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To the Graduate Council:

I am submitting herewith a thesis written by Millard Daniel, Jr. entitled "Comparison of the Performance of Straightbred and Crossbred Pigs." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

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COMPARISON OF THE PERFORMANCE OF STRAIGHTBRED
AND CROSSBRED PIGS

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Millard Daniel, Jr.

August 1965

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CHAPTER I

INTRODUCTION

Increased efforts to improve performance characteristics in swine has prompted producers to take a closer look at the effects of crossbreeding. Success obtained with hybrid corn has led many to believe that beneficial results might be expected from crossbreeding swine. Crossbreeding for production advantages in market animals has been in practice for several years, especially swine and sheep. Its use has been opposed by a few breeders who contend that continuous usage will result in lowering of the general quality of livestock.

Swine producers are seeking a market hog capable of rapid and economical conversion of feed into pork. Improved performance through expression of heterosis should aid in the attainment of this goal. Experimental work indicates that heterosis results from the mating of genetically divergent animals. Heterosis effects are demonstrated in the offspring through larger litters, greater viability and faster gains. Reliable systems of obtaining some degree of heterosis are: (1) straightbreeding, the mating of unrelated animals within a breed; (2) crossbreeding, the crossing of different breeds; (3) linecrossing, the crossing of inbred lines within breeds; and (4) linecrossbreeding, the crossing of inbred lines of different breeds.

Considerable research data is available on crossbreeding in swine, and its usefulness in commercial swine production has been

widely accepted. However, there is limited research work to support which of the various breed crosses produce the greater advantage in the important economic traits.

Heritability estimates indicate that improvement in the important economic performance traits of swine should be attained through selection (Craft, 1958). Environmental and other factors, such as season of birth and age of dam, hamper the breeder's ability to select those animals having the greatest breeding value. There is a need for more detailed information on the magnitude and extent of these effects so that performance records can be more accurately adjusted before selections are made.

The objectives of this study were: (1) to compare certain litter performance traits of pigs produced by straightbreeding and crossbreeding; (2) to compare the relative performance of straightbred with two- and three-breed crosses and to attempt to determine the more desirable breed crosses; and (3) to study the effect of age of dam and season of birth on litter performance traits.

CHAPTER II

LITERATURE REVIEW

I. BREED (CROSSBRED VS. PUREBRED)

Limited experimental work has been conducted in the past 10 years on the usefulness of crossbreeding for the production of market hogs. The merits of crossbreeding or any breeding system must be considered according to its influence on economically important traits such as: litter size, vigor of pigs as indicated by their survival ability, weaning weights and growth rate.

Litter size. Large litters are essential to economical pork production. A brood sow's efficiency is measured by prolificacy, suckling ability, number of pigs weaned and rate and economy of gains of the pigs. The relative importance of large litters was brought out by Wilson, Whatley and Harington (1961) who observed that, up to a point, the number of pigs weaned per litter improved as the number of pigs farrowed increased. Sows farrowing from 11-14 pigs per litter raised the greatest number of pigs to weaning (eight per litter). Litter sizes of 15 to 20 pigs resulted in fewer pigs weaned. They observed almost a linear relationship between number farrowed and litter weight at farrowing. In a study where the average number of pigs farrowed per litter was 8.1 and the average litter weight was 20 lb., Carmichael and Rice (1920) found litter weight to vary almost in direct proportion to the number of pigs

in the litter. The average weight of pigs in litters of less than average size (8.1 pigs per litter) was 2.67 lb. and 2.47 lb. in litters greater than average in litter size. The mean weight of all pigs was 2.55 lb. They also observed a greater proportion of dead or immature pigs in larger litters than in smaller litters. The litters above average in size contained 10.5 per cent dead pigs and litters below average, 7.7 per cent. Weaver and Bogart (1943) stated that the birth weight of pigs in large litters may be slightly lower than those in litters of smaller size, but that some large litters included strong pigs of moderate to heavy weights. Pigs in litters of 10 pigs averaged 3 lb. while pigs in smaller litters exceeded this by only 0.1 to 0.3 lb. per pig. The smaller litters had the greatest percentage of pigs raised, but generally the number of pigs weaned was greater for litters of 10 or more. They concluded that, within limits, large litters were superior to small litters in number of pigs weaned.

Vogt, Comstock and Rempel (1963) reported that to their knowledge no other estimate of the genetic correlation between litter size and growth rate has been reported in the literature. They obtained a genetic correlation of 0.06 and suggested that the two traits are genetically independent. Baker et al. (1958) observed a genetic correlation between litter size and litter average fetus weight of 0.30 at the 25th day of gestation and -.06 at 70 days. They also found purebred fetuses to be significantly heavier than crossbred fetuses at the 25th day of gestation but observed no significant difference at the 70th day.

Carroll and Roberts (1942) reported that the number of pigs farrowed per litter was the result of two factors: (1) number of eggs produced and fertilized and (2) the prenatal mortality of the embryos. They pointed out that there is no evidence that crossbreeding affects the number of eggs produced and fertilized and that prenatal mortality was not lower in crossbred litters than purebred litters. Their study, involving 2,619 purebred and 1,515 crossbred litters, showed there was no appreciable difference in litter size between purebreds and crossbreds. In several different crossbreeding studies, Robison (1946) observed no marked difference between purebreds and crossbreds in size of litters farrowed.

There was no significant difference found between crossbreds and straightbreds in litter size at farrowing in a study by Bradford, Chapman and Grummer (1953). Also, in a comparative study of crossbreds (Duroc x Poland) and outbred Durocs, Whatley, Chambers and Stephens (1954) found the crossbreds and outbred Durocs to be equal in size of litter. Pani et al. (1963) observed no significant difference in litter size between Landrace x Poland sows and Poland x Landrace sows when both kinds of sows were bred to Duroc boars.

Several workers, however, have found that crossbreds surpass purebreds in litter size. Carlisle et al. (1964) published a summary of the results of some crossbreeding research and this summary is given in Table I.

It was noted that the difference in the first generation cross could be attributed to greater pig survival and more rapid pig growth.

TABLE I
 SUPERIORITY OF SUBSEQUENT CROSSES EXPRESSED AS A PERCENTAGE
 OF AVERAGE PUREBRED PERFORMANCE

Trait	Purebred	First cross	Three-breed cross	Four-breed cross
(Per cent)				
Litter size at birth	100	101	111	113
Litter size at 8 weeks	100	107	125	126
Weaning weight	100	108	110	109
154-day weight	100	114	113	111
Litter production at 154 days	100	112	141	140

They suggested that the advantage in later crosses, including the 40 per cent advantage in 154-day litter production of the four-breed cross was due to the farrowing and raising of larger litters by crossbred dams.

Gaines and Hazel (1957) indicated that crossbred sows were superior to purebred sows in litter size at all ages. However, they found the method of crossing to be an important factor and suggested a rotational crossbreeding system to secure and maintain high production.

Smith, Moorman and McLaren (1960) found that crossbred sows (two- and three-breed crosses) farrowed 9 to 11 per cent more pigs than straightbred sows. Winters et al. (1936) showed that first-cross litters averaged nearly one pig more per litter and three-breed crosses 1.67 more pigs per litter than purebreds.

While working with various lines and their crosses, England and Winters (1953) found that linecrosses had a larger number of pigs born per litter than the individual lines. Rotational crosses had a larger number of pigs born alive than either crisscrosses or single crosses.

A study conducted by Sheritt et al. (1954) indicated that crossbred gilts produced larger litters at farrowing than purebreds. Smith and King (1964) found crossbred litters contained 2 per cent more pigs than purebred litters and crossbred sows farrowed 5 per cent more pigs than purebred sows.

Nance (1959) concluded that crossbred sows farrowed larger litters than straightbreds. Differences between crossbred and straightbred litters varied from 0.6 to 3.6 pigs with an average difference of 1.5 pigs per litter (20 to 25 per cent) in favor of crossbreds. Total litter

weight was in favor of crossbreds with differences ranging from 198 to 1,026 lb. and an average difference of 400 to 500 lb. (30 to 35 per cent).

Lush, Shearer and Culbertson (1939) pointed out that crossbred sows were efficient pig producers when mated either to a purebred boar of one of the parent breeds or to a boar of a third breed. Pani et al. (1963) concluded that the genotype of the dam has a marked influence on litter size and weight. They suggested that to take advantage of hybrid vigor in both males and females a crossbreeding program should include at least three breeds.

Birth weight. Pig weight at birth is associated with subsequent performance. Vestal (1936) reported an inverse relationship between average litter birth weight and percentage of pigs born dead. He concluded that pigs weighing 2 lb. or less at birth are a poor risk since less than 50 per cent survived to normal weaning age.

Birth weight as a factor in determining weaning weight of pigs has been studied by many workers. Kuhlman (1928) obtained a genetic correlation of 0.49 between birth and weaning weight. Additional estimates of genetic correlations were reported by several other workers. Baker (1939) in two different studies found correlations of 0.44 and 0.48; Hazel, Marvel and Rienmiller (1943) and Blunn, Baker and Hanson (1953) obtained correlations of 0.84 and 0.708, respectively, between birth and weaning weight. Forshaw et al. (1953) reported a highly significant correlation between birth and weaning weight.

The advantage of additional weight at birth has been reported by numerous researchers (Kuhlman, 1928; Baker, 1939; Weaver and Bogart, 1943; and Forshaw et al., 1953). These workers observed that an additional 1 lb. of birth weight accounted for a 7 to 8 lb. advantage at weaning.

Most data suggest that little if any advantage in birth weight is obtained through crossbreeding. However, Winters et al. (1936) found crossbred pigs were, on the average, heavier at birth than purebreds. They also reported that crossbreds excelled purebreds in total litter weight of live pigs.

Crossbred (Duroc x Poland) and outbred Durocs were found by Whatley, Chambers and Stephens (1954) to produce pigs similar in birth weight. Landrace x Poland and Poland x Landrace sows bred to Duroc boars showed no significant difference in pigling and litter weight (Pani et al., 1963).

Work by Bradford, Chapman and Grummer (1953) indicated that weight of pigs at birth was not significantly higher for crossbreds than straightbreds. In agreement with this, Carroll and Roberts (1942) reported no consistent difference in birth weight of crossbreds and purebreds.

