A COMPARISON OF PROGENY SIRED BY HIGH AND LOW INDEXING HAMPSHIRE AND DUROC CENTRAL TEST STATION BOARS

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CHAPTER I

INTRODUCTION

The achievement of livestock improvement is an age old problem that probably began soon after animal domestication. Robert Bakewell, in the 1700's, became one of the first seedstock producers to develop systematic methods for livestock improvement. The advancement of livestock selection methods did not continue until after the rediscovery of Gregor Mendel's qualitative genetics work and the development of quantitative genetics by Sir R. A. Fisher and Sewell Wright. Methods for livestock improvement were developed from the theory of quantitative genetics by such individuals as J.L. Lush, L.N Hazel and G.E. Dickerson. These methods are still, for the most part, the methods of choice today.

Despite numerous technological advances in livestock selection a problem of accurately identifying outstanding replacement animals from outside one's own herd remained. Environmental effects can distort animal performance from herd to herd such that performance of animals cannot be compared directly. With the development of artificial insemination for cattle, the dairy industry has minimized this problem with the ability to use sires in many different herds. Sires with progeny in many different herds can be used as reference sires and all comparisons made between herds are done through the reference sires. This negates much of the bias due to environmental differences between herds.

Those classes of livestock that cannot or have not been able to utilize artificial insemination are at a loss when trying to make across herd comparisons. One method that has been implemented world wide is the gathering of animals at a central location for the evaluation of growth potential. This method had been used for progeny testing as well as the testing of potential parents. The central testing of prospective parents has recently come under criticism for lacking the ability to properly identify genetically superior individuals. Prominent pretest environmental effects coupled with small genetic differences between contributing herds could cause bogus ranking of potential parents and thus bias evaluation. Therefore the purpose of this study to 1) evaluate progeny sired by superior and inferior ranking central test station boars, and 2) to estimate the genetic parameters for the evaluation index along with its components.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Growth of swine is a broad category that can include discussion on several related traits. In swine, growth is often measured as gain per day (often referred to as average daily gain) or the age of an animal when reaching a certain weight. In the earlier literature growth was often measured as the weight an animal obtained at a particular age. When discussing growth, one cannot overlook the efficiency of feed utilization during the growing period or the composition of the increase in body weight. Efficiency of feed utilization in swine is often characterized as feed efficiency which is measured as either the amount of feed consumed per unit gain or the average increase in body weight per unit of feed consumed. Composition of swine growth has been historically characterized by changes in average backfat thickness at the end of a growth test. As technology has become more advanced, composition of growth can be measured as a percentage of lean cuts at a constant age or constant live weight or possibly as average lean tissue growth.

The purpose of this literature review is to examine experiments where swine were selected for changes in rate of growth, efficiency of feed utilization or composition of growth, either as single trait selection or selection for a combination of these traits as an index score. Swine improvement, as influenced by on-farm testing and central test stations, will also be discussed.

Rate of Growth

In the early literature, through the study of resemblance of relatives, growth rate was reported to be influenced by some amount of genetic control (Lush, 1936). Little information was available on how swine would respond to continuous selection for rate of growth. Mice experiments showed encouraging results when selecting for growth (Goodale, 1938).

Selection experiments where the only selection criterion was rate of growth are summarized in table 1. In an early experiment, Hampshire swine were selected for either an increased or decreased weight at a constant age (weight at 180 days for the first two generations, then weight at 150 days of age for the third and fourth generations) (Krider et al., 1946). In the fourth generation there was an average difference of 6.9 kg and 10.3 kg between the lines at 150 and 180 d, respectively. In a later report, selection for differences of weight at 154 d of age had been practiced after generation four and the rapid growth line had accumulated ten generations of selection while the slow growth line had accumulated eight generations of selection (Craig et al., 1956). Differences between the lines for 154 d weight and 180 d weight were 24.9 and 27.6 kg, respectively. The authors reported realized heritability estimates of .17 and .16 for 154 d and 180 d weight, respectively.

Another method of measuring growth rate is age to a common weight. Market animals are commonly evaluated at a slaughter weight of 100-110 kg; however, it has been suggested that boars should be evaluated at heavier weights than that of their subsequent slaughter progeny, to more accurately predict progeny performance (Kuhlers et al., 1976). This hypothesis was examined in a study where Duroc and Landrace pigs were selected for age at 105 kg, age at 135 kg, average backfat thickness at 105 kg and average backfat thickness at 135 kg for one generation (Kuhlers and Jungst, 1983). Divergent selection lines were developed for each trait. Selection was made within breed and sex. Selected parents were mated assortatively within lines and across breeds to produce crossbred progeny that were tested for age and average backfat thickness at 105 and 135 kg. Response and realized genetic parameters are summarized in tables 1 and 3. The results indicate that accuracy of selection may be improved by selecting boars at heavier weights; however, this may cause an increase in testing costs and could decrease the number of boars tested which would lower selection intensity. The realized heritability estimates reported were larger than what was ascertained when selecting for postweaning average daily gain (.126 ± .029; Rahnefeld, 1971). In this study seven generations of selection had been practiced for increased average daily gain post-weaning (42 d of age) to an average market weight of 89 kg in a population of Lacombes while a herd of Yorkshires were maintained as a random bred control. Response to selection was estimated to be 33% of predicted response. Correlated response for feed efficiency was determined to be 10% of predicted correlated response and the genetic correlation of feed efficiency (feed/gain) with average daily gain was estimated to -.346 (Rahnefeld, 1973). After 11 generations, Rahnefeld and Garnett (1976) reported that the observed response was 61% of predicted response. Predicted response was computed by multiplying an intraclass correlation estimate of heritability by the cumulative selection differential, while predicted correlated response was estimated as the ratio of the cumulative selection differential with the phenotypic variance multiplied by the genetic covariance. Realized heritability was .198. Inbreeding had little effect on the results, advancing at a rate of .6% per generation.

Efficiency of Feed Utilization

Feed costs determine seventy to seventy five percent of the total costs of slaughter hog production. Other than reproductive rate, efficiency of feed utilization is the most important concern to the commercial hog industry. To properly study feed efficiency it is necessary to determine a proper measure of feed utilization. The two most common ways of measuring feed efficiency, during post-weaning gain, are the amount of feed consumed per unit gain (feed/gain) or the average weight gained per unit of feed consumed (gain/feed). Feed/gain was found to have a smaller coefficient of variation and a greater heritability and so it is thought to be more appropriate selection criterion if feed efficiency for post-weaning growth between two constant ages or two constant weights is the selection objective (Robison and Berruecos, 1973).

Limited documentation of selection experiments for feed efficiency exists, possibly due to the difficulty of individually feeding animals so that accurate selection of new parents could be accomplished. A summary of experiments selecting for feed utilization can be found in table 2. In one of the first reported swine selection experiments Duroc pigs were individually fed and underwent five generations of selection for superior and inferior feed utilization. Pigs were started on test at 72 d of age and completed the test at 102.06 kg. In the fifth generation, superior line pigs needed .25 kg less feed per kilogram of gain than did pigs of the inferior line (Dickerson and Grimes, 1947). Actual response was 24.5% of predicted response and realized heritability was .24. This is somewhat larger than the realized heritability (.126 ± .029) that was reported after 10 generations of selection for improved feed efficiency in a closed Yorkshire herd (Bernard and Fahmy, 1970). In this study, three lines were maintained. Line One was selected for improved feed efficiency, Line Two, for improved carcass score and Line Three was selected for an improved index score that the combined the two traits. The authors reported that preliminary results indicated these two traits were uncorrelated and Line Two was a control for Line One and Line One a control for Line Two. The average inbreeding coefficient in the tenth generation for the three lines was .21; however, no significant effect due to inbreeding was found and the data were not adjusted for inbreeding effects. Four pigs from each litter were group fed while one intact male was fed separately. Intact males from the highest ranking litters were then selected as sires of the next generation. It was later established that carcass score and feed utilization were highly correlated genetically (-.52). The authors stated that the control lines were corrected for correlated response. If this correction was not complete this could bias the realized heritability estimate. Even though the realized heritability may be biased, Jungst et al. (1981) reported a realized heritability that was lower (.09 ± .08) when selecting for improved feed efficiency in Yorkshire boars. Boars were fed individually and randomly bred to group fed gilts. An unselected control line and an improved feed efficiency line were developed from a single base population and then closed during five generations of selection. Line-season-generation means were corrected for inbreeding. Correlated response for average daily gain and average backfat thickness were favorable but not significantly different from zero (.003 ± .018 kg and -.021 ± .052 cm, respectively).

Direct selection for feed/gain does not appear promising. This point is more apparent in a study where Landrace boars that were fed individually or in full-sib pairs and Landrace gilts that were fed in littermate groups of up to four were selected for seven generations for improved feed/gain. Selection for feed/gain was futile (-.0003 kg feed/kg gain$\cdot$gen^{-1}) and the realized heritability differed little from zero (.007 ± .088). Correlated response; however, was favorable for average daily gain (16 g/gen) but was not favorable for average backfat thickness (.53 mm/gen).

The realized heritabilities for feed conversion are less than those estimated from similarities among relatives. Realized heritabilities not only are a measure of genetic response, but may include effects due to random drift and inbreeding. These non-genetic factors could cause realized heritabilities for feed efficiency to be lower than expected. Another possibility could be how feed efficiency is measured. When feed efficiency is expressed as a ratio of two traits (e.g. feed consumed/weight gained) the result may not have the optimum distributional properties of its components and cause prediction of future change to be difficult (Gunsett, 1984). Selection directly for the ratio can cause greater selection pressure to be put on the numerator. Gunsett (1984) suggests selecting for the two traits of the ratio in unison using classical selection index theory. This allows for greater predictability of change for the components of feed efficiency.

Composition of Growth

The amount of lean a carcass contains is more important now than in any previous time period in the history of the swine history. Approximately 40% of the slaughter hogs are purchased on a grade and yield system which is more than ever before and this trend should continue. The swine industry must now be concerned with not only rate of growth and efficiency of growth but also with composition of growth. Selection for changes in composition of growth has historically come about through changes in average backfat thickness. Hazel and Kline (1952) developed a relatively quick and accurate method of estimating backfat thickness in the live animal. The method involved making small incisions 3.81 cm off the longissimus dorsi. This was done at three locations which were; behind the shoulder, the middle of the back and the middle of the loin. A small ruler was then inserted until reaching the connective tissue covering the muscle and a measurement was taken. The average of these three measurements were found to be highly correlated with the average of the corresponding carcass measurements (.81) and with percent lean cuts (-.499). More recently, backfat in the live animal is measured using an ultrasonic probe and measurements are taken behind the shoulder, at the last rib and at the last lumbar vertebra.

The advances of a quick and reliable method of measuring backfat thickness allowed for greater experimentation involving backfat thickness. A summary of experiments, selecting for changes of backfat thickness and body composition is given in table 3. A study that commenced in 1954 applied selection pressure to changes in average backfat thickness for eight and 10 generations in Yorkshire and Duroc populations, respectively (Hetzer and Harvey, 1967). In each population three lines were developed from a common base with one line being selected for increased average backfat thickness while the other was being selected for decreased in average backfat thickness. A third line was maintained as an unselected control. Selection was based on average backfat thickness at 79.4 kg. Effects of inbreeding were prevalent with an average inbreeding coefficient of 7.0 and 8.6% in the control populations of the Duroc and Yorkshire lines, respectively. Average inbreeding coefficients were similar, but larger than the control lines, for the increased and decreased backfat thickness lines of the Duroc (10.3 vs 10.7%, respectively) and Yorkshire (10.0 vs 10.0%, respectively) populations. The Duroc decreased backfat line was not affected by inbreeding while the increased backfat line decreased significantly in backfat thickness due to inbreeding. The opposite was true for the Yorkshire population with the decreased backfat line having significantly decreased in backfat thickness due to inbreeding and the increased backfat thickness line showing no inbreeding effects. Response was greater in the Duroc increased and decreased average backfat lines (38 and 30%, respectively) than in the corresponding Yorkshire lines (17 and 27%, respectively), due to greater selection intensity in the Duroc lines. Changes in average daily gain and weight at 140 d of age due to selection for changes in average backfat thickness were measured at generations 11 and 13 for the Yorkshire and Duroc populations, respectively (Hetzer and Miller, 1972). Selection for increased backfat thickness caused a decrease in weight at 140 d of age in both the Yorkshire and Duroc lines. Average daily gain increased, in the Duroc increased backfat line while no significant change was observed in the Yorkshire increased backfat line. Weight at 140 d of age and average daily gain improved in Duroc decreased backfat line while both declined in the Yorkshire decreased backfat line.

Estimation of response has been considered to be more valid when selection lines are compared to an unselected control line. An unselected control is maintained to monitor environmental trend and thus when select lines are compared to unselected control lines, the estimate of response is less affected by environmental causes. Gray et al. (1968) reported an experiment where a spring and fall lines for Poland China swine were selected for decreased backfat thickness for five generations; however, no unselected control line was maintained. Pigs, in this study, were measured at approximately 77 kg and selection was based on average backfat thickness adjusted to 79.4 kg. Inbreeding was unimportant in this study. Response was calculated as the difference between the means of each parental generation and that of their offspring. Net response in the spring and fall lines for average backfat thickness was -6.4 and -5.2 mm, respectively. The realized heritability estimate was .32 ± .09. This is similar to the realized heritability estimate for decreased backfat thickness (.27) reported by Berruecos et al. (1970). In this study, a line selected for decreased average backfat thickness was compared to an unselected control line developed from the same base crossbred population. Prospective parents were selected for average backfat thickness adjusted to 63.6 kg. After five generations, the average inbreeding coefficient in the select line was .138, while in the control line it was .172. Inbreeding did cause a decrease in average backfat thickness. Response, after correction for inbreeding, was -.065 ± .005 cm per generation. Correlated response for weight at 140 d of age was -.19 ± .10 kg per generation. Kuhlers and Jungst (1983) reported larger realized heritabilities for average backfat thickness than those reported in the previous studies. Divergent selection was practiced for average backfat thickness at 105 and 135 kg for one generation. Realized heritabilities were .78 ± .09 and .65 ± .10 for average backfat thickness at 105 and 135 kg, respectively.

The previous experiments were concerned with selecting for changes in backfat thickness. This can be considered as an indirect way of selecting for changes in carcass lean. Except for infrequent circumstances, direct selection will yield greater response than indirect selection; however, direct selection for carcass lean has been impractical until the development of more recent knowledge of how muscle and fat traits relate to each other and how ultrasonic equipment can measure them. Through the use of ultrasonic measurement of traits of the live animal the lean portion of the carcass can be more accurately estimated. A study, which used this knowledge, selected for increased percent lean cuts and weights of lean cuts using prediction equations which incorporated five ultrasonic backfat measurements, an ultrasonic ham fat measurement and live weight at evaluation (Leymaster et al., 1979a). These lines, along with a unselected control line, were developed from a Yorkshire herd and selected for four generations. Percent lean cuts was adjusted to 81.6 kg while weight of lean cuts was adjusted to 160 d of age. Average individual inbreeding coefficients were .177, .172, and .210 for the control, weight of lean cuts and percent lean cuts lines, respectfully (Leymaster, 1979b). Inbreeding did cause a small decrease in the traits selected; however, inbreeding was similar for the three lines. Estimates of response were not adjusted for inbreeding effects. Direct selection for improved weight of lean cuts and percent lean cuts yielded a response of .50 ± .19 kg and .38 ± .10% per generation, respectively. Correlated response for percent lean cuts in the weight of lean cuts line was important (.23 ± .09% per generation), while the correlated response for weight of lean cuts in the percent lean cuts line was trivial (-.05 ± .21 kg per generation). Estimated realized heritability for percent lean cuts and weight of lean cuts were .174 and .325, respectively. Since two selection lines were developed, two estimates of a realized genetic correlation for percent lean cuts and weight of lean cuts was calculated. Using the weight of lean cuts line as the primary select line gave rise to a realized correlation estimate that was outside the parameter space (1.22). When allowing the percent lean cuts to be the primary select line, the realized genetic correlation was estimated to be -.04. No explanation for this asymmetry was given; however, a genetic correlation of .22 ± .18 for two traits, calculated from the sires' covariance components, was reported.

