TESTING BOARS FOR FEED LOT PERFORMANCE AND PROBE BACKFAT THICKNESS

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I. INTRODUCTION

A knowledge of the performing ability of the breeding herd is needed for a sound plan of swine improvement. Selection is one of the breeder's important tools for improvement. One of the factors that limits the progress which may be made through selection is the extent to which variations in a particular character are heritable, in the sense that the offspring will exhibit part of the superiority or inferiority which their parents exhibited in the character. Performance characters are affected greatly by environment. The response to selection, therefore, is reduced according to environmental effects. If breeders are to make the best use of selection and various breeding systems, it is important to know something regarding the relative importance of environment and inheritance in respect to a certain character.

Breeders realize the emphasis that must be placed upon selection of a herd sire. Regardless of the breeding system used, the herd sire, or sires, constitute one-half of the breeding herd. The resulting progeny of the herd is, to a certain extent, determined at fertilization by the inheritance received from its sires through the male gametes and the inheritance received from its dams through the female gametes. Misjudgement in selection of the herd sire may reverse the direction in which improvement was intended.

For nearly half a century the show ring has played an important role in livestock progress. It has done much to help mold and perfect breed type and has been invaluable as a display window for promotion and publicity. It is questionable how well this fits the picture today. The junior or grand champion boar may be close to perfection in meat type appearance, but the boar may look that way because of expert fitting, exercise and a non-fattening ration. In that case, he may be a boar that will sire over-fat pigs. It is doubtful if many farmers and commercial producers care much about the show ribbons won by the sire of their next boar. It becomes important for those lacking the training or ability to properly appraise the live hog to have a more subjective measurement of the performing ability of the live animal.

The objectives of the present study were (1) to determine the various factors that may affect the average daily gain, feed economy and probe backfat thickness in a performance test, (2) obtain estimates of phenotypic correlations between the various performance traits, and (3) determine if there is a difference in performance of boar pigs tested on pasture or in dry lot.

II. REVIEW OF LITERATURE

A. Performance as Affected by Environment

Lush (1936) studied Danish progeny testing records and observed changes which had occured during the period from 1907 to 1935 in feed economy, daily gain, body length, thickness of backfat and belly. The data showed a decline in the feed units used per unit of gain. This decline was attributed to an increase in physiological efficiency and also was thought to represent changes in sanitation, ventilation and other management practices. Yearly differences were noted in the data concerning daily gain. The rate of gain was 16 to 18 percent higher during the last six years of the study as compared to the average before 1923. There were also year to year differences noted in body length, backfat and belly thickness.

Baker *et al*. (1943) working with six lines of Duroc swine at the North Platte experiment station in Nebraska reported that a large fraction of the variance of weights from 56 to 168 days could be attributed to differences between four spring or four fall periods. This indicated that the responsible factors were peculiar to each season, and hence to each year. They concluded that the responsible factors were almost certainly environmental in origin.

In their investigation of the effects of selecting for rapid and slow growth in swine, Krider *et al*. (1946) found that in the later generations their estimates of heritability were smaller than those found in the initial generations. They partly attributed the decline to the fact that variations peculiar to each of the later years were pronounced.

Johansson and Korkman (1950) reported data on the Large White and Swedish Landrace breeds of swine from the Swedish pig testing stations covering a 14-year interval. Yearly differences had a significant effect upon all the performance traits considered. The effects of years were found responsible for the following percentages of the total variation of the various traits: body length, 9; backfat thickness, 14; size and shape of ham, 12; daily gain, 10; age at slaughter, 9; and feed economy, 11.

Craig _et al._ (1956) reported on a ten-year experiment involving ten generations of selection for heavy weights and eight generations of selection for light weights at 154 and 180 days of age in Hampshire swine. Extreme season-to-season and year-to-year environmental variation in weight at 154 and 180 days of age was graphically illustrated.

Ellis and Zeller (1934) studied the effect of kind and quantity of feed on the body composition in hogs. They found that pigs restricted in their intake of corn and wheat, as compared with pigs on unrestricted diets, contained a greater proportion of lean meat, yielded a higher percentage of lean cuts and showed a decrease in the entire fat content of the body.

Callow (1935) observed an association between rate of growth and firmness of fat. He suggested that firm fat is built from carbohydrates. The slow gaining pigs derive their fat from the fat in feeds, resulting in soft fat.

McMeekan (1940a, 1940b, 1940c, 1941) and McMeekan and Hammond (1940) studied the effects of different planes of nutrition on the form and composition of hog carcasses. Eighty inbred pigs were divided into four lots. Lot I was full-fed from birth to 200 pounds (High-high); lot II was full-fed from birth to 16 weeks of age, thereafter the amount of feed was restricted until slaughter (high-low); lot III was fed a restricted diet to 16 weeks of age, thereafter full-fed until slaughter (low-high); and lot IV was fed a restricted diet from birth to slaughter (low-low).

The pigs producing carcasses with the least amount of fat were on the low-low diet. They showed a high proportion of bone and were generally undeveloped. The low-high pigs produced the poorest carcasses in that they showed an excessive amount of fat, an underdeveloped skeleton and underdeveloped muscling. The best carcasses were from pigs of the high-low group. They had maximum muscular and skeletal development with the least amount of fat. This is evidence that rapid rate of growth early in life when the skeleton and muscles are developing is conducive toward a carcass having a large proportion of lean, while rapid later growth, as in the low-high group, tends more toward fat deposition.