Survival rate. The most critical time in a pig's life is from 1 to 3 days after birth. Wilson, Whatley and Harington (1961) indicated that the higher mortality in larger litters (15 to 18 pigs) was probably due to decreased birth weights of pigs and to the inability of the sow

to produce sufficient milk to meet the nutrient demands of the litter.

Several workers have found crossbreeding reduces the mortality rate of baby pigs. Bradford, Chapman and Grummer (1953) noted that litters from crossbred dams had a lower mortality rate than those from straightbreds and that viability contributed to the significantly greater litter size, litter weight and sow productivity index of crossbred sows. Smith and King (1964), working with data from 34,800 litters, found crossbred litters had a lower mortality rate than purebreds. Crossbred litters from purebred dams contained 2 per cent more pigs at birth and 5 per cent more pigs at weaning than purebred litters. Crossbred dams showed more heterosis than purebred dams by producing 5 per cent more pigs at birth and 8 per cent more pigs at weaning. They reported that the total litter weight at weaning for crossbred litters was 10 per cent greater than purebred litters. They also found that crossbred sows had an 11 per cent advantage over the purebred sows in total litter weight at weaning.

Crossbred litters have been shown by Winters et al. (1936), Lush, Shearer and Culbertson (1939), Carroll and Roberts (1942) and Robison (1946) to possess a lower percentage of stillborn pigs and a greater survival rate to weaning than purebreds. McMeekan (1936), in Australia, showed that purebred pigs of four breeds had a death loss up to weaning of 21.2 per cent compared to 12.8 per cent for crossbred pigs.

Rotational and linecross pigs were found by England and Winters (1953) to have a superior rate of survival as compared with those from single crosses, crisscrosses or individual lines. In a study by Whatley,

Chambers and Stephens (1954), 10 per cent greater liveability was observed in crossbred litters (Duroc x Poland) than in outbred Duroc litters at both weaning and 154 days of age. Smith, Moorman and McLaren (1960) stated that pigs in three- and four-breed cross litters had greater survival ability than purebreds.

Weaning weight (56-day wt.). The importance of heavy weaning weights was indicated by Hazel, Marvel and Reinmiller (1943), Blunn, Baker and Hanson (1953), Vogt, Comstock and Rempel (1963), and Ward, Rempel and Enfield (1964) who calculated genetic correlations of 0.45, -.12, 0.88, 0.47 and 0.69, respectively, between weaning weight and post-weaning daily gain. Ward, Rempel and Enfield (1964) stated that selection based solely on post-weaning growth rate would account for 91 per cent of the possible improvement in weaning weight.

Donald (1939), studying the relative importance of nutrition and breeding in the growth of a suckling pig up to weaning, concluded that milk production of the sow was the most important factor influencing weaning weight. Similarly, Vogt, Comstock and Rempel (1963) suggested that their observed genetic correlation of 0.47 between weaning weight and post-weaning growth rate was influenced in part by the milk production of the sows.

It was demonstrated by Hutton and Russell (1939), Robison (1946), Sherrit et al. (1954), Nance (1959) and Smith, Moorman and McLaren (1960) that crossbred litters were larger and the individual pigs in crossbred litters were heavier at 56 days than purebreds. In similar studies,

Winters et al. (1936) obtained an advantage of 4 to 7 lb. per pig and Lush, Shearer and Culbertson (1939) an advantage of 3 to 4 lb. per pig in weaning weight in favor of crossbreds.

The superiority of crossbreeding was clearly revealed in work by Winters et al. (1936) who found weaning weight per crossbred litter was 96 lb. greater than that for purebreds. Of this 96 lb., 39 lb. were credited to the crossbreeding of the pigs and 57 lb. to the superiority of the crossbred dam over the purebred dam. Smith and King (1964) noted that total litter weight at weaning was 10 per cent greater in crossbred litters than purebred and that crossbred sows produced 11 per cent heavier litters at weaning than did purebred sows.

Working with crossbreds produced by various combinations of five breeds, Shaw and MacEwan (1963) found crossbreds averaged 39.4 lb. at weaning as compared to 35.7 lb. for purebreds. Pani et al. (1963) reported a significant difference of 107 lb. between crossbred litters and purebred litters at weaning. Whatley, Chambers and Stephens (1954) showed that crossbred litters were 38 per cent heavier at 56 days than straightbred litters.

Weight at 154 days. Relatively high genetic correlations of 0.51 and 0.89 between growth rate and days of age (112 to 168) were obtained in two separate studies by Blunn, Baker and Hanson (1953). Hazel, Marvel and Reinmiller (1943) reported a genetic correlation of 0.701 between growth rate and days of age.

MacDonald, Moxley and Hamilton (1959) found that with purebred Yorkshires, the best indicator of 154-day weight was 56-day weight; that with Landrace x Yorkshire crossbreds, birth weight was the best indicator of 154-day weight; and with backcrosses of these two breeds, weaning weight was the best indicator of 154-day weight.

Several workers including Bradford, Chapman and Grummer (1953), Nance (1959), MacDonald, Moxley and Hamilton (1959), and Smith and Moorman (1959) reported that crossbred litters were superior to straightbreds in the number of pigs raised to 154 days and litter weight at 154 days. Nance (1959) suggested that the advantage in litter size at 154 days was due primarily to the increased viability of crossbred pigs rather than to the increase in numbers of pigs farrowed in crossbred litters.

Crossbred litters (Duroc x Poland) were found by Whatley, Chambers and Stephens (1954) to be 21 per cent heavier at 154 days of age than outbred Duroc litters. Pani et al. (1963) found that crossbred sows, obtained by reciprocal crossing of the Landrace and Poland China breeds, produced litters that were significantly heavier by 407 lb. at 154 days of age than litters of straightbred (Duroc) sows.

Weight at 180 days. Weight for age is highly desirable in swine because of the economic importance of early marketing. Smith, Moorman and McLaren (1960) reported that at market time the average litter weights of two-, three- and four-breed cross litters were 13, 34 and 20 per cent larger, respectively, than straightbred litters. Crossbred pigs

gained faster from birth to market and were from 6.1 to 8.1 per cent heavier than purebreds. Crossbred litters were also significantly heavier than purebred litters at 180 days of age.

Robison (1948) found that at 180 days of age crossbred litters averaged from 203 to 206 lb. heavier than purebred litters and had from 0.7 to 1.4 more pigs per litter. Similar results were obtained by Robison (1946) who showed crossbreds consistently surpassed purebreds by 10 to 15 lb. per pig and from 150 to 250 lb. in total litter weight at 180 days. Nance (1959) stated that crossbred pigs were about 8 to 10 per cent heavier at 180 days than straightbreds.

Backfat thickness. Efficient methods of reducing backfat are highly desirable since our present market demands are for hogs with less fat and more lean meat. Tucker, Dickerson and Lasley (1952) noted that crossbreds under full feeding yielded carcasses with slightly less lean and more fat than purebreds. However, under limited feeding, carcasses from crossbreds were slightly longer and leaner.

Smith and Moorman (1959) found Landrace pigs had significantly lower backfat thickness than other straightbreds and that Landrace were very effective in reducing backfat thickness in crossbreds.

While comparing purebred and crossbred boars, Rempel, Comstock and Enfield (1964) observed unexplainable differences in backfat thickness in favor of the purebred sires. Whiteman, Hillier and Whatley (1951), however, concluded that crossbred carcasses were leaner and had less per cent fat trim than outbred lines of Durocs.

Average daily gain. Rapid growth is a highly desirable characteristic in swine because of its relationship to profits returned to the producer. Tucker, Dickerson and Lasley (1952) discovered that, under a full-feeding program, crossbred pigs gained 7 per cent faster, consumed 6 per cent more feed daily and were no more efficient than purebreds. However, the same crosses during an equalized feeding program gained 12 per cent faster, consumed 2 per cent more feed daily and were 6 per cent more efficient than purebreds.

In three trials, Robison (1948) found crossbred pigs reached market weight 9, 15 and 20 days earlier, respectively, than purebred pigs. Winters et al. (1936) and Robison (1946) found crossbred pigs reached a market weight of 220 lb. from 17 to 22 and 10 days earlier, respectively, than purebreds. At 225 lb. Whetham (1935) reported that crossbred pigs averaged 10 days younger than purebreds.

In feeding trials, Shaw and MacEwan (1963) noted that crossbred pigs outgained purebreds by an average 0.10 lb. per day. Crossbred pigs in a study by Lush, Shearer and Culbertson (1939) gained from 0.09 lb. to 0.12 lb. faster than purebreds and reached a weight of 225 lb. about 10 days to 2 weeks earlier than purebreds. Tucker, Dickerson and Lasley (1952) found crossbreds reached market weight 10 days earlier than purebreds when full fed. Similarly, crossbreds fed on an equalized (limited) feeding system reached a market weight 14 days earlier than purebreds.

Carroll and Roberts (1942) obtained a small but non-significant difference in average daily gain between crossbreds and the faster

gaining purebreds of 0.006 lb. per head daily. However, when crossbreds were compared with the slower gaining purebreds a significant difference in daily gain was found in favor of crossbred pigs. England and Winters (1953) and Nance (1959) also reported that crossbreds gained faster than purebreds from birth to market.

However, Whatley, Chambers and Stephens (1954) and Rempel, Comstock and Enfield (1964) found purebred pigs outgained crossbred pigs.

II. AGE OF DAM

Litter size. The age of the dam at breeding and farrowing has a marked influence on her own performance and the subsequent performance of her litter. Age of the sow has been found by several workers to be directly related to number of pigs farrowed per litter.

Stewart (1945) observed that the effect of age of dam at first farrowing on litter size was greatest at ages of 12 months or less and ceased to be a factor after 15 months of age. Johansson (1929) showed that the number of pigs in a sow's first litter increased with age at farrowing up to about 16 months of age. Stewart (1945) stated that 320-day-old gilts at farrowing averaged one pig per litter less than 1-year-old gilts and gilts that farrowed at 410 days of age had 0.5 pig per litter more than 1-year-old gilts. His data further showed an increase of 0.75 pig per litter for gilts 12 months of age at farrowing compared to 11-month-old gilts. Additional increases of about 0.5 and 0.25 to 0.67 pig per litter were observed in gilts farrowing at 13 and 14 months of age, respectively. Squires et al. (1952) reported that each 10 day

increase in age of gilts at breeding resulted in an additional 0.5 pig per litter. Olbrycht (1943) showed that gilts averaging 352, 404 and 513 days of age at farrowing produced first litters which averaged 8.04, 8.66 and 9.11 pigs per litter, respectively. Carlisle et al. (1964) reported marked advantages for gilts 14 months old as compared with 11-month-old gilts (Table II).