Index Selection

The previous discussion concerned results of experiments where selection involved only a single trait. In swine production, monitoring several traits is necessary to optimize production efficiency. To improve several traits genetically, it has been demonstrated theoretically, that selecting for these traits simultaneously, in a selection index, will be more efficient than selecting for improvement of these traits one at a time or using independent culling levels (Hazel and Lush, 1943). A selection index incorporates the genetic and phenotypic relationships among traits and also includes the relative economic importance of each trait (Hazel, 1943). This allows development of a selection program that is pertinent to a particular producer's production system.

The theory of the selection index must be tested experimentally for wide spread acceptance. A summary of experiments assessing selection for changes in an evaluation index can be found in table 4. Sather and Fredeen (1978) reported the results of an experiment comparing pigs from a unselected control line with a selection line in which selection for an evaluation index that gave equal weight to increased average daily gain and decreased backfat continued for 15 years. Pigs from the index selection line were leaner (1.51 standard deviations less backfat), grew faster (.95 standard deviations greater average daily gain) and were more efficient (1.07 standard deviations less feed/gain). This is similar to an experiment conducted in Norway where pigs were selected for indices that emphasized increased average daily gain and decreased average backfat thickness (HP), decreased average daily gain and increased average backfat thickness (LP) or were from an unselected control during eight generations (Vangen, 1979,1980).

Correlated response in the HP line was favorable for average backfat thickness (-.70 mm/gen), average daily gain (6.4 g/gen) and feed/gain (-.0059 ± .0038 kg feed/kg gain$\cdot$gen^{-1}). In the LP line, average daily gain, average backfat thickness and feed conversion ratio increased (2.4 g/gen, 1.70 mm/gen and .0326 ± .0038 kg feed/kg gain$\cdot$gen^{-1}). The author indicated that the index in retrospect showed that the equal weightings of the two traits for the HP line index changed somewhat, causing a small increase in the weighting of average daily gain (.57) while diminishing the emphasis on average backfat thickness (-.38). A large shift was observed in the LP line with a large emphasis placed on backfat (.77) while emphasis declined on average daily gain (-.34). Realized heritability estimates for the actual selected indices were .55 ± .08 for the LP line and .42 ± .12 for the HP line. The genetic correlation between the index and feed/gain was significant and favorable for the HP line (-.15 ± .07) while being nonsignificant in the LP line (-.14 ± .11). Similar trends were reported from an artificial insemination unit in France (Ollivier, 1980). Boars in a specific artificial insemination zone (region) were evaluated on an index applying positive pressure on average daily gain and negative pressure on average backfat thickness. Response was measured using a repeat sire design. Average daily gain was evaluated from 30 to 80 kg and average backfat thickness was measured at 80 kg. Feed conversion (feed/gain) was measured on a pen basis. Favorable but nonsignificant sire genetic response were reported for average daily gain, average backfat thickness and feed/gain (table 4).

The previous experiments developed selection indices by arbitrarily assigning weights to the traits measured by the index. Classical index theory states that maximum improvement will be made in net merit, by incorporating the phenotypic and genetic relationships among the traits in the index with the relative economic emphasis of each trait when estimating the regression coefficients used in the index. In an experiment where this approach was taken in index construction, improved average daily gain from 42 d of age to 79.4 kg and decreased average backfat thickness adjusted to 90.7 kg were the traits of interest (Cleveland et al., 1982). Pigs for the Nebraska gene pool population were used in developing an unselected control line and a line selected for improved index score. After five generations of selection the average inbreeding coefficient of the litters in the select line was 5.15% while in the control line it was 1.49%. The data were not adjusted for the level of inbreeding. Index in retrospect indicated that the actual selection weights were similar to the intended selection weights. Realized heritability for the index was .19 ± .029. Correlated response, relative to the control line, for average daily gain and average backfat thickness were 11.8% and -6.8%, respectively.

Selecting for increased post-weaning average daily gain and decreased average backfat thickness in an index appears to cause favorable changes in feed efficiency. This could alleviate the difficulty of trying to directly measure feed efficiency and still improve feed utilization. Even so, there has been a large interest in incorporating measures of feed utilization in an index with growth and average backfat thickness. The recommended index for boar central test stations includes a group feed efficiency on sibs, for those test stations that measure feed efficiency (Hubbard, 1981). In Australia, an experiment was conducted with crossbred pigs which were selected for improvement of an index score which included post-weaning growth rate, individual feed utilization (feed/gain) and average backfat thickness (McPhee, 1981). Select line pigs were compared to an unselected control of similar origin. After four generations of selection, response, per generation, for the traits included in the index were .11 ± .01 kg for average daily gain, -.63 ± .01 kg feed/kg gain for feed efficiency and -.584 ± .14 mm for average backfat thickness. In Scotland, a Large White herd has been selected for ten generations for an index that includes post-weaning average daily gain, group feed/gain ratio and backfat thickness. An unselected control has been maintained for comparisons with the select line. For the entire period, no change in growth rate has been observed but feed/gain has improved 12.1% and backfat has decreased by 15.7% (Ellis and Smith, 1979). These large responses were not observed in a diverse breed composite select line (Webb and King, 1976). Nine different pure breeds and two hybrids were incorporated into a single select line which had undergone 11 generations of selections. Immigration was conducted during the entire period. An unselected control was not maintained, therefore genetic response was not estimated. Carcass length and average backfat thickness were the traits under selection for the first five generations while for the remaining generations pigs were selected for an improved index score which incorporated post-weaning average daily gain, feed/gain ratio and average backfat thickness. Significant phenotypic change, in those generations where the selection criterion was the index, was found only for backfat thickness for males and females (.05 ± .02 cm/gen) and growth rate of males ($.014 \pm .005 \mathrm{kg/d \cdot gen^{-1}}$).

On-Farm and Central Testing

On the farm performance testing and selection has become accepted world wide as the method of choice to bring about genetic improvement in the commercial swine industry. Many countries have national on-farm testing programs where measurement is taken by a government technicians and data are centrally processed. Efforts in developing extensive on-farm testing programs in this country began as early as 1945 (Bernard et al., 1954).

On-farm performance testing is relatively inexpensive when compared to progeny testing and extensive central testing. On-farm testing lends itself to a greater number of animals per herd involved in testing, when compared to the two previously mentioned methods, and allows for greater selection intensity to be placed on economically important traits. Concern exists; however, about possible increases in measurement error, improper data collection and large herd effects (Hofstra and Minkema, 1973; Standal, 1973). This has caused concern that the heritability of economically important traits would be decreased due to a possible increase in phenotypic variation. Several authors have estimated genetic parameters from data collected from on-farm performance tests and have reported estimates to be different than those found in the literature (Bernard et al., 1954; Hofstra and Minkema, 1973; David et al., 1983) while Morris et al., (1982) reported estimates of heritability for growth rate and fat thickness of farm tested pigs to be similar to literature estimates. This is in accord with reports from the Ontario Record of Performance program (Kennedy et al., 1985). Average backfat thickness and age at 90 kg for 74,661 Yorkshire, 46,347 Landrace, 16,860 Duroc and 13,697 Hampshire on-farm and station test records were analyzed within breed to estimate heritabilities that ranged for .4 to .61 and .27 to .46 for the two traits, respectively. The genetic correlation between the two traits ranged from -.43 to -.05 for the four breeds.

The possible benefits that on-farm testing and selection can have on the commercial swine industry will occur only when seedstock producers understand it advantages and actively use on-farm testing and selection in their management systems. A check of how well producers use the selection criteria of on the farm testing programs can be done from existing records. In a summary of the Wisconsin Swine Selection Cooperative (Bernard et al., 1954) it was reported that participating producers had been using only half of the possible top indexing gilts produced in their herds. Small genetic changes were found in two research herds which randomly sampled the Hampshire and Duroc breeds in Iowa (Cox and Smith, 1968). Genetic trend was positive for both the Hampshire and Duroc breeds for average backfat thickness (.49 ± .12 mm/gen and .04 ± .18 mm/gen, respectively); however, genetic trend for average daily gain from 98 to 154 kg was positive for Hampshires (.55 ± .25 kg/gen) and negative for Durocs (-.55 ± .30 kg/gen). Concern that producers may not be using selection procedures to their best advantage was also addressed in an analysis of Nebraska SPF field records (David, 1981). Small significant negative genetic trend for average backfat thickness for females was observed in three of 18 herds studied. Genetic trend for average backfat thickness was not different from zero for males in any of the 18 herds. Positive genetic trend of consequence for weight at 140 d of age was reported for three herds for females and three herds for males. Two of the herds had positive genetic trend for both males and females. None of the herds investigated had significant genetic trend for both decreased average backfat thickness and increased weight at 140 d of age. In contrast, genetic trend was found to be favorable for data consisting of both on-farm and station tested pigs for average backfat thickness and age at 90 kg for both sows and boars in the Yorkshire, Landrace, Hampshire and Duroc breeds in Ontario (Hudson and Kennedy, 1985). The Landrace breed showed the greatest genetic improvement for average backfat thickness and age at 90 kg (-.14 mm/gen and -.43 d/gen, respectively), while the Hampshire showed the least improvement for average backfat thickness (-.04 mm/gen) and the Durocs were the poorest for improvement of age at 90 kg (-.15 d/gen).

In Europe, national performance testing programs have been conducted for many years. Producer acceptance of performance testing and within herd selection would be thought to be more wide spread. Smith (1962) reported results from a Large White herd in Great Britain in which age at slaughter had not been changed but carcass length and loin fat depth had been improved. This was not the case when results for the National Pig Testing Board indicated that only 5-20% of the poorest progeny tested parents were being culled (Smith, 1965). Favorable results were reported form Norway in which genetic trend was estimated to -.7 mm and 3-5 g per year for backfat thickness and weight per day of age, respectively (Standal, 1973). It has been suggested that producers had concerned themselves with a larger number of traits, than those investigated in many of these reports when making selection decisions (Smith, 1965; Cox and Smith, 1968).

The development and use of common facilities for the performance testing of livestock assembled from many different herds has been practiced for 25 to 30 years, either as progeny testing stations or for performance testing of prospective parents. Recently, central testing stations have been criticized for their inability to influence genetic improvement. However, before criticism can be justified the test station's role must be better defined. Some authors state that the role of central test stations is to identify genetically superior individuals to be used as parents in the next generation (Dalton and Morris, 1968; Baker et al., 1984), while Brown (1975) suggested that central test stations were more of an educational tool. The former may be true for many countries of the world while the latter is probably more appropriate for the United States.

Many European countries first used central testing stations for progeny testing purposes. Several authors have looked at how genetic progress may have been influenced by these progeny testing stations. During an eight year period it was reported that the Danish Landrace decreased in average backfat thickness by two standard deviations. After examining Denmark progeny testing station records, genetic change accounted for only 20% of the decrease (Smith, 1963). Progeny testing results from a five year period in Norway indicated that genetic change caused a decrease in backfat by .42 standard deviations while feed/gain decreased .2 standard deviations and growth rate improved only .07 standard deviations (Standal, 1979). This is contrasted by genetic correlations reported for traits measured in pigs tested on the farm and in test stations during the same time period in Norway (Standal, 1977). Genetic correlations ranged, in magnitude, from .04 (-.04 for feed/gain with weight per day of age and an index using test station daily gain and average backfat) to .63 (.63 for index measured on the farm and the same index using test station records). Large favorable genetic correlations did exist for weight per day of age on the farm and average daily gain at the test station (.45), backfat thickness measured on the farm and at the end of test at the test station (.63) and the index calculated for the test station and backfat thickness measured on the farm (-.57).

Reports from Great Britain are not as encouraging when comparing boars tested in central test stations with their female sibs tested on-farm. Genetic correlations were small to moderate with the correlations for on the farm and test station weight per day of age being .23, shoulder fat thickness .49, and an index combining weight per day of age and fat thickness having a correlation of .25 for the two testing situations (Bampton et al., 1977). A later report, combining data for boars and gilts tested both on-farm and at test stations, indicated lower correlations for weight per day of age measured on the farm and at the test station (.00 for females, .04 for males), but higher correlation for shoulder fat thickness (.72 for females, .55 for males) and the aforementioned index (.75 for females, .73 for males) (Roberts and Curran, 1981). Many countries which had been using central test stations for progeny testing have since changed their central testing philosophy and use the test stations for the gain testing of boars which will be candidates for sires of the next generation (McPhee, 1973). The author states that test stations will have their greatest benefit with a

> ...test station design that is accurate in the identification of animals with superior breeding values' and a '... means of utilizing these animals for maximum benefit of the population being improved (p. 647).

Genetic improvement from the use of superior performing test station boars will be larger than using superior boars tested on farm when the heritability of the trait(s) is low, the on the farm environmental influence and the effective number of parents contributing progeny are low and the genetic differences between farms are high (McPhee, 1975).

Cox and Smith (1968) reported that there may be little, if any between herd genetic differences in Iowa for Hampshire and Duroc swine and there appears to be large environmental differences between herds. This suggests that on-farm performance testing and selection may be more beneficial; however, reports from Australia indicate that the realized heritability of an index combining average daily gain, feed/gain and measures of fat thickness, muscling and carcass qualities for sires and sons tested in central test stations was similar to its expectation of .51 (McPhee, 1974).

The pig, being a simple stomached animal must be utilize a concentrate diet for optimum growth. Countries maintaining a large commercial swine industry feed slaughter hogs a diet consisting mainly of cereal grains. This is not the case for beef cattle. Beef cattle utilize roughages readily and in many countries slaughter cattle are grown out on a diet consisting only of roughages whereas some countries (e.g. the United States) generally fatten slaughter cattle, for the most part, on high concentrate diets. Thus, different philosophies exist for beef bull central testing procedures. In those countries that do not grain feed slaughter cattle, central performance tests are conducted as grazing tests. Concerns exist that pretest environment and compensatory growth during performance test will not allow for proper identification of genetically superior bulls for growth in central grazing tests (Dalton and Morris, 1978; Morris, 1981; Baker et al., 1984). In a study conducted in New Zealand 100 Hereford bulls from several different herds over four years were alloted to four central grazing tests. Bulls for the grazing test were selected on their own record for weaning weight or their dam's previous weaning weight records. Of the bull's tested 63 had semen collected and AI progeny from dairy or dairy cross cows were produced. Progeny were suckled on foster cows or artificially reared. At three or four months of age, progeny were assembled at one of two grazing stations. Effective heritabilities for 550 d weight and total test gain were not different from zero (.07 ± .05 and .09 ± .06, respectively). The correlation between a sires' final test weight and his progenies' difference as estimated by best linear unbiased predictors was not significantly different from zero. This contrasts with reports from the Canadian Beef Sire Monitoring Program where bulls tested in feedlot central test stations had sons that were tested in a feedlot central test station (Wilton and McWhir, 1985). Bulls also had estimated predicted differences for weaning weight and yearling weight. The difference in average daily gain for bulls in a central test station from a contemporary group mean was expressed in a single trait index. The correlations of estimated predicted differences with average progeny performance in test stations were small but close to their expectations (e.g. .15 for the average daily index with the deviation of weaning weight from yearling weight predicted differences; .17 for yearling weight). The same was true for the correlations of estimated predicted differences and individual performance (.16 for the average daily gain index with the deviation of weaning weight from yearling weight predicted difference; .30 for yearling weight). Heritabilities estimated from the average son performance regressed on sire performance for sire-son groups tested in government stations were similar or larger than literature estimates (e.g. .50 ± .08 for the average daily gain index; .84 ± .12 for yearling weight); however, for those sire-son groups tested in private test stations, estimates were lower than literature estimates (e.g. .24 ± .08 for the average daily gain index; .12 ± .12 for yearling weight).