Pomeroy (1941) agreed with McMeekan that early growth primarily involves the skeleton and muscles, while later growth is mostly the laying on of fatty tissue. By feeding a submaintenance diet to pigs approaching slaughter weight he observed that the amount of fatty tissue declined rapidly and that muscle and bone were not affected as rapidly or as severely. The later developing fatty tissue was penalized more on a submaintenance diet than earlier developing tissues.

Winters _et al_. (1949) and Cummings and Winters (1951) conducted an experiment somewhat similar to that of McMeekan (1940). Pigs from three breeds were started on experiment at approximately 80 days of age. Lot I was full-fed throughout the entire experiment; lot II was self-fed to 125 pounds, thereafter receiving a daily feed allowance of three percent of their body weight; lot III was fed the three percent restricted diet to 125 pounds, thereafter it was full-fed; lot IV received the restricted diet throughout the entire experiment. Results showed that lot I yielded the fattest carcasses, while lot IV yielded the leannest with the least amount of fat. Lots II and III showed about the same degree of fatness intermediate between I and IV. No apparent breed differences were noted.

Differences in the results of the two experiments by McMeekan (1940) and Winters et al. (1949) may be due to differences in experimental procedure. In McMeekan's work, the pigs went on experiment at birth, whereas in Winters study, the pigs did not go on experiment until approximately 80 days of age. Hence, in McMeekan's study the pigs were on trial during the period of time when maximum skeletal and muscular development were occuring. In Winters' study the four lots were fed on pasture until the pasture season was over. The pigs receiving the restricted diets at this time may have compensated for the restricted feeding by eating more forage.

Gregory and Dickerson (1952) observed that pigs fed on a restricted diet yielded carcasses having less fat and more muscling as compared with pigs on the unrestricted diet.

The above citations illustrate that there may be yearly differences which have an important effect on performance traits in swine. It is also apparent that quantity of feed can have a noticeable effect on carcass composition. The effect, however, is dependent on the severity of the restriction in the diet. These studies have been mentioned not because the present study investigated the effects of different planes of nutrition on carcass composition, but rather to illustrate and emphasize the need for standardized feeding conditions in conducting performance tests.

B. Influence of Mating Systems on Performance

Differences in the feed lot performance, as well as differences in carcass composition of pigs produced by inbreds, crosslines and crossbreds, are generally pronounced. Such differences should be considered in any complete analysis of performance traits.

Hammond and Murray (1937) observed that crossbred pigs tended to produce carcasses which were intermediate between the parental breeds for backfat and belly thickness, but that body length was slightly above the mean of the parents.

Eaton (1941), reported on growth rate in guinea pigs and found that crossline hybrids tended toward the higher parent in growth rate. Heterosis was more pronounced when three lines were involved in the cross than in crosses of only two.

In an investigation covering a three year period, Winters et al. (1943) found that crosslines had a 24 pound advantage over the parental stock for weight at 180 days while crossbreds displayed a 65 pound advantage. The data were limited, especially for the controls. These workers presented data relative to the results of crosses between the Tamworth and Landrace breeds. The crossbreds consumed an average 308 pounds of feed per hundred pounds of gain and weighed 239 pounds at 180 days. No values were given for the parental strains for comparison.

Dickerson et al. (1946) made 28 intra-sire comparisons of the first crosses between inbred lines of Poland-Chinas with inbreds by the same boar. The linecrosses exceeded the inbreds by 25 pounds at 154 days of age. Although the crosses had a faster rate of gain, they required as much feed as the inbreds for the period from 84 days to 225 pounds. Limited slaughter data suggested that linecross pigs yielded less fat than inbreds.

Studying the effects of plane of nutrition on carcass composition, Winters et al. (1949) observed that four groups of crossbred pigs required less feed and made faster gains than a group of outbred pigs raised under similar conditions. The greater efficiency of the crossbred pigs over the purebreds was reflected in carcasses with a higher content of lean cuts, and a lower content of fat cuts.

For rate and economy of gain, Gregory and Dickerson (1952) found crossline pigs markedly superior to inbreds in rate and economy of gain. Carcasses from crossline pigs were intermediate to inbreds of the parental lines.

Whiteman et al. (1951) and Whatley et al. (1953) reported on the performance of inbred, crossline and crossbred pigs. Crossbred pigs yielded the most desirable carcasses with more body length and lean cuts. Significant differences between breeding groups were evident for average daily gain.

Pigs from crossbred gilts showed a slightly heavier weight at 154 days of age than did pigs from purebred gilts, in the work reported by Bradford et al. (1953).

The above review was not intended to compare the advantages and disadvantages of crosslines or crossbreds over their respective parental stock. It was presented to show that differences in performance do sometimes exist between groups of pigs produced by different kinds of mating systems.

C. Influence of Lines and Breeds on Performance

Menzies-Kitchin (1937) observed that there were differences as great or greater in growth rate between strains within a breed than differences between breeds.

Molln (1940) found significant differences between breeds in weight at 180 days, but no noticeable differences between lines within breeds. The lines in this study were not highly inbred.

Working with 601 pigs from eight breeds, Miranda et al. (1946) found highly significant breed differences in rate of gain per day. Breed differences accounted for 21 percent of the total variation in average daily gain.

Dickerson (1947) reported that only in yield of lean cuts and in leg length were differences between lines of Poland-Chinas appreciably larger than those between sire progenies within lines.

Blunn and Baker (1947) suggested that breed differences may have caused their correlations between fatness and rate of gain to differ from those of Dickerson (1947). Dickerson's study was primarily with Poland-Chinas while their study was with Durocs.

