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To the Graduate Council:

I am submitting herewith a thesis written by Charles Wallace Robertson entitled "Effects of Season of Birth, Breed and Age of Dam on Litter and Pig Performance Traits." 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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EFFECTS OF SEASON OF BIRTH, BREED AND AGE OF DAM ON LITTER AND PIG PERFORMANCE TRAITS

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Charles Wallace Robertson

December 1965

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CHAPTER I

INTRODUCTION

In Tennessee there is wide variation in the practices followed by swine producers with reference to the breed and age of the breeding animals used in their herds. Some swine producers use gilts almost exclusively, whereas others depend largely on mature sows. On most Tennessee farms, both gilts and mature sows are used to produce pigs, but the number of gilts or sows a farmer keeps varies from farm to farm. There is no definite plan used by many swine raisers in maintaining their herds of breeding sows, and there may be wide variation in the breeding of sows and gilts on the same farm from year to year.

It is the practice of some farmers to use only one breed of gilts, breeding them to farrow their first and only litter when they are about 1 year old. When the litters are weaned, the gilts are marketed. To produce next year's pigs, gilts are selected in the fall from the spring pigs on hand. Many sows are sold for slaughter before they reach their peak performance.

One of the major elements contributing to profits in the swine enterprise is the size of litters sows and gilts produce. It requires on the average the gross returns from about six pigs to pay the cost of carrying the sow. The total cost of carrying a sow in the breeding herd remains practically constant whether she produces 2 or 10 pigs.

With larger litters less feed is required to produce 100 pounds of marketable pork.

A sow's value in the herd is determined largely by the number and quality of pigs farrowed and raised. Performance in these traits is influenced by age and breeding of the sow and other genetic and environmental factors.

Therefore, the swine producer who does not take advantage of all means available to maximize litter size, growth rate and efficiency may be robbing himself of extra profit.

I. OBJECT OF STUDY

This study seeks to evaluate the influence of season of birth, breed and age of dam on:

1. Litter size
2. Survival rate
3. Weaning weight
4. 154-day weight
5. 180-day weight.

CHAPTER II

REVIEW OF LITERATURE

I. SEASON OF BIRTH

The season of birth has been found to influence litter and pig performance. Wilcox, Carroll and Hornung (1933) found late-farrowed, spring pigs had about 8 per cent lower mortality rate than early spring pigs and 2 per cent lower than fall pigs. Work by Korkman (1947) showed that late spring- or summer-born pigs had lower mortality rates than pigs born in other seasons. On the other hand, Asdell and Willman (1941) noted that spring-farrowed litters had nearly twice the mortality rate as fall-farrowed pigs.

Season of birth has been reported to effect survival. Kernkamp (1943) observed that 30.5 per cent of spring pigs and 26.2 per cent of fall-born pigs died before weaning. Bradford, Chapman and Grummer (1953) reported viability to 154 days of age was 73.6, 74.7 and 73.8 per cent for early-, middle- and late-farrowed groups, respectively.

Wiggins, Casida and Grummer (1950) investigated sexual development in market gilts slaughtered at four seasons of the year. A highly significant seasonal difference in the percentages of pre-puberal animals was found. The highest percentage was found in October and the lowest in April. The percentage of sexually immature animals was significantly higher for pigs farrowed in the early spring than the group

born late in spring, although the latter group was younger at slaughter.

Robison (1948) observed spring-born pigs were heavier at birth and heavier at weaning. He attributed these heavier weights to be due to the availability of pasture in the spring.

II. PUREBRED VS. CROSSBRED

With the success of hybrid corn, many swine producers have used crossbreeding in order to take advantage of hybrid vigor in the production of market hogs. The pork producer should consider all breeding methods which result in larger litters, stronger pigs at birth, fewer death losses, faster gains and less feed per pound of gain.

Litter size. Since sows carry their pigs about 112-114 days before birth and nurse them about 56 days after birth, pigs are mainly dependent on the sow for about 168 days. Anything that materially improves the sow in vigor should greatly benefit the pigs. One of the objects of crossbreeding is to increase the vigor of the offspring. In hogs an increase in vigor can be manifested in more pigs farrowed and saved per litter, in faster gains and in greater per unit of feed consumed.