Growth traits, historically, have been found to be moderately heritable. A review of experiments selecting for growth traits confirms this point. Realized heritability estimates for rate of growth ranged from .126 to .36. Realized heritability estimates resulting from selection for changes in average backfat thickness were larger than those for growth rate (.38 to .78). Selection for changes in percent lean cuts and weight of lean cuts was successful with resulting realized heritabilities being .325 and .174, respectively. The realized genetic correlation between growth rate and average backfat thickness ranged from -.18 to .36. This conflicts somewhat with the findings in the analysis of field records where the genetic correlation between age at 90 kg and average backfat thickness ranged from -.43 to -.05 for four breeds of swine (Kennedy et al., 1985). Selection for feed efficiency proved to be disappointing with all but one study reporting very small changes in feed conversion due to selection. Realized heritabilities ranged from .007 to .24.

Selection for changes in units of an evaluation index was effective. In all but one study, appropriate changes for index units were observed along with the traits included in the index. Indices that selected for average daily gain and average backfat thickness in opposite directions of each other did show that feed/gain changed as well. Those experiments that used indices that put selection pressure on increased average daily gain and decreased backfat reported a decrease in feed/gain. This could solve the problem of trying to decrease feed/gain without measurement of the trait itself.

Improvement of growth performance in the commercial industry through on-farm testing and selection has had mixed results. In those herds where management has emphasized performance testing of growth traits reasonable results have been reported. On-Farm testing allows for a greater number of animals per herd to be tested and thus a greater selection intensity can be attained. Proper education of producers in the use of uniform whole herd testing and measurement procedures will minimize measurement error and help keep the environmental variance from changing drastically and not allow heritability to be detrimentally influenced. Central testing of potential parents does not allow for large numbers of animals to be tested and coupled with pretest environmental effects maximum genetic improvement will not occur. Fears of central test stations identifying bogus superior prospective parents are not well documented; however, problems do exist. For those producers who do not utilize on-farm performance testing and selection, utilizing superior centrally tested boars may be their best alternative.

TABLE 1. RESULTS OF EXPERIMENTS SELECTING FOR CHANGES IN GROWTH RATE

Reference	Selection Criterion	Generation	Trait	Response	Realized h^2 or r_g
Krider et al. (1946)	±180 d weight (or 150 d weight)	4	180 d weight	2.22 kg/gen	.291
			150 d weight	1.81 kg/gen	.224
Craig et al. (1956)	±154 d weight (or 180 d weight)	10	154 d weight	2.08 kg/gen	.17
			180 d weight	1.69 kg/gen	.16
Kuhlers and Jungst (1983)	± d to 105 kg	1	d to 105 kg	10.2 ± 4.5 d	.22±.09
			d to 135 kg	13.1 ± 4.8 d	.94±.07
			average backfat at 105 kg	-.13 ± .04 cm	-.24±.14
			average backfat at 135 kg	-.15 ± .06 cm	-.19±.17
	± d to 135 kg	1	d to 135 kg	21.6 ± 3.7 cm	.36±.08
			d to 105 kg	14.9 ± 3.4 cm	
			average backfat at 135 kg	-.30 ± .06 cm	-.18±.13
			average backfat at 105 kg	-.14 ± .04 cm	

TABLE 1. (Continued)

Reference	Selection Criterion	Generation	Trait	Response	Realized h^2 or r_g
Rahnefeld (1971)	average daily gain	7	average daily gain	.0082 ± .0019 kg/gen	.126±.029
Rahnefeld (1973)	average daily gain	7	feed/gain	-.583±.582 kg feed/kg gain·gen^{-1}	
Rahnefeld and Garnett (1976)	average daily gain	11	average daily gain	.013 ± .002 kg/gen	.198±.016

TABLE 2. RESULTS OF EXPERIMENTS SELECTING FOR DECREASED FEED/GAIN

Reference	Generation	Trait	Response	Realized h^2 or r_g
Dickerson and Grimes (1947)	5	feed/gain	46.3 kg feed/ 45.4 kg gain	.24
		average daily gain	.136 kg	
Bernard and Fahmy (1970	10	feed/gain	2.5%	.11±.13
Jungst et al. (1981)	5	feed/gain	-.019 ± .025 kg feed/kg gain·gen^{-1}	.09±.08
		average daily gain	.003 ± .018 kg/gen	
		average backfat	-.021 ± .052 cm/gen	
Webb and King (1983)	6	feed/gain	-.0003 kg feed/ kg gain·gen^{-1}	.007±.088
		average daily gain	16 g/gen	
		average backfat	.53 mm/gen	

TABLE 3. RESULTS OF EXPERIMENTS SELECTING FOR CHANGES IN COMPOSITION OF GROWTH

Reference	Selection Criterion	Generation	Trait	Response	Realized h^2 or r_g
Hetzer and Harvey (1967)	-average backfat	10 (Duroc)	average backfat	-30%	.48±.02
		8 (Yorkshire)	average backfat	-27%	.47±.03
	+average backfat	10 (Duroc)	average backfat	38%	.47±.02
		8 (Yorkshire)	average backfat	17%	.38±.02
Hetzer and Miller (1972)	-average backfat	13 (Duroc)	weight at 140 d of age	-.7±.02 kg/gen	
			average daily gain	2.5±8.0 g/gen	
		11 (Yorkshire)	weight at 140 d of age	-.592±1.0 kg/gen	
			average daily gain	-6.2±1.0 g/gen	
	+average backfat	13 (Duroc)	weight at 140 d of age	-.083±.096 kg/gen	
			average daily gain	2.4±.7 g/gen	

TABLE 3. (Continued)

Reference	Selection Criterion	Generation	Trait	Response	Realized h^2 or r_g
Hetzer and Miller (1972)	+average backfat	11 (Yorkshire)	weight at 140 d of age	-.21±.106 kg/gen	
			average daily gain	.1±.9 g/gen	
Kuhlers and Jungst (1982)	±average backfat at 105 kg	1	average backfat at 105 kg	.57±.05 cm	.78±.09
			average backfat at 135 kg	.67±.06 cm	.90±.04
			d to 105 kg	2.5±3.4 d	.22±.09
			d to 135 kg	-.1±3.9 d	-.03±.11
	±average backfat at 135 kg	1	average backfat at 135 kg	.61±.06 cm	.65±.10
			average backfat at 105 kg	.41±.04 cm	
			d to 135 kg	1.4±3.5 d	.36±.08
			d to 105 kg	-1.5±3.4 d	

TABLE 3. (Continued)

Reference	Selection Criterion	Generation	Trait	Response	Realized h^2 or r_g
Leymaster et al. (1979b)	+percent lean cuts	4	percent lean cuts	.38±.10%/gen	.325
			weight of lean cuts	-.05±.21 kg/gen	-.04
	+weight of lean cuts	4	weight of lean cuts	.50±.19 kg/gen	.174
			percent lean cuts	.23±.09%/gen	1.44

TABLE 4. RESULTS OF EXPERIMENTS SELECTING FOR CHANGES IN INDEX POINTS

Reference	Traits Used in Index	Generation	Trait	Response	Realized h^2 or r_g
Vangen (1979)	+average daily gain -average backfat	8	index		.42±.12
			average daily gain	2.54±1.64 g/gen	
			average backfat	-.57±.11 mm/gen	
	-average daily gain +average backfat	8	index		.55±.08
			average daily gain	.29±1.78 g/gen	
			average backfat	1.66±.13 mm/gen	
Vangen (1980)	+average daily gain -average backfat	8	feed/gain	-.0059±.0038 kg feed/kg gain·gen^{-1}	
	+average daily gain -average backfat	8	feed/gain	.0326±.0038 kg feed/kg gain·gen^{-1}	

TABLE 4. (Continued)

Reference	Traits Used in Index	Generation	Trait	Response	Realized h^2 or r_g
Ollivier (1980)	+average daily gain -average backfat	10	average daily gain	.012±.008 g/gen	
			average backfat	-.54±.39 mm.gen	
			feed/gain	-.04±.458 kg feed/kg gain·gen^{-1}	
Cleveland et al. (1982)	+average daily gain -average backfat	5	index	5.76±.30/gen	.19±029
			average daily gain	.014±.002 kg/gen	
			average backfat	-.045±.01 cm/gen	
McPhee (1981)	+average daily gain -feed/gain -average backfat	4	average daily gain	.03 kg/gen	
			feed/gain	-.15 kg feed/kg gain·gen^{-1}	
			average backfat	1.38 mm/gen	

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CHAPTER III

A COMPARISON OF PROGENY SIRED BY HIGH AND LOW INDEXING HAMPSHIRE AND DUROC CENTRAL TEST STATION BOARS: PROGENY PERFORMANCE

Summary

A two-year study was conducted to compare progeny performance of high (HI) and low (LI) indexing central test station boars purchased in Iowa, Missouri, Nebraska and Oklahoma. Boars were evaluated on an index that was recommended by the National Swine Improvement Federation and combined average daily gain, pen feed efficiency on half or full sibs and probe backfat thickness. The first year, twenty four Hampshire boars were bred to three- and four-breed cross gilts of Duroc, Yorkshire, Landrace and Spotted breeding. Two Hampshire boars did not sire progeny. A disease outbreak the first farrowing season caused severe death loss and reduced performance. From 198 litters, 826 pigs completed performance gain test. The second year 25 Duroc boars were randomly mated to gilts produced the previous year. Two Duroc boars did not sire progeny. From 181 litters, 1,070 pigs completed the gain test. Progeny comparisons for the two sire groups for pre-weaning traits were inconsistent. No significant differences were found for postweaning average daily gain (ADG), probe backfat thickness (PBF) or any carcass traits measured when comparing progeny of the two Hampshire boar groups. Progeny sired by the HI Hampshire boars were on the average 5.66 units better for the evaluation index (I) but spring born HI sired pigs were .24 kg feed/kg gain less efficient and ate .28 kg more feed/d than LI Hampshire sired pigs. Gilt progeny of HI Duroc boars were .03 kg greater for ADG, .79 mm greater for PBF, and 3.93 units greater for I than LI Duroc sired gilts. Barrow progeny of LI Duroc boars were gained .01 kg/d faster better had .59 mm more PBF and were no different for I than barrows sired by HI Duroc boars. Barrows had more muscle (.56%) and less average backfat (1.47 mm) when sired by HI Duroc boars. Maternal grandsire effects were important for Duroc sired pigs with gilts and pigs born in the spring growing .01 kg better for ADG when having a HI maternal grandsire yet barrows and fall born pigs of HI maternal grandsires were .02 kg less for ADG when compared to pigs with LI maternal grandsires. Barrows with LI maternal grandsires had heavier hams and more lean cuts as percentage of slaughter weight (.29 kg and 8.0%, respectively) and fall born barrows with LI maternal grandsires had heavier shoulders, loins, bellies and total lean cuts (.35, .64, .36 and 1.34 kg, respectively) than did barrows with HI maternal grandsires.

(Key Words: Central Test Station Boars, Index, Progeny Performance.)

Introduction

Genetic improvement of economically important traits should be a primary objective of seedstock producers. Genetic improvement can be made efficiently through within herd selection; however, it is sometimes necessary to introduce outside replacement animals to supplement a selection program and to lessen inbreeding effects. In the swine industry this is usually accomplished through the purchase and immigration of boars. It is difficult to make those across herd selection decisions when boars, for the most part, sire progeny only within one herd and genetic differences are confounded with herd environmental effects. One solution to this problem has been central performance testing for growth and carcass traits of boars assembled from different herds. Central test stations have been used for the testing of boars for 25 to 30 years. A goal of central test stations is to demonstrate to producers testing procedures but their continued existence is justified only if they accurately identify superior herd boars. Little documentation of the actual effectiveness of central test stations exists. Reports from stations in Australia indicate that boars that tested above average for an index which incorporated average daily gain, feed efficiency and loin fat thickness produced sons that were above average for the index in their respective herds (McPhee, 1974). In a study from New Zealand, a Hereford bull's performance in a central grazing test station did not resemble his progenies' subsequent performance (Baker et al., 1984) while reports from Canada indicate that the relationship between a beef bull's performance in a central test station with his progenies' subsequent performance was near to what was expected (Wilton and McWhir, 1985). It was the purpose of this research to compare the performance of progeny sired by high and low indexing central test station boars.

Material and Methods

This project was undertaken at the Oklahoma Agricultural Experiment Station to evaluate progeny sired by boars purchased form central test stations in Iowa, Missouri, Nebraska and Oklahoma. Twelve to thirteen boars were purchased for each of two breeding seasons each year for two years, starting in the fall of 1979. Hampshire boars were purchased the first year and Duroc boars were purchased the second. A summary of the purchased boars' performance is given in table 1. A minimum of two boars were purchased from each test station with one boar having a minimum index value of 118 while the other had an index value less than 90. Boars were evaluated for an index recommended by the National Swine Improvement Federation for test stations measuring pen feed efficiency, $(I=100+60(G-\bar{G})-75(F-\bar{F})-70(B-\bar{B}))$, where G represents average daily gain, F represents feed efficiency (kg feed consumed/kg gain) and B represents live backfat thickness (Hubbard, 1981). Symbols with bars over them represent contemporary central test station averages.

Upon purchase, the boars were transported to the Southwestern Livestock and Forage Research Station located near El Reno, Oklahoma. The first year 12 Hampshire boars were purchased for each breeding season and mated to three- and four-breed cross gilts consisting of Duroc, Yorkshire, Landrace and Spotted breeding. These gilts were produced from mating two-breed cross females to a purebred or crossbred boar of dissimilar breed makeup. A more complete description of three- and four-breed pig development is given by Buchanan and Johnson (1984) and McLaren (1985). Gilts were classified into five breeding of dam groups, based on their breed of sire (one group of gilts sired by each breed of boar as a purebred and one group which included all four-breed cross gilts). Two of the six high indexing Hampshire boars purchased for the first breeding season were infertile and did not sire progeny.

The second year, 25 (13 high indexing and 12 low indexing) Duroc boars were purchased and randomly bred to gilts produced from the previous years' matings. Dams were grouped into one of two breeding of dam categories depending on her sire's classification as either a high or low indexing boar. Two of the high indexing boars purchased for the fall of 1981 were infertile and did not sire progeny.

The two breeding seasons each year were confined to eight weeks beginning in mid May and mid November. Gilts were hand mated and remained in dirt lots during gestation. Gilts were individually fed 2.25 kg of a 14% crude protein sorghum grain (IFN 4-04-444) based diet. At 109 d of gestation, gilts were brought into a central farrowing barn and housed in individual farrowing crates on slatted floors. A total of 379 litters were farrowed during the two years. The number of litters for each sire group by breeding of dam combination are given in table 2. Sire groups were designated as boars being high or low indexing.

Three to seven days after farrowing, dams with their litters, were moved to a nursery where they remained in individual pens until weaning at approximately 42 d post-farrowing. Creep feed was made available to the piglets and boars were castrated at three weeks of age. At weaning, dams were removed from the nursery pens and the litters remained for two weeks. Pigs were then moved to one of two confinement feeding barns for gain test. Gilts and barrows sired by Hampshire boars were penned in groups of 12 to 20 pigs/pen by sire group. Barrows and gilts sired by Duroc boars were penned in similar size clusters in breeding of dam by sire group combinations. Pigs were allowed to consume a 16% crude protein corn, (IFN 4-02-931) or hard, red winter wheat (IFN 4-05-268) based diet ad libitum, until the average weight of the pigs in a pen was approximately 54 kg. For the remainder of the test period, pigs were allowed to consume a 14% crude protein diet ad libitum. Pigs were weighed off test weekly at a weight of approximately 100 kg.

If pigs weighed more than 77 kg they were measured for backfat thickness with an ultrasonic probe. Measurements were taken behind the shoulder, at the last rib and the last lumbar vertebra. One randomly chosen barrow from each litter was slaughtered after gain test for carcass evaluation. The first year 132 barrows were slaughtered while the second year 136 barrows were slaughtered.