From their data on Large White and Swedish Landrace, Johansson and Korkman (1950) concluded that breed differences were responsible for five percent of the total variation in body length, seven percent for backfat thickness, three percent for circumference of ham, six percent for daily gain and one percent for feed economy.

In the light of the previous reports it seems reasonable that differences between breeds and between lines within breeds are of sufficient magnitude to justify considering the effects they might have in causing differences among pigs.

D. Phenotypic Correlations

Correlations between various economic traits in swine have been reported by numerous investigators. The workers are in good agreement as to the correlation between feed economy and rate of gain. Evvard *et al.* (1927) reported a correlation of -.54 between feed per 100 pounds of gain and rate of daily gain for 479 lots including 2833 pigs. Lush (1936) and Stothart (1938) gave the respective correlations for these traits of -.68 and -.44. Dickerson and Grimes (1947) found a value of -.73, Fredeen (1953) cited a value of -.51, and Anderson (1954) obtained a value of -.43 for the correlation between these traits.

It is reasonable to expect the correlation between economy and rate of gain to be high. One reason for this is the fact that in many instances the gain which appears in the numerator in calculating rate of gain also appears in the denominator in calculating economy of gain. The statistical nature of such a relationship allows the correlation to be high.

Correlations involving either economy or rate of gain with certain carcass characteristics are not as consistent as between rate and economy of gain. Hazel (1943) decided that, for pigs on full-feed, changes in carcass conformation were little affected by variations in growth rate. Blunn and Baker (1947)noted a significant association between feed

TABLE I

SUMMARY OF REFERENCE DATA PERTAINING TO PHENOTYPIC CORRELATIONS

Trait	Economy of Gain	Backfat Thickness	Source
Rate of Gain	-.54		(a)
		.29	(b)
	-.68	.07	(c)
		.10	(d)
	-.43		(e)
		.13	(f)
	-.44		(g)
	-.73		(h)
Backfat Thickness	.09		(c)
	-.02		(i)
	.12		(d)
	-.14		(e)

The small letters indicate the source: (a) Evvard et al. (1927), 2833 pigs, (b) Blunn and Baker (1947), 357 d.f., (c) Lush (1936), 1285 litters, (d) Dickerson (1947), 746 pigs, (e) Anderson (1954), 215 d.f., (f) Anderson (1954), 420 d.f., (g) Stothart (1938), 57 d.f., (h) Dickerson and Grimes (1947), 74 d.f., (i) Fredeen (1953), 1638 d.f.

economy and Backfat thickness. Fredeen (1953) found a significant correlation between rate of gain and backfat thickness.

The correlations which have been metioned are summarized in Table I.

E. Heritability

The literature pertaining to estimates of heritability was considered too lengthy to be discussed in detail. The numerous estimates are presented in Table II.

Rate of gain has received much attention, the heritability estimates ranging from .02 to .61. Much of this variation may be attributed to different methods utilized in estimation. Craft (1953), in reviewing research in the Regional Swine Breeding Laboratory, pointed out that discrepancies in heritability estimates may arise from: (1) small samples of data, (2) correlation between variations caused by the environment, (3) the mating system differing from random more or less than calculated, and (4) the animal as a unit performing differently than is expected from the sum of the average of the separate effects of its total genes.

F. Probe Backfat Measurement as an Indicator of Carcass Merit

Carcass traits are rather highly hereditary and are of economic importance. Consequently, proper selection may be reasonably effective in improving hog carcass merit. However, the swine breeder may have difficulty in making rapid carcass improvement because direct carcass measurements and evaluation can be obtained on the carcass only after slaughter. No direct carcass evaluation can be made of breeding stock. Therefore, the breeder must base his selection for

TABLE II

SUMMARY OF HERITABILITY ESTIMATES FOUND IN THE REFERENCES

Trait	Estimate	Method[1]	Notes	Reference
Backfat Thickness	.44	P	122 d.f.	Lush (1936)
	.47	A	122,320 and 230 d.f. in average	Lush (1936)
	.12	P	40 d.f.	Blunn and Baker (1947)
	.54	P	62 d.f.	Dickerson (1947)
	.37	R_{fs}	58 d.f.	Stothart (1947)
	.52	P	445 d.f.	Johansson and Korkman (1950)
	.38	P	647 d.f.	Fredeen (1953)
Feed Economy	.08*	A	122,320 and 230 d.f. in average	Lush (1936)
	.29	P	122 d.f.	Lush (1936)
	.26	R_{mp}	62 d.f.	Dickerson and Grimes (1947)
	.23	R_{os}	62 d.f.	Dickerson and Grimes (1947)
	.57	P	62 d.f.	Dickerson (1947)
	.23	P	391 d.f.	Johansson and Korkman (1950)
	.12	P	391 d.f.	Johansson and Korkman (1950)
	.30	P	647 d.f.	Fredeen (1953)

[1] P refers to paternal half-sib correlation from an analysis of variance.
R_{mp} refers to regression of progeny on mean of parents.
R_{fs} refers to regression of progeny on mean of parental full sibs.
R_{os} refers to the regression of offspring on sire.
A refers to average of three methods; paternal, maternal and correlation between progeny averages of sire and son.
*Still to be multiplied by 1 plus $3r_{oo}$, where r_{oo} is the unascertained correlation between litter mates.