Several workers have found that the breed of dam has great influence on litter size. Lush and Molln (1942) published a summary as given in Table I on the average number of pigs farrowed, arranged by breed and age of sow.

TABLE I

AVERAGE NUMBER OF PIGS FARROWED ARRANGED BY BREED AND AGE OF SOW

Age of sow (years)	Poland China	Duroc-Jersey	Chester White	Hampshire	Yorkshire	Berkshire	Tamworth	Danish Landrace
1	7.02	8.67	8.38	7.87	9.54	6.98	6.71	8.40
1.5	7.46	9.20	8.23	8.10	10.39	7.34	7.97	9.35
2	8.72	10.06	10.05	8.72	11.76	7.90	7.90	11.11
2.5	8.65	10.19	9.77	9.21	10.59	8.23	7.57	10.92
3	8.69	10.58	10.20	9.93	12.50	8.14	7.54	12.10
3.5	8.64	10.61	10.31	9.58	12.43	8.73	8.22	9.50
4	8.40	10.53	10.27	7.70	11.60	7.70	7.60	8.00
4.5	7.81	10.92	10.35	9.33	12.33	8.39	4.83	9.00
5	8.09	10.17	9.67	13.00	11.00	7.74	6.00	--
5.5	8.00	9.09	10.38	6.00	14.00	8.83	4.00	--
6	8.50	9.82	8.00	--	12.00	8.00	6.00	--
6.5	7.00	11.00	7.00	7.00	7.00	8.40	6.00	--
7	5.00	9.50	--	13.00	--	7.25	--	--
7.5	--	11.00	--	11.00	--	9.00	--	--
8	--	--	--	--	--	9.50	--	--
Average	7.98	9.78	9.33	8.66	10.75	7.74	7.43	9.74
Number of litters included	1,851	3,337	832	267	194	483	218	114

Bradford, Chapman and Grummer (1953) found that 3,005 straightbred gilts farrowed an average of 6.53 pigs per litter, while 836 crossbred gilts farrowed 7.20 pigs per litter. It was found that in the initial cross it is wise to select the more prolific breed as the female parent. Carlisle et al. (1964) noted crossbred sows averaged from 1.5 to 2 more pigs per litter or about 12 per cent larger litters than purebred sows. Crossbred gilts averaged 10 pigs per litter and crossbred sows averaged 11.5 to 12 pigs per litter. The advantage in first generation crosses could be attributed to greater pig survival and a more rapid pig growth. Nance (1959) found crossbred sows farrowed larger litters than straightbred sows by some 1.5 pigs per litter or 20 to 25 per cent on the average. In similar studies, Smith, Moorman and McLaren (1960), comparing straightbred and two- and three-breed crosses, found crossbred sows farrowed 9 to 11 per cent more pigs than straightbred sows; and Whatley, Chambers and Stephens (1954) noted crossbred gilts farrowed 16 per cent more pigs than purebred gilts.

Winters et al. (1936) reported that crossbred gilts farrowed 1.66 more pigs per litter than purebred gilts. Robison (1946), in a comparison made between crossbred gilts and three pure breeds of gilts, noted purebreds averaged 7.6 pigs and crossbreds averaged 8.6 pigs, but 1.5- to 2.5-year-old crossbred sows averaged only 9.4 pigs farrowed while purebred sows averaged 10.2 pigs per litter.

Several workers have noted that hybrid vigor may be obtained if three or four breeds are used in producing crossbred pigs. Lush, Shearer and Culbertson (1939) found crossbred sows were more productive if they

were bred back to a boar of the parent breed or to a boar of a third breed. Winters et al. (1936), using three types of crossbreds (first cross, three-breed-cross and backcross), found that all were superior to the purebreeds for producing market hogs, and noted that the three-breed-cross possessed the greatest advantage.

Carlisle et al. (1964) noted in his study that the four-breed-cross produced the largest litters at farrowing. The performance of each breed group was expressed as a percentage of average purebred performance. With the purebred group expressed as 100 per cent, performance in the crosses were: first cross, 101 per cent; three-breed-cross, 111 per cent; and four-breed-cross, 113 per cent. There was a 13 per cent advantage over purebreds in favor of four-breed-crosses.

Data compiled by Carroll and Roberts (1942) showed that litter size at birth was the same for high producing purebred sows as for crossbred sows. They noted no advantage for crossbreds if good type purebreeds were available.