Nalbandov (1958) stated that sow prolificacy reaches its peak with the fifth litter and remains unchanged until the seventh litter, then declines slightly to the ninth litter. Keith (1930) and Lush and Molln (1942) reported that litter size increased up to 4.5 years of age after which it began to decline. Russell (1936) showed that sows reached their peak in terms of number of pigs farrowed between 2 and 4 years of age and then litter size started to decline. The influence of advancing age on litter size reported by Olbrycht (1943) is shown in Table III. Maximum litter size occurred at the fourth, fifth and sixth litters.

Stewart (1945) concluded that "age and weight of sows at mating account for 4 per cent of the variance in size of first litters and together they provide the most reliable criteria for use in selection for fertility."

Ovulation rate is one of the important factors governing fertility in mammals. Its importance was demonstrated by Squires et al. (1952) who found that the number of ova shed was significantly correlated ($r = 0.47$) with litter size at the 25th day of gestation.

Hammond (1914) found a smaller number of ova were released during estrus by younger than old sows and he offered this as an explanation

TABLE II
COMPARISON OF GILTS 11, 12, 13 AND 14 MONTHS
OF AGE AT FARROWING

Trait	Increase per litter for each additional month of age of gilt
Litter size, pigs	
At birth	0.5
At birth, alive	0.6
14 days	1.0
42 days	1.3
Litter weight, lb.	
At birth	0.3
42 days	27.0

TABLE III
NUMBER OF PIGS PRODUCED IN SUCCESSIVE LITTERS
OF THE SAME SOWS

Litter no.	Average number of pigs	Range
1	9.5	2-18
2	10.7	3-18
3	11.4	4-22
4	11.8	4-22
5	11.9	5-20
6	11.7	4-21
7	11.3	4-19
8	11.2	5-20
9	10.8	2-18
10	10.1	2-18

for the smaller litters of young sows. Similarly, Robertson et al. (1951, 1951a) indicated that gilts produced an increasing number of ova at each succeeding heat period for the first three periods and that litters conceived at the second and third periods contained increasing number of pigs.

Hammond (1914) and Squires et al. (1952) observed the number of corpora lutea of gestating gilts and sows and found gilts averaged 14.3 ± 0.39 and 11.5 whereas mature sows contained 19.8 ± 1.26 and 15.4 , respectively. Newman (1963) estimated ovulation rates by counting corpora lutea after slaughter at 50 ± 4 or 100 ± 4 days of gestation. Gilts contained 14.5 ± 3.2 and sows 21.4 ± 4.4 corpora lutea. However, they suggested that ovulation rate was subject to a high degree of genetic control and was not highly correlated with litter size at the stages of pregnancy examined. Robertson (1951) concluded that calendar age was not as important as was "sexual age" in determining ovulation rate.

Robison (1946) found that 1.5- to 2.5-year-old sows produced larger litters than 1-year-old sows. Carmichael and Rice (1920) found the average number of pigs per litter from 1.5-year-old sows to be 7.5 compared to 8.6 for 2-year-old sows. However, Vestal (1936) stated that 2-year-old sows consistently farrowed larger litters than 1- and 3- to 5-year-old sows.

These data (Figure 1) by Lush and Molln (1942) show that average litter size increased a little more than 0.5 pig from the first to the second litter, increased by one more pig per litter by 2 years of sow

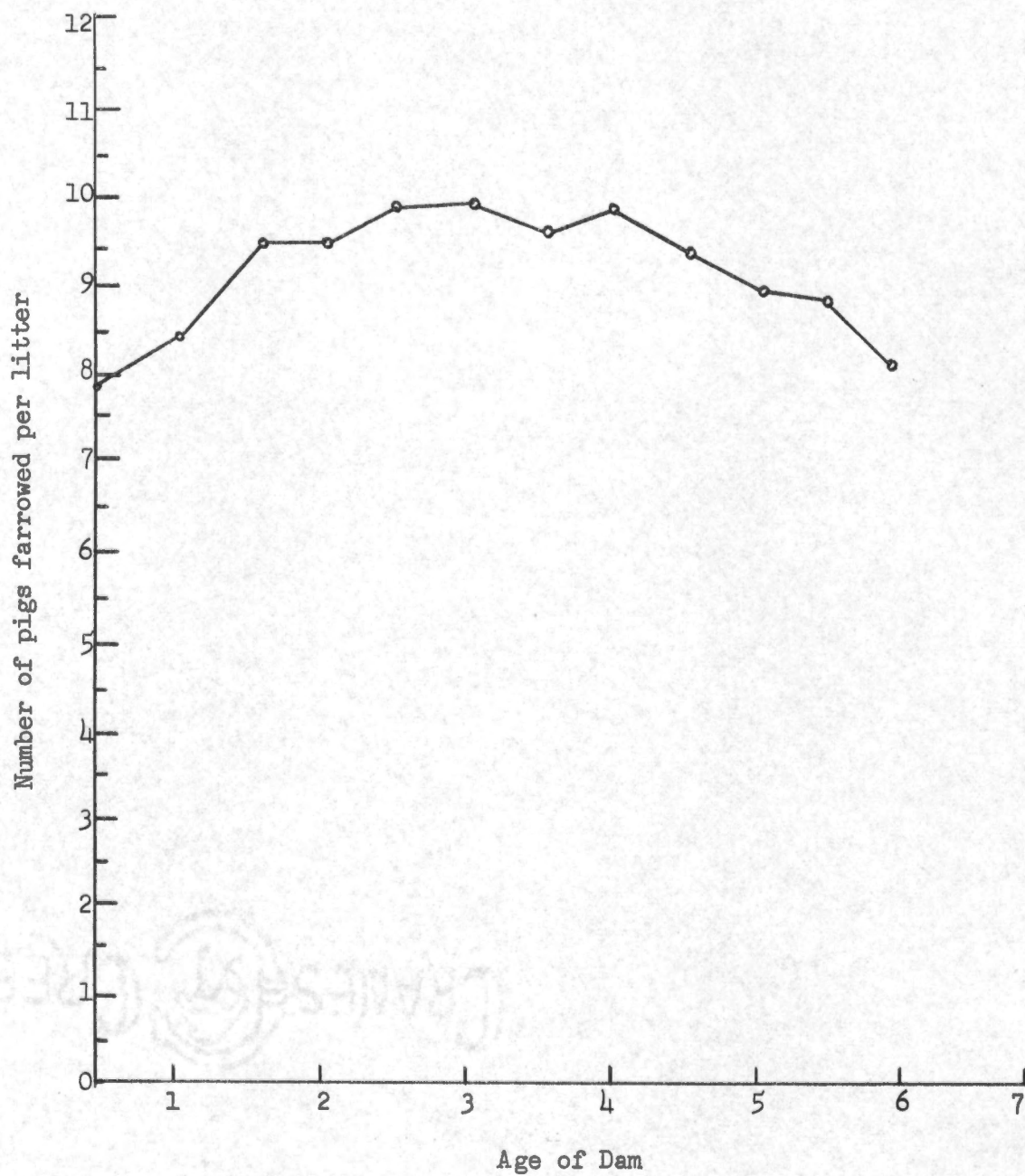


Figure 1. Relationship of age of dam to the number of pigs farrowed per litter.

age, varied slightly between 2- and 4.5-years-old, and declined after 4.5 years.

Birth weight. Pig weight at birth is closely related to survival ability. Vestal (1936) found that pigs from 2-year-old sows were considerably heavier than pigs from 1- and 3- to 5-year-old sows. Carmichael and Rice (1920) noted that the birth weight of pigs from sows 1.5 years old was 2.44 lb. compared to 2.61 lb. from sows at 2 years of age or older. However, a report by Russell (1936) showed no difference in birth weight of pigs in sows ranging from 1 to 6.5 years of age.

Survival rate. Robison (1948) found that gilts and sows in the 1- and the 1.5-year-old groups had fewer stillborn pigs and saved a larger percentage of their pigs than did older sows. In close agreement, Russell (1936) showed that the percentage of pigs farrowed dead for sows from 1 to 3.5 years of age averaged 6.5 per cent compared to 18.9 per cent for sows from 4 to 6.5 years of age. From a study of 5,778 pigs, Carmichael and Rice (1920) found that 8.1 per cent of pigs farrowed from sows 1 to 2.5 years of age were dead or immature compared to 12.3 per cent for sows 3 years old and over.

Weaning weight (56-day wt.). Vestal (1936) found 2-year-old sows surpassed 1- and 3- to 5-year-old sows in number of pigs weaned per litter, weaned litter weight and weaning weight of pigs. Robison (1946) observed that pigs from 1.5- to 2.5-year-old sows were heavier at weaning than pigs from 1-year-old gilts. In a later study, Robison

(1948) reported that sows between 1.5 and 3.5 years of age had heavier litters at weaning than younger or older sows.

Lush and Molln (1942) found that the number of pigs weaned from first litters averaged almost 0.5 pig smaller and litters from 2-year-old sows were nearly 0.5 pig larger than the average (Figure 2). They also observed in the same study that weaning weight for first litters was distinctly lighter than average. Maximum weights occurred in litters from 2-year-old sows. Weaning weight of litters declined after sows reached 3 to 3.5 years of age. Lush and Molln (1942) concluded that age of dam has less effect on the numbers of pigs weaned than on the number farrowed.

Weight at 180 days and average daily gain. Few workers made reference to age of dam effect on market weight and daily gain. Robison (1946) found that pigs from sows ranging in age from 1.5 to 2.5 years were heavier at 180 days than pigs from 1-year-old dams. Whatley (1942) noted that age of dam affected the pig weight at 180 days of age but the effect was small.

Robison (1946) observed faster growth rates in pigs from sows 1.5 years of age and above than from 1-year-old sows.

