FEEDING TESTS WITH INBRED LINES AND LINE CROSSES OF SWINE

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INTRODUCTION

Animal breeding is a building process by which the livestock producer constantly seeks to improve domestic animals. The three basic tools available for bringing about genetic improvement are: inbreeding, selection, and outbreeding. Although these tools have been used by man since the domestication of animals, the first constructive use of these methods in a systematic breeding program was by Robert Bakewell in improving some of the native livestock of England. Modern livestock breeders are using these same practices to improve the present breeds and to raise the productivity of commercial livestock.

The remarkable results achieved by the plant breeders through inbreeding and crossing of inbred lines to improve the yield of corn seem to justify investigations into the possibility of using similar methods in swine production. Much work has been initiated in this direction during recent years. The major projects in this field are being conducted cooperatively by the Bureau of Animal Industry of the Department of Agriculture and various state experiment stations through a Regional Swine Breeding Laboratory with headquarters at Ames, Iowa.

Uniform breeding lines are to be developed and their usefulness tested under different breeding systems. Thus selection by lines, as well as by individuals, will be possible. The breeder will then be able to select superior breeding stock with greater accuracy. In both the development and use of inbred lines, the roles of inbreeding and crossbreeding will assume added importance.

The use of inbred lines and crosses of these lines may assume increasing importance in animal production. Individual differences in

nearly all of the characteristics of economic importance in livestock are not highly hereditary. In swine, only 18 per cent (Lush, 1943) of the individual differences in economy of gain, and 1/3 to 1/5 of the differences in rate of gain from birth to 6 months of age (8th. Ann. Rpt. of Reg. Swine Br. Lab., 1946) were found to be hereditary. The rest of the differences between individuals were apparently due to environment. Consequently, improvement by individual selection for these traits would be slow. A single unfortunate selection of a sire--one good phenotypically but poor genotypically--could possible destroy the progress of past generations of selection. If hereditary differences could be fixed through the development of inbred lines, the possibility of selecting the wrong individuals for breeding stock would be much reduced.

Many inbred lines will undoubtedly prove undesirable and will be eliminated, but the good ones can be highly inbred, thus making them breed relatively true. The crossing of these inbred lines, especially if they have been developed from widely unrelated parental stock, may be expected to give a combination of desirable characters and the offspring of such crosses may be superior to the parental stock. Certain crosses that "nick" well may show a high degree of hybrid vigor.

The combining ability of inbred lines may be very different, yet this ability cannot be accurately predicted by the performance of the line itself. Due to this great variation in the combining ability of inbred lines, and since this phase is highly important in measuring the genetic value of the line, an experiment was undertaken to gather preliminary information on the combining ability of three of the inbred lines of Duroc swine developed at Oklahoma A. and M. College.

REVIEW OF LITERATURE

General Effects of Inbreeding.

For centuries, the use of inbreeding in livestock production has been the subject of much discussion. In general, livestock breeders have tried to prevent close inbreeding, thinking that it would produce progressive degeneration. They believed this to be exemplified by reduction in constitutional vigor, size, growth rate, economy of gain, and lowered fertility. On the other hand, most of the present breeds of livestock are the products of inbreeding of selected stock during the formative years of their history. The first systematic breeding of livestock began in the middle of the eighteenth century when Robert Bakewell demonstrated the use of inbreeding in improving Leicester sheep, Shire horses, and Longhorn cattle. He made extensive use of inbreeding to fix the type he desired. Much the same method was followed by many of the early breeders during the development of the present breeds of livestock.

The views of early livestock breeders such as Bakewell, Bates, and the Colling brothers were not universally accepted. Such biologists as Darwin, Weisman, and Von Guita considered inbreeding as injurious and thought it would produce abnormal individuals and progressive degeneration. Many of these views have changed, and today plant and animal geneticists consider inbreeding as a powerful tool in the improvement of both plants and animals.

Since 1918-19, when Helen D. King published the results of her experiments with inbred rats, much work has been done on the value of

inbreeding, both in the laboratory and on the farm. Although the results of these experiments have been variable, the same general effects are apparent.

King reported that Albino rats which were inbred by twenty-five generations of full-sib matings were superior to the non-inbred control stock in all of the measures of vigor studied. From this work, she concluded that inbreeding was not detrimental if careful selection of lines and individuals were practiced.

In experimental work with guinea pigs by Wright (1922), it was found that after twenty generations of brother x sister matings, the inbreds were, on the average, inferior to the outbred control stock in all of the measures of vigor. However, there were a few inbred lines that did not suffer any appreciable degeneration. Comparison of the inbred lines showed considerable variation in such factors as fertility, growth rate, and mortality. These elements of vigor appeared to be inherited independently of each other, and each family became characterized by a particular combination of traits, usually involving strength in some respects and weakness in others.

From a common foundation, through continued brother x sister matings accompanied by careful selection, Morris, Palmer, and Kennedy (1933) developed two strains of rats which (in the ninth generation) differed markedly in efficiency of food utilization. The low-performance line was forty per cent less efficient and more variable than the highly efficient line. The feed requirements of each inbred strain was more uniform than for the outbred controls.

Plant breeders have shown that inbred lines may be developed which

excell in a few characteristics. Jenkins (1936) states that inbred lines of corn have been developed which differ in their resistance to disease, insect injury, cold, drought, productivity, and composition of the plant and grain. However, it has been impossible to combine all of the good traits in one line.

Waters and Lambert (1935) inbred White Leghorn chickens for ten years, developing six inbred lines with inbreeding coefficients ranging from 41 to 82 per cent. Neither egg weight nor growth rate appeared to be affected by inbreeding. There was no general decrease in egg production or fertility, but there was a decrease in hatchability and mortality.

Eaton (1940), in his studies of inbreeding in mice, found that on the average the outbred control mice were heavier than the inbred strains both at weaning and 120 days of age. However, of the nine inbred strains studied, two were almost equal to the average of the three control lots. This study also demonstrated that there is a great variation among inbred strains, and that the same inbred line is not likely to be superior in all characteristics.

Inbreeding in Swine.

Of all the farm animals, swine are among the best suited for inbreeding studies because of their high prolificacy and relatively short generation interval.

In 1919, Hays presented a report on the inbreeding program which was conducted with Berkshire hogs at the Delaware station from 1908 to 1918. The birth weight of the pigs did not seem to be affected by the inbreeding of the litters, but inbreeding did have a detrimental effect

on the post-natal growth rate. During the 300 days following birth, the average daily gain of the outbreds was .550 pound per day as compared to .387 pound per day for the inbreds.

Hughes (1933) reported on the results of inbreeding Berkshire swine by brother x sister matings for a period of eleven years. He found, as did King, that no decrease in the size or vigor of the inbred individual results when careful selection is practiced.

In 1932, Godbey and Starkey reported a study on inbreeding Berkshire swine which involved 63 litters and 585 pigs. They found no correlation between the coefficient of inbreeding and birth weight of the inbred pigs, but did find a correlation between the weaning weight and the degree of inbreeding -- the greater the inbreeding, the smaller the weaning weight. The final weights were also decidedly lower for the inbred pigs.

Observations on five generations of Duroc swine which were inbred by half-brother x half-sister matings (54 litters in all) were reported by Craft (1931). A check lot of outbred pigs was included in this study. The average rate of gain was sixteen per cent in favor of the outbred group. The inbreds required 7.4 per cent more feed to produce 100 pounds of gain than did the outbreds. These pigs were not raised on clean ground and the author comments that the lower resistance to disease and internal parasites by the inbred pigs may have accounted for some of the differences.

Craft (1934) reported the performance of the inbred and outbred pigs farrowed at Oklahoma A. and M. College during 1932-33. The inbreds were produced by two different systems of mating: Half-brother x half-sister,

and mating sire to daughter. In this study, the pigs were weighed at various intervals up to 180 days of age. The outbred pigs were heavier at every age and the half-sib inbreds were heavier than the sire-daughter group. Results from digestion trials for representative pigs of each group suggested that the outbreds were more efficient in the digestion of feed than were the inbreds.

Hodgson (1935) developed three highly inbred lines of Poland China hogs by brother x sister matings for eight generations. These lines were checked against outbred stock for various measures of vigor. The outbreds reached market weight of 200 pounds in three weeks less time, but there was very little difference in the rate of gain for the first sixteen weeks after birth. No definite data were secured regarding efficiency of gain, but from the records of the pigs entered in the National Swine Record of Performance work at Minnesota, it appeared that the loss of vigor from inbreeding as expressed in efficiency of gain was slight. Some of the inbreds produced in this work were excellent from a show standpoint.

In 1937, the U. S. Bureau of Animal Industry started inbreeding six lines of Poland China, six lines of Tamworth, and two lines of Chester White swine, by full brother x sister matings. Several lines of the inbreds were discarded because of poor performance, but some were continued for seven generations. In general, inbreeding resulted in a loss of vigor. The rate of growth decreased and the feed requirement per 100 pounds of gain increased in the inbred lines.

