight. Corresponding figures obtained on females were 0.63 (-0.35) with gain on test, -0.42 (-0.42) with age on test, -0.53 (-0.53) with birth weight. They concluded that calves which were heavier at birth were more efficient, also fast-gaining calves were more efficient, especially when the gains were corrected for maintenance. Multiple correlations showed that birth weight, gain on test, and age on test accounted for 04.0% of the observed variations in feed efficiency.

Conformation Score

The average heritability estimates 0.25 for weaning score and 0.40 for slaughter score calculated from several reports (Gregory, 1961) indicates moderate level of heritability. Upper and lower limits computed by Koch and Clark (1955) from paternal half-sib analysis were 0.27 and 0.11 for weaning score; 0.49 and 0.18 for yearling score.

McDonald and Borgart (1955) studied the relationship between production factors and type score. They reported 0.39 coefficient of repeatability. Further, they found that type score increased with increase in body weight from 500 to 800 lbs., and since it was not found to be correlated with any of the production factors either at 500 or 800 lbs, they suggested that both type score and production factors should be included in selection indexes.

Birth and weaning weights on 4,553 calves, 3,831 weaning score records, 1,694 yearling weights and 1,483 fall yearling scores, collected over the period of 1929-51 on range-raised grade Hereford calves (Koch and Clark, 1955) were used to compute genetic, environmental and phenotypic correlations between some production factors. Paternal half-sib analysis showed that the genetic, environmental and phenotypic correlations of yearling score were 0.14, 0.49 and 0.63, respectively, for gain from birth to weaning; 0.23, 0.27 and 0.26 for weaning score; 0.44, 0.35, and 0.38 for gain from weaning to yearling.

Marlowe, et al (1965) evaluated the sources and magnitude of non-genetic variation in calf performance. Using data from 111 Angus herds with 17,294 records and 82 Hereford herds with 11,663 records they observed that heifer calves graded slightly higher than bull calves; both heifer and bull calves grading significantly higher than steer calves by 0.4 to 1.0 grade point. Month of birth had a mild effect on type score, with a slight increase in grade from August until March, and a decline thereafter until June. The effect of age of dam on type score was found to be too small to be of any consequence in practical considerations.

In studies undertaken to determine the causes of variation between bulls in record of performance tests, Schalles and Marlowe (1967) analyzed data from 979 performance tested bulls, 775 of which were group-fed, while the rest (222) were individually fed at Culpeper and Front Royal, Virginia. On the individually fed bulls, they observed that preweaning type score was positively related to end-of-test type score, but negatively associated with lifetime average daily gain, record-of-performance average daily gain, and 365-day weight. The same general but non-significant trend was observed in the group-fed bulls.

In the United States and other countries, conformation has been used for a long time as the basis for selection of breeding animals. In recent years, performance testing has been increasingly used, particularly as it became more and more evident that there is little relationship between conformation score and total production potentialities in beef cattle.

Selection Criteria

Three main selection methods have been used in the last half century, Craft (1958). The tandem method involves selecting for one trait at a time until the trait is fixed in the population, then selecting for another. The method of independent culling levels establishes levels of desirability for each of the trait being considered, below which the individual is culled regardless of its merit in other traits. The third, total score, uses index of net merit based on two or more characters for which simultaneous selection is made.

Hazel and Lush (1942) discussed the relative efficiency of using tandem, independent culling levels and total score in selection plans and concluded that the tandem method was the least efficient, while total score was the most efficient. They estimated that selection using total score would be n as efficient as tandem selection for the same set of traits, where n is the number of traits being considered. Further they noted that in actual selection practice, a combination of total score and independent culling levels was generally employed.

Hazel (1943) reported that the genetic gain expected from the use of a selection index involving several traits depends on (1) selection differential; (2) multiple correlation between average breeding value and selection index; and (3) genetic variability. He pointed out that the one that could be most easily manipulated for increased progress in selection is the multiple correlation between aggregate breeding value and selection index. An example of three selection indexes constructed by the method of multiple correlation using data on boars and gilts was presented. The first index included 180 day weight and market score of each animal; the second included the productivity of the dam in addition to the two traits used in the first, and the third index included the three traits used in the second index in addition to the average weight and score of the litter to which each pig belongs. Expected genetic progress from the use of the indexes were estimated at between 36.0 and 40.0 per cent, compared to a perfect index. The loss of accuracy was attributed to effects of environment, dominance and epistasis on genotype of individuals. Thus effective estimation of those factors would lead to the development of more accurate selection indexes. The constants required for computation of the indexes are (1) relative economic values for each trait (2) phenotypic values, including standard deviations for each trait, and correlations between each pair of traits and (3) heritabilities of each trait, and (4) genetic correlations between each pair of traits.

Three basis for selection, mass selection, family selection, and a combination were elaborately discussed by Lush (1947). He concluded that a combination of mass and family selection was at least equal to each of the other methods under all conditions; and that it might even be slightly superior either when r is moderate and t is smaller or t is distinctly larger than r (where t is the phenotypic correlation between menbers of a family, and r is the correlation of their breeding values). Mass selection was found to be more effective than purely family selection in most cases. Finally, it was observed that inbreeding would increase the effectiveness of family and combination selection once in a breeding cycle, by increasing correlation between breeding values when inbred families are selected and crossed.

MATERIALS AND METHODS

The data used in this study were obtained from the first sixteen years (1950-65) of State Project 286 conducted on Beef Shorthorns at The Kansas State University Experiment Station, at Manhattan, Kansas. It was part of a larger NC-1 project: "The Improvement of Beef Cattle Through Breeding Methods."

Procedure

Two lines were established from the Kansas State College Shorthorn herd; the Wernacre Premier line with Sire College Premier 29th, 2368167 in 1949, and the Mercury line with Sire Gregg Farm's Hoarfrost, 2492499 in 1950. Inbreeding was initiated in 1949 in the Wernacre Premier line and in 1952 in the Mercury line, and was continued in both lines by half-sibbing in successive generations.