III. SEASON OF BIRTH

There has been little published research on the effect of season of birth upon performance traits in swine. Robison (1948) reported in their study that spring litters had some advantages over fall litters

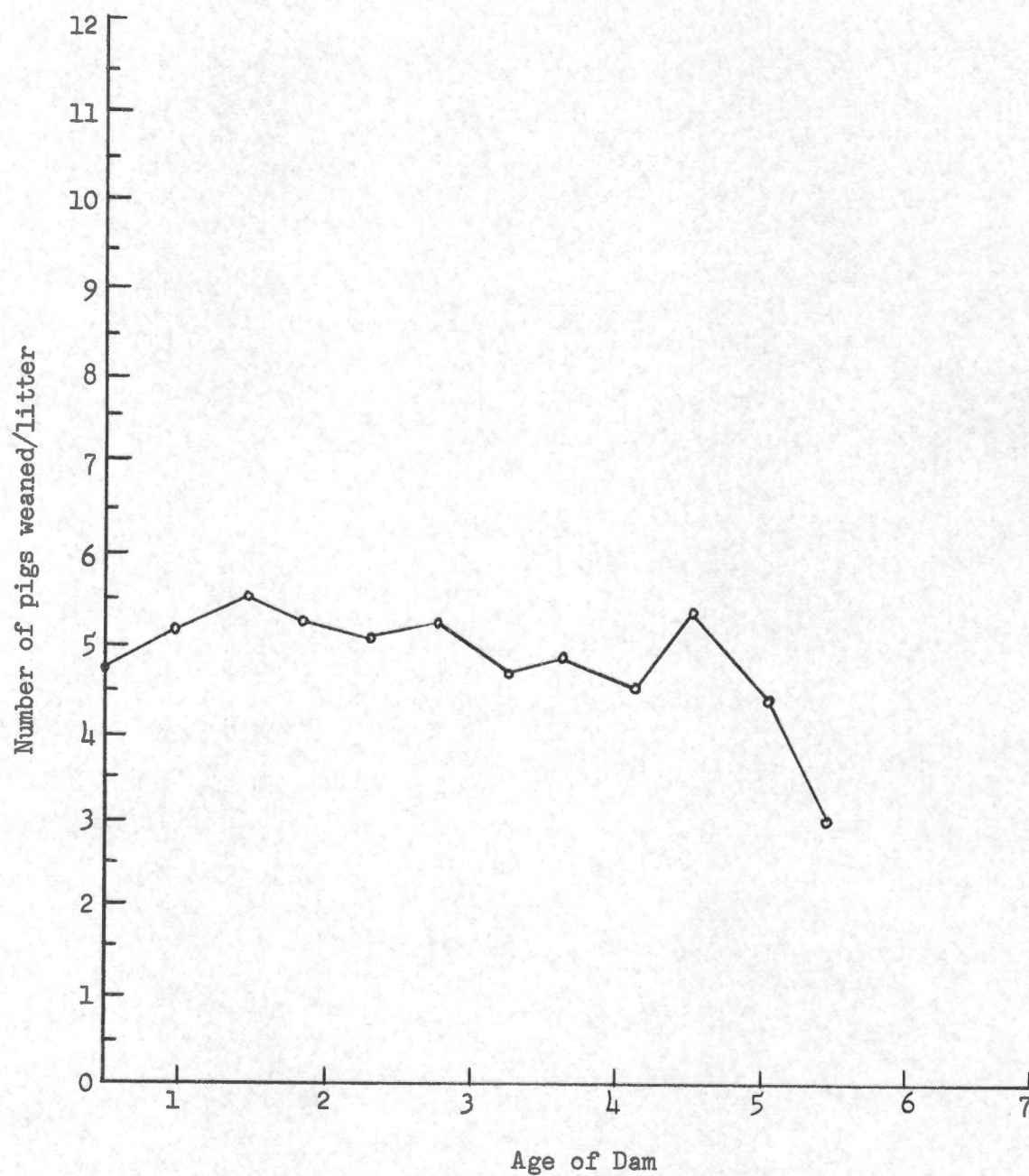


Figure 2. Relation of age of dam to the number of pigs weaned per litter.

since spring litters were from dams of 1.5 years of age compared to fall litters farrowed by gilts approximately 1 year of age. Also, season was confounded with availability of pasture. Spring pigs had access to pastures throughout the growing period whereas it was not available for fall pigs.

Working with data from ten different experiment stations, Lush and Molln (1942) found highly significant differences between seasons for number of pigs farrowed per litter, number of pigs weaned per litter and weight per litter at weaning. However, these differences were not consistent from one station to another and were not independent of other sources of variations.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. SOURCE OF DATA

The data used in this study were collected as a part of an extended swine breeding project being conducted at Ames Plantation, Grand Junction, Tennessee, by the Animal Husbandry-Veterinary Science Department, Agricultural Experiment Station, University of Tennessee, Knoxville, Tennessee. This study included data from eight farrowing seasons during the years of 1960 through 1963.

Performance data were obtained from purebred Hampshires and Durocs and various two- and three-breed repeat crosses. Purebred Hampshire, Duroc, Landrace, and Yorkshire boars were used in the various crosses. Data were obtained for the following performance traits: litter size at birth, 56 and 154 days; pig weight and litter weight at birth, 56, 154 and 180 days; average daily gain from birth to market weight; and live backfat probe at market weight.

II. EXPERIMENTAL ANIMALS

The number and kinds of matings which were made to produce pigs during both spring and fall seasons for the 4-year period included in the study are shown in Table IV. The actual number of litters produced in the various breeding groups varied somewhat from this in some seasons,

TABLE IV

NUMBER AND KINDS OF MATINGS MADE TO PRODUCE STRAIGHTBRED AND
CROSSBRED PIGS IN SPRING AND FALL FARROWING
SEASONS, 1960 THROUGH 1963

No. of sows ^a	Breed of sire ^b	Breed of dam	Breeding of pig ^c
15	D	D	D
15	H	H	H
6	H	D	HD
6	D	H	DH
6	L	H	LH
6	L	D	LD
6	Y	H	YH
6	Y	D	YD
6	L	HD	LHD
6	Y	HD	YHD
6	H	YD	HYD
6	D	YH	DYH
6	H	LD	HLD
6	D	LH	DLH

^aNumbers of sows in each group are approximations.

^bBreed code: H - Hampshire; D - Duroc; L- Landrace; and Y - Yorkshire.

^cFirst letter denotes breed of sire. Second and third letters denote breed of dam.

but an effort was made to come as close as possible to the number shown in the table.

Sows were reallocated to breeding groups each season on the basis of breed, age and previous performance. Also, sows of similar breeding were randomly assigned to as many sire-breeding groups with the same breed of sire as possible.

III. HERD MANAGEMENT

Sows within groups were divided into three subgroups and one-third of the sows were put with boars for breeding at 2-week intervals. A practical central farrowing house with farrowing stalls was used. The 2-week interval allowed time for putting the sows in the farrowing stalls a few days before farrowing, and steam cleaning disinfecting the stalls for the next sows.

The program was designed to farrow two litters per sow each year. Matings were made so that spring and fall litters were farrowed beginning about April 1 and October 1, respectively. All sows were pasture bred, with 8 to 12 sows per sire group depending on the age and size of the boar and length of breeding season. Approximate farrowing dates were obtained by checking the sows daily and recording the ones in estrus. Gilts were bred to farrow first at 10 to 14 months of age.

After being brought to the farrowing quarters, sows were thoroughly washed, using soap and a disinfectant, and wormed with piperazine. Both before and after parturition, each sow was turned out of the stall twice daily for feed and water. Farrowing stalls were used

to minimize pig losses due to crushing by the sows.

Sows were vaccinated once each year for erysipelas, cholera and leptospirosis. A brucellosis test was run twice a year. The sows were wormed twice a year in addition to the worming at farrowing time. They were rung as needed to prevent excessive rooting.

Boars were managed somewhat similar to sows. They received the same vaccinations, were tested for brucellosis, and were rung and wormed as needed. During the non-breeding season they were allowed to run together in groups according to size and age. Tusks were kept trimmed.

At birth, pigs were ear notched using the U.S.D.A. system. This system gives a numerical value to each notch, with the left ear indicating the litter number and the right ear indicating the individual pig number within the litter. The needle teeth of the pigs were cut and the gums treated with tincture of iodine. Iodine was also applied to the freshly cut notches and to the umbilical cords. Pigs were weighed to the nearest 0.1 lb. and injected with 3 cc. of erysipelas serum. Also at birth a teat count was made on both boar and gilt pigs.

At 3 to 5 days of age the pigs were injected with an iron compound for the prevention of anemia, and at 7 to 10 days of age, pigs and dams were moved to pasture lots. Four-acre pasture lots were stocked at the rate of about eight sows and their litters. At weaning time, sows were removed from the lots and the pigs remained in the lots to be finished to market weight. Portable type hog houses that could be used for shelter or shade were available in each pasture lot.

The first selection of boars in purebred litters was made at 4 weeks of age. Boars which did not show promise at this age were castrated. All pigs were vaccinated with a mixed bacterin for erysipelas at this time.

Litters were weaned and weighed at approximately 8 weeks of age. Second selection for boars was made at this time. At weaning all pigs were rung and vaccinated for cholera. The weaned pigs were sorted into groups according to age, size and weight. Pigs were wormed with piperazine 2 weeks after weaning and again at 4-week intervals depending on the level of parasite infestation.

The pigs were weighed again at approximately 154 days of age and divided into the following groups: 200 lb. and over; 185 to 200 lb.; 165 to 185 lb.; and 165 or less. At approximately 180 days of age, the pigs were weighed and those weighing around 220 lb. were marketed or sold as breeding stock. A live-animal backfat probe was taken at the seventh rib, 2 inches off center of the back, using a knife and an official backfat probe ruler.

IV. FEEDS AND RATIONS

Rations containing corn grown on Ames Plantation were fed to all animals. The corn was fed as ground ear corn, whole ear corn, or shelled corn depending upon the animals receiving the ration. Protein supplements were purchased and mixed on the Plantation. The amounts and proportions of tankage, soybean oil meal and alfalfa leaf meal fed varied, depending upon the quality and amount of available pasture

and upon age and condition of the animals.