It has been recognized by several workers (Baker, 1939; Weaver and Bogart, 1943; and Kuhlam, 1928) that an increase in birth weight will result in a heavier weaning weight. Forshaw et al. (1953) observed that each additional 1 pound at birth accounted for a 7- to 8-pound advantage at weaning. It was noted in this study that there was a highly significant correlation between birth weight and weaning weight. Hazel, Marvel and Rienmiller (1939) obtained a correlation of 0.840, whereas Blunn, Baker and Hanson (1953) noted a correlation of 0.708 between birth weight and weaning weight.

In a study by Lush, Hetzer and Culbertson (1934), it was found that the breed of parents has a definite influence on litter size and birth weight. Winters et al. (1936) found that, on the average, crossbred pigs were heavier at birth than purebreds.

Wilson, Whatley and Harington (1961) pointed out that if more than eight pigs were in the litter, there seemed to be no individual weight advantage, but if an average weight of the pigs were taken, pigs from crossbred sows were heavier.

Carroll and Roberts (1942) found no difference in birth weight of purebreds and crossbreds. Work by Bradford, Chapman and Grummer (1953) noted no significant difference in birth weight of purebred and crossbred pigs.

Survival rate. The weight of a pig at birth has a great influence on future pig performance. The most critical time in a pig's life is during the first week after birth. Vestal (1936) noted a close relationship between birth weight and survival rate. Less than 50 per cent of pigs weighing 2 pounds or less survived to weaning age.

Crossbred pigs have been found to be superior to purebred pigs in survival ability. Roberts and Carroll (1939), using a double mating system to produce purebred and crossbred pigs in the same litter, noted that crossbred pigs were stronger at birth and there were fewer death losses to weaning. Lush, Shearer and Culbertson (1939) stated that crossbred pigs were more vigorous at birth and crossbred litters contained fewer stillborn pigs than purebred. Robison (1948) found that

purebred sows lost 35.85 per cent of pigs from birth to weaning and only 30.47 per cent was lost for crossbreds. In a similar study, McMeekan (1936) noted that the death loss for purebreds from birth to weaning was 21.2 per cent and 12.8 per cent for crossbred pigs.

In close agreement with this study, Smith and King (1964), using data from some 35,000 litters, noted that crossbred litters contained 2 per cent more pigs at birth and 5 per cent more pigs at weaning.

Weaning weight. The weaning weight of a pig has been found to be associated with future performance. Several studies have been conducted in which the genetic correlations between weaning weight and post-weaning weight and post-weaning daily gain were determined. Vogt, Comstock and Rempel (1963) and Ward, Rempel and Enfield (1964) found high genetic correlations of 0.88 and 0.69, respectively, whereas Blunn, Baker and Hanson (1953) obtained a negative correlation of -0.12. Hazel, Marvel and Reinmiller (1943) noted a correlation of 0.45.

The weight at which a pig is weaned has considerable bearing on its future development. Winters et al. (1936) noted that crossbred sows produced litters which averaged from 0.66 to 2 more pigs at weaning, with each pig weighing from 5 to 7 pounds more than purebreds at weaning. In a similar study, Lush, Shearer and Culbertson (1939) observed a 3- to 4-pound weaning advantage in favor of crossbred pigs.

Lush and Molln (1942) noted a 63- to 96-pound litter advantage for crossbreds and Pani et al. (1963) found a 107-pound litter advantage for crossbred pigs. Shaw and MacEwan (1936) stated that crossbred litters had an advantage over purebred litters by only 4 pounds.

Whatley, Chambers and Stephens (1954) demonstrated that crossbred pigs were 13 per cent heavier than purebred pigs, whereas Smith and King (1964) noted an 11 per cent weight advantage for crossbred pigs. Robison (1946), Smith and Moorman (1959) and Sherrit et al. (1954) found that crossbred pigs were heavier at 56 days than purebred pigs. Carroll and Roberts (1942) suggested that good purebred sows will produce as outstanding pigs as crossbred sows for most traits but found that crossbred sows weaned pigs weighing from 1 to 4 pounds heavier at weaning.