Cows were pasture-bred for spring and early summer calving. Calves were weighed at birth, and suckled without creep. At 182 days (196 days in 1950) they were weaned, weighed, and scored for conformation. Approximately three weeks after weaning, calves were weighed again and placed on feeding trial. The heifers received 55 per cent corn and 45 per cent chopped alfalfa hay while the steers and bulls were fed 75 per cent corn and 25 per cent chopped alfalfa hay. Each calf was fed weighed quantities of the ration for 182

(196 days for 1st year) days. Selection was based primarily on rate of growth and conformation score.

Until 1957, about half of the male calves in each calving season were castrated, and fed as steers; thereafter none were castrated so as to obtain more data on bull calf performance.

The Wernacre Premier Line

Seven sires had been used in the Premier line over the period included in this report. In the sixteen years under consideration, they sired 126 calves varying from 5 to 59 offspring per sire, distributed as follows: 49, 20, 5, 22, 5, 7, and 18 for an average of 18.0.

The coefficient of inbreeding of sires varied between 0.00 and 32.00 with a mean of 17.6. Forty-nine dams, having an average coefficient inbreeding of 10.39, were used. The average inbreeding of the calves was 20.4 per cent; 20 of them were less than 10.0 per cent inbred, 42 were between 10.1 and 20.0; 37 were between 20.1 and 30.0 and 25 were more than 30.0 per cent inbred. The coefficient of inbreeding increased inconsistently from an averages of 8.40 (heifers), 10.0 (bulls), and 7.3 (steers) in 1950 to 23.5 (heifers), and 22.50 (bulls) in 1965; down from a peak of 34.57 for heigers and 27.85 for bulls in 1961. The calves weighed 70.88 lbs on the average at birth, 400.98 lbs at start of test, had weaning score of high good to low choice

The cylinder speed was set at three different settings. These were 1250 RPM, 1100 RPM, and 950 RPM. Each time the speed was changed it was checked with a hand tachometer to insure the proper speed. The rate of feed was also set at three different rates and was controlled by using different ground speeds. The wheat was cut from a uniform portion of the field and the height of cutting was held constant. The actual forward speed of the combine was found by measuring the time required for ten revolutions of the combine wheel. The effective diameter of the wheel was measured and forward speed was calculated. Knowing the forward speed, the rate of feed was found by hand cutting the wheat at the same height as the cutter bar for a given area and weighing it in order to calculate rate of feed. Hand cut wheat was then hand shelled and used as a control.

Three samples were collected for each setting. All possible combinations of settings were used. This resulted in nine different tests with a total of 27 samples. The samples were collected at the clean grain delivery elevator before entering the grain bin. Samples were taken after sufficient time had been allowed for the combine to reach a steady state condition. The samples were collected in paper bags lined with plastic. The top of the bag rolled down and sealed the bag against moisture loss. Each sample was approximately one pound. The samples were numbered with a two digit number such as A-B. Letter B represented the rate of feed since it was the easiest variable to control and letter A represented the cylinder speed.

EXPLANATION OF PLATE II

Boerner sampler used to divide field samples into equal parts.

days on test. Gain on test was the difference between initial weight and final weight.

Final type score was the conformation grade as determined by visual observation at the end of test. The grades were Fancy, Choice, Good, Medium and Commercial, represented numerically as 1+, 1, 1- for Fancy; 2+, 2, and 2- for Choice, etc. In the analysis, these were converted to two numerical scales. The first was the 100-point system, where 100, 97, 94 represented high, average and low fancy; 91, 88, 85 represented high, average and low choice; etc., -- and 64, 61 and 48 represented high, average and low commercial. The second, and more commonly used, was the 17-point system described by Marlowe, <u>et al</u> (1958) in which 15-17 represented three sub-grades of Fancy, 12-14, 9-11, 6-8, and 3-5 represented Choice, Good, Medium and Commercial respectively.

The effects considered as independent variables were cow age, line, weaning type score, sex, year, inbreeding of dam, inbreeding of sire, inbreeding of calf, initial weight, birth weight, and age at beginning of test.

Cow age was classified into seven discreet groups as follows: 2 years or less, 3, 4, 5-8, 9-10, 11, and 12 or more years. There were two lines, the Wernacre Premier and the Mercury. Weaning type score was the conformation grade determined at weaning time, and represented numerically on the 17-point system as described for final type score above. Weaning type score varied from a low of 9 to a high of 15 for a total of 7 classifications. Three sexes were represented and were designated numerically as 1, 2, and 3 for bull, heifer, and steer respectively.

The inbreeding of dam, sire and calf were actual inbreeding coefficients calculated by means of covariance charts as described by Wright (1923). The inbreeding coefficients which varied from 0.00 to 37.50 in dams, 0.00 to 32.00 in sires and 0.00 to 41.40 in calves were represented as regressions. Initial weights were actual post-weaning weights taken at the start of test. Birth weights were actual weights on each calf taken soon after birth. Age at test were actual ages at beginning of feeding trial. Birth weight, initial weight and age at test were also regressions.

Statistical Analysis

Constants were fitted by least square analysis using multiple classification model with regressions and unequal subclass numbers as outlined by Harvey (1960).

Model:

$$Y_{ijkmno} = + A_i + L_j + T_k + S_m + Y_n + b_1(X^1_{ijkmno} - \bar{x}^1) + b_2(X^2_{ijkmno} - \bar{x}^2) + b_3(X^3_{ijkmno} - \bar{x}^3) + b_4(X^4_{ijkmno} - \bar{x}^4) + b_5(X^5_{ijkmno} - \bar{x}^5) + b_6(X^6_{ijkmno} - \bar{x}^6) + e_{ijkmno}$$

Where

Y_{ijkmno} = the o^{th} calf tested in the n^{th} year, belonging to the m^{th} sex, the k^{th} type score class, in the j^{th} line and i^{th} age of dam group.

u = the overall mean or effect common to all calves tested

A_i = effect common to all calves belonging to the i^{th} age of dam group

L_j = effect common to all calves within the j^{th} line

T_k = effect common to all calves having the k^{th} score

S_m = effect common to all calves belonging to the m^{th} sex

Y_n = effect common to all calves tested in the n^{th} year

b_1, b_2, b_3
b_4, b_5, b_6 = partial regression coefficients of the dependent variable Y on each of the independent continuous variables X^{123456}_{ijkmno}