Traits measured. Litter traits, individual pig pre-weaning traits, growth traits, feed consumption, feed efficiency and carcass traits were investigated. Litter traits measured were: litter size born, litter size at 21 d post-farrowing, litter size at weaning, litter weight at birth, litter weight at 21 d post-farrowing, litter weight at weaning, survival rate from birth to 21 d post-farrowing, survival rate from birth to weaning and survival rate from 21 d post-farrowing to weaning. Pig pre-weaning traits are; pig birth weight, pig weight at 21 d of age and pig weaning weight. Growth traits reported are average daily gain from approximately eight weeks of age to 100 kg and probe backfat thickness adjusted to 100 kg. Probe backfat thickness is the numerical average of ultrasonic measurements taken behind the shoulder, at the last rib and at the last lumbar vertebra. Feed efficiency, measured as kg feed consumed/kg live weight gain and average daily feed consumed (kg/d) were measured on a pen basis. The first year 66 pens were included in the analysis while the second year 81 pens were measured. The index described earlier was calculated for each pig finishing test and having been probed for backfat thickness. The measurement for feed efficiency of each pen was assigned to each pig in the pen and then the pigs' observations for average daily gain, feed efficiency and probe backfat thickness were deviated from the year-season-barn means and incorporated into the index. The first year 730 records were included in the index analysis, while the second year year, 1032 records were analyzed for the evaluation index. Carcass traits for barrows that were chosen randomly from each litter were shoulder weight, ham weight, loin weight, belly weight, carcass length, total lean cuts (shoulder, loin and ham), total lean cuts as a percentage of slaughter weight and carcass weight, fat thickness at the 10th rib and an average for carcass backfat thickness measured at the first rib, the tenth rib and the last lumbar vertebra, loin eye area and percent muscle adjusted to 72.58 kg carcass weight.

Feeding trials were superimposed on the growing pigs and the gestating gilts (Maxwell et al., 1982; Maxwell et al., 1983ab; Luce et al., 1983) during the continuance of this study. The data were corrected additively if significant treatment differences were reported. A few pens were not assembled by sire group the first year and by sire group by breeding of dam combinations the second year. These pigs were included in the data set for average daily gain and probe backfat thickness; however, they were excluded for the analysis of feed efficiency, average daily feed consumed and the evaluation index.

Statistical Analysis. One generation of selection for the evaluation index was practiced during the first year of this study. The second year was a replicate of the first year completing one generation of selection. Each year was analyzed separately for progeny performance.

A linear model was assumed for the analysis of all traits. The zero sum restriction was placed on the model for the fixed effects and the usual distributional assumptions were presumed for the random effects. The models for the litter size traits, litter weight traits, the survival rate traits as well as the carcass traits were the same except for the covariates used. Fixed effects were, an unknown constant common to all observations, season farrowed (spring or fall), sire group (a boar being high or low indexing), breeding of dam (differing crossbred dam groups the first year, having a high or low indexing sire the second year) and all possible two way interactions. The term of sire nested within season farrowed by sire group combinations was assumed to be random and the estimated ratio of the residual variance to the sire variance was included. Estimates taken from the literature of the variances were used when available, otherwise, estimates of the variances were obtained from the data. Sire equations were then absorbed. The solutions for the fixed effects are generalized least squares constants when the variances are known (Harvey, 1982). The covariables used in the analysis of the litter survival rate traits are as follows. Weight change of the dam during pregnancy was used as a covariate for litter size at birth and 21 d post-farrowing and survival rate from birth to 21 d post-farrowing. Weight change of the dam from 109 d of gestation to weaning was used as a covariate for litter size and weight at weaning, survival rate from birth to weaning and survival rate from 21 d post-farrowing to weaning. A second covariate of litter size born was included in the analysis of litter weight at birth and survival rate from birth to to 21 d post-farrowing and from birth to weaning while litter size at 21 d post-farrowing was included as a second covariate in the analysis of litter weight at 21 d post-farrowing and survival rate from 21 d post-farrowing to weaning. In the analysis of litter weight at weaning the second covariate was litter size at weaning. The covariable for the carcass traits analysis, except for carcass length, carcass backfat thickness, loin eye area and percent muscle was slaughter weight. The four previously mentioned carcass traits were corrected for slaughter weight before analysis.

The model for the pre-weaning pig traits included the same fixed effects as the litter traits, except the effect of sex and all two way interactions with sex were included as fixed effects. The random effect for pre-weaning pig traits was litter nested within combinations of sire group by breeding of dam by season farrowed. The components for the ratio of the residual variance to the litter variance were estimated from the data. Litter equations were absorbed. Covariables for birth weight were weight change of the dam during pregnancy and litter size born. Covariables for 21 d weight were weight change of the dam during pregnancy and litter size at 21 d post-farrowing. The covariables for pig weaning weight were weight of the dam from 109 d of gestation to weaning and litter size at weaning.

The linear model used to analyze average daily gain and probe backfat thickness was the same as that used in the analysis of the pre-weaning pig traits except the fixed effect of feeding barn was included as a blocking variable and the covariable used was the beginning test weight within sire group. The model used to analyze the evaluation index was similar to the one used for average daily gain and probe backfat thickness except the fixed effect of feeding barn was not included since the component traits of the index were deviated from year-season-barn means and no covariable was used.

Feed efficiency and average daily feed consumed were analyzed using a fixed model. The model used for the first year's data included the fixed effects of feeding barn, season farrowed, sire group and the interaction of sire group with season farrowed. Covariables included were average on-test weight and the average number of pigs per pen. Analysis for the second years' data was similar except breeding of dam, due to the penning of pigs by sire group breeding of dam combinations, was included in the model, along with the interactions of breeding of dam with season farrowed and sire group.

Results and Discussion

Pre-weaning and Litter Traits. Mean squares for pre-weaning litter and pig traits are given in tables 3-6. For the litters sired by Hampshire boars, sire group by breeding of dam effects were important ($P<.10$) for litter size born and pig weaning weight while the interaction of sire group with season farrowed was significant for birth weight. Sire group effects were important ($P<.10$) for survival rate from birth to weaning and pig 21 d weight.

Low indexing boars bred to gilts of 50% Duroc breeding sired larger litters (2.02 pigs) at birth than high indexing boars (table 7). The opposite was true with 50% Landrace and 50% Spotted dams which had larger litters at birth when mated to high indexing boars (1.37 and 1.4 pigs, respectively). A severe disease outbreak occured during the first farrowing season of this study. Extreme death loss and poor performance resulted during the first year. Other differences for litter size at birth between high and low indexing boars within breeding of dam groups were not significant.

Pigs born in the fall were heavier at birth (.07 kg) (table 8) when Hampshire low indexing boars were their sires. No significant difference was found among sire groups for birth weight of spring born pigs. In a study where pigs were selected for an index that placed positive emphasis on increased average daily gain and decreased backfat thickness, birth weight increased by .18 kg (Sather and Fredeen, 1978). Birth weight also increased when pigs were selected for an index that applied selection pressure to increased average daily gain and decreased backfat thickness (Vangen, 1980) and when pigs were selected for increased weight at 150 or 180 d of age (Krider et al., 1946). Birth weight declined when divergent selection was practiced for feed efficiency (Dickerson and Grimes, 1947) and when pigs were selected for an index which emphasized decreased average daily gain and increased backfat thickness (Vangen, 1980). No significant changes in birth weight was detected when divergent selection was practiced for 180 or 154 d weight (Craig et al., 1956) or when crossbred pigs were selected for decreased backfat thickness (Berruecos et al., 1970). Litters sired by high indexing Hampshire boars tended to have a greater survival rate from birth to weaning (6.02%; P<.10) (table 8), but pigs in those litters were .18 kg lighter for 21 d weight (table 7). In an earlier study, pig weight at 21 d of age was found to increase when divergent selection was practiced for weight at 150 and 180 d of age (Krider et al., 1946) or weight at 180 or 154 d of age (Craig et al., 1956). Weight at 21 d of age decreased when pigs were selected for an index which emphasized decreased average daily gain and increased backfat, yet no significant change was reported when pigs were selected for an index which emphasized increased average daily gain and decreased backfat (Vangen, 1980). Small differences ($P>.10$) were observed for pig weaning weight when comparing sire groups within breeding of dam groups except for those from 50% Landrace gilts whose pigs were 1.48 kg heavier (table 7) when sired by low indexing Hampshire sires. Rahnefeld (1973), selecting for increased average daily gain, did report increases in weight at 42 d of age, as did Sather and Fredeen (1978) selecting for an improved index which stressed increased average daily gain and decreased backfat. In contrast, no significant change was reported for weight at 42 d of age in two lines in which one was selected for an index which put selection pressure on improved average daily gain and decreased backfat thickness while the other stressed decreased average daily gain and increased backfat thickness (Vangen, 1980). Pre-weaning traits not previously mentioned did not exhibit significant sire group differences and are listed in table 8.

Pigs born the second year were the product of high and low indexing Duroc boars randomly mated to gilts from the previous years' matings. The sire group by season farrowed interaction was important ($P<.10$) for survival rate from birth to weaning and from 21 d post-farrowing to weaning, pig birth weight, 21 d weight and weaning weight (tables 5 and 6). Improvement in survival (from birth to weaning and

21 d post-farrowing to weaning) was detected for litters sired by low indexing Duroc boars and born in the fall (7.52 and 4.52%, respectively), compared to those fall born litters sired by high indexing Duroc boars. Conversely, no significant sire group differences were observed for these two traits for spring born litters. Pigs born in the fall and sired by high indexing Duroc boars were heavier for pig birth weight and 21 d weight with high indexing boars having pigs with a .06 and .27 kg advantage for the two traits, respectively. No significant sire group advantage was observed in spring born pigs for 21 d weight or weaning weight but pigs sired by low indexing Duroc boars tended to be heavier at birth (.02 kg; $P<.10$) when compared to pigs sired by high indexing boars. Litters produced in a line of pigs selected for an index combining average daily gain and carcass score were superior for litter weight at birth and at 21 d of age when compared to single trait lines selecting for the index component traits (Fahmy and Bernard, 1972). Litter weights were not affected by selection when pigs were propagated for increased percent lean cuts (DeNise et al., 1983) or in Duroc and Yorkshire populations which were selected for increased and decreased backfat thickness (Hetzer and Miller, 1970). The supremacy of pigs born in the fall and sired high indexing boars was evident for pig weaning weight (.59 kg). This trend was not as apparent for litter weight at weaning with high indexing litters being non-significantly heavier than litter sired by low indexing

boars with the generalized least squares means being 84.10±1.65 and 82.00±1.61, respectively).

Several traits did exhibit an important sire group by breeding of dam interaction (table 10). Breeding of dam in this case refers to the gilts sire designation as a high or low indexing boar. Those gilts which had a high indexing Hampshire sire and were mated to a low indexing Duroc boar had larger litters at 21 d post-farrowing (1.11), at weaning (1.27) and improved survival rate from birth to 21 d post-farrowing (7.12%) and from birth to weaning (9.68%) when compared to gilts which had high indexing sires and were mated to high indexing boars (table 10). In contrast, comparisons of sire groups among litters that had low indexing maternal grandsires, high indexing boars sired litters which tended to be larger at 21 d post-farrowing (.38; P<.10) and did have a higher survival rate form birth to 21 d post-farrowing (4.13%) when compared to litters that were sired by low indexing boars. No significant differences were detected for litter size at weaning when gilts which had low indexing sires were mated to high or low indexing Duroc boars. The interaction of breed of dam with sex was important (P<.10) for pig weight at 21 d of age. Gilt pigs which had high indexing maternal grandsires were .35 kg heavier at 21 d of age than those gilts which had low indexing maternal grandsires (table 11). The opposite was true for boar pigs, with those having a high indexing maternal grandsire being .1 kg lighter than boar piglets with low indexing maternal grandsires.

Litters from 50% Duroc females were smaller at birth when sired by high indexing Hampshire boars, yet when high indexing Hampshire boars were mated to 50% Landrace and Spotted gilts, litters were larger at birth than those sired by low indexing Hampshire boars. Litters sired by high indexing Duroc boars and born in the fall had lower survival rates yet were heavier than those sired by low indexing Duroc boars. Those litters which had a high indexing maternal grandsire and a low indexing Duroc sire were superior for litter size and survival to weaning, compared to those litters which had a high indexing maternal grandsire and Duroc sire. Among those litters with a low indexing maternal grandsire, no significant difference existed between litters sired by high and low indexing Duroc boars for litter size weaning and survival rate to weaning.

Postweaning Performance. Mean squares and for postweaning performance of pigs sired by Hampshire boars are presented in table 12. Generalized least squares means by sire group for average daily gain, probe backfat thickness and the evaluation index are given in table 13. Differences among sire groups for average daily gain and probe backfat thickness were not significant. The interactions of breeding of dam with season farrowed and sex were important (P<.10) for average daily gain and probe backfat thickness, respectively, while the interaction of breed of dam with season farrowed was significant for probe backfat thickness, as well. Orthogonal contrasts within season farrowed among breeding of dam groups were calculated (table 14). Of those pigs born in the spring the average of those with 50% Duroc and Spotted dams grew faster than the average of those pigs with 50% Yorkshire and Landrace dams. Spring born pigs which had 50% Duroc dams grew faster than those with 50% Spotted dams and pigs with 50% Yorkshire dams were inferior for average daily gain when compared to pigs with dams of 50% Landrace breeding. Of the fall born pigs, offspring from the four-breed cross gilts were superior gaining compared to the average of pigs from three-breed cross gilts. In contrast to the spring, the average of pigs born to 50% Landrace and Yorkshire dams was larger for average daily gain when compared to the average of pigs with 50% Duroc and Spotted dams. McLaren (1985) reported that Duroc breed of dam effects were larger than Spotted breed of dam effects which were larger than Yorkshire and Landrace for average daily gain. This was the case for spring born pigs but conflicted with the results of fall born pigs. The interactions of breeding of dam with season farrowed and with sex were significant for probe backfat thickness (tables 14 and 15). Except for barrows from 50% Landrace gilts being fatter than barrows from 50% Yorkshire gilts (table 15) contrasts among breeding of dam groups within season farrowed and sex were not significant. Fall born pigs were fatter than spring born pigs in all cases, but the magnitude among breeding of dam groups differed thus causing the interaction to be significant. Barrows were fatter than gilts in all breed of dam groups but, the magnitude among breed of dam groups differed. The rank of the four breeds, fattest to leanest, for breed of dam effects for probe backfat thickness is Duroc, Landrace, Spotted and Yorkshire (McLaren, 1985).

Differences between sire groups were significant for the evaluation index with progeny sired by high indexing Hampshire boars averaging 5.66 index points higher than those progeny sired by low indexing boars. If we assume a heritability of .37 for the evaluation index (calculated from parameters given by Hubbard, 1981) and a weighted average selection differential for the boars of 44.00 index points, predicted response is 8.14 index units. Actual response is 69.54% of predicted response. Cleveland et al. (1982) selecting for an index that applied pressure to increased average daily gain and probe backfat thickness reported response to the index to be 5.76±.30 units per generation.

Mean Squares and for feed efficiency and consumption are found in table 16. The interaction of sire group by season farrowed was significant for both feed efficiency and average daily feed consumed. Pigs with high indexing Hampshire sires that were born in the spring ate .28 kg more feed per day and were less efficient (.24 kg feed/kg gain) than pigs with low indexing sires (table 17). The opposite was true for fall born pigs sired by high indexing Hampshire boars being more feed efficient and consuming less feed per day when compared to pigs sire by low indexing sires and born in the fall; however, these differences were not significant. McPhee (1981) selecting for an index which emphasized improved improved average daily gain, decreased feed efficiency and loin fat thickness, reported a phenotypic advantage of the select line over the control line of -.2 kg feed/kg gain for the last two generations.