Lush and Culbertson (1937) started an inbred herd of Poland China swine for the purpose of studying the effects of inbreeding in a closed-

herd breeding program in which four boars were used each breeding season. After twelve years, the average inbreeding coefficient of the herd was 15.4 per cent, with a range of 3 to 37 per cent. The highly inbred individuals were smaller at weaning and gained slower after weaning. There was a correlation of -.41 between the intensity of inbreeding and the growth rate to six months of age.

Willham and Craft (1939) conducted an experiment with Duroc hogs to study the effects of continuous, but relatively mild, inbreeding in swine. Matings of approximately half-brother x half-sister were made for eight generations, and an outbred control group was maintained. At the end of eight generations, the average inbreeding of the inbred lines was 45.6 per cent. The inbred pigs in this study made smaller daily gains than the outbred pigs throughout the period from birth to market weight. The difference tended to increase with age until the pigs were 180 days of age, at which time the difference tended to decrease. The inbred pigs were more uniform in the amount of feed required per 100 pounds of gain, but on the average required 21 more pounds of feed per 100 pounds of gain than did the outbreds.

Winters and others (1943) started an inbreeding program with Poland China swine in which no definite plan of inbreeding, such as brother x sister was used, but rather the inbreeding was advanced as fast as possible without sacrificing performance. They found that for each increase in inbreeding of one per cent, the rate of gain for males decreased .0035 pounds per day, and for females, .0029 pounds per day. Both of these values were statistically significant.

The Merits of Crossbred Hogs:

Crossbreeding for the production of market animals has been practiced for many years, particularly with swine, and sheep, and to a limited extent with beef cattle. By this method, the breeder takes advantage of the hybrid vigor that frequently results from the crossing of distinct lines and breeds.

The most extensive experimental work in this field has been with swine. Roberts and Liable (1925) conducted a double mating experiment which has been the method used in some of the later work. They mated a Duroc sow to both a Poland China and a Duroc boar during the same heat period. From this mating, ten pigs were farrowed, four crossbreds and six purebreds. At six months of age, the four crossbreds averaged 235 pounds each, while the two purebreds still living averaged 185 pounds each. While this experiment did not prove much in itself, it did introduce an accurate method of testing the hybrid vigor produced in breed crosses. By use of this method, environmental variation could be reduced to a minimum.

Carroll and Roberts (1924-25-26), Shearer (1926), and Lush, Shearer and Culbertson (1939) conducted experiments in which Duroc and Poland China sows were double-mated to boars of both breeds in the same heat period. In these tests, the crossbreds were generally superior to the purebreds in both rate and efficiency of gain, although not all of the results were statistically significant.

Headley (1940) found crossbred Duroc x Poland China pigs to be superior to purebreds for rate and efficiency of gain. These tests were made on pasture feeding trials. The crossbreds required 287 pounds of feed per 100 pounds of gain, as compared to 321 pounds of feed for the

purebreds. The rate of gain was 1.45 pounds per day for the crossbreds and 1.30 pounds per day for the purebreds.

Shaw and MacEwan (1936) and Robison (1938) compared various purebreds with the first crosses of these breeds. The results indicated that the crossbreds held a slight advantage over the purebreds for both rate and efficiency of gain.

Carroll and Roberts (1942) summarized the performance of over 50,000 crossbred and purebred hogs which were included in numerous experiments conducted by the United States Department of Agriculture, nine state agricultural colleges, and experiment stations in six foreign countries.

In this work, crossbreeding was considered beneficial only when the performance of the crossbred pigs excelled that of the better of the two parental strains in each of the six traits considered. These six traits were: 1. number of pigs farrowed per litter; 2. average weight per pig at birth; 3. vigor of the pigs as shown by their survival ability; 4. weight of the litters at weaning; 5. rate of gain, and 6. economy of gain. These workers found the crossbreds to be intermediate to their two parental strains in all items except survival ability and rate of gain. In survival ability the crossbred pigs were just equal to the better parental strain by .006 pounds per day.

From these results, Carroll and Roberts concluded that hybrid vigor cannot be expected in crossbreeding, but that it is a grading-up process from the poorer to the better purebred.

Lush, Shearer and Culbertson (1939) summarized the results of many of the important experiments in this field. They point out that no one

experiment, especially where small numbers are involved, appears to warrant any real advantage in favor of crossbreeding. Yet, the majority of experiments indicate that such an advantage is probable.

These workers conclude that the combined weight of all the evidence is an overwhelming indication that crossbreeding results in increased production. The crossbred pigs tend to be somewhat more vigorous and thrifty than their parental stock. Generally, they require less feed per 100 pounds of gain, while putting on weight at a slightly faster rate. Lush and his co-workers emphasize that these are the results that can be expected on the average, but they should not be expected to happen in every case.

Crossing of Inbred Lines.

The crossing of inbred lines is widely used in plant production, but has been of little importance in livestock operations on the farm. Essentially, it consists of maintaining distinct, widely divergent lines of stock and then crossing these lines to produce improved progeny for either market or production.

In general, the crossing of inbred lines produces progeny that are superior to the parental lines, but in order to get a progeny superior to good outbred stock, carefully selected and tested lines must be used. In corn production, Wallace (1938) estimates that out of the hundreds of thousands of inbred lines developed, only 40 to 50 have been really outstanding. Jenkins (1936) states that crosses between promising inbred lines have increased corn yields by 10 to 30 per cent above the parental strains. This increase in yield holds only for the first generation, but near maximum production has been produced by crossing two unrelated

F_1 hybrids.

Animals do not lend themselves as well to the development of inbred lines as do plants. In the first place, the success of hybrid corn breeding rests on the fact that corn can be self-fertilized, generation after generation. Swine cannot be self-fertilized at all and would require eleven generations of brother x sister matings to attain the same degree of inbreeding as four generations of self-fertilization in plants. Also, inbred lines of animals cannot be maintained in as pure a form as self-fertilization permits. The development of an inbred line of animals is much slower and more costly than in plants. However, some advantage may be obtained in crossing selected inbred lines of animals and several experiments have been conducted to determine how much hybrid vigor may be produced in crossing inbred lines.

Wright (1922) found that line cross guinea pigs were superior to random bred stock when all of the items of vigor were considered, but all measures of vigor were not affected to the same degree. The mortality between birth and weaning was found to depend 3/4 on the breeding of the young, and 1/4 on the breeding of the dam. In rate of gain between birth and weaning, the breeding of the dam and young were found to be of about equal importance. The line cross individuals were 16 per cent more efficient than their parental lines.

Eaton (1941) found the phenomenon of heterosis to express itself in growth rate when crossing inbred lines of guinea pigs, but much of this vigor is not manifested until the progeny approaches maturity. Of six crosses made, two were significantly larger than that of the

heavier parental line, the other crosses being approximately equal to that of the heavier parental line.

Eaton (1941) reported work with inbred lines of mice. When these lines were crossed, the F_1 litters showed improvement over both of the parental lines in weaning weight and 120-day weight. When an inbred male was mated to random bred stock, the F_1 individuals were not as heavy at weaning and 120 days as the outbred stock.

Crossing Inbred Lines of Swine.

The work with crossing inbred lines of swine has not progressed to a point where definite generalizations can be made. The results to date indicate that possibly the breeder can make effective use of inbred lines in speeding up improvement in swine breeding. The Regional Swine Breeding Laboratory has conducted various experiments in an effort to find more profitable ways to produce swine. While many problems are as yet unsolved, some tentative observations can be made. The 9th. Annual Report of the Regional Swine Breeding Laboratory (1946) states that inbreeding (as one would expect from the results with plants and small animals) depressed functional characters. The vitality of the pigs and productivity of the sows appear to be depressed more than growth rate and economy of gain of the pigs.

When inbred lines are crossed, the progeny are generally superior to the parental lines, but performance of line cross pigs superior to that of good outbred stock can be expected only when selected and tested inbred lines are used. Inbred lines developed from widely unrelated stocks have produced more favorable results when crossed than lines developed from related stock. Inbred lines developed from different

breeds have generally given more favorable results than those from the same breed. This emphasizes the fact that inbred lines should be produced from stock as nearly unrelated as can be found within a breed for best results in crossing lines of the same breed.

Some improvement may be expected in the form of growth and vigor from topcrossing or the use of good inbred boars on outbred sows of the same breed.

From the work of the Regional Swine Breeding Laboratory, it appears that inbred lines, which have inbreeding coefficients of 30 to 40 per cent, differ in physiological characters that are not evident in the appearance of the animals.

Dickerson (1946) made a study of the hybrid vigor exhibited by single crosses of inbred lines of Poland China Swine. In this study, eleven different inbred lines were used to produce 60 single cross litters and 56 inbred litters. As found in most experimental work on crossing breeds or lines within a breed, there was a greater expression of hybrid vigor in viability than growth rate, although the two are related in that the faster growing pigs are more likely to survive. Line cross pigs were very little heavier than inbreds at birth and 21 days but exceeded the inbreds by 3.4 pounds per pig at 56 days of age and by 25 pounds, or 21 per cent, at 154 days of age. There was no expression of hybrid vigor in efficiency of gain for although the line cross pigs grew more rapidly, they required as much feed per 100 pounds of gain as did the inbred pigs.