X^1_{ijkmno} = the continuous independent variable, inbreeding of dam

$\bar{x}^1$ = the arithmetic mean of the variable X^1_{ijkmno}

X^2_{ijkmno} = the continuous independent variable, inbreeding of sire

$\bar{x}^2$ = the arithmetic mean of the variable X^2_{ijkmno}

X^3_{ijkmno} = the continuous independent variable, inbreeding of calf

$\bar{x}^3$ = the arithmetic mean of the variable X^3_{ijkmno}

X^4_{ijkmno} = the continuous independent variable, initial weight of calf

$\bar{x}^4$ = the arithmetic mean of variable X^4_{ijkmno}

X^5_{ijkmno} = the continuous independent variable, birth weight of calf

$\bar{x}^5$ = the arithmetic mean of the variable X^5_{ijkmno}

X^6_{ijkmno} = the continuous independent variable, age at start of test

$\bar{x}^6$ = the arithmetic mean of the variable X^6_{ijkmno}

eijkmno = the random error common to each calf and assumed to be normally and independently distributed with a mean of zero, and variance σ^2_e.

It was believed from past experience that none of the main effects would interract in any significant manner, interraction terms were therefore excluded from the model.

The normal least squares equations were solved, to obtain estimates of constants and regression coefficients, by inversion of matrix on IBM 360. The restriction imposed was that the sum of the subset constant estimates equals zero, ($\sum_i \hat{a}_i = 0$).

Standard errors were calculated and LSD tests were performed.

Equations used to obtain standard errors of estimated constants, a_i or u is

$$S_{\hat{c}_i} = \sqrt{C_{ii}\,\hat{\sigma}_e^2} \qquad \text{(Harvey, 1960)}$$

The standard error of the constant obtained by addition of the constants in a sub-set were estimated using the equation

$$S\hat{c}_b = \sqrt{\left(\sum_{i=1}^{n} C_{ii} + 2\sum_{i=1}^{n}\sum_{j=i+1}^{n} C_{ij}\right)\hat{\sigma}_e^2} \qquad \text{(Schalles, 1965)}$$

Where C_{ii} and C_{ij} are elements of the inverse matrix, and ^2_e is the error mean square.

Test of significance for differences between the least squares constants, $\hat{a}_i$, and $\hat{a}_b$ in a sub-set were made by means of LSD test using the equation

$$\text{LSD} = \sqrt{\frac{2\,\hat{\sigma}_e^2}{\bar{x}_i}}\,(t_\alpha)$$

where $\hat{\sigma}_e^2$ is the estimate of error mean square, $\bar{x}_i$ is the arithmetic mean of the number of observations used per treatment, and t_α is the table value of student-t at the desired level of significance. Any algebraic difference between any pair of computed constants, ($\hat{a}_i$ and $\hat{a}_j$) or a computed constant and constant obtained by subtraction, ($\hat{a}_i$ and $\hat{a}_b$) which exceeded the LSD value is regarded as indication of significant difference between the pair of constants involved.

Estimates of genetic and environmental changes were obtained using a method similar to one suggested by Schalles (1966). The method was based on the assumption that observed differences between full-sibs produced in different years were due to environmental causes. The computation was accomplished by carrying out a least squares analysis as previously described and absorbing the sire and dam effect by using maximum likelihood estimate. The estimate of genetic effect was then obtained by setting the least squares constant estimates previously obtained, equal to sum of the sire-dam effect and environmental effect thus:

$$\hat{a}_i = \hat{a}_{sd} + \hat{a}_j$$

Where $\hat{a}_i$ is the least squares constant estimate in previous analysis, $\hat{a}_{sd}$ is the estimate of genetic effect contributed by the sire and dam, and $\hat{a}_j$ is the corrected estimate of environmental effect. Two hundred and forty-five calves from 10 sires and 72 dams were used in the absorption procedure.

RESULTS AND DISCUSSION

The least squares constants for each of the sources of variation and their subclassifications given as deviations from least squares means of each dependent variable, and the analysis of variance, provide a measure of the extent to which each factor considered affected the performance traits studied.

The relevant portion of the analysis of variance, the mean square, the degrees of freedom associated with them, and the probabilities of chance occurrence needed to determine level of significance are shown in Table 1. The least squares means for gain on test, ROP test ADG, lb. TDN/lb. gain, and final type score, the deviations from least squares means and their standard errors, and a result of an LSD test between subclassifications of the variable factors, in alphabetical code, are presented in Table 2. Table 3 shows the genetic and environmental factors in the determination of observed phenotypic deviations from least squares means. The deviations obtained before the absorption of dam and sire effects represent the genetic and environmental effects, while those obtained after absorption are equivalent to the environmental effects. The least squares constants obtained for environmental effects were computed setting 1965 effects equal to zero. This required adjustments making the sum of all year effect equal to zero, to put the estimates on a basis comparable to the phenotypic constants earlier obtained. A discussion of the general trends, and specific effects of each independent variable follows.

Cow Age

Age of cow at the time of birth of calf appeared to be of minor importance with regard to the performance traits studied. The effect was significant on ROP test ADG, approached significance on final type score, and has no statistically significant effect on either gain on test or lb. TDN/lb.gain. It seems out of place that cow age had a significant effect on ROP test ADG but had no significant effect on gain on test, particularly since the ROP test ADG was obtained directly from gain on test by averaging over the total number of days on test.

Similar incongruencies, sometimes in reverse, were observed on some other variables considered, notably inbreeding of dam and initial weight of calf. This situation is probably due to the fact that gain on test data included calves tested for 196 day; the succeeding years were made up of calves tested for 182 days. While the ROP test ADG properly took the number of days on test into consideration, there was no adjustment for gain on test in respect of the first year of test. The other probable explanation involves magnification of possible errors of measurement as a result of mathematical calculations needed to obtain sums of squares.

Thus large errors which are deviations from the mean of the trait measured, would tend to be enlarged several times more than similar errors on a smaller scale, when squared. Such errors on ROP test ADG would be in fractions which would be smaller still when squared. The above probable sources of error, which are mutually exclusive, favor ROP test ADG as the more accurate criterion to judge growth rate in the analysis. However, the ratio of error sum of squares to total sum of squares calculated for each of the traits (0.24 for gain on test and 0.33 for ROP test ADG) suggests that variations observed were better accounted for on gain on test.