Mean Squares and for postweaning performance traits of Duroc sired pigs are given in table 18. The sire group by sex interaction was significant for average daily gain, probe backfat thickness and the evaluation index while the interactions of breeding of dam with season farrowed and sex were significant for average daily gain as well. Gilt progeny sired by high indexing boars grew .03 kg/d faster, were .79 mm fatter at 100 kg and had an average evaluation index score which was 3.93 units greater than their females contemporaries sired by low indexing boars (table 19). In contrast, barrow progeny sired by high indexing boars grew .01 kg/d less, were .59 mm leaner and had an average index score that was not significantly different from their counterpart barrows with low indexing sires. Averaging over sexes response for the index was 2.30. The weighted average selection differential for the boars was 51.46 index units, therefore selection response was 24.16% of predicted response. In a study in which pigs were selected for an index that put equal emphasis on increased average daily gain and decreased backfat thickness, average daily gain and backfat thickness improved 6.7 g and -.7 mm per generation, respectively (Vangen, 1979). Cleveland et al. (1982), selecting for an index calculated by classical methods which emphasized improved average daily gain and decreased backfat thickness, achieved changes of .014 kg and -.045 cm per generation, respectively.

The maternal grandsire (high vs low index) did influence pig growth. Pigs born in the spring that had a high indexing maternal grandsire grew .01 kg/d faster than those pigs with a low indexing maternal grandsire (table 20). The opposite was true in the fall for those pigs with high indexing maternal grandsires growing .02 kg less/d than their contemporaries with low indexing maternal grandsires. Gilts having high indexing maternal grandsires grew .01 kg/d faster than their female contemporaries with low indexing maternal grandsires, while barrows having high indexing maternal grandsires gained .02 kg/d less than barrows having low indexing maternal grandsires.

Similar to several of the litter size and survival rates, feed efficiency and average daily feed consumed had an important ($P<.10$) sire group by breeding of dam interaction (table 21). High indexing boars mated to gilts with high indexing sires had pigs that ate .24 kg less feed per day and were more efficient (.35 kg/kg gain) than those produced from matings of low indexing boars to dams that had high indexing sires (table 22). This was not true of progeny sired by high indexing boars with a low indexing maternal grandsire. Those pigs ate more (.31 kg/d) and were less efficient (.33 kg feed/kg gain) when compared to pigs with a low indexing sire and maternal grandsire.

Pigs sired by high indexing Hampshire boars were not significantly better for average daily gain and probe backfat thickness, yet spring born pigs of high indexing Hampshire boars ate more and were less efficient than pigs sired by low indexing Hampshire boars and born in the spring. Pigs sired by the high indexing Hampshire boars were better for the evaluation index. Gilts sired by high indexing Duroc boars were faster growing, fatter, yet greater for the evaluation index than gilts sired by low indexing Duroc boars, while barrows sired by high indexing Duroc boars were slower growing, leaner but were not significantly different for the evaluation index, when compared to barrows sired by low indexing Duroc boars. Pigs having a high indexing maternal grandsire and sired by a high indexing Duroc boar ate less and were more efficient than pigs with a high indexing maternal grandsire and low indexing Duroc sire. Among those pigs with a low indexing maternal grandsire, progeny of low indexing Duroc boars ate less and were more efficient than those sired by high indexing Duroc boars.

Carcass Traits. The relationship of postweaning growth, feed efficiency and live backfat with carcass traits has been suggested to be favorable (Warwick and Legates, 1979) and thus an important part of this study was to determine if central tested boars evaluated for growth, feed efficiency and backfat thickness produce progeny with improved carcass traits. Sire group effects were not significant for any of the carcass traits measured in the first year (tables 23 and 24). Generalized least squares means by sire group for the carcass traits of Hampshire sired pigs are listed in table 25. Breeding of dam effects were important (P<.10) for loin weight while the interaction of breed of dam with season farrowed was important (P<.10) for belly weight (table 23) loin eye area and total lean cuts as a percentage of carcass weight (table 24). Orthogonal contrasts were conducted within the breeding of dam for loin weight (table 26). Of the four comparisons made, only the comparisons of the average of barrows from three-breed cross dams with barrows from four-breed cross dams was significant with four-breed cross females producing barrows with .23±.13 kg heavier loins. Orthogonal comparisons were made across dams groups within season for those carcass traits with important breeding of dam by season farrowed interactions (table 27). Four-breed cross gilts had barrows born in the spring with lighter bellies and more total lean cuts as a percentage of carcass weight when compared to the average of the barrows produced by the three-breed cross dams. The 50% Spotted dams produced barrows in the spring that had more total lean cuts as a percentage of carcass weight and lighter bellies when compared to spring born barrows of the 50% Duroc dams. This agrees with the reports of McLaren (1985) who reported similar rankings for breed effects of Spotted and Duroc dams for these two traits. The author also stated that the breed effects for belly weight would be larger for progeny of Yorkshire dams when compared to progeny of Landrace dams. This was not true among fall born barrows with those pigs having 50% Landrace dams having heavier bellies than those with 50% Yorkshire dams.

Mean squares for carcass traits of Duroc sired progeny are presented in tables 28 and 29. Carcass backfat thickness, tenth rib fat thickness and percent muscle exhibited important (P<.10) sire group effects. Barrows sired by high indexing boars tended to have 1.34 mm less fat (P<.10) at the tenth rib, 1.47 mm less average carcass backfat and .56% more muscle (table 30). Belly weight and total lean cuts as a percentage of carcass weight showed an important (P<.10) sire group by season farrowed interaction. Barrows sired by high indexing boars that were born in the spring had .34 kg lighter bellies and had 1.27% more total lean cuts on a carcass weight basis (table 31). Among fall born barrows, no significant sire group difference for belly weight was observed but barrows sired by low indexing boars had 1.08% more total lean cuts on a carcass weight basis when compared to barrows sired by high indexing boars. Breeding of dam effects were relevant for ham, shoulder, loin and belly weights, total lean cuts and total lean cuts as a percentage of slaughter weight. Barrows with low indexing maternal grandsires had ham weights that were .29 kg larger and also had 8.09% more lean cuts on a slaughter weight basis (table 32). The same was true among fall born barrows for shoulder, loin and belly weights and total lean cuts; however, no significant breeding of dam effects were prevalent among spring born barrows for those traits (table 32). Differences among carcass traits of barrows were not significant between high and low indexing sire groups. Barrows sired by high indexing Duroc boars were leaner and had more muscle than barrows with low index Duroc sires.

General Discussion

To determine the effectiveness of central test stations, its purpose must be better defined. If the purpose of the central test station is only to demonstrate uniform performance testing methods, then a study such as this is unnecessary. While central test stations were originally developed partially as an educational tool, more recently they have become a source of prospective herd boars for commercial producers. It is then necessary to evaluate the ability of central test stations to identify superior sires.

Sire group (high vs low indexing) effects were important for several of the pre-weaning traits. The differences observed are difficult to interpret and not consistent from year to year. The evaluation index and feed utilization traits exhibited an important sire group effect during both years while average daily gain and probe backfat thickness did not the first year. Selection was placed on the evaluation index and the correlated response of the component traits of the index are not expected to demonstrate the magnitude of the index response. The small difference that exists between barrows sired by high and low indexing Duroc boars for average daily gain, probe backfat thickness and the evaluation index may be a further indication that boars may need to be tested to heavier weights so to be able to better predict the performance of their subsequent barrow progeny (Kuhlers and Jungst, 1983). It may also be that variation in pretest management of the boars diminished the effectiveness of selection. Sire group effects were of greater importance the second year than the first for carcass traits. Barrows sired by high indexing Duroc boars were leaner and had more muscle than barrows sired by low indexing Duroc boars.

Breeding of dam effects were important for several of the pre-weaning and some of the growth performance and carcass traits. The different dam groups represented the first year have been reported to differ for reproductive and maternal traits and exhibit different breed effects for performance and carcass traits (Johnson, 1980). In some instances the differences observed in this study may be more influenced by the small number of observations per subclass than real differences among the breeding of dam groups. A puzzling result was the sire group by breeding of dam interaction observed during the second year. Pigs that had a maternal grandsire that differed in index classification from their own sire were often above the average of their counterparts whose sires and grandsires had the same index classification, not only for the litter traits but for the performance and carcass traits as well.

This study did not yield a clear advantage of the progeny performance of superior as opposed to inferior central test station boars. The disease problem did cause death loss and reduced performance and may have reduced the observed differences. Some of the large season of birth effects could also have been an indication of some of the underlying disease influences.

A possible important source of variation, station of origin, was not included in the analysis. Since so few boars were purchased per sale and different breeds of boars were used for the two different years, it would be impossible to accurately determine the genetic differences of the boars offered for sale at the different central test stations.

In an attempt to determine the worth of high indexing boars, an economic efficiency analysis was undertaken using a microcomputer farrow to finish enterprise budget software program (Miller et al., 1984). A 90 sow farrow to finish total confinement budget (Williams, 1985) was used as a model. Some of the general inputs included interest rate at

12%, 48 hours per week for labor, protein supplement at $220.50 per metric ton, corn purchase price of $3.00 per bushel, 5 boars maintained, 2 litters farrowed per sow per year with 8 pigs weaned, 1.5% death loss from weaning to market, a 2% death loss in the sow herd and a base slaughter hog selling price of $1.04 per kg. Average boar purchase price was set at $500.00. Changes in the average number of days to market weight resulted in changes in overhead costs of $.15 per head per day. It was estimated that pigs sired by high indexing boars compared to low indexing boar progeny took 3.2 fewer days to reach an average market weight of 104 kg, had 1.78 mm less fat at the tenth rib but took .07 kg more feed to gain a kilogram of body weight based on average production figures of 180 days of age at 104 kg, 27.94 mm of fat thickness at the tenth rib and 3.5 kg of feed needed to gain a kilogram of body weight. Market selling price for slaughter hogs was adjusted for tenth rib fat differences using the recommendation of the Pork Value Program (NPPC, 1982). Comparing net profit of the two budgets, the system using high indexing boars could have increased boar cost by $72.00 per boar and had the same profit level as the system using low indexing boars.

As an educational tool, central test stations serve as a useful demonstration to producers of uniform testing methods. As a market for potential herd boars, commercial producers purchasing high indexing central test station boars can expect small progeny improvement for the index value per generation and over time favorable correlated response of the indexes' component traits. However, boar test stations test such a small percentage of the boars needed by the commercial industry per year that any benefit from central testing of boars will only influence a small portion of the swine industry. Seedstock producers practicing extensive and deliberate on-farm testing and selection of economically important traits should experience greater genetic improvement and have a larger impact on the industry than would occur from using performance tested boars from a central test station.

Table 1. AVERAGE PERFORMANCE OF BOARS PURCHASED FROM TEST STATIONS

Season[a]	Breed	No.	Average Daily Gain (kg)	Feed Efficiency (kg feed/kg gain)	Probed backfat thickness (mm)	Index
			High Indexing Boars			
Fall 1979[b]	Hamp	6	1.03	2.34	18.54	131
Spring 1980	Hamp	6	.99	2.55	17.53	128
Fall 1980	Duroc	7	1.03	2.25	19.56	137
Spring 1981[b]	Duroc	6	1.08	2.52	18.08	129
			Low Indexing Boars			
Fall 1979	Hamp	6	.82	2.62	18.80	83
Spring 1980	Hamp	6	.85	2.84	18.03	87
Fall 1980	Duroc	6	.87	2.59	22.10	83
Spring 1981	Duroc	6	.89	2.68	21.60	83

[a] Hampshire boars were purchased the first two seasons while Duroc boars were purchased the last two.

[b] Two boars did not leave offspring.

Table 2. NUMBER OF LITTERS BY SIRE AND DAM GROUP

	Year 1		Year 2	
	Sire Group		Sire Group	
Breeding of Dam	High Index	Low Index	High Index	Low Index
1/2 Duroc (D)	11	14		
1/2 Yorkshire (Y)	13	12		
1/2 Landrace (L)	13	12		
1/2 Spotted (S)	12	14		
1/4 D:1/4 Y:1/4 L:1/4 S	47	50		
High Index[a]			45	46
Low Index[a]			45	45

[a] Designation For Sire of the Dam.

Table 3. GENERALIZED LEAST SQUARES ANALYSIS OF VARIANCE FOR LITTER TRAITS OF HAMPSHIRE SIRED LITTERS

Trait[a]		LSB	LS21	LS42	LWB	LW21	LW42	SUR21	SUR42	SUR36
Source	df	Mean Squares								
Season Farrowed (YRS)	1	68.05**	16.87^{+}	60.71**	.56	15.96	3968.08**	2.97	7295.53**	6517.15**
Sire Group(SG)	1	.02	4.35	8.05	2.96	26.22	2.53	582.18	1036.93^{+}	168.05
Breeding of Dam(BOD)	4	11.71^{+}	7.32	3.88	1.35	25.86	170.79	299.79	318.63	342.48
YRS x SG	1	.83	.01	2.81	2.13	2.75	7.11	16.07	186.40	279.45
YRS x BOD	4	15.31*	10.94^{+}	7.60^{+}	3.55	2.59	192.99	238.57	365.18	170.10
SG x BOD	4	13.20^{+}	1.86	3.62	1.44	8.87	120.39	139.66	414.32	176.25
Covariate(A)[b]	1	25.69*	13.22^{+}	221.65**	81.26**	268.26**	55.56	188.17	13183.48**	1130.37^{+}
Covariate(B)[b]	1				1173.94	12609.16**	49210.63**	9893.53**	21000.24**	2551.48**
Residual	181	5.68	4.65	3.56						
Residual	180				2.81	27.07	126.97	346.91	343.36	311.21

[a] LSB=Litter size born; Litter size at 21 d of age; LS42=Litter size at weaning; LWB=Litter weight at birth (kg); LW21=Litter weight at 21 d of age (kg); LW42=Litter weight at weaning (kg); Sur21=Survival rate from birth to 21 d of age; Sur42=Survival rate from birth to weaning; Sur36=Survival rate from 21 d of age to weaning;

[b] For LSB, LS21, Sur21, LWB and LW21 A=wt. change of dam during pregnancy; For LS42, Sur 42, Sur 36 and LW42 A=wt. change of dam during lactation; For LWB, Sur21, SUR42 B=LSB; For LW21, Sur36 B=LS21; For LW42 B=LS42;

**P<.01

*P<.05

$^{+}$P<.10

Table 4. GENERALIZED LEAST SQUARES ANALYSIS OF VARIANCE FOR INDIVIDUAL PRE-WEANING TRAITS FOR HAMPSHIRE SIRED PIGS

Trait[a]		BW	W21	W42
Source	df	Mean Squares		
Season Farrowed (YRS)	1	.18	1.43	704.32**
Sire Group (SG)	1	.33*	6.67*	4.52
Breeding of Dam(BOD)	4	.06	3.00*	10.60^{+}
Sex	1	.58**	.12	.11
YRS x SG	1	.30*	.01	.04
YRS x BOD	4	.21*	.68	25.59**
YRS x Sex	1	.44*	.06	.09
SG x BOD	4	.10	.79	15.34*
SG x Sex	1	.15	.25	4.28
BOD x Sex	4	.15^{+}	.49	2.65
Covariate(A)[b]	1	6.18**	39.52**	1.93
Covariate(B)[b]	1	8.44**	144.68**	150.22**
Residual	c	.07	1.05	5.62

[a] BW=Birth weight (kg); W21=Weight at 21-d of age (kg); W42=Weight at weaning (kg)

[b] For BW and W21 A=wt change during pregnancy; For W42 A=wt change during lactation; For BW B=LSB; For W21 B=LS21; For W42 B=LS42;

[c] For BW, df=1856; For W21, df=1301; For W42, df=1153.