154-day weight. The size and weight of a litter at 56 days is the best indicator of 154-day weight. MacDonald, Moxley and Hamilton (1959) found for purebred and backcross Landrace x Yorkshire sows that weaning weight was the best indicator for 154-day weight.

Bradford, Chapman and Grummer (1953) and Smith and Moorman (1959) stated that crossbred litters were superior to purebreds in litter weight at 154 days and in the number of pigs raised to 154 days. MacDonald, Moxley and Hamilton (1959) indicated that the major advantage in litter size at 154 days was due to increased viability of the crossbred pigs and not to the increase in number of pigs farrowed in crossbred litters.

Crossbred sows were found by Pani et al. (1963) to produce litters which were 407 pounds heavier per litter at 154 days than pigs farrowed by purebred Duroc sows. Whatley, Chambers and Stephens (1954) observed crossbred litters were 21 per cent heavier at 154 days.

180-day weight. Weighing pigs at 6 months of age is another method of measuring pig performance. Robison (1948) discovered crossbred litters had from 0.7 to 1.4 more pigs per litter and these litters averaged from 203 to 206 pounds heavier than purebred litters at 180 days of age. Crossbred pigs were found to be 8 to 10 per cent heavier than purebred pigs at 180 days by Nance (1959).

Crossbred litters were significantly heavier at 180 days of age than purebreds in work by Smith, Moorman and McLaren (1960). In this study two-, three- and four-breed crosses were used. Pigs in crossbred litters gained faster and were 6.1 to 8.1 per cent heavier at 180 days than straightbreds.

Average daily gain. A market hog's worth is measured by its ability to convert feed into edible meat in the least number of days to market. Winters et al. (1936) found crossbreds reached a market weight of 220 pounds from 17 to 22 days earlier on 27 to 36 fewer pounds of feed than purebreds. This was in close agreement with work conducted by Robison (1946).

Robison (1948), in three different trials, noted that crossbred pigs reached a market weight from 9 to 20 days sooner than purebred pigs. In a similar trial, Whetham (1935) found that crossbred pigs reached market 10 days earlier than straightbred pigs. In this trial, crossbreds averaged 1.28 pounds per day while the purebred averaged 1.21 pounds. Kyzer and Clyburn (1937) noted that crossbred pigs had an average daily gain of 1.92 pounds compared to 1.86 pounds for purebred pigs.

Several workers, including Tucker, Dickerson and Lasley (1952); Nance (1959); England and Winters (1953); and Carroll and Roberts (1942), noted that crossbred litters surpassed straightbred litters in average daily gain.

In a study comparing crossbreds with straightbreds, Rempel, Comstock and Enfield (1964) found straightbreds to outperform crossbreds in rate of gain.

Backfat thickness. To meet the meat quality demands of the modern housewife, the swine producer will have to market a leaner, meater type swine. Smith and Moorman (1959) found Landrace market hogs had significantly lower backfat than other straightbred hogs. It was noted in this study that Landrace also reduced backfat thickness when used in producing crossbred pigs. Whiteman, Hillier and Whatley (1951), working with outbred Durocs and crossbred pigs, observed that the crossbred carcasses were leaner and possessed less backfat.

Tucker, Dickerson and Lasley (1952) discovered that straightbreds yielded carcasses with more fat and less lean than crossbreds when both were under full-feed trials, but that when they were under equalized feeding, crossbred carcasses were longer and leaner. In a study conducted by Rempel, Comstock and Enfield (1964) comparing crossbred and purebred boars, it was noted that purebred boars sired pigs with less backfat than crossbred boars.

III. AGE OF DAM

Litter size. Many reports show a wide variation in the age a gilt reaches puberty. Rice and Andrews (1951) found gilts reached puberty at about 5 months of age. Phillips and Zeller (1943), Robertson et al. (1951 and 1951a), Self, Grummer and Casida (1955), Burger (1952) and Foote et al. (1956) found a range of from 6 to 8 months of age. For a gilt to farrow when she is a year old, she must be bred around 8 months of age. Gilts bred at an early heat period will farrow fewer pigs than gilts bred at a later heat period, as the ovulation rate is significantly affected by the age of the dam.

When slaughtering the gilt or sow after the second heat, ovulations at different heat periods can be detected by the characteristics of corpora lutea present. Warnick et al. (1951), using 48 gilts, found an average increase of 0.8 eggs at the second heat over the first. This study indicates a steady rise in ovulation rate from the first through the fourth heat period.