Calf gain on test was slightly less than average for cows that were 2 years old or less, otherwise, calves from younger dams gained more on test while calves from the oldest gained the least. Gain on test appeared to be highest for calves from 3-year old cows, decreasing somewhat steadily thereafter until it actually fell below average with cows that were 11 years or older. There was little or no difference with calves from cows that were 4 years through 10 years old. The same pattern was observed for ROP test ADG and final type score. This is in general agreement with earlier reports found in literature. It seems, if one presumes that genetic effect remains constant throughout life, that the effect of dam age is expressed through conditioning of the uterine environment for optimum activity after first calving, giving calves a head start, until about 10 years of age when activity declines.

The effect of lb. TDN/lb. gain did not show such trend. Calf feed efficiency was lower for calves from youngest and oldest cows, fluctuating rather inconsistently for cow ages in between.

Line

Analyses of variance indicated that the two lines performed essentially alike with regard to three of the traits studied (ROP test ADG, lb. TDN/lb. gain, and final type score) but showed significant differences in gain on test. The Wernacre Premier calves gained an average of 25 lbs. on test more than the Mercury calves, and implicit in observed larger gains, although not found significantly so, appeared not to gain faster on test. The Mercury calves on the other hand needed 0.08 lbs. less TDN/lb. gain, and scored higher on final type.

Weaning Type Score

Weaning type score had a highly significant relationship with final type score ($P<0.0005$). Showing a linear trend, calves that scored high at weaning time also scored high at end of test, likewise, calves scoring low at weaning also scored lowest on final type. Weaning type score also had a significant effect on ROP test ADG, approached significance ($P < 0.10$) on gain on test, but had no significant effect on lb. TDN/lb. gain with $P < 0.90$.

Calves scoring low choice at weaning gained 0.29 pound less on ROP than calves scoring average fancy at weaning. There was significant difference in ROP test ADG between calves scoring low good and those scoring average good, and between those scoring average good and essentially all the other higher classifications. There appeared to be no difference in ROP test ADG of calves scoring high good and better. Gain on test showed similar pattern; calves scoring low good at weaning gained 52.6 pounds less than those scoring average fancy, with low choice calves gaining about average. These findings are in disagreement with report by Patterson, et al (1955) which showed a negative correlation between weaning type score and test ADG, and by Schalles and Marlowe (1967) which showed significant negative association between preweaning type score and lifetime ADG, ROP test ADG, and 365-day weight of individually fed bulls, and similar trends in group-fed bulls.

Sex of Calf

Sex of calf had highly significant effect on all performance traits studied. Bulls gained a significant 44.8 pounds more on test than steers, and steers in turn gained about 87.2 pounds more than heifers for a total of 132.0 pounds difference between bulls and heifers. Bulls and steers showed no significant difference in rate of gain, but both gained significantly faster than heifers, 0.58 pound in favor of steers and 0.64 pounds in favor of bulls. Steers required significantly less TDN per pound of body gain than bulls, and bulls required a significant 0.84 pounds TDN less per pound of gain than heifers. Heifers scored highest on final type while steers scored lowest.

Several reports including those by Warwick (1958) and Gregory (1961) indicated that rate and efficiency of gain were highly correlated. The observation in this study that the slower gaining heifers are also the least efficient suggests that the association between rate and efficiency of gain may be due to effect of sex preweaning, such as increased secretion of sex hormones prior to maturity on both performance traits rather than a high correlation *per se* between the two traits.

Figures reported for differences in rate of gain on test varies between 20 pounds and 70 pounds, with adjustment factors to bull equivalent usually set at 24 pounds for steers and 48 pounds for heifers. The size of the differences observed in this study suggests that differences between sexes did not decrease as age advanced.

Year of Test

Year effect was highly significant on all the performance traits studied, with $P < 0.0005$ in all cases. There were significantly larger calf gains in 1950, primarily because of the longer feeding period, than in the three years that followed. Gains in 1957, 1958 and the years 1960-64 were essentially the same as gains in 1950. Gain on test was highest in 1961, exceeding the 1959 figures (year of lowest gains) by 114.8 pounds. Except for the 1950 figure which was below average, ROP test ADG followed the same pattern as gain on test. There were also significant year differences in feed efficiency and type score.

Inbreeding

The inbreeding of sire had no significant effect on any of the performance traits studied. This is not surprising in view of the level of inbreeding of the sires used. Besides, the inbreeding effect of sire would be expected to affect performance primarily through the genotype of the calves.

Inbreeding of dam had significant effect on gain on test but had no effect on the other traits.

Inbreeding of calf had significant effect on gain on test, ROP test ADG and final type score ($P < 0.025$), but had no significant effect on lb. TDN/lb. gain. Gain on test increased as inbreeding of calves increased, but conformation score and average daily gain declined slightly. These were probably a carry-over of the effect of calf inbreeding on preweaning performance as observed in the weaning data analysis of the first eleven years of this experiment by Gottlieb (1952), in which a trend of declining weaning weight and weaning score was indicated. The positive effect of inbreeding of dam on gain on test, and the persistently positive trend of its effect on the other traits, as opposed to the negative association of inbreeding of calf with those traits may be an indication that the dam inbreeding removes some of the depressing effect of calf inbreeding.

The lack of association between calf inbreeding and lb. TDN/lb. gain, even though it is negatively associated with the other performance traits, may be regarded as further evidence in support of the suggestion made above that the two performance traits, ADG and lb. TDN/lb. gain may not always be associated.

It is relevant to state at this point that no physical abnormalities that could be attributed to effect of inbreeding has been observed in the herd. There have been cases of still births but more of it occured in the Mercury line, which was the less inbred of the two lines.

Birth Weight of Calf

The birth weight of calf had significant influence on gain on test, ROP test ADG ($P < 0.005$), and lb. TDN/lb. gain, but had no effect on final type score.

Calves that were heavier at birth gained more and faster on test, and required significantly less pounds of TDN per pound of gain than calves that were lighter at birth.

Several factors including maternal ability, prenatal environment and others, which affect birth weight may not influence postweaning performance. Any association between heavy weights at birth and postweaning performance, therefore, may have been due largely to a headstart at early age. On the other hand, since inbreeding is believed to have depressing effect on birth weight, and also as noted earlier, negative effect on several postweaning performance traits, the influence of genotype may have been the decisive factor in the association between birth weight and gain on test.