**P<.01

*P<.05

$^{+}$P<.10

Table 5. GENERALIZED LEAST SQUARES ANALYSIS OF VARIANCE FOR LITTER TRAITS OF DUROC SIRED LITTERS

Trait[a]		LSB	LS21	LS42	LWB	LW21	LW42	SUR21	SUR42	SUR36
Source	df	Mean Squares								
Season Farrowed (YRS)	1	17.16^{+}	33.28**	48.11**	38.92**	774.50**	3927.86**	832.36*	2131.00**	122.61^{+}
Sire Group (SG)	1	4.93	4.81	14.39*	.92	25.02	131.39	83.36	589.69*	170.50*
Breeding of Dam (BOD)	1	.14	.13	5.75	11.61*	125.27^{+}	92.67	39.38	36.58	24.59
YRS x SG	1	9.27	2.04	.32	4.12	66.56	218.73	43.36	364.03**	167.78*
YRS x BOD	1	.14	.57	1.27	.00	.75	39.64	70.16	76.92	33.78
SG x BOD	1	8.67	24.42**	16.99**	.55	13.49	1.23	1395.00**	1319.80**	1.46
Covariate (A)	1	34.79*	21.82*	230.55**	38.99**	198.91*	583.34^{+}	109.83	6839.81**	371.73*
Covariate (B)	1				818.50**	12206.05**	27449.67**	5704.66**	930.60**	103.93^{+}
Residual	173	5.46	3.43	2.22						
Residual	172				2.27	33.40	161.30	172.89	152.36	40.06

[a] LSB=Litter size born; Litter size at 21 d of age; LS42=Litter size at weaning; LWB=Litter weight at birth (kg); LW21=Litter weight at 21 d of age (kg); LW42=Litter weight at weaning (kg); Sur21=Survival rate from birth to 21 d of age; Sur42=Survival rate from birth to weaning; Sur36=Survival rate from 21 d of age to weaning;

[b] For LSB, LS21, Sur21, LWB and LW21 A=wt. change of dam during pregnancy; For LS42, Sur 42, Sur 36 and LW42 A=wt. change of dam during lactation; For LWB, Sur21, SUR42 B=LSB; For LW21, Sur36 B=LS21; For LW42 B=LS42;

**P<.01

*P<.05

$^{+}$P<.10

TABLE 6. GENERALIZED LEAST SQUARES ANALYSIS OF VARIANCE FOR INDIVIDUAL PRE-WEANING TRAITS FOR DUROC SIRED PIGS

Trait		BW	W21	W42
Source	df	Mean Squares		
Season Farrowed (YRS)	1	3.66^{**}	88.65^{**}	470.95^{**}
Sire Group (SG)	1	.11	2.99	15.65^{+}
Breeding of Dam (BOD)	1	1.00^{**}	14.56^{**}	5.23
Sex	1	$.68^{**}$	1.64	13.12
YRS x SG	1	$.43^{**}$	7.80^{*}	21.04^{*}
YRS x BOD	1	.02	.05	.32
YRS x Sex	1	.04	.46	.32
SG x BOD	1	.10	.78	10.47
SG x Sex	1	.05	1.20	4.60
BOD x Sex	1	.00	5.10^{*}	3.78
Covariate (A)[b]	1	2.59^{**}	24.02^{**}	80.04^{**}
Covariate (B)[b]	1	12.04^{**}	38.89^{**}	217.88^{**}
Residual	c	.06	1.31	5.74

[a] BW=Birth weight (kg); W21=Weight at 21-d of age (kg); W42=Weight at weaning (kg)

[b] For BW and W21 A=wt change during pregnancy; For W42 A=wt change during lactation; For BW B=LSB; For W21 B=LS21; For W42 B=LS42;

[c] For BW, df = 1781; For W21, df = 1386, For W42, df = 1186,

$^{**}P<.01$

$^{*}P<.05$

$^{+}P<.10$

Table 7. GENERALIZED LEAST SQUARES MEANS FOR IMPORTANT SIRE GROUP INTERACTIONS OF PRE-WEANING TRAITS OF HAMPSHIRE SIRED PIGS

		Sire Group			
Trait	Breeding of Dam	High Index	Low Index	Standard Error	Significant Difference
Litter size born	50% Duroc(D)	7.61 (11)[a]	9.63 (14)	.70	**
Pig weight at weaning (kg)		10.31 (66)	10.42 (68)	.33	
Litter size born	50% Yorkshire(Y)	8.54 (13)	9.29 (12)	.99	
Pig weight at weaning (kg)		10.53 (72)	10.09 (71)	.33	
Litter size at birth	50% Landrace(L)	9.79 (13)	8.42 (12)	.69	*
Pig weight at at weaning(kg)		9.36 (75)	10.84 (62)	.34	**
Litter size at birth	50% Spotted(S)	10.77 (12)	9.37 (14)	.68	*
Pig weight at weaning(kg)		9.85 (81)	9.51 (93)	.30	
Litter size at birth	25%D:25%Y: 25%L:25%S	9.72 (47)	9.84 (50)	.37	
Pig weight at weaning		10.28 (287)	10.33 (303)	.16	
	Season Farrowed				
Pig birth weight	Spring	1.40 (456)	1.40 (518)	.02	
Pig birth weight(kg)	Fall	1.39 (449)	1.46 (458)	.02	**

[a] Number of observations in parentheses.

**P<.01.

*P<.05.

Table 8. GENERALIZED LEAST SQUARES MEANS BY SIRE GROUP FOR PRE-WEANING TRAITS OF HAMPSHIRE SIRED LITTERS

	Sire Group			
Item	High Index	Low Index	Standard error	Significant Difference
No. of litters	96	102		
Litter size at 21 d	6.79	6.41	.28	
Litter size at weaning	6.22	5.69	.26	
Survival rate from birth to 21 d (%)	74.82	70.44	2.38	
Survival rate from birth to weaning(%)	68.98	62.96	2.45	+
Survival rate from 21 d to weaning	91.79	89.34	2.34	
Litter weight at birth (kg)	13.14	13.48	.24	
Litter weight at 21 d (kg)	31.89	32.75	.61	
Litter weight at weaning (kg)	60.05	60.36	1.55	
Pig weight at 21 d (kg)	4.80 (652)[a]	4.98 (672)	.05	*

[a] Number of observations in parentheses.

*P<.05

+P<.10

Table 9. GENERALIZED LEAST SQUARES MEANS FOR SIRE GROUP BY SEASON FARROWED OF SOME PRE-WEANING TRAITS OF DUROC SIRED LITTERS

		Sire Group			
Item	Season Farrowed	High Index	Low Index	Standard Error	Significant Difference
No.of Litters	Spring	47	44		
Survival rate from birth to weaning (%)		80.67	81.56	2.10	
Survival rate from 21 d to weaning		98.32	98.35	1.09	
Pig birth weight (kg)		1.40 (448)[a]	1.42 (471)	.02	+
Pig 21 d weight (kg)		5.45 (363)	5.51 (371)	.07	
Pig weaning		11.74 (315)	11.78 (312)	.17	
No of litters	Fall	43	47		
Survival rate from birth to weaning		69.22	76.74	2.19	**
Survival rate from 21 d to weaning		94.05	98.57	1.14	**
Pig birth weight (kg)		1.32 (419)	1.26 (456)	.02	**
Pig 21 d weight (kg)		5.00 (312)	4.73 (353)	.07	**
Pig weaning weight (kg)		10.43 (259)	9.84 (313)	.17	**

[a] Number of observations in parentheses.

$^{**}P<.01$

$^{*}P<.05$

$^{+}P<.10$

Table 10. GENERALIZED LEAST SQUARE MEANS OF SIRE GROUP BY BREEDING OF DAM FOR LITTER SIZE AND SURVIVAL FOR DUROC SIRED LITTERS

Item	Breeding of Dam	Sire Group High Index	 Low Index	Standard Error	Significant Difference
No of Litters	High Index Sire	45	46		
Litter size at 21 d		7.15	8.26	.29	**
Litter size at weaning		7.02	8.29	.24	**
Survival rate from birth to 21 d (%)		75.12	82.29	2.08	**
Survival rate from birth to weaning (%)		72.66	82.34	2.00	**
No of Litters	Low Index Sire	45	45		
Litter size at 21 d		7.84	7.46	.29	+
Litter size at weaning		7.28	7.31	.24	
Survival rate from birth to 21 d (%)		81.71	77.58	2.09	**
Survival rate from birth to weaning (%)		77.23	75.95	2.00	

$^{**}P<.01$

$^{*}P<.05$

$^{+}P<.10$

Table 11. GENERALIZED LEAST SQUARES MEANS FOR 21 DAY WEIGHT OF DUROC SIRED PIGS

	Breeding of Dam			
Sex	High Index Sire	Low Index Sire	Standard Error	Significant Difference
Gilt	4.96(349)[a]	5.31(357)	.07	**
Boar	5.16(342)	5.26(351)	.07	*

[a] Number of observations in parentheses.

$^{**}P<.01$

$^{*}P<.05$

Table 12. GENERALIZED LEAST SQUARES ANALYSIS OF VARIANCE FOR PERFORMANCE TEST TRAITS OF HAMPSHIRE SIRED PIGS

Trait		Average Daily Gain	Probe Backfat Thickness	Index
Source	df	Mean Squares		
Barn	1	.012	11.92	
Season Farrowed (YRS)	1	$.145^{**}$	428.75^{**}	13.51
Sire Group (SG)	1	.008	4.10	2310.778^{**}
Breeding of Dam (BOD)	4	.014	7.73	274.95
Sex	1	$.894^{**}$	599.16^{**}	2036.94^{**}
YRS x SG	1	.006	9.68^{**}	105.46
YRS x BOD	1	$.048^{**}$	16.23^{+}	706.81^{*}
YRS x SEX	1	$.059^{**}$	2.55	1066.80^{*}
SG x BOD	1	.001	5.85	90.97
SG x SEX	1	.011	10.01	20.19
BOD x SEX	1	.009	2.37^{*}	373.19
On-test Weight	1	2.26^{**}	1.07	
Residual	a	.008	8.11	267.85

[a] Average daily gain, df=843; Probe backfat thickness df=802; Index df=707.

$^{**}P<.01$

$^{*}P<.05$

Table 13. GENERALIZED LEAST SQUARES MEANS BY SIRE GROUP OF POST-WEANING PERFORMANCE OF HAMPSHIRE SIRED PIGS

	Sire Group			
Trait	High Index	Low Index	Standard Error	Significant Difference
Average Daily Gain (kg)	.65(434)[a]	.64(434)	.01	
Probe Backfat Thickness (mm)	23.08(409)	23.29(417)	.21	
Index	103.44(352)	97.78(378)	1.38	**

[a] Number of observations in parentheses.

**P<.01

Table 14. GENERALIZED LEAST SQUARES MEANS OF SEASON FARROWED BY BREEDING OF DAM COMBINATIONS FOR AVERAGE DAILY GAIN AND PROBE BACKFAT THICKNESS OF HAMPSHIRE SIRED PIGS

		Breeding of Dam				
Items	Season Farrowed	50% Duroc(D)	50% Yorkshire(Y)	50% Landrace(L)	50% Spotted(S)	25%D:25%Y 25%L:25%S
No.	Spring	43	46	50	51	170
Average (1) Daily gain(kg)		.72 ±.02[a]	.62 ±.02	.67 ±.02	.66 ±.02	.66 ±.01
Probe backfat Thickness (mm)		22.36 ±.52	20.98 ±.57	22.78 ±.54	22.27 ±.51	21.84 ±.28
	Fall					
No.		62	64	48	63	271
Average (3) Daily gain(kg)		.61 ±.02	.66 ±.02	.63 ±.02	.59 ±.02	.64 ±.01
No.		61	63	39	53	250
Probe backfat(4) Thickness (mm)		23.49 ±.47	24.67 ±.47	24.75 ±.56	24.15 ±.52	24.58 ±.23

Contrast Coefficient					Probability of a Larger t-statistic			
					1	2	3	4
-1/4	-1/4	-1/4	-1/4	1	.39	.40	.04	.37
-1/2	1/2	1/2	-1/2	0	.06	.47	.04	.14
-1	0	0	1	0	.00	.65	.48	.41
0	-1	1	0	0	.05	.49	.33	.92

[a] Standard error

Table 15. GENERALIZED LEAST SQUARES MEANS OF BREEDING OF DAM BY SEX COMBINATIONS FOR PROBE BACKFAT THICKNESS OF HAMPSHIRE SIRED PIGS

	Breeding of Dam				
Sex	50% Duroc(D)	50% Yorkshire(Y)	50% Landrace(L)	50% Spotted(S)	25%D:25%Y 25%L:25%S
No.	49	61	54	43	229
Gilt(1)	21.77	22.13	22.02	22.64	21.99
	±.46	±.44	±.46	±.51	±.22
No.	55	48	35	61	191
Barrow(2)	24.08	23.51	25.50	23.77	24.43
	±.45	±.49	±.55	±.44	±.24

Contrast Coefficient					Probability of a Larger t-statistic	
					1	2
-1/4	-1/4	-1/4	-1/4	1	.66	.63
-1/2	1/2	1/2	-1/2	0	.92	.30
-1	0	0	1	0	.33	.45
0	-1	1	0	0	.91	.05

Table 16. LEAST SQUARES ANALYSIS OF VARIANCE FOR FEED UTILIZATION TRAITS OF HAMPSHIRE SIRED PIGS

		Feed Efficiency	Average Daily Feed Consumed
Trait Source	df	Mean Squares	
Barn	1	2.29^{**}	1.37^{**}
Season Farrowed(YRS)	1	.27	$.26^{+}$
Sire Group (SG)	1	.09	.07
YRS x SG	1	$.40^{+}$	$.44^{*}$
ON-Test Weight	1	2.40^{**}	.01
Number of Pigs/Pen	1	.00	$.23^{*}$
Residual	59	.14	.08

**P<.01

*P<.05

Table 17. LEAST SQUARES MEANS FOR FEED CONSUMPTION AND UTILIZATION OF HAMPSHIRE SIRED PIGS

Item	Season Farrowed	Sire Group High Index	Sire Group Low Index	Standard Error	Significant Difference
No of pens	Spring	10	14		
Feed efficiency (kg feed / kg gain)		3.06	2.82	.12	**
Average daily feed consumed (kg)		1.80	1.52	.09	**
No of pens	Fall	21	21		
Feed efficiency (kg feed / kg gain)		3.06	3.15	.08	
Average daily feed consumed (kg)		1.79	1.89	.06	

**P<.01

Table 18. GENERALIZED LEAST SQUARES ANALYSIS OF VARIANCE FOR PERFORMANCE TEST TRAITS OF DUROC SIRED PIGS

Trait		Average Daily Gain	Probed Backfat Thickness	Index
Source	df	Mean Squares		
Barn	1	.074**	95.95**	
Season Farrowed(YRS)	1	.055**	319.42**	1.03
Sire Group(SG)	1	.018+	1.54	765.32*
Breeding of Dam (BOD)	1	.010	.43	441.51
Sex	1	.604**	622.72**	1911.30**
YRS x SG	1	.002	.18	95.12
YRS x BOD	1	.030*	13.72	731.80*
YRS x SEX	1	.002	62.98*	776.47*
SG x BOD	1	.001	5.27	318.21
SG x SEX	1	.106**	107.17**	1506.60**
BOD x SEX	1	.038*	.79	543.67+
On-test[b] Weight	1	1.273**	113.40**	
Residual	[a]	.006	11.41	201.51

[a] Average daily gain df=1067; Probe backfat thickness df=1056; Index df=1021.

[b] Regression of on-test weight is within sire group. Mean square is of the average of both regressions.