Winters (1944) conducted an experiment to gain some preliminary information on the combining ability of inbred lines. The results of

this work indicate that out of the 13 crosses made, the progeny of 12 crosses were superior to the average of parental lines in the five measures of performance used. This performance was measured by figuring the advantage in fertility, survival, rate of gain, economy of gain, and score for body conformation on a percentage basis. These five percentage values were then averaged to get the individual's score.

Further comparisons made in this study indicate that line cross pigs were superior to outbred pigs in both rate and economy of gain. Also, the crosses of inbred lines of different breeds were superior to crosses of lines within the same breed for rate and efficiency of gain.

Willham (1944) presented the results obtained from crossing two inbred lines and checking the performance of these line cross pigs with crossbred pigs, as well as with their parental lines. The crossbred pigs were produced by mating inbred Duroc sows to an inbred Poland China boar. The line cross pigs were superior to the better parental line and crossbred pigs for rate of gain. The average daily gain of the line cross pigs from weaning to six months was 1.38 pounds per day as compared to 1.14 pounds for the better parental purebreds, and 1.11 pounds per day for the crossbred pigs. There was no difference in economy of gains for these different lots. In another feeding trial the average daily gain of line cross pigs were compared to the gains made by outbred pigs. The line cross pigs gained a quarter of a pound per head per day more than the outbred stock.

Further work on the crossing of inbred lines was reported by Willham (1945). Two of the lines used in this experiment did not "nick" well, the progeny of the cross were inferior to their parental

lines. However, the crosses of other lines did produce hybrid vigor. These single crosses of lines within the same herd were superior to the cross of two lines from different breeds, but were inferior to the three-way-cross of lines within the same herd for rate of gain.

From this work, it appears that rigid selection must be practiced in the development of the inbred lines. Each inbred line must possess some special merits that will offset the loss of vigor due to inbreeding. For two lines to "nick" well they must be genetically different so that each one can contribute certain desirable genes to the line cross pigs that may be lacking in the other line. This scheme of breeding is not far different from that of crossbreeding, the big difference being that lines are inbred much faster and to a higher degree than that practiced by the breeder of purebred livestock.

Whatley (1946) summarized the performance of line 3 (one of the lines used in this experiment) in comparison with other inbred lines and a line cross 1 x 3 for rate and efficiency of gain. In this work, line 3 was the fastest gaining of any of the groups and was excelled only by the 1 x 3 line cross in efficiency of gain. In comparing the line cross 1 x 3 with a line 1 topcross it was found that the rates of gain were equal, but the topcross was slightly more efficient.

Intra-sire comparisons between inbred and line cross litters by Dickerson (1946) indicated: 1. Litter size declined .26 pig per litter at birth and .39 pig per litter at 154 days for each 10 per cent increase in inbreeding of the litter. 2. The inbreeding of the litter had no effect on pig weights at birth, but caused a decline in weight of .9 and 6.8 pounds respectively at 56 and 154 days, for each 10 per

cent rise in inbreeding, and 3. The faster growing crosses required just as much feed per pound of gain but tended to have slightly less fat and more muscular carcasses than the inbred lines. Apparently, hybrid vigor stimulates early growth so that the pig reaches 225 pounds at a slightly earlier stage of the fattening period. The pronounced hybrid vigor in viability and lack of it in feed utilization suggests that hybrid vigor consists of increased activity and rate of metabolism which reduces or delays fat deposition and offsets the lower feed cost per unit of gain which would otherwise result from faster gains.

OBJECTIVES OF THE EXPERIMENT

The primary objective of this feeding experiment was to obtain some preliminary information on the combining value of lines 3, 5, and 7 as to rate and efficiency of gain, and to compare their performance to outbred control stock and the parental lines.

Eight different breeding groups were represented, consisting of the three inbred lines (3, 5, and 7), their three single crosses (3x5, 3x7, and 5x7), the line 3 topcross, and an outbred group.

In addition, some information was secured on the carcass value and body conformation of the pigs on test.

HISTORY OF THE LINES

When the three lines used in this experiment were founded, it was planned to use ten females and two males per line per generation. However, death losses, failure of certain individuals to breed, and other difficulties have made it necessary to deviate from time to time from the general breeding plan.

Line 3

Line 3 was started in 1938. The foundation stock consisted of eleven females and three males. Ten of the females were purchased from the Cameron herd located at Herman, Nebraska, and one bred gilt was selected from the Joe Pudenz herd of Carroll, Iowa. The three foundation boars were the sires of four litters purchased in dam from these two herds. Since 1939, this line has been bred as a closed herd. During the period from 1940 to 1942, the line was split into two sublines, but these were later combined again into one line.

At present, this line has an average inbreeding coefficient of .24 to .25. Although the individuals are inclined to be plain and coarse-haired, the growth rate of the pigs and the productivity of the sows are above average. The type of this line is intermediate between lines 5 and 7.

Line 5

The foundation stock of line 5 came from the herds of Clarence Miller, Alma, Kansas; Ira Johnson, Perry, Iowa; H. D. Youngmen, Baxter Springs, Kansas; and the Texas Experiment Station. In 1946, an outcross was made by adding breeding stock from the J. Ward Stevenson herd

of Graham, Missouri. Since that time, this line has been bred as a closed herd and now has an average inbreeding coefficient of .10.

In type, this line is the largest of the three lines in this experiment, the individuals being rather long bodied and leggy. The production of the sows is fairly good.

Line 7

In 1923, three sows and one boar from the Oklahoma A. and M. College herd were placed on an inbreeding experiment. Their descendants were bred by half-brother x half-sister matings until 1938. At this time, a mild outcross from the College herd was introduced to form line 1. From 1938 to 1945, this line was bred as a closed herd. In 1943, several litter mates were purchased from Willard Klein of Iowa Falls, Iowa, and were mated to each other. Three boars and one sow were selected from the offspring. These were crossed with line 1 in 1945 to form line 7, which has been bred as a closed herd since that time. The average inbreeding of this line is approaching 24 per cent.

EXPERIMENTAL PROCEDURE

In the fall of 1947, eight pigs from each of the eight breeding groups were placed on a feeding test. The pigs from the three lines and the three single crosses were farrowed at the Oklahoma station. Four outbred pigs and four line 3 topcross pigs were obtained from the Panhandle A. and M. College, Goodwell, Oklahoma. An equal number from each group were obtained from the Western Oklahoma Hospital, Fort Supply, Oklahoma. Each of the eight breeding groups was divided into two lots of four pigs each, making sixteen lots in all. In order to eliminate individual litter effects as much as possible, an attempt was made to have at least four litters represented in each group. However, not enough litters of near equal age were available to make this possible in the line 3 and line cross 3x7 groups. The pigs selected from each litter were those nearest the average weaning weight of that litter.

The feeding pens used in this experiment were identical in design. They consisted of a 5' x 8' house with a board floor, and an adjoining 8' x 10' concrete floored pen. The pens faced the south and the front of the sheds were opened on warm, sunny days.

All lots were fed identical rations consisting of self-fed free-choice ration of ground yellow corn and a protein supplement composed of 30 per cent alfalfa leaf meal, 30 per cent meat and bone scraps, 20 per cent cottonseed meal, and 20 per cent soybean oilmeal. In addition, each lot had access to a salt-manganese sulfate mixture, fed in an open trough. Considerable wastage of the mineral mixture occurred in the

open troughs exposed to weather and hence no record was kept of the amount used. Water was supplied to all lots in automatic waterers.

All pigs were placed in their lots and started on the test ration at least one week before the test started. During this time they were treated for worms with sodium-flouride and sprayed with lime-sulfur to control mange. During the course of the experiment, the pigs were sprayed several additional times for mange. Each lot was started on test when the average weight of each pig in the lot was as close to 50 pounds as possible. Throughout the experiment, each pig was weighed at 28 day intervals and removed from the test when he weighed between 218 and 232 pounds and as close to 225 pounds as possible. At the time he was removed from the test, each pig was scored for body conformation.

Five representative pigs from each breeding group were selected to use for carcass studies. These pigs were slaughtered the day after they were weighed out and their carcasses scored according to their cutout value.

DESCRIPTION OF DATA

Table I shows the preweaning performance records of all the line 3, 5, and 7 litters and their respective single crosses that were farrowed in the experiment station herd during the fall of 1947. All of the line and line cross pigs used in this feeding test were selected from these litters. The outbred and line 3 topcross pigs were selected from other herds and equivalent data are not available on them.

The number of litters represented is small and consequently no definite conclusions can be made from these data, but general observations may be made. The average size of the inbred litters farrowed was .8 of a pig larger than the average of the line cross litters. At weaning, the line cross litters were on the average .6 of a pig larger then the inbred litters.

At birth, the average weight of the line and line cross litters were almost identical, but the individual pig average was .16 of a pound more for line cross pigs. However, at 56 days of age, the line cross litters were 30 pounds heavier than the inbred litters. This difference was due partly to the larger number of pigs per litter at weaning and partly to the heavier weight of the individual pigs.