Robertson et al. (1951), using Chester White and Poland China gilts, found gilts shed two more eggs at the second heat than at the first. He reported an increase in ovulation rate at least through the third heat period. Squiers, Dickerson and Mayer (1952) found gilts and sows averaged about 11.5 and 15.4 ova, respectively, whereas Hammond (1914) observed 14.3 corpora lutea for gilts and 19.8 corpora lutea for mature sows.

Burger (1952), working with Large White and Large Black breeds, found the mean number of ova for 7- to 8-month-old gilts to be 14.1 and 16.2 ova, respectively, at 17 months; and Newman (1963) found gilts to have 14.5±3.2 corpora and 21.4±4.4 corpora for mature sows. This agrees closely with work done by Lasley (1957).

Squiers, Dickerson and Mayer (1950) observed that for each 10-day increase in the age of the gilt between 5.5 and 9 months, 0.5 more pigs were found in the reproductive tract of the gilts slaughtered 25 to 30 days after breeding.

Stewart (1945), in a study of 749 inbred Poland China and Minnesota No. 1 gilts, found litter size increased with an increase of the dam's age at farrowing. Gilts farrowing at 14 months of age farrowed an average of one pig more than gilts farrowing at 12 months. The findings of Carlisle et al. (1964) were in close agreement with those in that study. It was found that the litter size increased 0.5 of a pig for each month of age a gilt advanced between 11 and 14 months.

It was shown by Carmichael and Rice (1920) that 1.5-year-old sows averaged 7.5 pigs per litter as compared to 8.6 pigs for 2-year and older sows. Warnick et al. (1951) found gilts bred at the third heat farrowed 1.4 pigs more than those bred at the second heat and 2.5 more than gilts bred at first heat.

Work done by Lush and Molln (1942) indicates that litter size will increase 0.5 of a pig from the first to the second litter and 1 pig from the second to the third litter. It was noted that maximum prolificacy was reached at 4.5 years of age. Sinclair and Syrotuck

(1928) found litter size increased up to 4 years of age. Two-year-old sows farrowed 1.6 more pigs than yearling sows.

Olbrycht (1943) used 156 Large White sows to produce 10 litters each. Of the 1,560 litters produced, the work showed that peak performance was reached with the third litter, leveled off through the fifth litter and then declined (Table II).

Many workers agree that the age of dam has a marked effect on the number of pigs farrowed. Russell (1936) stated that dams reached their peak performance at 2 years of age and maintained it through the fifth year. Four and one-half years of age was the peak for performance given by Keith (1930). Stewart (1945a), Russell and Hutton (1938) and Munford, Hogan and McKenzie (1926) were all in agreement that, on the average, mature sows farrow larger litters than gilts.

Warwick (1926 and 1928) reported that uterine size had a large influence on the number of pigs farrowed. He found that crowding in the uterus causes more prenatal deaths. He noted that sows should farrow more pigs due to a larger reproductive tract.

The age of the dam has been found to influence birth weight. Carmichael and Rice (1920) found sows 2 years of age and older farrowed pigs weighing 0.17 pounds heavier than younger sows. In a similar study, Vestal (1936) observed heavier pigs from 2-year-old sows. Sows from 3 to 5 years of age farrowed heavier pigs than 1-year-old sows. Olbrycht (1943) noted that pigs from gilts, even though farrowed in somewhat smaller litters on the average, tend to be lighter at birth than pigs of mature sows. In a study by Russell (1936), it was reported that there

TABLE II

FARROWING DATA COLLECTED FROM 156 SOWS FARROWING
10 CONSECUTIVE LITTERS EACH

Litter no.	Average number of pigs per litter
1st	9.5
2nd	10.7
3rd	11.4
4th	11.8
5th	11.9
6th	11.7
7th	11.3
8th	11.2
9th	10.8
10th	10.1

was no difference in birth weight of pigs from sows between 1 to 7 years of age.