Initial Weight

The influence of calf weight at beginning of test was highly significant on gain on test, lb. TDN/lb. gain and final type score, but had no effect on ROP test ADG.

Calves that were heavier at start of test gained more on test. This fits well into the trend observed with regards to other effect previously considered, particularly the effect of birth weight. Thus, calves that were heavier at birth would be presumed to be heavier at start of test, and as analysis indicated, gained more on test as a result of heavier birth and initial weights. The superior growth factor thus appeared to persist from prenatal through the preweaning and postweaning periods of development. These findings are in general agreement with report by Christian, et al (1965) which indicates that birth weight was positively correlated to both weaning weight and slaughter weight.

Pounds TDN per pound of gain increased as calf initial weight increased. This is a reverse of the effect of birth weight on the same performance trait, and disagrees with report by Pierce, et al (1951) which indicates that calves were heavier at birth gained less on test. Heavier calves at start of test also had a higher type score at end of test.

Age at Start of Test

Gain on test was significantly influenced by age at the beginning of test. Calves that were older at start of test gained more on test. Similarly significant positive effect was observed for ROP test ADG.

Pounds TDN per pound gain was significantly influenced by age at start of test. As age at which calves went on test increased, there was a decrease in the pounds of TDN required per pound of gain. Since heavier calves were found to be less efficient, the effect of age at test could not have been through heavier weights at start of test. It is probable that the condition of the calf at time of going on test accounted for the observed effect of age on lb. TDN/ lb. gain. Thus, older calves that were fatter at time of test, spent more fattening time on test, and therefore, had greater gains and greater efficiency. Age at test had no significant effect on final type score, however, a positive trend was indicated.

Genetic Effect

The yearly changes in the performance traits attributable to genetic effect is of interest as a measure of that portion of response to selection that is transmissible.

Environmental changes varied widely from year to year in all traits, in close association with observed phenotypic changes, (Figures 1 to 4 in Appendix). The ratios of genetic to total variation, estimated from a comparison of the least squares means before and after absorption of dam and sire effect, indicate that most of the observed phenotypic changes was non-genetic.

The simple regression of genetic change of ADG on year ($b = 0.00015$) suggests that there was no increase in genetic effect with years. The same is true for gains on test, indicating that there was essentially no genetic gains in rate of growth. The regression with changes in lb. TDN/lb. gain showed a tendency towards a small genetic loss of feed efficiency. Final type score showed a small, insignificant progressive increase in genetic gains relative to the least squares means.

The presence of large environmental component of observed variations explains the lag in genetic gains over the years.

SUMMARY

Data collected on 425 Shorthorns at Kansas State University Agricultural Experiment Station at Manhattan, Kansas, as part of regional project NC-1, "The Improvement of Beef Cattle Through Breeding Methods," was examined by using least squares analysis for a study of effects of several variables on gain on test, ROP test ADG, lb. TDN/lb. gain, and final type score. The study was started with the establishment in 1949 and 1950 of two lines that had been progressively inbred and selected for growth and conformation. The present analysis includes data from calves raised and fed in the period 1950-65.

Age of dam significantly influenced ROP test ADG but had no influence on other traits. Effect of line was significant only on gain on test, with the Premier calves, the more highly inbred, making larger gains. Weaning type score had significant effect on final type score and ROP test ADG. Sex of calf had significant effect on all performance traits studied. Bulls gained more and faster, steers were the most efficient, while heifers scored highest. The effect of year of test was highly significant on all four performance traits. Inbreeding of calf influenced all traits significantly except lb. TDN/lb. gain; the effect of dam and sire inbreeding could be assumed to be partly confounded with the effect of calf inbreeding. Calf initial weight did not have any effect on ROP test ADG but significantly influenced gain on test,

lb. TDN/lb. gain and final type score. Calves that were heavier at time of going on test gained more, scored higher and needed more TDN per pound of gain. Effect of birth weight showed trends similar to the effect of initial weight with the important difference that calves that were heavier at birth were more efficient on test. The effect is probably expressed through genotype of calf since inbreeding is believed to have depressing effect on both birth weight and feed efficiency. Age at beginning of test had no significant effect on final type score, but significantly influenced the other traits.

Environmental effect appeared to be the major component of the year to year changes in calf performance. This situation explains the lag in genetic gain.

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APPENDIX

TABLE 1. ANALYSIS OF VARIANCE

Source of Variance	df	Gain on Test		ROP Test ADG		lb TDN/lb gain		Final Type Score	
		MS	P	MS	P	MS	P	MS	P
Cow Age	6	3220.5182	0.25	0.1093	0.05	0.3291	0.50	3.2916	0.10
Line	1	12219.6779	0.025	0.0598	0.25	0.1900	0.50	1.3603	0.50
Weaning Type Score	7	6314.0122	0.10	0.1170	0.05	0.1420	0.90	35.9932	0.0005
Sex of Calf	2	658827.1925	0.0005	15.9573	0.0005	27.9360	0.0005	23.4530	0.0005
Year of Test	15	17212.6468	0.0005	0.4709	0.0005	3.0643	0.0005	7.7953	0.0005
Inbreeding of Dam	1	9785.4893	0.05	0.0973	0.20	0.1109	0.50	1.1274	0.50
Inbreeding of Calf	1	22831.4473	0.001	0.2961	0.025	0.2125	0.50	8.8468	0.025
Inbreeding of Sire	1	1545.4358	0.50	0.0524	0.25	0.0039	0.90	0.1968	0.75
Initial Wt.	1	584165.6794	0.0005	0.0119	0.75	8.4130	0.0005	13.5114	0.005
Birth Wt.	1	60451.9738	0.0005	1.4553	0.0005	1.5664	0.025	1.8423	0.25
Age at Test	1	35894.6884	0.0005	0.6388	0.0005	1.6407	0.025	0.1077	0.75
Error	387	2403.7393		0.0560		0.3336		1.7494	
Total	424								

P = Probability of chance occurrence of a mean square of that size. P of 0.05 regarded as significant, 0.01 as high significant and 0.001 as very high significant deviation from chance occurrence.