Sows were fed one of two supplement mixtures. Supplement "A" fed on "good" pasture consisted of a mixture of 100 lb. of tankage and 100 lb. of soybean oil meal. Supplement "B" fed on "poor" pasture consisted of a mixture of 100 lb. of tankage, 100 lb. of alfalfa leaf meal and 100 lb. of soybean oil meal. Ten lb. of dicalcium phosphate and 2 lb. of salt were added per 100 lb. of either mixture.

From weaning until re-breeding, sows were hand fed a daily ration of 2 to 5 lb. of ground ear corn and 0.5 to 1 lb. of supplement "A" or "B," the amount depending upon the quality of the pasture and on the age and condition of the sows.

Sows were flushed at breeding time by increasing the amount of the ground ear corn by about 2 lb. and the supplement by 0.5 to 1 lb. This feeding level was continued through the first month of gestation. After this the concentrate level was reduced to prevent sows from becoming excessively fat.

Three to 4 weeks prior to farrowing, the amount of supplement fed was increased to 1.5 to 2 lb. daily and the amount of ground ear corn was also increased. After farrowing, sows were started on a small amount of ground ear corn plus supplement "B." After the sows were placed on pasture with their pigs, their ration was increased to a full-feed level and they were self-fed ear corn and supplement until the pigs were weaned. If the pastures were good, no feed was given the first day or two following the weaning of the pigs. A limited amount of feed was fed during the rest of the drying-up period.

Boars received the same ration as the sows but were kept in a thrifty condition at all times. They were fed according to their condition.

From weaning until approaching market weight pigs were self-fed ear corn or shelled corn and supplement free-choice. They were fed one of two supplements depending upon the age of pigs and the amount and quality of the available pasture. Pigs up to 4 months of age on "good" pasture were self-fed a supplement mixture consisting of 100 lb. of soybean oil meal and 100 lb. of tankage. An additional 100 lb. of soybean oil meal was added to the mixture from 4 months to market weight. Pigs up to 4 months of age on "poor" pasture were self-fed a supplement mixture of 150 lb. of soybean oil meal, 150 lb. of tankage and 50 lb. of alfalfa leaf meal. For pigs from 4 months to market weight, the soybean oil meal was increased by 50 lb. and the tankage was decreased by 50 lb. Ten lb. of dicalcium phosphate and 2 lb. of salt were added per 100 lb. of either supplement. An antibiotic was added at the rate of 4 grams of activity per 100 lb. of supplement mixture.

Permanent pastures of Ladino clover, alfalfa and orchardgrass were provided for spring litters. Oats and crimson clover were provided as temporary pastures for fall litters. Pastures were grazed at the rate of approximately 20 growing-finishing pigs per acre.

A record was kept of death losses and health problems encountered in all groups. Atrophic rhinitis was diagnosed as a serious disease problem in the swine herd during a part of the period during this study. This disease is apparently transmitted by direct contact between a

carrier sow and young pigs which are most susceptible from birth to about 6 to 8 weeks of age. Its effect on the growth rate and thriftiness of the pig may not be evident until weaning time or later in the growth period. In this study there was no evidence to indicate that the incidence of the disease among pigs was greater in any one of the breeding groups compared.

V. METHODS AND ANALYSIS

Individual pig weights of both straightbred and crossbred pigs were adjusted to three standard ages to allow mean comparisons between litters and breeding groups.

A standard 56-day weight (weaning weight) was obtained by subtracting the birth weight from the actual weight at weaning, dividing the remainder by the weaning age to calculate the average daily gain, multiplying the average daily gain by 56 and adding the product back to the birth weight.

A standard 154-day weight was obtained by subtracting the actual weaning weight from the actual weight at approximately 154 days, dividing the remainder by the days from weaning to the weigh date to get the average daily gain for the period, multiplying the average daily gain by the number of days between the weigh date and 154 days and adding the product to the actual weight if the pig was less than 154 days old and subtracting it if the pig was older than 154 days. A similar procedure was used to obtain the adjusted 180-day weight.

Backfat measurements of pigs were adjusted to a standard weight of 200 lb. by use of an adjustment table devised by H. W. Bean of the University of Illinois.

All pigs farrowed, whether farrowed alive or stillborn, were included in litter size at birth.

Estimates of the effects of age of dam, season of birth and breed of pig upon total number of pigs born, number born alive, birth weight, number alive and weight at 56 days of age, number alive and weight at 154 days, number alive and weight at market, market age, average 180-day weight, average daily gain from birth to market and average adjusted backfat thickness at market weight were obtained by least squares analysis method described by Harvey (1960).

Before estimates of the effects due to age of dam, season of birth, and breed of pig could be obtained, it was necessary to construct a mathematical model to describe the population from which the data came. Unequal numbers of litters in each subclass warranted the use of least squares analysis. The following mathematical model was used to obtain least squares constants:

$$Y_{ijklm} = u + y_i + s_j + a_k + g_l + (sa)_{jk} + (ag)_{kl} + e_{ijklm}$$

where:

Y_{ijklm} = The total number of pigs born, number born alive, number alive at 56 days, average 56-day weight, number alive at 154 days, average 154-day weight, number alive and weight at market, market age, average daily gain birth to market, average 180-day weight or average adjusted backfat thickness at market for the l th breed of pig, the k th age of dam, the j th season of birth and the i th year.

u = The theoretical population mean with equal subclass frequencies.

y = The effect of year of birth with i classification (absorbed), $i = 1, 2, 3, 4$ as follows:

1. 1960
2. 1961
3. 1962
4. 1963

s = The effect of season of birth with j classification, $j = 1$ or 2 as follows:

1. Spring
2. Fall

a = The effect of age of dam with k classification, $k = 1, 2, 3, 4$, and 5 as follows:

1. 1-year-old gilt
2. 1.5-year-old sow
3. 2-year-old sow
4. 2.5-year-old sow
5. 3-year-old or older sows

g = The effect of breed of pig with l classification, $l = 1, 2, \dots, 14$ as follows:

- | | |
|-------|---------|
| 1. D | 8. YD |
| 2. H | 9. LHD |
| 3. HD | 10. YHD |
| 4. DH | 11. HYD |
| 5. LH | 12. DYH |
| 6. LD | 13. HLD |
| 7. YH | 14. DLH |

$(sa)_{jk}$ = Interaction effects for season of birth and age of dam.

$(ag)_{kl}$ = Interaction effects for age of dam and breed of pig.

e_{ijklm} = Random errors.

This model was considered appropriate for use in comparisons involving all traits.

Orthogonal comparisons were made among the breed groups where significant breed effects were observed. The comparisons made are shown in Table V.

When significant difference due to age of dam effects was detected, Duncan's Multiple Range Test (1955) as modified by Kramer (1957) was used for mean separation.

TABLE V
ORTHOGONAL COMPARISONS AMONG THE FOURTEEN BREED GROUPS

Orthogonal comparison	Breed Groups ^a												
	D	H	HD	DH	LH	LD	YH	YD	LHD	YHD	HYD	DYH	DLH
1	-1	1	0	0	0	0	0	0	0	0	0	0	0
2	1	1	-1	-1	0	0	0	0	0	0	0	0	0
3	0	0	1	-1	0	0	0	0	0	0	0	0	0
4	0	0	0	0	-1	0	-1	1	0	0	0	0	0
5	0	0	0	0	0	0	0	0	1	-1	0	0	0
6	0	0	0	0	0	0	0	0	0	0	-1	0	0
7	0	0	0	0	0	0	0	0	0	0	0	-1	0
8	0	0	0	0	0	0	-1	-1	0	0	0	0	1
9	0	0	0	0	1	1	0	0	0	0	1	0	0
10	0	0	0	0	0	-1	0	0	0	0	0	-1	-1
11	1	1	1	1	-1	0	-1	-1	0	0	1	0	0
12	0	0	0	0	0	0	0	0	+2	+2	-1	-1	-1
13	6	6	6	6	6	6	6	6	-8	-8	-8	-8	-8

^aBreed code as described on page 27.

CHAPTER IV

RESULTS AND DISCUSSION

I. GENERAL

Data from 745 litters were analyzed by least squares analysis to determine the effects of season, age of dam and breed on average litter performance traits. The litter performance traits were separated into pre-weaning and post-weaning traits. Interaction effects were calculated for season of birth and age of dam and also for age of dam and breed of pig. These interactions were found to be non-significant and were therefore eliminated from the model.

Means and their standard errors by years for the traits studied are shown in Table VI. The overall means and their standard errors are presented in Table VII.

Atrophic rhinitis was diagnosed as a serious disease problem in the herd during most of the period when these data were collected. This disease was apparently responsible for the low 154- and 180-day weights and also the increase in market age of the litters in 1963 (Table VI).

II. SEASON OF BIRTH

The influence of season of birth was significant for most litter performance traits (Tables VIII and IX). Generally, spring farrowed litters were superior in performance as compared to fall litters. The least squares effects of season of birth on pre-weaning and post-weaning

TABLE VI
MEANS AND THEIR STANDARD ERRORS FOR VARIABLES STUDIED IN 1960, 1961, 1962 AND 1963

Variables	1960		1961	
	Mean	Standard error	Mean	Standard error
Birth weight, lb.	3.07	0.038	3.00	0.032
Number at birth	11.45	0.214	10.22	0.216
56-day weight, lb.	29.74	0.589	28.49	0.568
Number at 56 days	8.02	0.226	7.50	0.212
154-day weight, lb.	142.87	2.328	136.79	2.642
Number at 154 days	7.46	0.236	6.94	0.222
Market weight, lb.	207.35	2.682	196.47	3.175
Number at market	7.24	0.234	6.70	0.224
Litter size alive	10.74	0.204	9.51	0.217
Number of males/litter	5.48	0.157	5.25	0.156
Market age, days	193.52	2.695	196.57	3.364
Total gain, birth - market, lb.	204.17	2.643	193.40	3.127
Average daily gain, birth - market, lb.	1.03	0.015	0.96	0.017
180-day weight, lb.	181.26	2.887	169.73	3.196
Backfat probe, in.	1.46	0.022	1.31	0.024
Adjusted backfat probe, in.	1.37	0.020	1.26	0.022

TABLE VI (continued)