**P<.01

*P<.05

+P<.10

Table 19. GENERALIZED LEAST SQUARES MEANS OF SIRE GROUP BY SEX OF POST-WEANING PERFORMANCE OF DUROC SIRED PIGS

		Sire Group			
Trait	Sex	High Index	Low Index	Standard Error	Significant Difference
	Gilt				
Average Daily gain (kg)		.69 (307)[a]	.66 (322)	.01	**
Probe Backfat Thickness (mm)		21.98 (303)	21.19 (319)	.23	**
Index		101.64 (284)	97.71 (316)	.98	**
	Barrow				
Average Daily gain (kg)		.72 (217)	.73 (235)	.01	*
Probe Backfat Thickness (mm)		22.92 (216)	23.51 (232)	.27	**
Index		101.91 (201)	102.25 (231)	1.46	

[a] Number of observations in parentheses

** $P<.01$

* $P<.05$

Table 20. GENERALIZED LEAST SQUARES MEANS OF BREEDING OF DAM INTERACTION FOR AVERAGE DAILY GAIN (KG) OF DUROC SIRED PIGS

Season Farrowed	Breeding of Dam High Index Sire	 Low Index Sire	Standard Error	Significant Difference
Spring	.70(254)[a]	.69(324)	.006	*
Fall	.70(283)	.72(220)	.007	**
Sex				
Gilts	.68(299)	.67(330)	.005	*
Barrows	.72(238)	.74(214)	.006	**

[a] Number of observations in parentheses.

**P<.01

*P<.05

Table 21. LEAST SQUARES ANALYSIS OF VARIANCE FOR FEED UTILIZATION TRAITS OF DUROC SIRED PIGS

Trait Source	df	Feed Efficiency Mean Squares	Average Daily Feed Consumed
Barn	1	.04	.09
Season Farrowed (YRS)	1	7.54**	3.04**
Sire Group (SG)	1	.01	.02
Breeding of Dam (BOD)	1	.23	.05
YRS x SG	1	.04	.11
YRS x BOD	1	.01	.00
SG x BOD	1	2.05+	1.36*
On-test weight	1	.02	.03
No. of pigs/pen	1	7.50**	3.35**
Residual	71	.64	.32

**P<.01

*P<.05

+P<.10

Table 22. LEAST SQUARES MEANS FOR FEED CONSUMPTION AND UTILIZATION OF DUROC SIRED PIGS

Item	Breeding of Dam	Sire Group High Index	 Low Index	Standard Error	Significant Difference
No. of Pens	High Index Sire	19	20		
Feed Efficiency (kg feed/ kg gain)		2.61	2.96	.19	**
Average daily Feed consumed (kg)		1.84	2.08	.13	*
No. of Pens	Low Index Sire	19	23		
Feed Efficiency (kg feed/ kg gain)		3.06	2.73	.19	*
Average daily feed consumed (kg)		2.16	1.85	.13	**

**$P<.01$

*$P<.05$

Table 23. GENERALIZED LEAST SQUARES ANALYSIS OF VARIANCE FOR CARCASS PARTS OF HAMPSHIRE SIRED PIGS

Trait Source	df	Shoulder Weight(kg)	Ham Weight(kg)	Loin Weight(kg)	Belly Weight(kg)	Carcass Length(cm)
		Mean Squares				
Season Farrowed (YRS)	1	4.990**	4.34**	17.13**	.41	41.68**
Sire Group(SG)	1	.002	.57	.03	.03	8.44
Breeding of Dam (BOD)	4	.566	.04	.86+	1.44**	5.42
YRS x SG	1	.108	.02	.06	.01	2.85
YRS x BOD	4	.348	.37	.57	.55*	2.17
SG x BOD	4	.112	.02	.27	.09	.62
Slaughter Weight	1	12.035**	14.43**	18.95**	8.76**	
Residual	115	.407	.43	.48	.20	3.69[a]

[a] Residual df for carcass length is 116.

**P<.01

*P<.05

+P<.10

Table 24. GENERALIZED LEAST SQUARES ANALYSIS OF VARIANCE FOR INDICATORS OF CARCASS LEAN FOR HAMPSHIRE SIRED PIGS

Trait[a] Source	df	TLC	LCLW	LCCW	CBF	LEA	Permu
		Mean Squares					
Season Farrowed (YRS)	1	48.46^{**}	40.33^{**}	55.52^{**}	144.33^{**}	45.63^{*}	45.97^{**}
Sire Group (SG)	1	.57	.71	2.42	.05	3.12	.10
Breeding of Dam (BOD)	1	6.08	5.49	14.29^{+}	4.62	2.36	.81
YRS x SG	1	.16	.14	.01	.73	2.02	.31
YRS x BOD	1	.05	5.31	17.04^{*}	8.95	16.37^{+}	1.63
SG x BOD	1	.61	.86	1.35	3.08	10.81	.82
Slaughter Weight	1	165.89^{**}	1.25	1.45			
Residual	b	3.80	3.45	6.60	6.90	8.55	2.42

[a] TLC = Total lean cuts(kg); LCLW = Total lean cuts as a percent of liveweight; LCCW = Total lean cuts as a percentage of carcass weight; CBF = Carcass backfat thickness (mm); LEA = Loin eye area (cm^2); Permu = Percent muscle.

[b] For TLC, LCLW and LCCW df=115, otherwise df=116.

**P<.01

*P<.05

$^{+}$P<.10

Table 25. GENERALIZED LEAST SQUARES MEANS BY SIRE GROUP FOR CARCASS TRAITS FOR HAMPSHIRE SIRED PIGS

Item	Sire Group High Index	Sire Group Low Index	Standard Error	Significant Difference
No. of pigs	61	71		
Shoulder Weight(kg)	12.66	12.64	.13	
Loin Weight(kg)	13.07	13.12	.14	
Belly Weight(kg)	7.94	7.98	.09	
Ham Weight(kg)	13.07	13.12	.14	
Total lean Cuts(kg)	41.06	40.85	.39	
Carcass Backfat Thickness(mm)	26.63	26.69	.53	
Tenth rib fat Thickness(mm)	22.81	22.32	.82	
Loin eye Area(cm^2)	27.71	27.22	.58	
Percent Muscle(%)	53.64	53.73	.32	
Total lean Cuts as a Percentage of Slaughter wt(%)	39.28	39.02	.37	
Total lean Cuts as a Percentage of Carcass wt(%)	59.78	59.35	.51	
Carcass Length(cm)	78.76	79.57	.38	

Table 26. GENERALIZED LEAST SQUARES MEANS BY BREEDING OF DAM FOR LOIN WEIGHT OF HAMPSHIRE SIRED PIGS

	Breeding of Dam				
Item	50% Duroc(D)	50% Yorkshire(Y)	50% Landrace(L)	50% Spotted(S)	25%D:25%Y 25%L:25%S
Loin Weight(kg)	12.78(.19)[a]	12.32(.18)	13.06(.25)	13.03(.19)	13.276(.11)

Contrast Coefficient					Probability of a larger t-statistic
-1/4	-1/4	-1/4	-1/4	1	.05
-1/2	1/2	1/2	-1/2	0	.16
-1	0	0	1	0	.36
0	-1	1	0	0	.39

[a] Standard error

Table 27. GENERALIZED LEAST SQUARES MEANS FOR CARCASS TRAITS OF HAMPSHIRE SIRED PIGS

Item	Season Farrowed	Breeding of Dam 50% Duroc(D)	 50% Yorkshire(Y)	 50% Landrace(L)	 50% Spotted(S)	 25%D:25%Y 25%L:25%S
Number	Spring	6	7	3	6	25
Number	Fall	12	11	10	11	41
Belly (1)	Spring	8.54(.20)	7.98(.18)	8.50(.27)	7.56(.20)	7.66(.11)
Weight(kg)	Fall	7.97(.14)	7.65(.15)	8.13(.15)	7.83(.15)	7.75(.09)
Loin eye (2)	Spring	24.59(1.43)	27.82(1.25)	26.29(1.96)	26.82(1.40)	26.38(.73)
Area (cm)	Fall	29.56(.88)	27.41(.91)	29.01(.97)	28.07(.95)	28.48(.54)
Total (3)	Spring	55.95(1.17)	58.38(1.05)	57.53(1.59)	60.72(1.16)	59.92(.62)
Lean Cuts as a Percentage of Carcass wt.	Fall	60.82(.82)	60.93(.84)	60.19(.90)	60.66(.87)	60.57(.49)

Season Farrowed	Contrast Coefficients					Probability of a Larger t-statistic 1	 2	 3
Spring	-1/4	-1/4	-1/4	-1/4	1	.00	.99	.09
Fall	-1/4	-1/4	-1/4	-1/4	1	.16	.96	.86
Spring	-1/2	1/2	1/2	-1/2	0	.28	.28	.72
Fall	-1/2	1/2	1/2	-1/2	0	.99	.58	.88
Spring	-1/2	0	0	1/2	0	.00	.26	.04
Fall	-1/2	0	0	1/2	0	.39	.38	.82
Spring	0	-1	1	0	0	.18	.50	.62
Fall	0	-1	1	0	0	.00	.22	.96

[a] Standard error in parentheses.

Table 28. GENERALIZED LEAST SQUARES ANALYSIS OF VARIANCE FOR CARCASS PARTS OF DUROC SIRED PIGS

Trait Source	df	Shoulder Weight(kg)	Ham Weight(kg)	Loin Weight(kg)	Belly Weight(kg)	Carcass Length(cm)
		Mean Squares				
Season Farrowed (YRS)	1	2.49*	9.21**	5.46**	.01	38.58
Sire Group(SG)	1	.00	.03	.00	.20	50.61
Breeding of Dam (BOD)	1	.40	2.41*	4.44**	.94+	32.66
YRS x SG	1	.02	.20	.01	.88+	72.64
YRS x BOD	1	1.61+	.14	1.94+	.98+	57.37
SG x BOD	1	.1	.14	.11	.46	36.34
Slaughter Weight(kg)	1	.18	.88	.00	1.68*	
Residual	128	.52	.53	.61	.31	50.84[a]

[a] Residual df for carcass length is 129.

** $P<.01$

* $P<.05$

+ $P<.10$

Table 29. GENERALIZED LEAST SQUARES ANALYSIS OF VARIANCE FOR INDICATORS OF CARCASS LEAN FOR DUROC SIRED PIGS

Trait[a] Source	df	TLC	LCLW	LCCW	CBF	LEA	Permu
		Mean Squares					
Season Farrowed (YRS)	1	48.25^{**}	264.11	63.68^{**}	3020.63	162.88^{**}	10.99^{**}
Sire Group (SG)	1	.03	35.90	.06	3459.15	.38	5.13^{*}
Breeding of Dam (BOD)	1	18.41^{*}	1961.43^{*}	6.49	2971.49	14.74	2.15
YRS x SG	1	.43	146.29	29.39^{+}	2722.03	1.25	.01
YRS x BOD	1	9.19^{+}	10.05	1.02	3260.53	15.78	.92
SG x BOD	1	.15	73.86	2.15	1627.28	3.10	.4
Slaughter Weight	1	1.94	646569.32^{**}	.72			
Residual	b	3.32	429.60	9.84	2957.11	11.45	1.46

[a] TLC = Total lean cuts(kg); LCLW = Total lean cuts as a percent of liveweight; LCCW = Total lean cuts as a percentage of carcass weight; CBF = Carcass backfat thickness (mm); LEA = Loin eye area (cm^2); Permu = Percent muscle;

[b] For TLC, LCLW and LCCW df=115, otherwise df=116.

$^{**}P<.01$

$^{*}P<.05$

$^{+}P<.10$

Table 30. GENERALIZED LEAST SQUARES MEANS BY SIRE GROUP FOR CARCASS TRAITS OF DUROC SIRED PIGS

Item	Sire Group High Index	 Low Index	Standard Error	Significant Difference
No. of pigs	68	68		
Shoulder Weight(kg)	12.68	12.67	.13	
Loin Weight(kg)	13.16	13.16	.14	
Ham Weight(kg)	14.90	14.85	.13	
Total lean Cuts(kg)	40.74	40.69	.32	
Carcass Backfat Thickness(mm)	26.67	28.14	.54	*
Tenth rib fat Thickness(mm)	20.73	22.07	.56	+
Loin eye Area(cm^2)	27.78	27.93	.58	
Percent Muscle(%)	54.77	54.21	.21	*
Total lean Cuts as a Percentage of Slaughter wt(%)	46.12	47.59	3.58	
Carcass Length(cm)	79.12	80.26	1.23	

$^*P<.05$

$^+P<.10$

Table 31. GENERALIZED LEAST SQUARES MEANS OF SIRE GROUP BY SEASON FARROWED FOR BELLY WEIGHT AND TOTAL LEAN CUTS AS A PERCENTAGE OF CARCASS WEIGHT FOR DUROC SIRED PIGS

Item	Season Farrowed	Sire Group High Index	Sire Group Low Index	Standard Error	Significant Difference
No. of pigs	Spring				
Belly Weight(kg)		7.84	8.18	.12	**
Total lean Cuts as a Percentage of Carcass wt(%)		57.89	56.62	.68	*
No. of pigs	Fall				
Belly Weight(kg)		8.06	7.94	.15	
Total lean Cuts as a Percentage of Carcass wt(%)		58.82	59.90	.85	*

**P<.01

*P<.05

Table 32. GENERALIZED LEAST SQUARES MEANS OF BREEDING OF DAM FOR CARCASS TRAITS OF DUROC SIRED PIGS

		Breeding of Dam			
Item		High Index Sire	Low Index Sire	Standard Error	Significant Difference
No. of pigs		69	67		
Ham Weight(kg)		14.73	15.02	.11	*
Total lean Cuts as a Percentage of Slaughter wt(%)		42.81	50.90	3.16	*
	Season Farrowed				
No. of pigs	Spring	43	41		
Shoulder Weight(kg)		12.54	12.42	.14	
Loin Weight(kg)		12.81	12.94	.15	
Belly Weight(kg)		8.02	8.01	.11	
Total lean Cuts(kg)		39.75	39.98	.35	
No. of pigs	Fall	26	26		
Shoulder Weight(kg)		12.69	13.04	.17	**
Loin Weight(kg)		13.12	13.76	.19	**
Belly Weight(kg)		7.82	8.18	.13	**
Total lean Cuts(kg)		40.89	42.23	.44	**

$^{**}P<.01$

$^{*}P<.05$

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CHAPTER IV

A COMPARISON OF PROGENY SIRED BY HIGH AND LOW INDEXING HAMPSHIRE AND DUROC CENTRAL TEST STATION BOARS: GENETIC PARAMETER ESTIMATION

Summary

Data were collected on 1,762 progeny of high and low indexing Hampshire and Duroc boars purchased from Iowa, Missouri, Nebraska and Oklahoma central test stations. The criterion for choosing boars was an index recommended by the National Swine Improvement Federation, which emphasized average daily gain, pen feed efficiency on three half or full sibs and live backfat thickness. Boars were purchased in pairs with the minimum index difference, of the pair, being 30 points. Heritabilities and genetic correlations for the evaluation index (I), average daily gain (ADG) and probe backfat thickness (PBF) were calculated using regression methods and a realized heritability estimate for I. Regression estimates of heritability for I, ADG and PBF (.65±.40, .52±.20, and .43±.25, respectively) were similar to or larger than the estimates used in the central test station index construction. The realized heritability estimate for I (.16±.08) is much smaller and may better reflect commercial progeny performance of superior boars purchased from a central test station. The genetic correlations of I with ADG and PBF were moderate and favorable (.53±.13 and -.69±.18, respectively), while the genetic correlation of ADG with PBF was moderate and positive (.44±.14). Correlations between boar central test performance compared to station contemporaries with subsequent progeny performance as estimated by best linear unbiased predictors for I, ADG and PBF were .30, .30 and .24, respectively and were smaller than their expectations. Correlations of I with ADG (.26) and PBF (-.25) were similar to or smaller than their expectations while the correlation of ADG with PBF (-.13) was the same in magnitude but opposite in sign compared to its expectation.

(Key Words: Central Test Station Boars, Heritability, Genetic Correlation Performance Testing.)