TABLE II (Continued)

Trait	Estimate	Method	Notes	Reference
Gain from 56 to 112 days	.51	P	67 d.f.	Blunn *et al.* (1953)
	.35	P	16 d.f.	Blunn *et al.* (1953)
	.28	R_{od}	446 pigs and 86 sows	Blunn *et al.* (1953)
	.18	P	40 d.f.	Blunn and Baker (1947)
Gain from 56 to 225 lbs.	.18	P	40 d.f.	Blunn and Baker (1947)
Gain from Weaning to 200 lbs.	.31	R_{od}	133 d.f.	Comstock *et al.* (1942)
	.40	P	340 litters	Nordskog *et al.* (1944)
Daily gains	.24	R_{os}	62 d.f.	Dickerson and Grimes (1947)
	.29	R_{od}	62 d.f.	Dickerson and Grimes (1947)
	.43	R_{mp}	62 d.f.	Dickerson and Grimes (1947)
	.31	P	62 d.f.	Dickerson (1947)
	.26	P	445 d.f.	Johansson and Korkman (1950)
	.24	A	122,320 and 230 d.f. in average	Lush (1936)
Weight for age at 150 days	.14	P	41 d.f.	Krider *et al.* (1946)
154 days	.16	R	186 litters	Craig *et al.* (1956)
168 days	.27	P	312 d.f.	Nordskog *et al.* (1944)
180 days	.61	R_{od}	23 boars, 151 sows	Whatley (1942)
	.20	P	23 boars, 151 sows	Whatley (1942)

TABLE II (Continued)

Trait	Estimate	Method	Notes	Reference
Weight for age at 180 days	.14	R	209 litters	Craig *et al.* (1956)
	.24	P	41 d.f.	Krider *et al.* (1946)
	.14	R_{od}	133 d.f.	Comstock *et al.* (1942)
	.34	P	62 d.f.	Dickerson (1947)
Age at 200 lbs.	.55	P	647 d.f.	Fredeen (1953)

R_{od} refers to the regression of offspring on dam.

carcass merit on some indirect method. One such method is by carcass tests with progeny or brothers and sisters of an individual. This method may be very effective, but has the disadvantage of being time consuming, expensive, and somewhat limited in application. Another method is by live animal appraisal of external indications of carcass merit.

Hazel and Kline (1952) described a simple and rapid "probing" method of measuring backfat thickness on live hogs. The method causes little discomfort to the pigs and has the advantage of being available immediately. The accuracy of the method as a criterion of carcass value is expressed in the correlations of average backfat thickness on the carcass with the individual live-hog measurements at the following sites: behind the shoulder, .79; middle of the back, .59; middle of the loin over the longissimus dorsi, .69; middle of the loin over the vertebra, .73; and average of the four live-hog measurements, .81. From correlation studies with lean cuts it appeared that live-hog measurements were more accurate indicators of leanness and carcass value than the average of the carcass backfat measurements.

Hazel and Kline (1953) subsequently reported the locations behind the shoulder, over the loin and the top of the ham to have the greatest accuracy as measures of fatness and leanness. The correlation between four backfat measurements taken on the carcasses and the percentages of lean cuts and fat cuts were -.75 and .79, respectively. These figures are evidence that measurements at some of the sites reflect fatness and leanness as accurately as backfat measurements on the carcasses.

DePape and Whatley (1956), studying the accuracy of live hog probes involving 73 pigs, reported a correlation of -.67 between percentage primal cuts and the average of six live hog backfat measurements. The average of six probes correlated with carcass backfat was .69.

From their study of the relationship between various carcass measurements and live hog backfat measurements at different weights and locations, Hetzer et al. (1956) suggest that measurements taken at weights between 175 and 225 pounds are generally as accurate as are carcass backfat measurements. Also, live hog measurements have greater accuracy for measuring fatness than for measuring percentage preferred cuts or percentage lean meat in hams.

In 1955 an instrument called the Lean Meter became available for probing backfat thickness. Whatley (1956) reports comparable results with this instrument to results obtained with the knife-ruler probe. Thirty six pigs were probed with both the Lean Meter and the knife-ruler probe. Correlation between the two was .88. The knife-ruler probe and the Lean Meter gave the respective correlations of .78 and .81 with carcass backfat. The correlations with percent lean cuts were -.79 and -.70 for the two methods.

III. DESCRIPTION OF DATA

The boar pigs used in this study were farrowed in the Swine Breeding Project conducted at the Oklahoma Experiment Station in collaboration with the Regional Swine Breeding Laboratory. There were records for 77 boars at the Fort Reno station and 33 boars at Stillwater. The Stillwater data were collected only for the fall of 1956, whereas the Fort Reno data were collected from both fall and spring farrowed boars in 1955 and 1956.

The Stillwater data consisted of 10 boars from OK Line 9 (Beltsville No. I breed) and 23 OK Line 8 (Duroc breed) boars. The data at the Fort Reno station included 41 OK Line 14 (Hampshire breed) and 36 OK Line 3 (Duroc breed) boars.

General management practices at both Fort Reno and Stillwater were to produce litters both in the spring and in the fall. The litters were farrowed in a central farrowing house and the sows and litters were moved to small houses on pasture after three to seven days. The pigs were creep-fed and the sows were fed standard rations. Pigs were vaccinated for hog cholera before weaning. Boar pigs to be performance tested were selected before weaning and the other male pigs castrated. All pigs were weaned at approximately 56 days.

The Fort Reno boar pigs were placed on an individual performance test in which each boar was self-fed individually from 50 to 170 pounds weight in small concrete floored pens. At 170 pounds the backfat thickness on each boar was measured with a Lean Meter. The average daily gain and feed required per 100 pounds gain were calculated from 50 to 170 pound weight period. In the fall of 1956 boars were continued on test to 210 pounds.