Variables	1962		1963	
	Mean	Standard error	Mean	Standard error
Birth weight, lb.	2.84	0.037	2.95	0.033
Number at birth	10.00	0.221	10.03	0.218
56-day weight, lb.	30.36	0.575	25.73	0.449
Number at 56 days	7.66	0.195	7.59	0.190
154-day weight, lb.	145.80	1.932	116.04	1.866
Number at 154 days	7.41	0.196	7.22	0.194
Market weight, lb.	207.37	1.622	204.57	2.505
Number at market	7.09	0.203	6.81	0.197
Litter size alive	9.26	0.191	9.28	0.202
Number of males/litter	5.11	0.161	5.12	0.164
Market age, days	199.61	1.896	218.63	2.862
Total gain, birth - market, lb.	204.31	1.597	201.48	2.469
Average daily gain, birth - market, lb.	1.03	0.011	0.91	0.013
180-day weight, lb.	183.04	2.116	147.20	2.371
Backfat probe, in.	1.39	0.016	1.49	0.019
Adjusted backfat probe, in.	1.32	0.015	1.41	0.018

TABLE VII

OVERALL MEANS AND THEIR STANDARD ERRORS FOR ALL VARIABLES
STUDIED FROM 1960 THROUGH 1963

Variables	Mean	Standard error
Birth weight, lb.	2.97	0.017
Number at birth	10.43	0.109
56-day weight, lb.	28.49	0.273
Number at 56 days	7.68	0.104
154-day weight, lb.	134.84	1.121
Number at 154 days	7.25	0.107
Market weight, lb.	203.72	1.315
Number at market	6.95	0.108
Litter size alive	9.70	0.103
Number of males/litter	5.25	0.080
Market age, days	202.28	1.415
Total gain, birth - market, lb.	200.62	1.296
Average daily gain, birth - market, lb.	0.98	0.007
180-day weight, lb.	169.62	1.362
Backfat probe, in.	1.41	0.010
Adjusted backfat probe, in.	1.34	0.010

TABLE VIII

ANALYSIS OF VARIANCE FOR SEASON, BREED OF PIG AND AGE OF DAM EFFECTS ON
PRE-WEANING LITTER PERFORMANCE TRAITS

Source	df	Mean squares			
		Average birth weight	Number of pigs at birth	56-day weight	Number of pigs at 56 days
Season	1	.992*	38.047*	1.288	163.210**
Age of dam	4	4.258**	365.554**	1123.693**	108.178**
Breed ^a	13	.393*	28.542*	232.515**	41.516**
Residual	723	.201	6.171	46.888	6.538
					5.897

^aFor orthogonal comparison among breeds see Table XIV, page 55.

*p < .05.

**p < .01.

TABLE IX

ANALYSIS OF VARIANCE FOR SEASON, BREED OF PIG AND AGE OF DAM EFFECTS ON
POST-WEANING LITTER PERFORMANCE TRAITS

Source	df	Mean squares			
		154-day weight	Number of pigs at 154 days	Market weight	Number of pigs at market
Season	1	4785.644*	152.522**	9903.519**	141.625**
Age of dam	4	17570.229**	124.441**	4637.086**	135.788**
Breed ^a	13	5556.434**	52.806**	2855.350**	55.970**
Residual	723	756.653	6.800	1224.840	6.879
					9945.967**
					4159.489*
					954.046
					1479.670

TABLE IX (continued)

Source	df	Mean squares			
		Total gain birth - market	Average daily gain birth - market	180-day weight	Adjusted backfat probe
Season	1	9699.454**	.086	7195.591*	.121
Age of dam	4	4302.524**	.522**	26954.442**	.158
Breed ^a	13	2796.657**	.213**	7735.770**	.175**
Residual	723	1189.380	.032	1116.280	.069

^aFor orthogonal comparisons among breeds see Table XV, page 56.

*P < .05.

**P < .01.

litter performance are presented in Tables X and XI. The effects due to season of birth obtained in this study are in agreement with Robison (1948) who reported that spring litters had some advantages over fall litters.

Pigs from spring litters were heavier at birth and they contained about 0.5 pig more per litter at birth than fall litters. There was no significant difference between seasons for weaning weight, however, the spring litters produced almost one more pig per litter at weaning than the fall litters. Lush and Molln (1942) were in partial agreement since they observed a highly significant difference between seasons for number of pigs farrowed per litter and number of pigs weaned per litter. They also reported a highly significant difference between seasons for weaning weight which is not in agreement with results obtained in this study. Litters farrowed in the spring had more pigs alive at birth (about 0.5 pig more) than those which were farrowed in the fall.

Average pig weights at 154 and 180 days of age and at market age were significantly heavier for spring litters. At 154 days and at market age spring litters contained almost one more pig per litter than did fall litters. Pigs in spring farrowed litters reached market on the average 1 week sooner than fall pigs. Season of birth had no significant effect on average daily gain from birth to market, weaning weight, backfat probe or adjusted probe (Tables VIII and IX, pages 42 and 43).

III. AGE OF DAM

Age of dam had a highly significant effect upon most of the litter performance traits in this study (Tables VIII and IX, pages 42 and 43).

TABLE X

LEAST SQUARES CONSTANTS^a FOR AGE OF DAM AND SEASON OF BIRTH
ON PRE-WEANING LITTER PERFORMANCE TRAITS

Source	Average birth weight (lb.)	Number of pigs at birth	56-day weight (lb.)	Number at 56 days	Litter size alive at birth
Season					
Spring	0.037 ^b	0.229 ^b	0.042 ^b	0.475 ^b	0.235 ^b
Fall	-.037 ^c	-.229 ^c	-.042 ^b	-.475 ^c	-.235 ^c
Age of dam					
1 year	-.253 ^b	-2.307 ^b	-3.857 ^b	-1.215 ^b	-1.926 ^b
1.5 years	-.009 ^c	-.482 ^c	0.239 ^c	0.481 ^c	0.017 ^c
2 years	0.105 ^c	0.823 ^d	0.966 ^c	0.600 ^c	0.835 ^d
2.5 years	0.095 ^c	0.887 ^d	-.333 ^c	0.152 ^c	0.563 ^{cd}
3 years ^e	0.061 ^c	1.080 ^d	2.985 ^d	-.018 ^c	0.513 ^{cd}

^aConstants are deviations from the overall mean.

^{b,c,d}Constants in this class of effects not superscripted with the same letter are significantly different ($P < .05$).

^eSows 3 years and older are included.

TABLE XI
LEAST SQUARES CONSTANTS^a FOR AGE OF DAM AND SEASON OF BIRTH ON
POST-WEANING LITTER PERFORMANCE TRAITS

Source	154-day weight (lb.)	Number of pigs at 154 days	Market weight (lb.)	Number of pigs at market	Market age (days)	Total gain birth - market (lb.)	Average daily gain birth - market (lb.)	180-day weight (lb.)	Backfat probe (in.)	Adjusted backfat probe (in.)
<u>Season</u>										
Spring	2.573 ^b	0.459 ^b	3.701 ^b	0.443 ^b	3.709 ^b	3.663 ^b	0.010 ^b	3.155 ^b	-.008 ^b	-.013 ^b
Fall	-2.573 ^c	-.459 ^c	-3.701 ^c	-.443 ^c	-3.709 ^c	-3.663 ^c	-.010 ^b	-3.155 ^c	0.008 ^b	0.013 ^b
<u>Age of dam</u>										
1 year	-15.760 ^b	-1.328 ^b	-6.416 ^b	-1.390 ^b	7.479 ^b	-6.088 ^b	-.083 ^b	-19.386 ^b	-.042 ^b	-.035 ^b
1.5 years	3.623 ^c	0.476 ^c	4.297 ^c	0.453 ^c	2.480 ^c	4.117 ^c	0.019 ^c	3.405 ^c	0.039 ^b	0.030 ^b
2 years	5.007 ^c	0.552 ^c	4.343 ^c	0.616 ^c	-.209 ^c	4.201 ^c	0.036 ^c	6.955 ^c	0.009 ^b	-.001 ^b
2.5 years	-.308 ^c	0.245 ^c	-5.586 ^{bc}	0.228 ^c	-6.695 ^c	-5.581 ^{bc}	-.017 ^c	-1.120 ^c	-.045 ^b	-.031 ^b
3 years ^e	7.432 ^c	0.054 ^c	3.462 ^c	0.093 ^c	-3.055 ^c	3.351 ^c	0.045 ^d	10.146 ^d	0.038 ^b	0.036 ^b

^aConstants are deviations from the overall mean.

^{b,c,d}Constants in this class of effects not superscripted with the same letter are significantly different ($P < .05$).

^eSows 3 years and older are included.

Average birth weight of pigs from 1-year-old gilts was found to be significantly lower than those from 1.5-year-old and older sows. There was no significant difference between sows ranging in age from 1.5 to 3 years and older. Similarly, Vestal (1936) found that pigs from 2-year-old sows were considerably heavier at birth than pigs from 1- and 3-5-year-old sows. However, Russell (1936) reported that there was no difference in birth weights in sows ranging from 1-6.5 years of age.

One-year old gilts and sows 1.5 years of age differed significantly from each other in litter size at birth, and they (1- and 1.5-year-old sows) had significantly smaller litters at birth than did sows 2 years old and older (Table X, page 46). Differences among sows 2, 2.5 and 3 years of age and older for litter size at birth were not significant. Sows 2 years and older farrowed on the average three more pigs per litter at birth than did 1-year-old gilts. Robison (1946) reported that 1.5- to 2.5-year-old sows produced larger litters than 1-year-old sows. Carmichael and Rice (1920) found the 2-year-old sows farrowed larger litters than 1.5-year-old sows. However, in disagreement, Vestal (1936) stated that 2-year-old sows consistently farrowed larger litters than 1- and 3- to 5-year-old sows.

Pigs from 1-year-old gilts weighed significantly less at weaning than pigs from 1.5- to 3-year-old sows. The older sows 3 years and older had significantly heavier pigs at weaning than sows ranging from 1 to 2.5 years of age. There was no significant difference between 1.5- to 2.5-year-old sows for average pig weight at weaning. Vestal (1936) found that 2-year-old sows surpassed 1- and 3- to 5-year-old sows in

weaned litter weight and number of pigs weaned per litter. Robison (1946) observed that pigs from 1.5- to 2.5-year-old sows were heavier at weaning than pigs from 1-year-old gilts. Litters from 1-year-old gilts had significantly fewer pigs at weaning than sows ranging 1.5 to 3 years old and older. No difference was observed between sows 1.5 years old through 3 years old and above for number of pigs per litter at weaning.