Line 3 was superior to lines 5 and 7 for number of pigs weaned, average weight per pig at weaning, and total litter weight at weaning. Although line 7 was superior in performance to either line 3 or 5 in rate and efficiency of gain during the feeding test, it was inferior to both 3 and 5 in preweaning performance.

Line cross 5x7 litters were larger and heavier at weaning than the

TABLE I

PREWEANING PERFORMANCE OF THE LINE AND LINE CROSS LITTERS FROM WHICH PIGS WERE SELECTED FOR THE FEEDING TRIAL
(Age of dam corrected to mature basis)

Breeding Group	No. of Litters	Fr. of Dam	Fr. of Litter	Number in Litter		Litter Weights (lbs)		Average Weight Per Pig at 56-Days (Lbs.)
				Farrowed	56-Days	Birth	56-Days	
3	5	.17	.24	10.7	7.1	24.3	215	30.3
5	6	.05	.21	9.6	6.2	22.6	187	30.1
7	4	.09	.23	12.3	5.9	26.1	156	26.6
3x5	6	.06	.00	9.4	6.3	23.4	211	34.5
3x7	3	.21	.00	10.2	7.2	22.8	203	28.2
5x7	4	.06	.00	10.4	7.5	27.5	234	31.2

other two line crosses, although they appeared to be inferior to these two crosses in the feeding test. However, the pre-weaning performance of the line cross litters is probably a poor indication of hybrid vigor in the pigs, since litter weights at weaning are largely a measure of the dam's performance as a brood sow rather than a measure of the gaining ability of the individual pigs.

Table 2 gives the feed lot performance of the pigs on test in rate and efficiency of gain. As could be expected from the work reported in the 9th Annual Report of the Regional Swine Breeding Laboratory, the inbred pigs were inferior to the outbred groups for both rate and efficiency of gain. The inbreds required 412 pounds of feed per 100 pounds of gain as compared to 392 pounds of feed per 100 pounds gain for the outbred lots. In rate of gain, the outbreds gained 1.50 pounds per day as compared to 1.35 pounds per day for the inbreds.

In this experiment, the average of all the line crosses was superior to the outbreds in rate of gain, but inferior in efficiency of gain. The average daily gain of all the line cross pigs was 1.53 pounds per day as compared to 1.50 pounds for the outbred stock, but the line cross pigs required 4 pounds more feed per 100 pounds gain than the outbreds. However, the best line cross (3x5) exceeded the outbreds by .10 of a pound per day in daily gain and required 4 pounds less feed per 100 pounds gain than the outbreds. The topcross pigs gained .07 pound more per day and consumed 5 pounds less feed per 100 pounds of gain than the outbred lot; indicating that there was a slight increase in vigor of the offspring from inbred boars mated to unrelated outbred sows.

Lines 3 and 5 were slower gaining and less efficient than the line

TABLE II.

FEED LOT PERFORMANCE OF PIGS ON TEST*

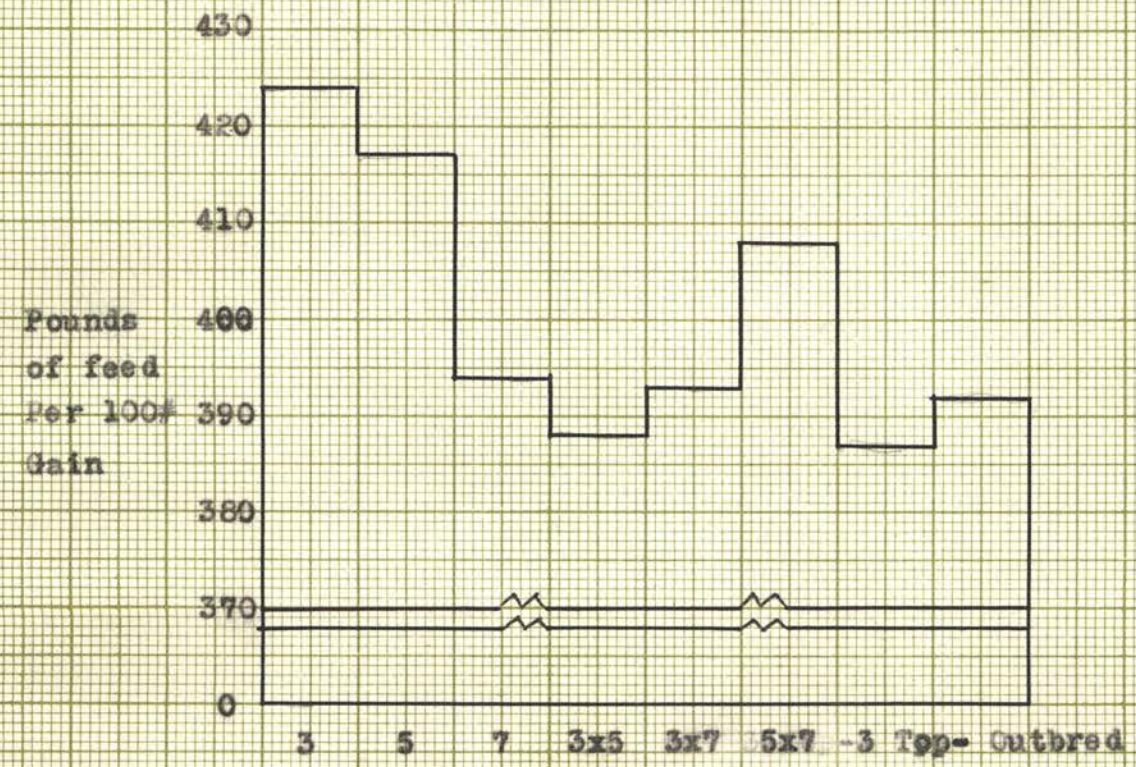
Breeding Group	No. of Pigs	No. of Litters Represented	Av. Daily Gains (lbs.)	Corn per 100 lb. Gain (lbs.)	Protein Supp. Per 100 lbs. Gain (lbs.)	Total Feed Per 100 lbs. Gain (lbs.)	Cost Per 100 lbs. Gain (dollars)
3	8	3	1.28	371	53	424	19.98
5	8	5	1.31	361	56	417	19.65
7	8	4	1.46	349	45	394	18.57
3x5	8	4	1.60	328	60	388	18.27
3x7	8	2	1.54	341	52	393	18.52
5x7	8	4	1.46	360	48	408	19.23
3 Topcross	8	4	1.57	331	56	387	18.22
Outbred	8	4	1.50	340	52	392	18.47
Av. of All			1.46	348	53	401	18.89

* One line 5 gilt was removed when she weighted 173 lbs. because of a hernia. As the facilaties used in this test were needed for other work, three pigs were removed before they reached the 225 pound weights. They included two line 3 pigs that weighed 201 and 185 pounds and one line cross 3x7 pigs that weighed 200 pounds.

Feed Prices

Corn	$ 2.65 per bushel
Alfalfa Leaf Meal	49.00 per ton
50% Meat and Bone Scraps	125.00 per ton
Soybean Oil Meal	98.00 per ton
Cottonseed Oil Meal	100.00 per ton
Salt and $MnSO_4$ not charged	

Graphic Representation of The Rate and Efficiency



Efficiency of Gain

FIGURE 1a

Rate of Gain

FIGURE 1b

crosses or outbreds, but line 7 was nearly as efficient as any of the other groups.

The line cross 3x5 was superior to the other crosses, but was not superior to the line 3 topcross. The line cross 5x7 was intermediate between its parental lines in both rate and efficiency of gain.

While line 3 was the inferior line in individual performance, it was the superior line in combining ability. The line cross 3x5 and the line 3 topcross were the two best groups in the test, and the 3x7 cross was exceeded only slightly by the outbred group.

Figure 1 illustrates graphically the rate and efficiency of gain of the eight breeding groups. In this study, there was a correlation of -.95 between rate of gain and amount of feed required per 100 pounds gain. Line cross 3x5 and line 3 topcross were the two most rapid gaining lots, as well as the most efficient. In contrast, lines 3 and 5 were the two slowest gaining lots and also the least efficient.

The growth curves for the different line crosses and topcross pigs are shown in comparison with their parental lines in figures 2, 3, 4, and 5. The difference in rate of gain tended to increase as the feeding period progressed, and would probably have been greater at the 112th. day of the feeding period (Winters, 1947, states that the heritability of the rate of gain increases as the feeding period progresses), but since many of the pigs weighed out before they were on feed four 28-day periods it was impossible to show the 112 day differences.

The line cross 3x5 and the topcross pigs were superior to the best parental line. These differences increased as the time on test advanced. The line cross 3x7 was approximately equal to the better parental line.