Survival rate. Pomeroy (1960) found gilts farrowed fewer pigs and pigs had a lower mortality rate than pigs from older sows. In this study, a preweaning mortality of 27.4 per cent for the first litter and then a gradual increase up to the eighth litter, which averaged 32.5 per cent mortality. In a similar study by Braude, Clarke and Mitchell (1954), it was found that gilts lost 23.0 per cent of pigs prior to weaning, whereas sows lost 31.0 per cent of pigs.

Robison (1948) observed that sows from 1.5 to 3.5 years of age saved more pigs than any other age group. Korkman (1947) noted that when equal number of pigs were born in each litter, the survival rate would decrease steadily with the age of dam.

Kernkamp (1965) found that preweaning survival decreased from the first through the sixth litter and then increased through the eighth litter. Lower mortality was noted for pigs in the seventh and eighth litters.

Weaning weight. Work by Russell (1936) demonstrated that first-year-gilts weaned pigs that were 5 pounds lighter than pigs of mature sows. The weaning weight of pigs increased with increasing age of dam through 6.5 years of age and then declined.

Sinclair and Syrotuck (1928) reported on 245 farrowings and found that 1-year-old dams produced pigs that were 4 to 4.5 pounds lighter at weaning than pigs from dams 2 to 5 years of age. Sows in this study

reached their highest production at about 4 years of age. Lush and Molln (1942) showed 2-year-old sows produced the heaviest litters at weaning, followed by 2.5-, 3-, 3.5- and 1.5-year-old sows. In this study, it was demonstrated that the first litter from gilts is distinctly lighter at weaning than litters from older sows.

Carlisle et al. (1964) found that pigs weaned at 42 days of age weighed, on the average, 1.3 pounds more for each additional month of age of gilts between 11 and 14 months of age. Pigs weaned at 56 days from sows averaged 40 pounds, whereas pigs weaned from gilts weighed 35 pounds. It was shown by Russell and Hutton (1938) that mature sows weaned pigs averaging 46.6 pounds and pigs from gilts averaged 38.7 pounds at 70 days of age. Nordskog, Comstock and Winters (1944), using 2,396 pigs from 312 sows and gilts, found pigs from sows were 4 pounds heavier at weaning than pigs from gilts.

It was demonstrated by Weaver and Bogart (1943) that sows farrowed heavier pigs than gilts. They found that a 1-pound advantage in the size of a pig at birth resulted in about a 7-pound advantage at weaning. The gain per day was, therefore, directly associated with size of pigs at birth. Winters, Cummings and Stewart (1947) found that for each additional pig in the litter, the total litter weight at weaning was 20.26 pounds more. An increase of 1 pound in average birth weight increased total weaning weight 15.9 pounds.

Wilson, Whatley and Harington (1961) found sows weaned heavier pigs at 56 days if they did not wean more than eight pigs. If there were more than eight pigs in the litter, there seemed to be no individual

weight advantage; but if an average weight of the pigs were taken, sows' pigs were heavier than pigs from gilts.

Donald (1939) and Zeller, Johnson and Craft (1937) showed the influence of milk production on weaning weight. They noted sows were much heavier milkers and weaned heavier litters than gilts. Smith and Donald (1937) found very fertile females to be heavy milkers. Only high-producing gilts were kept. Sows definitely milked heavier than gilts.

Research workers are in general agreement that age of the dam influences weaning weight. Generally, 1-year-old gilts wean the lightest litters.

154-day weight. Work by Lasley (1963) demonstrated that the weight of each pig at 154 days of age was an important economic trait. By taking a weight at this time, a total measurement of all gains from birth may be evaluated. He noted older sows milked heavier during the nursing period and had heavier pigs at 154 days.

Hetzer (1942), using data from 80 Chester White and 136 Landrace pigs, found pigs from sows were heavier at 154 days than pigs farrowed by gilts. Russell and Hutton (1938) stated that mature sow litters had a slight weight advantage over gilt litters at 154 days. Baker, Hazel and Reinmiller (1943) concluded that mature sow litters maintained a distinct advantage in weight up to 112 days of age and thereafter the advantage decreased.

Vestal (1936) found pigs from 2-year-old sows to be heavier at 154 days than from any other age sows. Robison's (1946) findings agree with this. He found 1.5- to 2.5-year-old sows produced heavier litters at 154 days of age. Robison (1948) found that sows between 1.5 to 3.5 years of age saved more pigs per litter, thus having a heavier total litter weight at 154 days of age. Pigs from 4-year-old sows were heavier at 154 days than any other age according to Russell (1936). These pigs had approximately a 7-pound advantage over pigs from sows of other ages. Nordskog, Comstock and Winters (1944) found that older sows' pigs maintained about a 4-pound advantage at 154 days.