Feed economy [1] was not measured on individual boars at the Stillwater station. They were tested in a group on pasture or as a pair in small concrete pens. Litter mate pairs, or a pair of paternal half brothers, were alloted to ten pens. The boar pigs were placed in the pens or in the group as they attained the weight of 50 pounds. The boars were probed at 170 and 210 pounds for a measure of backfat thickness. The average daily gain was calculated on each individual boar, but since the feed records were kept as a whole for the group and as one record for each pen there were no figures for feed economy on an individual pig basis. Feed economy was calculated as an average of the group or each pen.

Each boar pig on test at Stillwater received a feet and leg score at 50, 170, and 210 pounds. The scoring was based upon four factors for both front and hind legs: straightness, balance on toes, enlargements around the knees or hocks, and strength of pasterns. Each factor was given a score between 1 and 9 for both front and rear legs, and the scores added together for a final score. Hence, the highest possible score on any one boar for one scoring was 72.

Backfat probes were made immediately behind the shoulder (in the region of the seventh rib) and over the center of the loin (in the

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[1] Since economy of gain or feed economy is determined by the ratio of feed eaten per unit of gain, a high ratio indicates a less economical pig with high feed requirements and a low ratio indicates a pig with low feed requirements. Henceforth, whenever economy of gain or feed economy is used, consider it to mean feed required per 100 pounds gain.

region of the third or fourth lumbar). Two probes were made at each location, about 1½ inches on either side of the midline of the back. These four probes were then averaged to give the probe backfat measurement for each boar.

Probing was done as near the 170 and 210 pound weights as possible. However, all boars could not be probed at the exact weight and they were adjusted to the standard weight by the use of regression coefficients. These regression coefficients were estimated from unpublished data at the Stillwater station and data reported by Hetzer et al. (1956). The following probe backfat correction factors were used: OK 8, 3 and 14 boars for 170 pound weight, .005; OK 9 boars for 170 pound weight, .004; OK 8, 3 and 14 boars for 210 pound weight, .006; and OK 9 boars for 210 pound weight, .005. Each regression coefficient may be expressed as the average increase or decrease in probe backfat per increase or decrease of one pound in weight.

The boars at Stillwater and Fort Reno received basically the same 75 percent corn, 25 percent protein supplement ration. The Fort Reno boars received the ration in a pelleted form, whereas, the ration fed the Stillwater boars was ground. As the Stillwater boars attained a weight of 100 pounds, they were changed to a 80 percent corn, 20 percent protein ration. This ration was considered as being representative of a commercial type ration designed to produce market pigs.

IV. ANALYSIS OF DATA

A. Fort Reno Individual Boar Test

The objectives of the study at Fort Reno were to determine the various factors that may affect average daily gain, feed economy and probe backfat in conducting a performance test for boars.

The analysis of variance for unequal subclass numbers as outlined by Snedecor (1956, pages 268-275) was used to analyze the data. An analysis of variance was performed on average daily gain, feed economy and probe backfat thickness.

For the purpose of calculation, all of the boars in one line in the same season were called a block. There were eight such blocks, having seven degrees of freedom. The components of the blocks were line (1 d.f.), season (3 d.f.) and line X season interaction (3 d.f.). The sums of squares for the litters represented was calculated (45 d.f.). By subtracting the block sum of squares from the litters sum of squares, the sum of squares for between litters within blocks (38 d.f.) was obtained. In this breakdown the sum of squares for sires within line and season (13 d.f.) was calculated. This was then subtracted from the between litters within blocks to obtain sum of squares for litters by the same sire (25 d.f.). The sum of squares for within litters (31 d.f.) was obtained by subtracting the litters sum of squares from the total sum of squares.

Snedecors F test was applied for testing significance. The mean square for interaction was used to test season and line, and the interaction mean square was tested by using the mean square for within litters. Sires within line and season was tested against litters by the same sire. This in turn was tested by using the mean square for within litters.

B. Stillwater Pasture and Pen Test

The objectives were to determine if there is a difference between the testing of boar pigs on pasture as a group or on dry lot in pairs.

An analysis of variance with unequal subclass numbers was made for leg score, probe backfat and average daily gain for both 170 and 210 pounds. Sources and degrees of freedom are given as: treatments (1 d.f.); litters (9 d.f.), treatment X litters interaction (9 d.f.) and between littermates on the same treatment (7 d.f.).

Only boars that had at least one or more littermates on each treatment were included in the analysis, making a total of 27 boars from 10 litters. The treatments were boars on pasture as one treatment and boars in pens as the other treatment.

Treatments and litters mean squares were tested against the interaction mean square by use of the F test. The interaction mean square was tested against the between littermates on the same treatment mean square.

C. Phenotypic Correlations

The phenotypic correlations were calculated as between traits on the same boar. The data used in the calculation of the correlation coefficients were taken from only the fall data of 1956 from both stations. These sets of data contain measurements at 170 and 210 pounds for the same trait.

V. RESULTS AND DISCUSSION

A. Fort Reno Individual Boar Test

The analysis of variance for the Fort Reno data is given in Table III. A highly significant difference was found between lines for probe backfat at 170 pounds. The four season average for probe backfat in Table IV indicates that the OK 14 boars had .13 inch less backfat than did the OK 3 boars. Line differences in average daily gain and feed economy were not significant in these data.