Growth Curves of Line Cross 3x5 and the Parental Lines

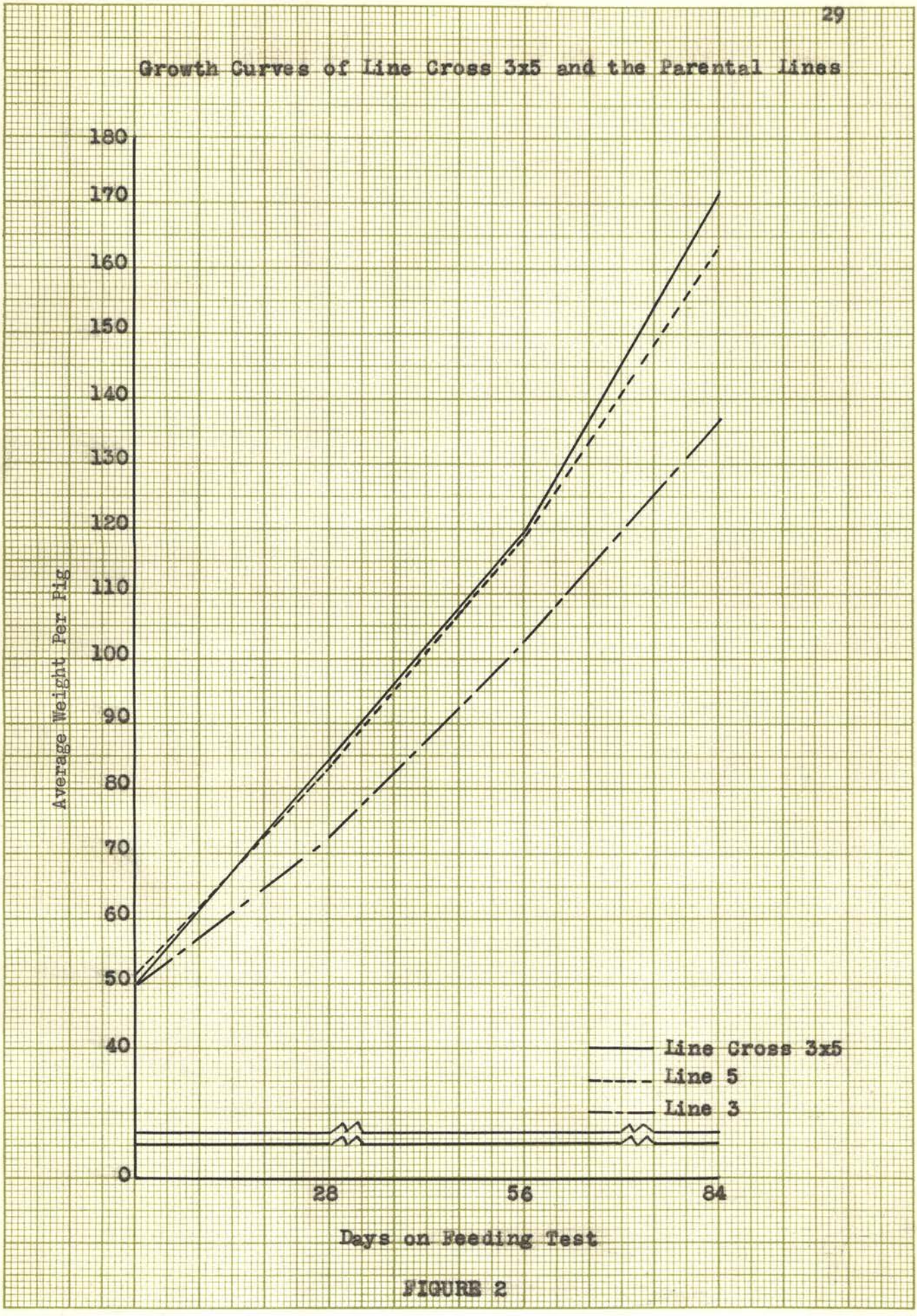


FIGURE 2

GROWTH CURVES OF LINE CROSS 3x7 AND THE PARENTAL LINES

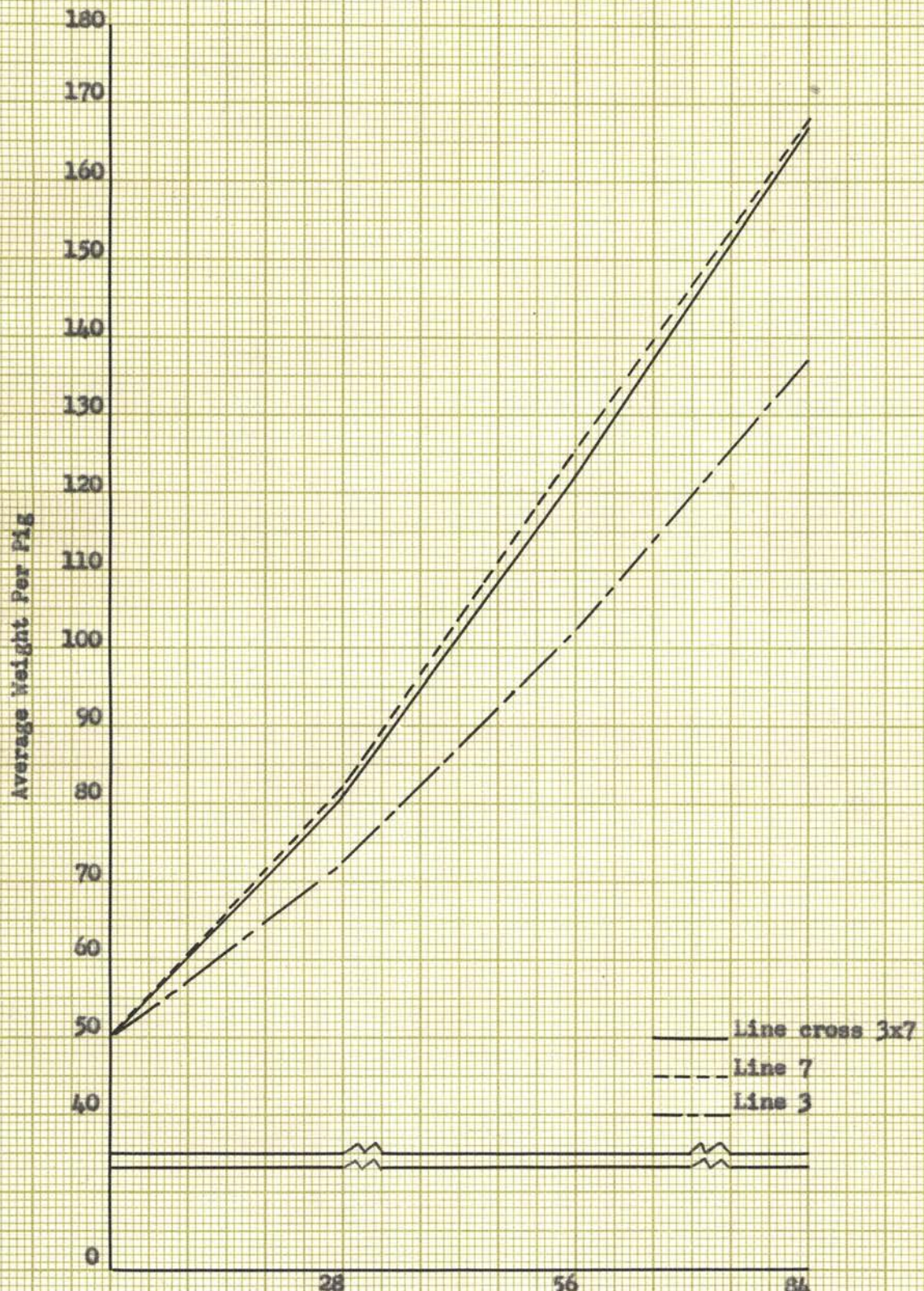


FIGURE 3

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10 x 10 to the half inch.