TABLE 2. LEAST SQUARES MEANS, DEVIATIONS FROM LEAST SQUARES MEANS AND STANDARD ERRORS

	Gain on Test	ROP Test ADG
Mean	318.833049	1.3774
<u>Cow Age</u>		
2 years or younger	$-1.13 \pm 7.72^{a,b,c}$	$0.0649 \pm 0.037^{a,b}$
3 year olds	15.70 ± 5.85^{a}	0.0803 ± 0.029^{a}
4 year olds	$4.87 \pm 6.17^{a,b}$	$0.0147 \pm 0.029^{a,b,c}$
5-8 year olds	$3.49 \pm 6.52^{a,b}$	$-0.0039 \pm 0.031^{b,c}$
9-10 year olds	$0.33 \pm 5.41^{a,b,c}$	$0.0051 \pm 0.025^{a,b,c}$
11 year olds	$-7.08 \pm 6.88^{b,c}$	$-0.0591 \pm 0.033^{c,d}$
12 years or older	-16.18 ± 16.05^{c}	-0.1021 ± 0.077^{d}
<u>Line</u>		
Premier	12.50 ± 5.54^{a}	0.0249 ± 0.024^{a}
Mercury	-12.5 ± 5.54^{b}	-0.0249 ± 0.024^{b}
<u>Weaning Type Score</u>		
Low Good	-34.93 ± 13.37^{d}	-0.1461 ± 0.064^{e}
Av. Good	$-19.23 \pm 8.27^{c,d}$	$-0.0459 \pm 0.039^{c,d}$
High Good	$-4.10 \pm 8.21^{b,c}$	$0.0183 \pm 0.039^{a,b}$
Low Choice	$2.84 \pm 5.39^{a,b}$	$0.0265 \pm 0.025^{a,b}$
Av. Choice	$6.37 \pm 5.58^{a,b}$	$0.0446 \pm 0.026^{a,b}$
High Choice	22.78 ± 6.81^{a}	0.0985 ± 0.032^{a}
Low Fancy	$8.51 \pm 7.96^{a,b}$	$-0.0109 \pm 0.038^{b,c}$
Av. Fancy	17.76 ± 22.14^{a}	$0.0146 \pm 0.106^{a,b,d}$

Figures in the same column under the same effect with at least one common superscript are not significantly different.

* P 0.05
** P 0.01
*** P 0.001

TABLE 2 CONTINUED

	Lb. TDN/lb. Test	Final Type Score
Mean	4.2887	10.2268
Cow Age		
2 years or younger	0.0088±0.0907[a]	0.5575±0.2802[a]
3 year olds	-0.0233±0.0771[a]	0.1417±0.1641[a,b,c]
4 year olds	0.0577±0.0717[a]	0.1836±0.1660[a,b]
5-8 year olds	-0.1471±0.0767[a]	0.0877±0.1757[b,c,d]
9-10 year olds	0.0767±0.0628[a]	0.2576±0.1448[c,d]
11 year olds	-0.0060±0.0801[a]	-0.0495±0.1834[b,c]
12 year or older	0.0333±0.1868[a]	-0.4879±0.4297[d]
Line		
Premier	0.0445±0.0489[a]	-0.1191±0.1351[a]
Mercury	-0.0445±0.0589[a]	0.1191±0.1351[a]
Weaning Type Score		
Low Good	0.0605±0.1573[a]	-2.1838±0.3604[f]
Av. Good	0.0109±0.0973[a]	-1.3835±0.2238[d]
High Good	-0.1023±0.0967[a]	-0.9162±0.2214[c,d]
Low Choice	0.0194±0.0631[a]	-0.5310±0.1450[b,c]
Av. Choice	0.0148±0.0655[a]	0.2995±0.1501[b]
High Choice	-0.0147±0.0793[a]	1.1995±0.1831[a]
Low Fancy	0.1090±0.0924[a]	1.4804±0.2147[a]
Av. Fancy	-0.0588±0.2595[a]	2.0349±0.5953[e]

TABLE 2 CONTINUED

	Gain on Test	ROP Test ADG
Sex		
Bull	58.98±13.57[a]	0.2379±0.026[a]
Heifer	-73.11±12.81[b]	-0.4149±0.025[b]
Steer	14.13±18.73[c]	0.1769±0.116[a]
Year		
1950	23.27±15.02[a,b,c]	-0.0310±0.075[e,f,g]
1951	-17.45±12.07[e,f,g]	-0.1402±0.057[g]
1952	-20.77±13.15[e,f,g]	-0.1313±0.061[f,g]
1953	-6.43±11.89[d,e,f,g]	-0.0126±0.055[e,f]
1954	-2.93±12.35[c,d,e,f]	0.1016±0.059[b,c,d]
1955	-25.77± 9.88[f,g]	-0.1372±0.047[f,g]
1956	10.06±11.07[b,c,d]	0.0143±0.059[c,d,e]
1957	24.09± 8.88[a,b]	0.1349±0.043[a,b,c]
1958	2.99±10.58[b,c,d,e]	-0.0435±0.050[e,f,g]
1959	-71.36±12.47[h]	-0.3509±0.059[h]
1960	-29.51±10.04[g]	-0.1286±0.048[f,g]
1961	43.59±11.61[a]	0.2577±0.055[a]
1962	18.93± 9.17[a,c,d]	0.1060±0.043[b,c,d]
1963	17.33±10.33[a,b,c,d]	0.1360±0.048[a,b]
1964	28.93± 9.89[a,b]	0.1433±0.046[a,b]
1965	5.03±52.82[b,c,d,e]	0.0813±0.222[b,c,d,e]