TABLE III

ANALYSIS OF VARIANCE FOR PROBE BACKFAT THICKNESS, FEED ECONOMY, AND AVERAGE DAILY GAIN (mean squares) FORT RENO BOARS INDIVIDUAL TEST

Source of variation	d.f.	Average daily gain	Feed economy	Probe backfat thickness
Season	3	.098	15175.06	.010
Line	1	.185	2873.34	.302**
Line X Season	3	.048	3459.27*	.006
Sires within line and season	13	.043	2929.83	.021
Litters by the same sire	25	.041*	2046.82*	.023
Within litters	31	.020	873.62	.017

* Significant at the 5% level
** Significant at the 1% level

TABLE IV

SEASONAL MEANS FOR LINES,
FORT RENO BOARS

		Line OK 14				Line OK 3			
Year	Season	No. boars	Average daily gain (pounds)	Feed economy	Probe backfat thickness (inches)	No. boars	Average daily gain (pounds)	Feed economy	Probe backfat thickness (inches)
1955	Spring	7	1.88	318	1.27	9	1.85	332	1.40
1955	Fall	11	1.79	371	1.29	6	1.98	330	1.41
1956	Spring	12	1.64	344	1.26	11	1.81	317	1.35
1956	Fall	11	1.82	280	1.22	10	1.87	298	1.39
	Average	10.2	1.78	328.2	1.26	9.0	1.88	319.2	1.39

There were significant differences in litters by the same sire for average daily gain and feed economy. This would indicate that there was probably some maternal or environmental influence causing the litters by the same sire to be different for feed lot performance.

A significant difference was found in line X season interaction for feed economy; whereas, no significant difference was found in this source for average daily gain and probe backfat.

No component analysis was run on the data for lack of sufficient numbers. With the accumulation of more data it may be possible in the future to perform a component analysis in order to obtain the percentage variation in each source of variation for each performance trait. Also estimates of heritability could be obtained for each performance trait from this component analysis.

B. Stillwater Pasture and Pen Test

There was no significant difference in the treatment variation for the performance traits as shown in Table V. However, by studying the means in Tables VI, VII, and VIII it may be seen that the boars on test in the pens averaged .1 pound more gain per day than those boars on pasture. The pasture boars had an average final leg score of 3 more points than did the pen boars on concrete.

There was a significant treatment X litter interaction for leg score at 210 pounds. This may be due in part to a difference in lines. Line 9 boars seem to have a greater tendency to have better scores on pasture than on concrete. Line 8 boars averaged better scores in both treatments than the line 9 boars. This line difference may account for the significant variation in the interaction.

TABLE V

ANALYSIS OF VARIANCE FOR LEG SCORES, PROBE BACKFAT THICKNESS AND AVERAGE DAILY GAIN (mean squares) IN THE PASTURE AND PEN TEST

Soruce of variation	d.f.	Leg score 170 lbs.	Leg score 210 lbs.	Probe Back-fat 170 lbs.	Probe Back-fat 210 lbs.	Average daily gain 50-170 lbs.	Average daily gain 50-210 lbs.
Treatments	1	42.5009	62.6832	.0037	.0040	.0466	.0496
Litters	9	51.7952	57.2037	.0810*	.1410**	.0388	.0307
Treatments X Litters	9	17.9721	27.0722*	.0174	.0174	.0254	.0199
Between littermates on the same treatment	7	15.8571	7.2857	.0178	.0119	.0117	.0065

* Significant at the 5% level
** Significant at the 1% level

TABLE VI

LITTER MEANS FOR AVERAGE DAILY GAIN IN THE PASTURE AND PEN TEST

Litter	Line	No. Pigs Pen	No. Pigs Pasture	Average daily gain in lbs. from 50-170 pounds Pen	50-170 pounds Pasture	50-210 pounds Pen	50-210 pounds Pasture
0	OK 8	1	2	2.34	1.96	2.27	1.94
10	OK 8	2	2	1.94	1.80	1.92	1.82
20	OK 8	1	1	1.87	1.66	1.74	1.70
70	OK 8	1	1	1.96	1.75	1.94	1.77
80	OK 8	1	2	1.88	1.79	1.92	1.91
90	OK 8	2	1	1.79	1.77	1.80	1.90
230	OK 8	1	1	2.13	1.74	2.10	1.69
210	OK 9	2	1	1.74	1.74	1.80	1.63
400	OK 9	1	1	1.55	1.79	1.69	1.65
490	OK 9	2	1	1.75	1.68	1.84	1.72
		14	13				
		Average -		1.87	1.79	1.88	1.79

TABLE VII

LITTER MEANS FOR PROBE BACKFAT IN THE PASTURE AND PEN TEST

Litter	Line	NO. Pigs Pen	NO. Pigs Pasture	Probe backfat in inches at 170 pounds Pen	170 pounds Pasture	210 pounds Pen	210 pounds Pasture
0	OK 8	1	2	1.60	1.43	1.89	1.67
10	OK 8	2	2	1.54	1.66	1.76	1.82
20	OK 8	1	1	1.50	1.26	1.55	1.20
70	OK 8	1	1	1.60	1.56	1.63	1.58
80	OK 8	1	2	1.71	1.48	1.99	1.92
90	OK 8	2	1	1.38	1.20	1.52	1.52
230	OK 8	1	1	1.46	1.60	1.71	1.90
210	OK 9	2	1	1.28	1.07	1.46	1.22
400	OK 9	1	1	1.18	1.18	1.32	1.33
490	OK 9	2	1	1.22	1.11	1.32	1.36
		14	13				
		Average -		1.42	1.39	1.58	1.61