GROWTH CURVES OF LINE CROSS 5x7 AND THE PARENTAL LINES

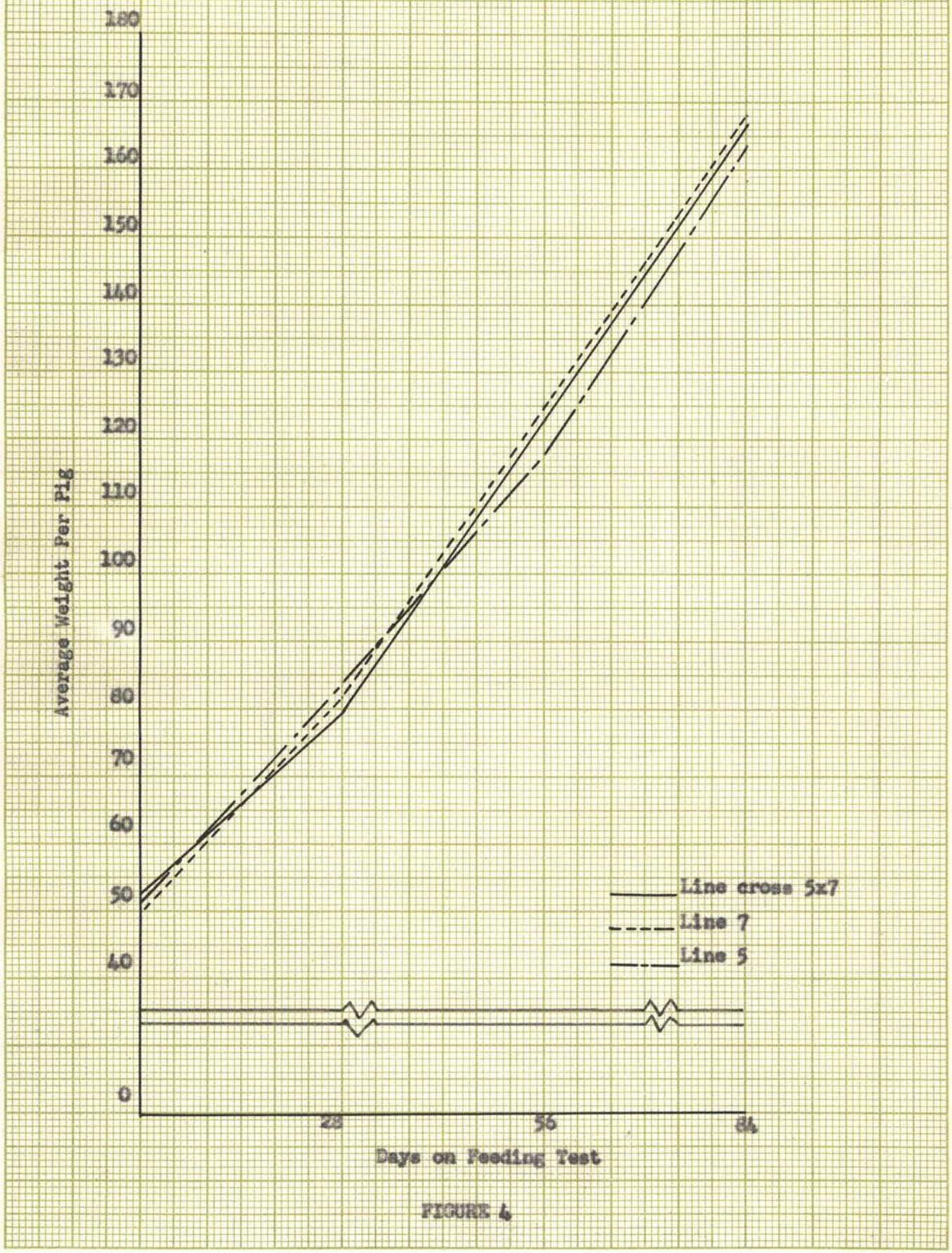

FIGURE 4

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10 x 10 to the half inch.

GROWTH CURVES OF LINE 3 TOPCROSS AND THE PARENTAL LINES

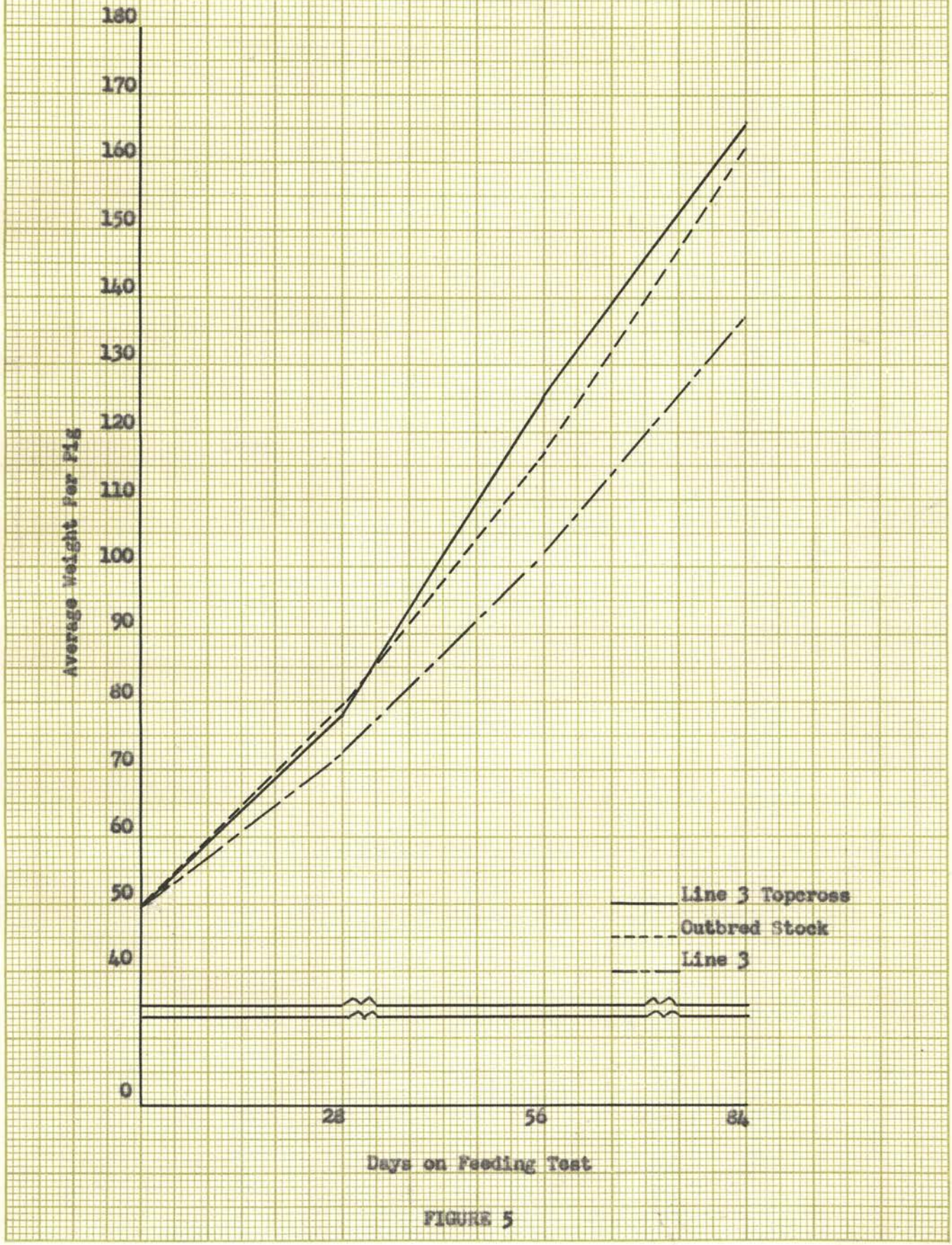

FIGURE 5

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The 5x7 cross was intermediate to its parental lines and gave very little indication of hybrid vigor in rate of gain.

Two different measures of hybrid vigor are given in the literature referring to crossbreeding hogs. One belief is that for a cross to demonstrate hybrid vigor, the performance of the crossbreds must excell the performance of the better of the two parental strains. The other measure, the one generally used today, is that hybrid vigor is expressed whenever the crossbreds or line crosses are better than the average of the two parental lines. The data were studied according to both viewpoints although it is believed that the latter interpretation of hybrid vigor, i.e. the difference between the crossbreds and the average of their parents, has a sounder genetic basis.

The line cross 3x5 gave the greatest expression of hybrid vigor for both rate and efficiency of gain, showing an increase of 24 per cent for rate of gain over the average of the parental lines (Table 3). The line 3 topcross and line 3x7 also possessed hybrid vigor, an added indication that line 3 contained the best combining possibilities. The expression of hybrid vigor was higher for rate of gain than for efficiency of gain. This can be expected as the literature indicates that rate of gain has a higher heritability than efficiency of gain.

The line cross 5x7 gave very little indication of hybrid vigor. When compared with the better parental line it showed no advantage in rate of gain and actually was inferior to the better parental line in efficiency of gain.

The average feed requirements of each lot and for each breeding group is shown in Table 4, together with the analysis of variance for feed

TABLE III.

HYBRID VIGOR EXHIBITED BY LINE CROSS AND TOPCROSS PIGS

AVERAGE DAILY GAIN (LBS.)

Breeding Group	Average Daily Gain	Average Daily Gain of the Two Parental Lines	Diff.	% Advantage Over Average of Parental Lines	Average Daily Gain of Superior Parental Line	Diff.	% Advantage Over Superior Parental Line
3x5	1.60	1.29	.31	24	1.31	.29	22
3x7	1.54	1.37	.17	12	1.46	.08	5
5x7	1.46	1.38	.08	6	1.46	.00	0
3 Topcross	1.57	1.39	.18	13	1.50	.07	4

FEED PER 100# GAIN (LBS.)

Breeding Group	Feed Per 100# Gain	Average Feed Req. of the Two Parental Lines	Diff.	% Advantage Over Average of Parental Lines	Average Feed Req. of Superior Parental Line	Diff.	% Advantage Over Superior Parental Lines
3x5	388	421	-33	7.8	417	-29	7.0
3x7	393	409	-16	3.9	394	- 1	.3
5x7	408	405	- 3	.7	394	+14	-3.6
3 Topcross	387	408	-21	5.1	392	- 5	1.3

TABLE IV.

FEED REQUIREMENTS PER 100 POUNDS GAIN (LBS.)