TABLE 2 CONTINUED

	Lb. TDN/lb. Test	Final Type Score
<u>Sex</u>		
Bull	-0.1463 ± 0.1983^{a}	0.4325 ± 0.4542^{a}
Heifer	0.7099 ± 0.1946^{b}	1.1651 ± 0.4462^{b}
Steer	-0.5636 ± 0.3822^{c}	-1.5977 ± 0.8873^{c}
<u>Year</u>		
1950	0.5553 ± 0.1828^{h}	$-0.8933 \pm 0.4186^{f,g,h}$
1951	0.93613 ± 0.1382^{i}	-1.1557 ± 0.3168^{h}
1952	$0.0031 \pm 0.1479^{a,b,c,d}$	$-0.5908 \pm 0.3481^{f,g,h}$
1953	$-0.3967 \pm 0.1342^{e,f,g}$	-1.1128 ± 0.3151^{h}
1954	$-0.4255 \pm 0.1449^{f,g}$	$0.1906 \pm 0.3320^{c,d,e}$
1955	$-0.3045 \pm 0.1138^{d,e,f,g}$	$-0.2855 \pm 0.2657^{d,e,f,g}$
1956	$-0.4199 \pm 0.1244^{e,f,g}$	$0.5294 \pm 0.2851^{b,c}$
1957	$-9.0330 \pm 0.0145^{a,b,c,d}$	$0.1667 \pm 0.2394^{c,d,e}$
1958	$-0.1110 \pm 0.1279^{b,c,d,e}$	1.4033 ± 0.2817^{a}
1959	$0.1209 \pm 0.1438^{a,b,c}$	$0.3298 \pm 0.3299^{b,c,d}$
1960	-0.5602 ± 0.1167^{g}	$0.2669 \pm 0.2675^{b,c,d}$
1961	$-0.1788 \pm 0.1339^{c,d,e,f}$	$0.9043 \pm 0.3069^{a,b}$
1962	$0.1527 \pm 0.1056^{a,b}$	$0.4815 \pm 0.2423^{b,c,d}$
1963	0.2382 ± 0.1180^{a}	$0.2095 \pm 0.2703^{b,c,d}$
1964	0.2330 ± 0.1134^{a}	$0.0675 \pm 0.2599^{c,d,e,f}$
1965	$0.1903 \pm 0.5424^{a,b}$	$-0.5115 \pm 1.2482^{e,f,g,h}$

TABLE 2 CONCLUDED

	Gain on Test	ROP Test ADG
Regressions		
Inbreeding of dam	0.7278*	0.0022
Inbreeding of calf	-1.1713***	-0.0041*
Inbreeding of sire	0.4607	0.0025
Initial wt.	0.07703***	0.0001
Birth wt.	1.7147***	0.0083***
Age at test	0.1945	0.0008***

	Lb. TDN/lb. Test	Final Type Score
Regressions		
Inbreeding of dam	-0.0024	-0.0077
Inbreeding of calf	0.0035	-0.0227*
Inbreeding of sire	-0.0007	-0.0049
Initial wt.	0.0029***	0.0037***
Birth wt.	-0.0087*	0.0095
Age at test	-0.0013*	0.0003

TABLE 3. THE GENETIC AND ENVIRONMENTAL COMPONENTS OF VARIATION BY YEARS

	Gain on test		ROP test ADG		lb. TDN/lb. Gain		Final Type Score	
	Env.	Genetic	Env.	Genetic	Env.	Genetic	Env.	Genetic
1950	33.31	-10.0408	0.0235	0.0545	0.6918	-0.1365	-0.0060	-0.8873
1951	21.3263	-38.7760	-0.1044	-0.0358	0.8824	0.0537	-0.9075	-0.2482
1952	-30.4027	9.6353	-0.1475	0.0162	0.0913	-0.0882	-0.0799	-1.5109
1953	-8.3464	1.9187	-0.0333	0.0207	-0.2761	-0.1206	-0.9553	1.0329
1954	22.4806	25.4109	0.1339	-0.0530	-0.2577	-0.1678	0.6113	-0.4207
1955	-32.4885	6.7174	-0.1875	0.0503	-0.1160	-0.1885	-0.5020	-0.2165
1956	-19.4340	29.4915	-0.1257	0.1400	-0.3614	-0.0585	0.2560	0.2734
1957	21.6381	2.4494	0.1157	0.0192	0.0324	-0.0006	0.0108	0.1559
1958	-18.2952	21.2826	-0.1165	0.0730	0.1637	-0.0527	1.1300	0.2733
1959	-20.5597	-50.7991	0.3177	-0.6686	-0.2991	0.4200	0.5569	-0.2271
1960	-42.3149	12.8038	-0.2478	0.1192	-0.7516	0.1014	0.2231	0.0438
1961	47.1102	-3.5188	0.2013	0.0564	-0.2502	0.0714	0.8518	0.0525
1962	1.3271	17.6004	-0.0547	0.1607	0.1181	0.0346	0.0678	0.4137
1963	27.2604	-9.9277	0.1050	0.0310	0.1331	0.1051	0.3645	-0.1550
1964	13.9817	14.4494	0.0269	0.1164	0.0293	0.2037	-0.3262	0.3937
1965	26.04	-21.0111	0.0975	-0.0162	0.1612	0.0219	-1.1940	0.7825

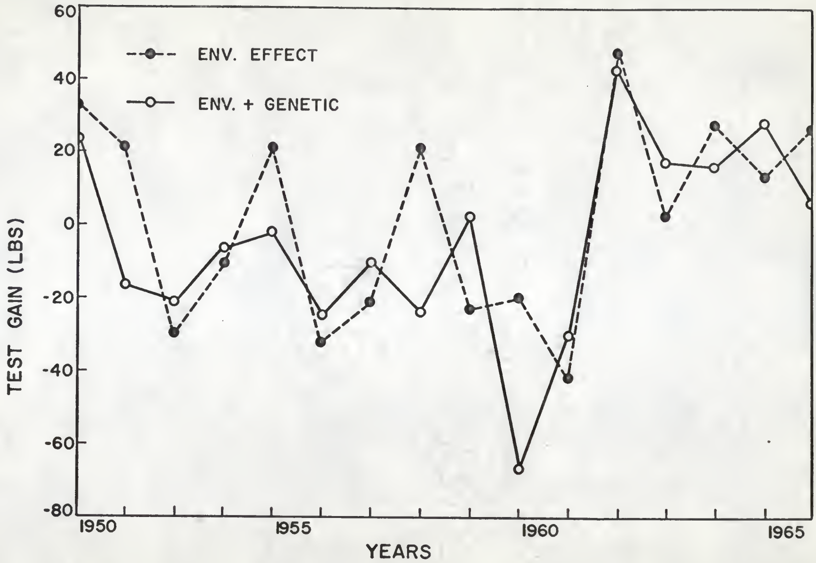

Fig. 1 Phenotypic and genetic changes (as deviation from l.s. means) on gain on test.