One-year-old gilts farrowed fewer live pigs per litter than older sows. This difference was significant ($P < .01$). The 1.5-year-old sows had significantly more pigs alive at birth than 1-year-old gilts. Two-year-old sows farrowed significantly more live pigs per litter than 1- and 1.5-year-old sows. No significant difference was found between sows from 2 through 3 years and older for the number of pigs alive per litter at birth. It is apparent from comparing the effects of age of dam on total number of pigs farrowed with the effects on number of live pigs farrowed that older sows produced litters with a greater number of stillbirths. These findings are in agreement with Carmichael and Rice (1920), Russell (1936) and Robison (1948).

Average pig weight at 154 days of age was significantly lower for litters from 1-year-old gilts than sows 1.5 years and older. There was no significant difference for 154-day pig weight between sows ranging from 1.5 years through 3 years of age and older.

There were significantly fewer number of pigs at 154 days of age and at market for 1-year-old gilts than for sows ranging in age from 1.5 years through 3 years and older. Sows 1.5 years old and older did not differ in the number of pigs per litter at 154 days of age and at market.

Pigs from 1-year-old gilts weighed significantly less at market than pigs from 1.5-year-old sows and older. However, there was no difference between 1-year-old gilts and 2.5-year-old sows nor was there any difference among sows ranging from 1.5 years of age through 3 years of age and older for the market weight of their pigs.

Pigs from sows ranging from 1.5 to 3 years old and older were significantly younger at market (7.6-14.2 days) than pigs from 1-year-old gilts. No difference was observed between sows from 1.5 to 3 years old and older in market age of their pigs.

At 180 days of age the average pig weight was significantly less for 1-year-old gilts than it was for sows 1.5 years of age and above. No significant difference was found between 1.5-, 2- and 2.5-year-old sows for 180-day average pig weight. Litters farrowed by 3-year-old sows had significantly heavier pigs at 180 days of age than the younger sows. These findings are in agreement with those of Robison (1946) who found that pigs from sows ranging in age from 1.5 to 2.5 years were heavier at 180 days than were pigs from 1-year-old dams.

Pigs from gilts (1-year-old) had significantly slower growth rates than did pigs from older sows. No significant difference was found between 1.5-, 2- and 2.5-year-old sows for average daily gain of pigs from birth to market. Also, pigs from 3-year-old and older sows had significantly faster growth rates than pigs from the younger sows. Robison (1946) observed faster growth rates in pigs from sows 1.5 years of age and above than from 1-year-old dams.

No significant differences were observed among age of dam groups for average backfat probe and adjusted backfat probe.

IV. BREED OF PIG

The least squares effects of breed of pig on pre-weaning and post-weaning litter performance are shown in Tables XII and XIII. The effect of breed of pig was highly significant for most all of the litter performance traits (Tables VIII and IX, pages 42 and 43). The breed effects will be discussed according to orthogonal comparisons among the groups (Tables XIV and XV).

D vs. H. Average pig weight of purebred Duroc litters was significantly ($P < .01$) greater at 56, 154 and 180 days of age and at market than was that of Hampshires. Duroc litters also included more pigs at 56 and 154 days of age and at market. There were significant weight differences between Duroc and Hampshire pigs at 154 days of age and older. The Duroc litters had approximately 1.5 more pigs per litter than Hampshires at all ages. Durocs significantly ($P < .01$) out-gained Hampshires, but Hampshires were significantly ($P < .01$) leaner than Durocs. These data indicate that Duroc sows are superior to Hampshire in maternal ability, and the individual pigs are superior in post-weaning growth rate.

D and H vs. HD and DH. Average pig weight of single cross litters (HD and DH) was significantly ($P < .05$) heavier at birth and at 56, 154 and 180 days of age than purebred pigs. Hence, crossbred pigs (HD and DH)

TABLE XII

LEAST SQUARES CONSTANTS^a FOR BREED OF PIG ON PRE-WEANING
LITTER PERFORMANCE TRAITS

Breed	Average birth weight (lb.)	Number of pigs at birth	56-day weight (lb.)	Number at 56 days	Litter size alive at birth
H	-.092	-.381	-3.965	-1.402	-.665
HD	-.015	-.079	-.916	0.282	0.137
HLD	0.103	1.069	0.450	0.521	0.947
HYD	0.087	-.531	2.800	-.267	-.208
DH	0.327	-1.366	5.497	0.373	-1.114
D	-.075	0.344	-1.259	-.178	-.122
DLH	0.052	0.806	-.395	0.979	0.882
DYH	-.052	-.446	2.631	-.143	-.371
LH	0.011	-1.216	-.032	-1.021	-1.367
LD	-.107	0.286	0.561	0.198	0.245
LHD	-.229	0.862	-.411	0.686	1.041
YH	-.001	-.994	-4.113	-1.596	-1.045
YD	0.030	0.158	-.543	0.191	0.050
YHD	-.039	1.488	-.305	1.568	1.264

^aConstants are deviations from the overall mean.

TABLE XIII
LEAST SQUARES CONSTANTS^a FOR BREED OF PIG ON POST-WEANING LITTER PERFORMANCE TRAITS

Breeds ^b	154-day weight (lb.)	Number of pigs at 154 days	Market weight (lb.)	Number of pigs at market	Market age (days)
H	-21.785	-1.732	-14.874	-1.863	6.422
HD	-.534	0.367	-1.884	0.348	-3.539
HLD	2.058	0.672	1.552	0.603	-.422
HYD	7.126	-.090	3.039	-.071	0.717
DH	14.933	0.534	9.474	0.721	-6.338
D	-2.978	-.298	-.456	-.408	2.445
DLH	2.567	1.024	2.890	0.974	-.897
DYH	1.563	0.037	1.987	0.044	-.866
LH	0.069	-1.125	-4.030	-.942	-4.943
LD	8.608	0.328	4.246	0.542	-.231
LHD	1.560	0.516	6.295	0.514	9.310
YH	-16.037	-1.633	-11.809	-1.726	-4.339
YD	-2.553	-.054	-3.531	-.111	-2.675
YHD	5.403	1.454	6.101	1.375	5.356

TABLE XIII (continued)

Breeds ^b	Total gain birth - market (lb.)	Average daily gain birth - market (lb.)	180-day weight (lb.)	Backfat probe (in.)	Adjusted backfat probe (in.)
H	-14.668	-.135	-25.848	-.159	-.111
HD	-1.805	0.001	0.637	-.054	-.044
HLD	1.416	0.007	2.004	-.051	-.058
HYD	2.998	0.033	8.973	0.006	0.008
DH	9.329	0.094	15.286	0.056	0.011
D	-.363	-.018	-3.404	-.041	-.032
DLH	2.867	0.020	2.519	-.041	-.044
DYH	2.084	0.035	7.138	0.032	0.036
LH	-4.234	-.017	-1.066	0.009	0.009
LD	4.312	0.053	8.589	0.001	0.006
LHD	6.377	0.013	1.044	0.043	0.038
YH	-11.702	-.098	-18.766	0.058	0.053
YD	-3.510	-.022	-3.707	0.044	0.044
YHD	6.899	0.034	6.601	0.097	0.084

^aConstants are deviations from the overall mean.^bBreed code as described on page 27.

TABLE XIV

ORTHOGONAL COMPARISONS AMONG BREED OF PIG FOR PRE-WEANING LITTER PERFORMANCE TRAITS

Orthogonal comparison ^a	Mean squares				
	Average birth weight	Number of pigs at birth	56-day weight	Number of pigs at 56 days	Litter size alive at birth
D vs. H	.018	.088	469.033**	95.963**	18.956
D & H vs. HD & DH	1.061*	9.161	444.161**	82.916**	.170
HD vs. DH	.603	10.773	212.262*	.044	8.090
LH vs. LD	.346	56.092**	8.743	37.009*	64.613**
YH vs. YD	.023	32.021*	307.511*	77.136**	28.983*
LHD vs. YHD	.427	4.636	.1329	9.203	2.680
HYD vs. HLD	.006	54.694**	117.984	26.893*	28.548*
DYH vs. DLH	.043	24.712*	78.820	1.344	24.792*
LH & LD vs. YH & YD	.192	.108	1244.833**	4.185	.201
HYD & HLD vs.					
DYH & DLH	.331	.290	9.405	3.119	.527
D, H, HD & DH vs.					
LH, LD, YH & YD	.147	.265	39.922	5.579	.407
LHD & YHD vs.					
HYD, DYH, HLD & DLH	1.425**	39.038*	129.260	31.564*	40.33**
All purebreds & two-way crosses					
All three-way crosses & backcrosses	.317	.6516	212.753*	33.543*	137.89**

^aBreed code as described on page 27.

*P < .05.

**P < .01.

TABLE XV

ORTHOGONAL COMPARISONS AMONG BREED OF PIG FOR POST-WEANING LITTER PERFORMANCE TRAITS

Orthogonal Comparison ^a	Mean squares			Number of pigs at market	Market age ^b
	154-day weight	Number of pigs at 154 days	Market weight		
D vs. H	22658.297**	131.716**	13315.330**	135.789**	
D & H vs. HD & DH	7087.680**	39.724*	2227.503	51.549**	
HD vs. DH	1234.442	.145	665.592	.721	
LH vs. LD	1813.451	52.567**	1703.061	54.759**	
YH vs. YD	2151.231	60.233**	1653.393	63.009**	
LHD vs. YHD	174.630	10.409	.445	8.790	
HYD vs. HLD	1801.880	12.404	47.302	9.704	
DYH vs. DLH	15.892	15.389	12.884	13.635	
LH & LD vs. YH & YD	7513.100**	9.676	2969.444	25.303	
HYD & HLD					
vs.					
DYH & DLH	237.173	2.107	.984	2.178	
D, H, HD & DH					
vs.					
LH, LD, YH & YD	.319	99.240	183.963	3.494	
LHD & YHD					
vs.					
HYD, DYH, HLD & DLH	1.025	10.461	634.642	13.456	
All purebred & two-way crosses					
vs.					
All three-way crosses & backcrosses	3844.622	122.123**	.448	110.805**	

TABLE XV (continued)

Orthogonal Comparison ^a	Mean squares			
	Total gain birth - market	Average daily gain birth - market	180-day weight	Adjusted backfat probe
D vs. H	13109.269**	1.519**	32265.809**	.410*
D & H vs. HD & DH	2351.009	.207*	9429.070**	.058
HD vs. DH	639.595	.045	1107.332	.015
LH vs. LD	1815.151	.122	2318.380	.001
YH vs. YD	1619.215	.139*	5472.358*	.002
LHD vs. YHD	3.224	.006	1103.061	.025
HYD vs. HLD	53.466	.014	1037.834	.093
DYH vs. DLH	9.690	.004	336.509	.012
LH & LD vs. YH & YD	2869.200	.299**	11043.886**	.087
HYD & HLD vs.				
DYH & DLH	2.628	.003	15.938	.018
D, H, HD & DH vs.				
LH, LD, YH & YD	190.705	.013	8.653	.272*
LHD & YHD vs.				
HYD, DYH, HLD & DLH	797.632	.017	77.142	.247
All-purebreds & two-way crosses vs.				
All three-way crosses & backcrosses	4794.081*	.045	7478.05	.036

^aBreed code as described on page 27.^bBreed of pig did not significantly effect market age.