	Breeding Groups							
	3	5	7	3x5	3x7	5x7	3 Topcross	Out-Bred
Lot 1	442	421	389	383	370	430	391	396
Lot 2	406	414	399	394	416	387	382	388
Average	424	417	394	388	393	408	387	392

ANALYSIS OF VARIANCE FOR EFFICIENCY OF GAIN

Source of Variation	d.f.	S.S.	M.S.
Total	15	5670	
Breeding Groups	7	2832	404.57
Lots Within Lines (error)	8	2838	354.75

TABLE V.

AVERAGE DAILY GAIN OF THE PIGS ON TEST (LBS.)

	Breeding Group							
	3	5	7	3x5	3x7	5x7	3 Topcross	Out-bred
Lot 1	.84	1.16	1.53	1.45	1.94	1.31	1.47	1.77
	.92	1.45	1.63	1.72	1.51	1.50	1.52	1.45
	1.27	1.32	1.38	1.62	1.92	1.40	1.27	1.16
	1.52	1.15	1.48	1.71	1.62	1.02	1.54	1.61
Lot 2	1.46	1.26	1.14	1.18	1.30	2.28	1.60	1.54
	1.47	1.50	1.27	1.37	1.18	1.72	1.66	1.26
	1.44	1.31	1.09	1.95	1.58	1.29	1.69	1.59
	1.30	1.38	1.41	1.61	1.30	1.30	1.83	1.67
Average	1.28	1.31	1.46	1.60	1.54	1.46	1.57	1.50

ANALYSIS OF VARIANCE FOR AVERAGE DAILY GAIN

Source of Variance	d.f.	S.S.	M.S.
Total	63	4.2245	
Breeding Groups	7	.7620	.1089
Lots Within Lines	8	.8744	.1093
Pigs in Same Lot (error)	48	2.5881	.0539

requirements. This table shows that, although there was a general tendency for the line cross pigs to show a lower feed requirement per unit of gain than the inbred pigs, the difference between the groups was not significant.

The average daily gain of each pig included in the feeding test, and the average daily gain of each breeding group, is shown in Table 5. While the line crosses did show an advantage over the inbred lines and outbred stock and differences between the groups are indicated, the differences were not significant.

Table 6 shows the scores given to the live pigs on their body conformation at the time they were weighed out. Table 7 shows the carcass index values of representative pigs of each breeding group. The live hog scores were computed by means of a score card, in which the total possible points each pig could receive was 100. Each of the following items in the score card was given a maximum value of 9 points: general appearance, finish, quality, dressing percent, fore quarters, sides, back, loin, rump and hams. The head and neck were allowed five points as were the legs. Differences between the breeding groups were not significant.

Carcass scores were computed by use of the formula presented by Dickerson (1946) in which the carcass is given an index score according to the cut-out value. Differences between the breeding groups in carcass indexes were statistically significant. The outbred group of pigs yielded the highest carcass index while the line 3 pigs were the lowest.

There was a very low negative correlation between the live animal score values and the carcass indexes, indicating that the best pigs on

TABLE VI.

LIVE HOG SCORE OF PIGS ON TEST

	Breeding Group							
	3	5	7	3x5	3x7	5x7	3 Topcross	Out-bred
Lot 1	68	60	78	69	81	76	66	78
	64	80	73	77	73	73	76	79
	75	75	71	82	79	73	75	75
	75	67	67	75	72	68	76	77
Lot 2	76	84	70	63	73	83	76	61
	77	74	69	76	73	80	76	76
	68	81	77	79	77*	76	82	80
	78	74	81	75	65	75	78	85
Average	72.6	74.4	73.3	74.5	74.1	75.9	75.6	76.4

* One pig in line cross 3x7 was injured and could not be scored so his score was replaced according to Snedecor's(1946) missing plot technique.

ANALYSIS OF VARIANCE FOR LIVE HOG SCORE OF PIGS ON TEST

Source of Variance	d.f.	S.S.	M.S.
Total	62	1,915.44	
Lots	15	413.94	27.60
Lines	7	94.69	13.53
Lots Within Lines	8	319.25	39.91
Pigs in the Same Lot (error)	47	1,501.50	31.95

TABLE VII.

CARCASS SCORES OF REPRESENTATIVE PIGS IN THE TEST

Breeding Groups							
3	5	7	3x5	3x7	5x7	3 Topcross	Outbred
57.0	56.9	58.5	62.2	59.1	61.9	59.7	64.2
60.1	61.9	61.1	60.2	59.4	59.9	61.0	64.8
61.1	61.2	59.0	60.5	61.1	59.9	59.6	61.8
60.0	58.9	61.7	62.7	62.3	58.4	59.0	60.5
---	62.2	60.2	62.6	60.4	---	60.0	63.5
Average							
59.5	60.2	60.1	61.6	60.5	60.0	59.8	62.9

ANALYSIS OF VARIANCE FOR CARCASS SCORES

Source of Variation	d.f.	S.S.	M.S.
Total	37	113.30	
Breeding Groups	7	43.56	6.22*
Pigs within breeding groups (error)	30	69.74	2.32

foot did not necessarily produce the best carcasses. The line 3 topcross and the 5x7 line cross pigs illustrate this difference very well. While these two groups were excelled only by the outbred pigs in score on foot, they in turn excelled only the line 3 pigs in the carcass index. The line cross 3x5 pigs possessed the second most desirable carcasses but ranked fourth in live score.

However, the outbred group was the best lot in both live scores and carcass index. Line 3 was the most undesirable in both items.

The line cross pigs were superior to the inbreds for body conformation, having an average score of 74.8 as compared to 73.4 for the inbreds. The topcross pigs were superior to both the inbred and line cross pigs, but were not as good as the outbred stock.

The line cross pigs were slightly superior to both the inbreds and topcross pigs in the carcass index, but again were not as good as the outbred lot.

Table 8 gives the degree of hybrid vigor shown by the line cross and topcross pigs for score and carcass index. Generally, the crosses show a slight improvement over their parental lines in scores, but are not as good as the outbred pigs. The percentage of hybrid vigor expressed in carcass index was very low. The 3x5 and 3x7 line crosses were slightly superior to their parental lines, but the other two breeding groups were not as good as the average of their parental lines.

This table indicates that from the standpoint of live scores and carcass values, very little hybrid vigor was obtained in the crossing of lines.

TABLE VIII.

HYBRID VIGOR EXHIBITED BY LINE CROSS AND TOPCROSS PIGS IN THE CARCASS INDEX AND LIVE HOG SCORE

CARCASS INDEX

Breeding Group	Av. Score	Av. Score of the Two Parental Lines	Diff.	% Advantage Over Av. Of Parental Lines	Av. Score of Better Parental Line	Diff.	% Advantage Over Better Parental Line
3x5	61.6	59.85	1.75	2.92	60.2	1.4	2.32
3x7	60.5	59.8	.70	1.17	60.1	.3	.50
5x7	60.0	60.15	- .15	- .25	60.2	- .2	- .33
3 Topcross	59.8	61.2	-1.4	- .23	62.9	-3.1	-4.93

LIVE HOG SCORE

Breeding Group	Av. Score	Av. Score of the Two Parental Lines	Diff.	% Advantage Over Av. Of Parental Lines	Av. Score of Better Parental Line	Diff.	% Advantage Over Better Parental Line
3x5	74.5	73.5	1.0	1.36	74.4	.1	.10
3x7	74.1	72.95	1.05	1.44	73.3	.8	1.09
5x7	75.9	73.65	2.25	3.05	74.4	1.5	2.01
3 Topcross	75.6	74.5	1.1	1.48	76.4	- .8	-1.05

DISCUSSION

It must be realized that the data presented in this study are taken from a limited number of individuals and represents only one season's results, hence no definite conclusions can be advanced. However, some tentative observations may be cited.

In general, inbreeding of the litter appears to bring about degeneration of the post-natal elements of vigor measured in this study but does not produce any harmful effects during the intra-uterine period. The size and weight of the inbred litters were equal to, or better than, the line cross litters. This is in accordance with the findings of Stewart (1945) and Winters (1945) that the inbreeding of the litter does not cause any detrimental effect on the size of litters farrowed, and Godbey and Starkey's (1932) statement that the weight of the litter at farrowing time is not affected by its inbreeding.

However, at weaning, the line cross litters were .6 of a pig larger than the inbred litters; the percentage of survival of pigs up to weaning was 70 for the line cross litters and 59 for the inbred litters. This coincides with the findings of Dickerson (1946) that the inbreeding of the litter had a detrimental effect on the viability of the pigs. The line cross pigs averaged 2.2 pounds more per pig than the inbreds at weaning time. Since total litter weight at weaning is a combination of the size of the litter and the weight of each individual pig, both of which exhibited hybrid vigor in this study, there was more of a pronounced advantage for total litter weight than for either of its components. The line cross litters in this study averaged 30 pounds heavier at weaning

than the inbreds. This is in keeping with the results of Dickerson (1946) who found an advantage for the line cross of 1.3 pigs per litter at weaning time, 3.4 pounds more per pig at 56 days, and a total litter weight advantage of 53 pounds at 56 days.