TABLE VIII

LITTER MEANS FOR LEG SCORES IN THE PASTURE AND PEN TEST

				Leg Scores at			
		No. Pigs		170 pounds		210 pounds	
Litter	Line	Pen	Pasture	Pen	Pasture	Pen	Pasture
0	OK 8	1	2	62.0	63.5	61.0	60.5
10	OK 8	2	2	60.5	63.0	60.0	59.0
20	OK 8	1	1	53.0	60.0	49.0	62.0
70	OK 8	1	1	57.0	59.0	58.0	55.0
80	OK 8	1	2	40.0	54.0	39.0	54.0
90	OK 8	2	1	59.0	64.0	58.5	63.0
230	OK 8	1	1	58.0	58.0	58.0	51.0
210	OK 9	2	1	59.0	62.0	52.0	55.0
400	OK 9	1	1	54.0	54.0	46.0	52.0
490	OK 9	2	1	56.0	51.0	49.5	52.0
		14	13				
		Average -		56.6	59.2	53.6	56.7

There was a highly significant difference between litters for probe backfat at 210 pounds. There was also a significant difference for probe at 170 pounds. This litter variation is probably due mostly to the difference in the probes between lines. However, there is considerable variation observed even between litters within the same line. This variation should help selection for this trait by making the selection differential larger.

Since there are apparently no real differences in testing boars on pasture or pens, it may be more economical for the farmer to test his boars as a group on pasture. Most commercial producers do not have the facilities for individual boar testing pens or even for feeding several boars together. They may be able to get the performance picture of the individual fed with a group. It must be remembered that there is no way to obtain individual feed records when boars are fed as a group and consequently the feed economy can not be figured except as an average for the group. This would be one advantage that the individual feeding would have over the group feeding.

C. Phenotypic Correlations

The phenotypic correlations summarized in Table IX and Table X were computed on the fall data of 1956. The correlations were computed from all boars on test at both Stillwater and Fort Reno. The phenotypic correlations measure the relationship between two traits as expressed in the same individual. As such they are composed of both genetic and environmental influences which may or may not be working in the same direction.

TABLE IX

PHENOTYPIC CORRELATIONS ON FORT RENO BOARS[1]

Trait	Average daily gain 50-210 lbs.	Feed economy 50-170 lbs.	Feed economy 50-210 lbs.	Probe Back-fat 170 lbs.	Probe Back-fat 210 lbs.
Average daily gain 50-170 lbs.	.74**	-.30		.32	
Average daily gain 50-210 lbs.			-.48*		-.17
Feed Economy 50-170 lbs.			.90**	.36	
Feed Economy 50-210 lbs.					.47*
Probe Backfat 170 lbs.					.87**

* Significant at the 5% level
** Significant at the 1% level

[1] Based on 20 degrees of freedom

TABLE X

PHENOTYPIC CORRELATIONS ON STILLWATER BOARS[1]

	Leg score 50 lbs.	Leg score 170 lbs.	Leg score 210 lbs.	Average daily gain 50-170lbs.	Average daily gain 50-210lbs.	Average daily gain 170-210lbs.	Probe Back-fat 170lbs.	Probe Back-fat 210lbs.
Initial age	.30	-.06	-.02	.04	-.16	-.32	.16	-.12
Leg score 50 lbs.		.32	.14	-.29	-.28	-.10	-.20	-.39*
Leg score 170 lbs.			.72**	.13	.15	.01	-.06	-.12
Leg score 210 lbs.				.21	.35*	.09	.11	.13
Average daily gain 50-170 lbs.					.76**	-.28	.51**	.49**
Average daily gain 50-210 lbs.						.35*	.43*	.54**
Average daily gain 170-210 lbs.							-.18	.02
Probe Backfat 170 lbs.								.87**

* Significant at the 5% level
** Significant at the 1% level
[1] based on 30 degrees of freedom

The correlations from the Fort Reno station are based on measurements made on 23 boars. The correlations from the Stillwater data were based on measurements made on 33 boars. To obtain statistical significance at the 5% and 1% levels, correlations must be higher than .423 and .537 for the Fort Reno data and higher than .349 and .449 for the Stillwater data.

The correlation of -.48 between average daily gain and economy of gain corresponds to previous estimates by Evvard (1927), Lush (1936), Dickerson and Grimes (1947), Fredeen (1953) and Anderson (1954). The correlation suggests that the faster gaining pigs are on feed a shorter time and hence consume less feed. It is also possible that faster gaining pigs require less feed for maintenance, or that they have the ability to digest feed more efficiently than slow gaining pigs. In all probability all three possibilities could be effective in causing a relation between economy and average daily gain.

The correlation between average daily gain from 50 to 170 pounds and probe backfat thickness at 170 pounds was highly significant in the Stillwater data. Line differences may account for this high correlation. Line 8 boars were fatter and made more rapid gains than the Line 9 boars. This correlation in the Fort Reno data was positive but not significant. There were less differences between Line 3 boars and Line 14 boars for gain and backfat thickness. The significant correlation of .54 between average daily gain from 50 to 210 pounds with probe at 210 pounds in the Stillwater data is not in agreement with the -.17 correlation obtained in the Fort Reno data. No explanation can be given for this being negative other than sampling variation. The other positive correlations between gain and probe backfat shows that fast gaining pigs tend to have a greater probe backfat thickness. Lush (1936) also noted a positive correlation between fatness and rate of gain as did Fredeen (1953), Anderson (1954), and Blunn and Baker (1947).

No simple explanation of the relation between fatness and rate of gain is possible. There may be some physiological explanation involving the neural and hormonal systems.