*P < .05.

**P < .01.

had significantly ($P < .05$) faster growth rate than the purebreds. They also had more pigs per litter at 56 and 154 days of age and at market than did the parent breeds.

Winters et al. (1936) found that crossbred pigs were, on the average, heavier at birth than purebreds. However, several workers such as Whatley, Chambers and Stephens (1954), Pani et al. (1963), Bradford, Chapman and Grummer (1953) and Carroll and Roberts (1942) reported no consistent difference in birth weight between crossbred and purebreds. The DH pigs in this study were heavier at birth than all the other breed groups and the Hampshire pigs were the lightest at birth.

Workers in agreement that crossbred litters are heavier and have more pigs per litter at 56 days of age and older than purebreds are Hutton and Russell (1939), Robison (1946), Bradford, Chapman and Grummer (1953), Sherrit et al. (1954), Nance (1959), Smith, Moorman and McLaren (1959) and MacDonald, Moxley and Hamilton (1959).

HD vs. DH. Pigs in DH cross litters were found to be significantly ($P < .05$) heavier than HD pigs for average litter weaning weight only. However, DH crossbred pigs were also heavier at birth, 154 and 180 days of age and at market than were HD pigs, but the differences were non-significant. Purebred Hampshire pigs weighed less than purebred Duroc pigs at all ages but the Hampshire sows surpassed the Durocs when mated to Duroc as compared to Duroc sows mated to Hampshire boars.

LH vs. LD. The LD litters contained significantly ($P < .05$) more total pigs per litter at birth, 56 days of age, 154 days of age and at market than LH litters. These differences were of similar magnitude as the differences between purebred Duroc and purebred Hampshire litters which again reflects the superior maternal ability of Duroc sows. The LD crossbred litters also included significantly ($P < .01$) more live pigs born than the LH cross litters. Since purebred Duroc and Hampshire litters were similar for this trait, it is apparent that the Landrace boars combined better with Duroc sows.

YH vs. YD. Litters from the YD crosses had significantly ($P < .01$) more pigs per litter at birth, 56 days of age, 154 days of age and at market. These differences were of similar magnitude to those observed between Duroc and Hampshire litters. Average pig weight of YD litters was significantly ($P < .05$) heavier at weaning than was that of YH cross litters. Compared against all the other breed groups, pigs from YH litters were the lightest at weaning. Also, YD crossbred litters had significantly ($P < .05$) more pigs alive per litter at birth and included faster growing individuals than did the YH litters. Hence, it is apparent that Yorkshire boars combine more favorably with Duroc sows than with Hampshires.

LHD vs. YHD. No significant differences were found between LHD litters and YHD litters for the traits studied. These results indicate that the performance of litters sired by Landrace and Yorkshire boars do not differ when they are bred to similar crossbred dams.

HYD vs. HLD. Litters from HLD crosses contained significantly ($P < .05$) more live pigs at birth per litter, more total pigs per litter at birth and at weaning than HYD cross litters. Relatively small differences existed between YD and LD litters for these traits. Therefore, these differences are the result of the greater combining ability of Hampshire boars on LD sows than the YD crossbred sows or a superior maternal environment provided by the LD sows.

DYH vs. DLH. The DLH crossbred litters had significantly ($P < .05$) more live pigs and more total pigs per litter at birth than did the DYH crossbred litters. There was relatively no difference between YH and LH litters for the number of pigs at birth and litter size alive at birth. The difference observed between the DLH and DYH crossbred litters can be attributed to the more favorable combining ability of the Duroc boars with the LH sows rather than the YH sows.

LH and LD vs. YH and YD. Where the LH and LD crossbred litters were compared with YH and YD litters the former were found on an average pig basis to be significantly ($P < .01$) heavier at 56, 154 and 180 days of age. Pigs from LH and LD litters also gained significantly ($P < .01$) faster than the YH and YD pigs. These results revealed that Landrace boars were superior to Yorkshire boars in producing faster-gaining, crossbred pigs from weaning to 180 days of age when bred to purebred dams.

D, H, HD and DH vs. LH, LD, YH and YD. The average number of pigs per litter at 154 days of age was significantly ($P < .01$) greater for D, H, HD and DH than for LH, LD, YH and YD crossbred litters. Pigs from D, H, HD and DH litters were significantly ($P < .05$) leaner than were pigs from LH, LD, YH and YD cross litters. It is evident that pigs from purebred and reciprocal cross litters were superior for these traits to crossbred litters produced from parent breed sows and boars of different breeds.

LHD and YHD vs. HYD, DYH, HLD and DLH. Average pig birth weight on a litter basis was significantly ($P < .01$) heavier for HYD, DYH, HLD and DLH crossbred litters. When compared to all other breeds and breed crosses, pigs from the purebred Hampshire litters were the leanest and crossbred pigs from YH litters had the thickest backfat measurements. Pigs from HYD, DYH, HLD and DLH litters were significantly ($P < .05$) leaner than pigs from LHD and YHD. The Landrace and Yorkshire boars contributed very little in these three-breed crosses to reducing backfat thickness. However, the LHD and YHD litters contained significantly ($P < .05$) more live pigs per litter at birth and total pigs per litter at birth and at weaning.

All purebreds and two-way crosses vs. all three-way crosses and backcrosses. Three-breed cross pigs were significantly heavier at weaning, 154 and 180 days of age. They also had significantly ($P < .05$) more pigs per litter at 56, 154 days of age and at market than did purebred and two-breed cross litters. Three-way cross litters had

significantly more live pigs per litter. Smith, Moorman and McLaren (1960) found that pigs in three- and four-breed cross litters had greater survival ability than purebreds. Winters et al. (1936) and Smith, Moorman and McLaren (1960) reported that three-breed cross litters were superior to purebred litters for the number of pigs per litter at various ages.

HYD and HLD vs. DYH and DLH. When HYD and HLD litters were compared with DYH and DLH litters, no significant differences were observed for the traits studied.

CHAPTER V

SUMMARY AND CONCLUSION

This study was undertaken to compare certain litter performance traits of pigs produced by straightbreeding and crossbreeding, to compare the relative performance of straightbred litters with two- and three-breed crosses and to attempt to determine the more desirable breed crosses, and to study the effect of age of dam and season of birth on litter performance traits.

Data were compiled from 745 litters representing 14 different breed groups, 2 purebreds and 12 two- and three-breed crosses. Initial purebred and crossbred litters were from purebred Hampshire and Duroc sows bred to either a Duroc, Hampshire, Landrace or Yorkshire boar. The two-breed cross sows were retained each year and bred to one of the purebred boars to produce the three-breed cross litters.

The season of birth effects were significant for most all litter performance traits. Spring farrowed litters were generally superior in performance as compared to fall litters. The spring litters had from 0.5 to 1 more pig per litter at birth, weaning, 154 days of age and at market age. Also, pigs in spring litters were consistently heavier than pigs in fall litters at 154, 180 days of age and at market. There was no significant effect of season of birth on average daily gain from birth to market, weaning weight, backfat probe or adjusted backfat probe.

Spring litters reached market age on the average 1 week sooner than fall litters.

Age of dam influences were highly significant for most litter performance traits. In litters from 1-year-old gilts, the pigs weighed significantly ($P < .05$) less at birth, 56, 154, 180 days of age and at market than older sows. The 1-year-old gilts had significantly fewer pigs per litter at all ages from birth to market than the older sows. Performance for litter and pig traits increased with age of dam up to 3 years of age. Differences among sows ranging from 2 to 3 years of age and above were non-significant for most of the litter and pig performance traits studied.

The effect of breed of pig was highly significant for most all of the litter and pig performance traits. Pigs from purebred Duroc litters grew significantly ($P < .01$) faster at all ages from weaning to market than pigs from Hampshire litters. Duroc litters were significantly ($P < .01$) larger at 56 and 154 days of age and at market age. Crossbred litters (HD and DH) were significantly ($P < .05$) larger at 56, 154 days of age and at market than the purebred litters. The pigs from the HD and DH crossbred litters had significantly ($P < .05$) faster growth rate than the purebreds.

Pigs from Hampshire sows mated to Duroc boars were superior in performance as compared with pigs from Duroc sows mated to Hampshire boars. Landrace and Yorkshire boars combined more favorably with Duroc sows than with Hampshire sows. The superior combining ability of Hampshire boars on LD sows than the YD crossbred sows resulted in the

HLD litters being significantly superior to the HYD cross litters. Performance of DLH cross litters surpassed the performance of DYH litters and the difference was attributed to the more favorable combining ability of the Duroc boars with LH sows as compared with YH sows. Landrace boars were superior to Yorkshire boars in producing heavier pigs in crossbred litters from weaning to 180 days of age when mated to purebred dams.

Purebred and reciprocal cross litters of the Hampshire and Duroc breeds excelled crossbred litters produced from sows of these breeds and boars of a third breed. The pigs from three-breed cross litters were significantly heavier at all ages from weaning to market. The three-breed cross litters also had more pigs from weaning to market than the two-breed cross and purebred litters. When the HYD and HLD were compared with DYH and DLH litters and the LHD compared with the YHD, no significant differences were observed for the traits studied.

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