The inbred pigs also demonstrated some inferiority in the feed lot, both as to rate and efficiency of gain. The inbred pigs were slower gaining with an average daily gain of 1.35 pounds per day as compared to 1.50 pounds per day for the outbred control stock. They also required 20 pounds more feed per 100 pounds of gain than the outbred stock. This is the same trend as was found by Craft (1931), Lush and Culbertson (1937), Hillham and Craft (1939), and Winters (1943), and would indicate that while these differences in themselves are not all statistically significant, the combined findings of these different projects might be significant.

The inbred pigs on the average were somewhat less desirable as to individual conformation and carcass value. The main reason for this progressive degeneration in merit of inbreds is explained by Lush (1945) when he states that inbreeding allows more pairs of genes to become homozygous and lowers the amount of heterozygosis in the line. Since this uncovers many recessive genes which would otherwise remain concealed by their dominant alleles, and because recessives generally have less desirable effects than dominants, there is usually some degeneration in the average merit and performance of the inbred stock.

There appears to be a difference in the desirable traits possessed by the different lines; some lines being superior in certain respects and inferior in others. In this study, line 7 was superior to the other lines

in both rate and efficiency of gain, but was inferior to the other lines in preweaning performance. Assuming that total litter weight at weaning is only slightly heritable (.074 by Winters, 1947) this difference in weaning weight could largely be attributed to the milking ability of the sows. This combination of poor milking ability and rapid and efficient rate of gain in line 7 would support the theory advanced by Dickerson (1947) and Dickerson and Grimes (1947) that the same genes which cause rapid and economical gains in swine also cause poor milking ability in the females. This same tendency is noted in line 3 which was the superior line in preweaning performance, but was inferior to the other lines in the feeding test.

This would indicate that lines differ in their desirable characters and that maximum performance can be secured only through judicious crossing of different strains. For example, sows of a line that are superior for milking ability could be mated to boars of a line which are superior for rate and efficiency of gain. However, the number of reciprocal crosses made in this study are not sufficient to warrant drawing conclusions on such matings.

The crossing of the inbred lines in this study produced progeny which were better than the average of the two parental lines, but the crosses were not superior to the outbred control stock in every respect. The greatest expression of hybrid vigor was in rate and efficiency of gain, two items which were very closely associated, having a correlation of +.95. While the increase in neither of these items was of statistical significance, it does indicate a trend in favor of the line cross and topcross pigs. However, consideration should be given to the fact that the outbred

and topcross pigs were not subject to the same environmental conditions as the line and line cross pigs prior to the feeding test. Comparisons can be made between line and line cross or between outbred and topcross pigs on an equal basis.

The average daily gain of the line cross pigs was .03 of a pound per day greater than the outbred group, while the line 3 topcross was .07 of a pound per day greater than the outbreds. The line cross 3x5, the most rapid gaining group in this study, gained .10 of a pound more per day than the outbreds. This increased rate of gain is in keeping with the trends obtained in a study of line crosses by Winters (1944) in which he found a .12 pound per day advantage of the line cross pigs over the outbred stock. However, lines 5 and 7 did not combine well, as shown by the rate of gain of the 5x7 cross which was inferior to the outbred stock. This cross was just equal to its better parental line for rate of gain and was intermediate to its parental lines for efficiency of gain.

This difference in combining ability of lines agrees with reports by Winters (1944) and Willham (1945) in which certain line crosses did not "nick" well, but other crosses did produce progeny which expressed hybrid vigor in the form of increased rate of gain. It also agrees with the 9th. Annual Report of the Regional Swine Breeding Laboratory which concluded, from a summary of the work conducted at the various stations, that the crosses of inbred lines generally produces a progeny superior to the parental lines, but the performance superior to good non-inbred stock can be expected only when carefully selected and tested lines are used. Thus, it appears that rigid selection of lines must be practiced

before hybrid vigor can be expected in crossing the lines.

The line cross pigs required 20 pounds less feed per 100 pounds of gain than the inbreds, but required 4 pounds more feed per 100 pounds of gain than the outbred pigs. The topcross pigs and the better line cross (3x5) were somewhat more efficient than the outbred group, while the poorer line crosses were inferior to the outbred pigs. This small increase in efficiency by two crosses and about an equal amount of decrease in the other two crosses would indicate that little hybrid vigor can be expected in the form of efficiency of gain unless selected lines are used. This is substantiated by the work of Dickerson (1946), Winters (1944), and Willham (1944), in which they state that no appreciable improvement in economy of gain can be expected from crossing different lines of swine.

In carcass scores and live hog scores, there was very little expression of hybrid vigor by the crosses (Table 8). Although the line cross individuals did average .8 point higher than their inbred parental lines, in carcass scores, they were inferior to the outbred stock by 2.2 points per carcass. The topcross pigs were almost equal to the average of the inbred pigs in this respect, having a score of 59.8 as compared to an average of 59.9 for the inbreds.

There was little variation in the average carcass scores of the inbred lines. Only .7 of a point difference existed between line 5, which was the highest, and line 3, which was the lowest, in carcass scores.

There was a greater variation in the scores of the line cross pigs than among the inbred lines, a difference of 1.6 points between the highest scoring line cross, 3x5, and line cross 5x7 which was the lowest.

The line 3 topcross which performed well in the other three measures

of merit was below average in carcass score -- only .3 of a point above line 3 which was the lowest scoring line in the study.

The live scores of the pigs on test (Table 6) show that the outbred group was the superior lot in conformation, with line cross 5x7 and the topcross pigs (two lots that did not score well in the carcass indexes) also rating high in body conformation.

The line cross pigs were somewhat superior to their inbred parental lines with an average score of 74.8 as compared to 73.4 for the inbreds. This indicates a small expression of hybrid vigor for live scores.

In this study, there was a correlation of -.09 for live score and carcass values, which agrees with Helmrich and Roth (1930) who found that in comparing the percentage of cuts with the grade of the carcass, that the percentage of rough belly, fat back, and fat trimmings based on carcass weight increased as the grades of hogs improved, while the percentage of lean cuts, ham, shoulder, and loin decreased as the grades of hogs increased. This also agrees with Willman and Krider (1943) that the thickness of the backfat is not correlated to the size of the loin eye muscle and the lean portion of the ham. Also, the work of Scott (1927) emphasizes this point. He found that as the finish of the live animal increases, the percentage of fat backs and bellies increases, while the percentage of loins and hams decreases.

There was no correlation between rate of gain and carcass index. This is in slight disagreement with the findings of Dickerson (1943) that the genetic superiority in growth rate from weaning to market weight was significantly correlated with thicker backfat and larger yield of fat, but with smaller yield of lean at 225 pounds. This

would mean that selection for rate of gain would also be indirect selection for fatter carcasses.

The results would indicate that some progress in rate and efficiency of gain could be attained by the crossing of inbred lines, but that the degree of increase would depend on the performance and combining ability of the lines used. Some lines will not combine well, and thus will not show much improvement in crosses. In this study, line 3 was the superior line in combining ability, producing the two best breeding groups in this test (3x5 and line 3 topcross). In contrast, the lines 5 and 7 did not combine well with each other and did not produce additional vigor.

In addition, it appears that line crosses used here produced some increase in carcass quality and individuality over that of the inbred lines, but did not produce a carcass which was as good as the non-inbred stock.

SUMMARY AND CONCLUSIONS

1. A feeding test was conducted to gain preliminary information on the combining ability of lines 3, 5, and 7. Sixty-four pigs were included in the test, consisting of eight pigs from each inbred line, eight of each single cross, eight of the line 3 topcross, and eight outbred pigs which served as a control lot.
2. The inbred stock showed a general degeneration in the measures of vigor studied in this test.
3. There was variation in the performance of the lines. The lines which were superior in preweaning performance were not as efficient in the feedlot performance.
4. The average of all the line cross pigs was superior to the inbred pigs in rate and efficiency of gain, live hog scores and carcass index, but was superior to the outbred stock only for rate of gain. However, the best line cross and the topcross were superior to the outbreds for both rate and efficiency of gain. The topcross and outbred pigs are comparable, but comparisons of line crosses with outbred and topcross pigs may be questionable because the topcross and outbred stock were not raised under the same environmental conditions as the line crosses prior to the feeding test.
5. Line 3 was found to be the best line for combining ability of the three lines tested. The line cross 3x5 and the line 3 topcross were the two superior crosses of the experiment, with the 3x7 superior to the 5x7 cross.

6. Lines 5 and 7 did not combine well in this test. The line cross 5x7 was inferior to the other crosses and outbreds in rate and efficiency of gain and carcass index. However, in live hog score, it was excelled only by the outbreds.

7. There was a correlation of -.95 between lot averages in rate of gain and amount of feed required per 100 pounds of gain.

8. There was an insignificant correlation of -.09 between live animal score and carcass index.

9. In this study, there was no correlation between rate of gain and carcass index.

10. It must be realized that these tentative conclusions are drawn from limited data and that most of the differences between breeding groups were not statistically significant. Further work will have to be done before any definite conclusions can be made.

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