Introduction

Central swine test stations have a twofold purpose: one to demonstrate to producers uniform performance testing methods and another is to provide a seedstock source, usually of several different breeds, of objectively tested boars to commercial producers. Boars are usually evaluated with an index which emphasizes average daily gain from 31.75 to 104.3 kg, live backfat thickness at 104 kg and a pen feed efficiency measured on themselves and two half or full sibs. The genetic parameters used in constructing the evaluation index are literature estimates that are recommended to buyers of test station boars to estimate expected response.

Literature estimates are usually taken from experiments where animals were managed uniformly in one environment. Boars tested in test stations are born in one environment, raised in a second and their subsequent progeny are raised in a third. Little documentation exists on how well the literature estimates of genetic parameters reflect the relationship between a boar's performance in a test station and his progenies' performance. In Australia, a realized heritability estimate of an index incorporating postweaning average daily gain, feed efficiency (kg feed consumed/kg gain) and backfat measurements for boars and their sons tested in central test station was very close to its expectation of .51 (McPhee, 1974). In beef cattle, the correlation of bull performance in a central grazing station with their subsequent progenies' performance was not different from zero (Baker et al., 1984), while the correlations of a beef sires' predicted difference with his progenies' average central test station performance and his own central station performance were very close to their expectations (Wilton and McWhir, 1985). It is the purpose of this paper to estimate the heritabilities and genetic correlations for the evaluation index, postweaning average daily gain, probe backfat thickness and to estimate the correlation between a boars' central test station performance with his predicted difference based on progeny performance.

Materials and Methods

Data were collected on progeny of high and low indexing boars purchased from central test station for two years starting in 1980. Boars were purchased from central test stations in Iowa, Missouri, Nebraska and Oklahoma. Twelve to thirteen boars were purchased for each of two breeding seasons per year. Hampshire boars were purchased the first year while Duroc boars were purchased the second. Boars were evaluated for an index recommended by the National Swine Improvement Federation for test stations measuring pen feed efficiency. The index is, $I=100+60(G-\bar{G})-75(F-\bar{F})-70(B-\bar{B})$ (Hubbard, 1981). Traits included in the index are average daily gain (G), pen feed efficiency (F) and average live backfat thickness (B). Symbols with bars over them represent contemporary central test station averages. Boars were purchased in pairs with one boar having a minimum index value of 118, while the other had an index value less than 90. The first year the Hampshire boars were randomly mated to three- and four-breed cross gilts of Duroc, Yorkshire, Landrace and Spotted stock which produced 198 litters. The second year, 181 litters were produced from the random matings of Duroc boars to gilts born the previous year and were sired by the high and low indexing Hampshire boars. Feeding trials were superimposed on the growing pigs and gestating gilts through the completion of this study (Maxwell et al., 1982; Maxwell et al., 1983ab; Luce et al., 1983). The data were corrected additively if significant treatment difference were reported. The first year barrows and gilts were placed into pens housed in two confinement feeding barns by sire group. Sire group designations refers to the classification of a boar as being high or low indexing. The second year pigs were penned by sire group, breeding of dam combinations. Breeding of dam designations for the second year referred to the sire of the dam as being a high or low indexing boar. Pen density was 12 to 20 pigs/pen. Pigs consumed a 16% crude protein diet, ad libitum, until average weight in a pen was 54.43 kg, they were then switched to a 14% crude protein diet. Pigs were removed from test at approximately 100 kg. Further details on animal management and experimental design are outlined by Bates and Buchanan (1986).

Traits included in the genetic analysis were average daily gain, probe backfat thickness and the evaluation index described earlier. Average daily gain was measured from approximately 8-9 weeks of age to approximately 100 kg. Pigs were measured by ultrasound for fat thickness at the shoulder, at the last rib and the last lumbar vertebra. Probe backfat thickness is the average of these three measurements. To be assigned an index value, pigs had to have a record for average daily gain and probe backfat thickness. Feed efficiency (kg of feed consumed/kg of gain) was calculated on a pen basis. The measurement of feed efficiency for each pen was assigned to each pig in that pen and then pig observations for the three traits were deviated from year-season-barn means and then used in the index. If pens were improperly grouped they were excluded from the analysis. A total of 730 records were available the first year, representing 22 Hampshire sires, while 1,032 records representing 23 Duroc sires were included the second year.

Genetic Parameter Estimation. Heritability of the evaluation index was estimated by two different procedures. The first is a realized estimate with heritability being the ratio of the mean response difference of the progeny sired by the bi-directionally selected boars to one-half the difference in mean performance of the bi-directionally selected boars weighted by the number of progeny produced. Selection was not practiced among the gilts. Heritability was estimated each year and weighted estimate combining the estimates was calculated. Standard errors for the realized heritability estimates were calculated using a formula reported by Hill (1972). The other method of heritability estimation was twice the regression of mean offspring performance on sire performance. This was done for the evaluation index as well as average daily gain and probe backfat thickness. Progeny performance was deviated from their respective year-season-barn means, averaged and then regressed onto their sires' performance deviated from his respective central test station mean. A weighted least squares analysis was conducted incorporating the number of progeny per sire and the ratio of the variances as described by Falconer (1963). Variances were literature estimates or estimated from the data and the number progeny per sire ranged from 8 to 63. Standard errors for the heritabilities were calculated using the usual regression theory (Falconer, 1963). Genetic correlations of average daily gain with the evaluation index and probe backfat thickness were estimated using the following formula, $r_g=[(b_{12'} \cdot b_{21'})/(b_{11'} \cdot b_{22'})]^{1/2}$, where 1 and 2 represent progeny mean performance for traits 1 and 2 and 1' and 2' represent sire performance. The genetic correlation between the evaluation index and probe backfat thickness was not estimable using the previous formula due to the numerator regression coefficients being different in sign. The genetic correlation between the evaluation index and probe backfat thickness was estimated using the formula, $r_g=(b_{12'}+b_{21'})/[2 \cdot (b_{11'} \cdot b_{22'})^{1/2}]$. The regression coefficients were calculated using the previously mentioned weighted least squares procedure. Standard errors were calculated using an approximation formula (Reeve, 1955).

Product-moment correlations of a given sire's own performance deviated from his respective central test station mean with his predicted difference estimated from his progenies' performance were calculated. The predicted differences were the sire solutions obtained using mixed model procedures. the data from each year were analyzed separately. Fixed effects included in the model were season of birth (spring or fall) and sire group (high or low indexing), breeding of dam (differing crossbred dam groups the first year; having a high or low indexing sire the second year), sex (barrow or gilt) and all possible two way interactions. Random effects were sires nested within sire group by season of birth combinations and dams nested within breeding of dam, season of birth, sire group and sire combinations. Known relationships among the sires and relationships among the dams were incorporated. Only full and half sib relationships were accounted for among the dams since the dams were of crossbred origin. Relationships of dams between years were ignored. A single trait sire model was used. The fixed effect equations and the dam equations were absorbed into the sire equations and a unique solution was obtained. The sire solutions estimate one half of the additive genetic effect of the sires and they are best linear unbiased predictors if the variances are known (Henderson, 1975). Multiple trait sire evaluation mixed model procedures have been shown to reduce prediction error variance over single trait sire evaluation models (Tong, 1977; Schaeffer and Wilton, 1981). To do multiple trait sire evaluation the genetic variances and covariances for the three traits must be "known". Estimates of the genetic covariances between the evaluation index with average daily gain and probe backfat thickness do not exist in the literature, therefore a single trait sire model appeared to be more appropriate.

The product-moment correlations of predicted difference with sires' performance were estimated across years and sire groups and are compared to their expectations. The expectations of the correlations were estimated as the average of the expectations of the correlations for each sire. The single sire expectation was;

$$Er_{SP(i)PD(j)} = nh_i r_g h_j/[n(4+(n-1)h^2_j]^{1/2},$$

where E stands for the expectation of the correlation, r represents the correlation, SP(i) refers to the sire performance for trait i, PD(j) refers to the predicted difference for trait j, n is the number of progeny of a sire, h_i is the square root of the heritability for trait i, r_g is the genetic correlation between traits i and j, and h_j and h^2_j are the square root of the heritability and the heritability for trait j. A similar formula was used by Wilton and McWhir (1985). The heritabilities and the genetic correlations used in the expectation calculations are those used in the index construction (table 2; Hubbard, 1981),except the genetic correlations of the evaluation index with average daily gain and probe backfat thickness, which were estimates from this study.

Results and Discussion

Heritabilities and genetic correlations among average daily gain, probe backfat thickness and the evaluation index are presented in table 1. The regression estimate of heritability for the evaluation index is almost twice that of the expected value of .37. (calculated from information given by Hubbard, 1981). The index calculated for the progeny is measuring somewhat different things than it is for boars in a test station. Average daily gain in a test station is measured from approximately 31 to 104 kg and feed efficiency is measured on a pen basis with three full or half sibs in a pen. In this study average daily gain was measured from approximately 8 weeks of age to 100 kg. Feed efficiency was measured on a pen basis but litters within sire group were often mixed when penned. These factors along with the relatively small number of sires could have caused the estimate to be inflated. The realized heritability estimate (.16±.08) is approximately one eighth that of the regression estimate. It is similar; however to realized estimate of .19 reported by Cleveland et al. (1982) when selecting for and index that emphasized increased average daily gain and decreased backfat thickness. Vangen (1979) reported a much larger realized estimate (.51) when comparing divergent selection lines for an index that put equal weight on increased average daily gain and decreased backfat thickness. In Australia, reports indicated that the realized heritability estimate of a central test station index combining average daily gain, feed efficiency and backfat measurements was very close to its expectation of .51 when sires and their sons tested in a central test station were compared (McPhee, 1974). Reports form New Zealand indicate that the effective heritability of a bulls' final weight in a central grazing test and their subsequent progenies' 550 d weight was only .07±.05 (Baker et al., 1984). This conflicts, somewhat, with a Canadian study that reported the heritability of yearling weight ranged from .12 to .84 for beef bulls, as well as their sons, tested in a central feedlot test station (Wilton and McWhir, 1985). The realized heritability estimate of the evaluation index may more appropriately represent the improvement that can be expected for the evaluation index for commercial barrow and gilt progeny sired by superior boars selected from a central test station. The heritability estimate for average daily gain (.52±.20) is somewhat larger than the heritability estimate used in the evaluation index construction (.3; Hubbard, 1981) and an average literature estimate (.38; Hutchens and Hintz, 1981). In the aforementioned New Zealand study, the heritability estimate for absolute weight gain during grazing test of beef cattle was .09±.06 (Baker et al., 1984). In Canada, the heritability of average daily gain during performance test for beef sires and their sons range from .02 to .50, depending if cattle were tested in government stations or in private stations (Wilton and McWhir, 1985). When average daily gain was deviated from the test mean and incorporated in a single trait index the smaller of the heritability estimates increased to .24. The heritability estimate for probe backfat thickness (.43±.25) is similar to an average literature estimate (.39; Hutchens and Hintz, 1981) but somewhat smaller than the heritability used in the evaluation index construction (.5; Hubbard, 1981).

An average literature estimate of the correlation of postweaning daily gain and live backfat thickness was small and negative (-.05; Hutchens and Hintz, 1981) and differed in sign and magnitude from the estimate reported in this study (.44±.14) and the one used in the evaluation index construction (.25; Hubbard, 1981). The genetic correlations of the evaluation index with average daily gain and probe backfat thickness are large and favorable (.53±.13 and -.69±.18, respectively). In a study comparing pigs selected for and against an index which put equal weight on increased average daily gain and decreased backfat thickness, the genetic correlation between between average daily gain and the index was lower (.22) than the estimate reported here while the genetic correlation between the two trait index and backfat thickness was larger negatively (-.96; Vangen, 1979).

The genetic parameters necessary for estimating the expectations of the product-moment correlations of sire performance with predicted difference are given in table 2. The heritabilities and genetic correlations are those used (other than the genetic correlations of the evaluation index with average daily gain and probe backfat thickness) in the construction of the evaluation index (Hubbard, 1981). The genetic correlation between two traits of the same name was assumed to be unity for calculation of the expectations. This is probably incorrect since the traits measured on boars and traits measured on their progeny are measured on different sexes, in different environments and at different points of the growth curve. Therefore the assumption of unity for the correlation between traits of the same name measured on boars in central test stations and their subsequent progeny may be too optimistic. The estimated expectations of the correlations between a sires' central test performance and his predicted difference for the same trait may then be inflated.

The correlations of sire performance with their predicted difference are presented in table 3. The correlations between sire performance and predicted difference for the evaluation index, average daily gain and backfat thickness are of the same sign but one and one-half to two and one-half times smaller than their expectations. The expectations are probably inflated as previously discussed. This contrasts with the correlations of a beef bull's predicted difference with their central test performance for average daily gain and yearling weight being very close to their expectations of .17 and .30, respectively (Wilton and McWhir, 1985). The correlations of sire performance for the evaluation index with their predicted differences for average daily gain (.26) and probe backfat thickness (-.25) are similar or somewhat smaller than their expectations. This indicates that boars that are superior for the evaluation index in central test stations should have the ability to sire progeny that are improved for average daily gain and probe backfat thickness. The correlation of sire performance for average daily gain with his predicted difference for probe backfat thickness is equal in magnitude to its expectation (.13) but opposite in sign. Boars were selected for and against an index which put pressure on these two traits in opposite directions. This may have caused the correlation between sire performance for average daily gain and his predicted difference for probe backfat thickness to be negative. Wilton and McWhir (1985) reported that the correlations were similar to or larger than their expectations when the relationship of a beef sires' performance for weaning weight with his predicted difference for weaning weight (.20) and with the deviation of the weaning weight from the yearling predicted difference (.16) were estimated. The same was true for the correlation of sire performance for average daily gain with the deviation of weaning weight predicted difference from yearling weight predicted difference (.27 vs expectation of .17).

Conclusions. The realized heritability estimate for the evaluation index may be more appropriate than the regression estimate when trying to predict progeny performance of boars purchased from a central test station. The genetic correlations of the evaluation index with average daily gain and probe backfat thickness indicate that selection for the index was properly effecting change in these two traits. The correlations between sire performance and predicted differences indicate that boars superior in a central performance test should sire progeny that differ favorably from the average for average daily gain, probe backfat thickness and the evaluation index. Consequently, the purchase of superior test station boars should complement a good within herd performance testing and selection program.

Table 1. HERITABILITIES AND GENETIC CORRELATIONS FOR AVERAGE DAILY GAIN, PROBE BACKFAT THICKNESS AND THE EVALUATION INDEX

	Index	Average Daily Gain	Probe Backfat Thickness
Index	.65±.40[a] .16±.08[b]	.53±.13	-.69±.18
Average Daily Gain		.52±.20	.44±.14
Probe Backfat Thickness			.43±.25

[a] Heritabilities on the diagonal.

[b] Realized heritability estimate.

TABLE 2. HERITABILITIES AND GENETIC CORRELATIONS USED IN ESTIMATING THE EXPECTATIONS OF THE PRODUCT-MOMENT CORRELATIONS BETWEEN SIRE PERFORMANCE AND HIS PREDICTED DIFFERENCES

	Index	Average Daily Gain	Probe Backfat Thickness
Index	.37[a,b]	.53[c]	-.69[c]
Average Daily Gain		.30[b]	.25[b]
Probe Backfat Thickness			.50[b]

[a] Heritabilities on the diagonal, genetic correlations above the diagonal.

[b] From Hubbard, 1981.

[c] Estimated from the data.

Table 3. PRODUCT-MOMENT CORRELATIONS BETWEEN SIRE PERFORMANCE AND HIS PREDICTED DIFFERENCES

Sire Performance	Predicted Difference	Correlation	Expectation
Index	Index	.30	.53
	Average Daily Gain	.26	.28
	Probe Backfat Thickness	-.25	-.39
Average Daily Gain	Average Daily Gain	.30	.47
	Probe Backfat Thickness	-.13	.13
Probe Backfat Thickness	Probe Backfat Thickness	.24	.64

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VITA

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