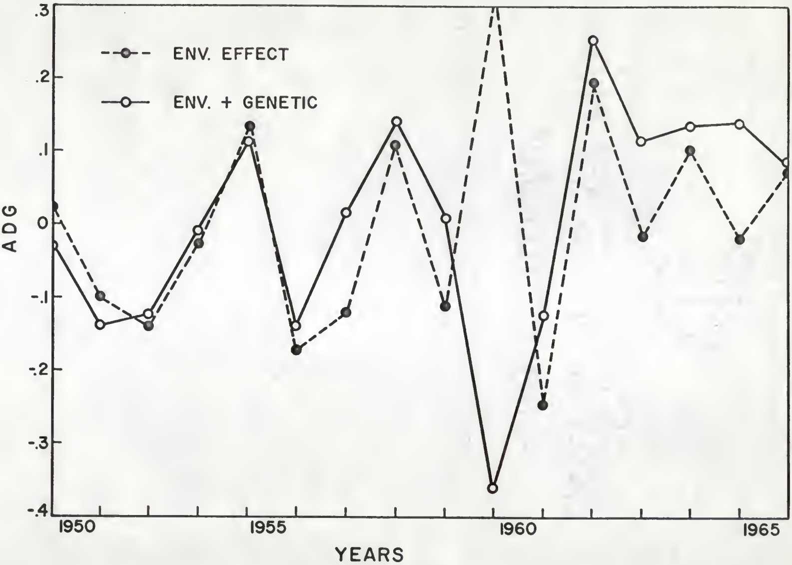

Fig. 2 Phenotypic and genetic changes (as deviations from l.s. means) on ROP Test ADG.

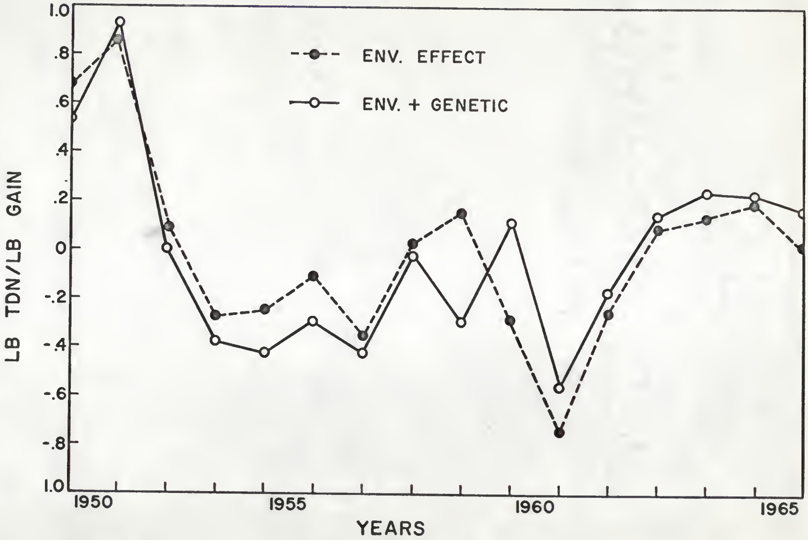

Fig. 3 Phenotypic and genetic changes (as deviations from l.s. means) on lb. TDN/lb. gain.

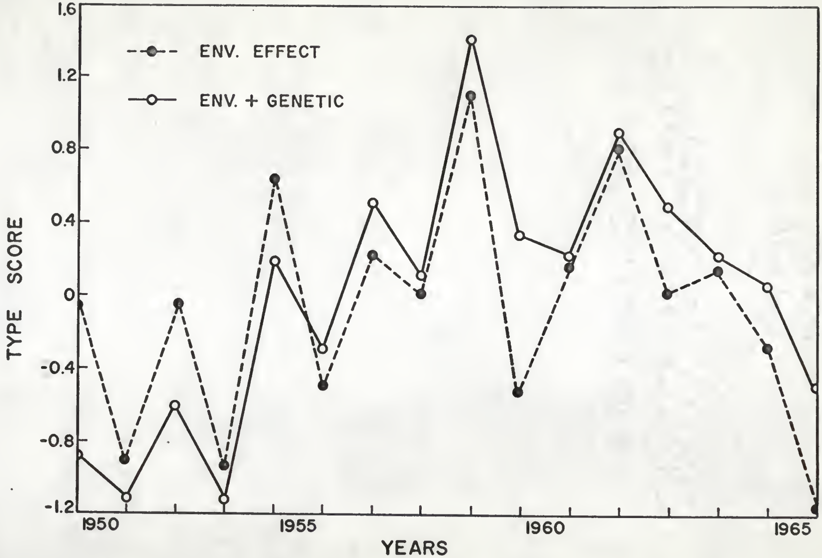

Fig. 4 Phenotypic and genetic changes (as deviations from l.s. means) on final type score.

A STUDY OF SOME PRODUCTION TRAITS IN AN INBRED HERD OF SHORTHORN CATTLE

by

JESSEE OSUOLALE AKINOKUN

B. S., Kansas State University, 1966

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

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MASTER OF SCIENCE
(Animal Breeding)

Department of Animal Husbandry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

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Data collected on 425 inbred Shorthorns on record of performance test, carried out as part of regional project NC-1, at Kansas State University Agricultural Experiment Station was analyzed for effects of several variables on gain on test, ROP test ADG, lb. TDN/lb. gain and final type score.

Age of dam significantly influenced ROP test ADG. Effect of line was significant only on gain on test. Weaning type score significantly influenced ROP test ADG and final type score. The relationship between weaning and final type score was positive and linear. All performance traits were significantly influenced by sex of calf. Heifers scored highest on conformation, bulls gained fastest and steers were the most efficient. Inbreeding of calf had no effect on lb. TDN/lb. gain but significantly influenced the other traits. Heavier calves gained more on test, scored higher at end of test, but required more TDN per pound of gain. Calves with heavier birth weight as well as those having heavier initial weight gained faster and required less TDN per pound of gain. There were essentially no genetic gains on the performance traits considered. Most of the variations from year to year were due to environmental causes.