The correlation between feed economy and backfat thickness was positive and was significant when computed at 210 pounds (feed economy and probe). This indicates that pigs making the most inefficient gains (that is, consuming more feed per hundred pounds of gain) tend to have thicker backfat. Lush (1936) and Dickerson (1947) also found that pigs with high feed requirements had the thickest backfat. Because of the much higher energy content of fat tissue, it may be that animals whose gains are more largely fat would require larger amounts of feed per unit of weight gain.

There are several part-whole correlations in the data involving measurements of the same trait taken at different times. It is expected that these correlations would be high since the latter measurement contains a large portion of what was in the first measurement. These part-whole correlations for the two stations are quite similar. Average daily gain between 50 and 170 pounds correlated with gain between 50 and 210 pounds was .74 and .76 at Fort Reno and Stillwater respectively. Correlation between probes at 170 and 210 pounds was .87 for both stations. At Fort Reno the correlation between feed economy from 50 to 170 pounds and economy from 50 to 210 pounds was .90. Leg score at 170 pounds correlated with leg scores at 210 pounds was .72 for the Stillwater data.

These highly significant part-whole correlations indicate that if a trait measures high at 170 pounds then it will probably measure high at 210 pounds.

There are other correlations in the Stillwater data that have no significance. They do in some cases indicate tendencies for one trait to be affected by another. If these correlations are real, they may obtain significance with an increase in sample size.

VI. APPLICATION

The changes to be expected from selection are contingent upon the heritabilities of the traits. The summary for heritability estimates as found in the literature was presented in table II. Heritability measures the fraction or percentage of the variation in a trait that is transmitted to the next generation. It is an average figure and will have many individual exceptions.

The literature suggests that carcass characteristics are more highly hereditary than the other economically important traits. Among these carcass traits is backfat thickness which seems to be one of the best indicators of carcass merit. The main handicap to progress by selection for backfat thickness lies in the correct appraisal of the breeding animal. By placing the breeding animal on the same kind of feeding conditions that his offspring will be under, the breeder may get a measure of the backfat thickness by use of the Lean Meter or ruler probe. Since backfat thickness seems to have a high heritability of about 50% it can be effectively improved by selection once it is correctly measured on the live hog.

In the light of the findings in the present study and by other workers in the field, selection for more rapid gains would result in fatter pigs. The evidence of this depends upon the validity of the positive correlation between rate of gain and backfat thickness. Some criteria of rapid and economical gain for which selection could be made without concomitant increases in fatness would be desirable.

Reports by Baker _et al._ (1943), Hazel _et al._ (1943) and Blunn _et al._ (1953) have indicated the feasibility of selecting for rate of growth for the period from 56 to 112 days. McMeekan (1940) observed that skeletal and muscle growth was more pronounced compared to that of fat at 112 days. Thus selection at about 112 days might provide a means of improving growth rate without excessive increase in fatness. Selection at this earlier age would be more nearly for rapid growth of muscle and bone than for fat.

Blunn _et al._ (1953) found that 112 day weight could be used satisfactorily in selecting boars. If a preliminary selection of boars was made at 112 days of age and double the number of boars finally desired were saved, the remaining boars could be castrated without fear of discarding good individuals.

The high correlations for the same trait measured at different times, suggest that as much selection could be practiced at 170 pounds as 210 pounds. This may actually become more economical for a boar testing program, because boars could be taken off test at 170 pounds before ranting could occur with more maturity.

Methods of selection directed solely towards one trait are not as effective as one based on a properly balanced combination of all desired traits (Hazel, 1943). Hence, a selection index utilizing some of the information obtained in a performance test might be desirable.

VII. SUMMARY

The objectives of this study were (1) to determine the various factors that may effect the average daily gain, feed economy and probe backfat thickness in the performance test; (2) to obtain estimates of phenotypic correlations between the various performance traits; and (3) determine if there is a difference between the testing of boar pigs on pasture in a group or on dry lot in pairs.

The data were based on records of 77 boars on individual performance test at the Fort Reno station and 33 boars on a pasture and pen test at the Stillwater station. The Stillwater data were collected only for the fall of 1956, whereas, the Fort Reno data represents the fall and spring seasons of 1955 and 1956. OK Line 9 (Beltsville No. I) and OK Line 8 (Duroc) were the breeds represented at Stillwater, and OK Line 14 (Hampshire) and OK Line 3 (Duroc) were represented at Fort Reno.

The boar pigs were self-fed in small individual concrete floored pens at Fort Reno and self-fed as pairs in concrete floored pens or as a group on pasture for the Stillwater boars. Each boar was probed and adjusted to 170 pounds and in the fall 1956 probed and adjusted to 170 pounds and 210 pounds.

A highly significant difference was found between lines for probe backfat thickness. There was a significant difference in litters by the same sire for feed lot performance, indicating that there may be some maternal or environmental influence causing the litters by the same sire to vary. There was a significant line X season interaction for feed economy but no significant interaction for average daily gain and probe backfat.

In this experiment there was no significant difference between feeding boars as pairs in concrete pens or as a group on pasture. Lack of the proper facilities for individual or pair testing should not hinder the breeder from obtaining some useful information. Group testing will supply information as to rate of gain and backfat thickness but not for feed required per 100 pounds of gain.

A negative correlation of -.48 was obtained between average daily gain and feed required per 100 pounds of gain. Average daily gain was postively correlated with backfat thickness. The correlation between feed requirements and backfat thickness was positive and significant at 210 pounds. The part-whole correlations (that is, between the same measurements taken at different times) were highly significant and quite similar at both stations, indicating that selection should be as effective at 170 pounds as at 210 pounds.

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