Sinclair and Syrotuck (1928), Carlisle et al. (1964), Weaver and Bogart (1943) and Gaines and Hazel (1957) all agreed that pigs from older sows have a slight weight advantage through 154 days of age. They also agreed that heavier pigs at 56 days maintain this advantage up to 154 days of age.

180-day weight. There is very little information concerning the influence of age of dam on 180-day weight. Robison (1946) reported that sows produced pigs weighing 32.9 pounds more at 180 days than pigs farrowed by gilts. He noted that pigs from gilts in every case were inferior in weight to pigs from sows.

Russell and Hutton (1938), using total litter weight and 190-day weight, found mature sows produced litters averaging 1,322 pounds and gilts produced litters averaging 1,260 pounds. They found a 62-pound advantage in litter weight for mature sows. Robison (1946) found that

1.5-year-old sows produced heavier pigs at 180 days than 1-year-old sows.

Nordskog, Comstock and Winters (1944) and Baker, Hazel and Reinmiller (1943) found pigs from older sows maintained a weight advantage over pigs from younger sows through 168 days. Whatley et al. (1952) observed no significant differences among various ages of dam for 180-day weight of pigs but differences were generally in favor of older sows.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. SOURCE OF DATA

The data for this study were taken from the records of an extended swine breeding project at Ames Plantation, Grand Junction, Tennessee, being conducted by the University of Tennessee Animal Husbandry-Veterinary Science Department, Agricultural Experiment Station, Knoxville, Tennessee. This study included data from eight farrowing seasons, beginning with the spring of 1956 and continuing through the fall of 1959.

Data were obtained for the following litter traits: litter size at birth, 56 days and 154 days; pig weight and litter weight at birth, 56, 154 and 180 days; survival rate and average daily gain from birth to market; and live backfat probe at market weight.

II. EXPERIMENTAL ANIMALS

The swine used for these data consisted of litters of purebred Hampshires, Durocs, Landrace and Poland Chinas and various two-, three- and four-breed repeat crosses. Purebred boars consisting of Hampshire (H), Duroc (D), Landrace (L), Poland China (P) and Yorkshire (Y) were used in the various crosses. The pigs represented in these data included purebred Hampshire, Duroc, Landrace and Poland China pigs and

crossbred HxD, DxH, LxH, LxD, LxP, HxP, DxP, HxLD, DxLH, LxHD, LxDH, YxHD, HxPL and DxHPL pigs. Data from 531 litters farrowed over the 4-year-period from 1956 through 1959 including 6,920 pigs were used in the analysis (Table III). The number of spring and fall farrowings was kept as close to the same as possible.

III. HERD MANAGEMENT

Sows were bred to farrow twice each year. All sows were re-allotted to breeding groups each season on the basis of breed, age and previous performance. Sows of similar breeding were randomly assigned to as many sire-breeding groups with the same breed of sire as possible. Each sire group was divided into three sub-groups and about one-third of the sows were bred so as to farrow at 2-week intervals. Using this program, the farrowing house could be steam cleaned and disinfected before each group of sows farrowed.

This program was designed for each sow to produce two litters per year. Sows were bred so that the spring farrowing season would begin about April 1 and the fall season about October 1. All sows were pasture-mated, with 8 to 12 sows per boar. Sows were checked daily for estrus and approximate breeding dates obtained. Gilts in the herd were bred to farrow initially at 10 to 14 months of age, depending on size and weight.

At farrowing time, sows were brought to a central farrowing house where they were placed in farrowing stalls. Each sow was washed with a soap and disinfectant, and wormed with piperazine before being placed in

TABLE III

DISTRIBUTION OF LITTERS BY YEAR, SEASON AND BREEDING

Breed[a] of pig	1956		1957		1958		1959		Total no. litters
	S[b]	F[b]	S	F	S	F	S	F	
H	8	10	14	8	10	10	11	11	82
D	9	10	15	13	10	15	16	16	104
L	7	6	5	6	8	6	8	11	57
P	5	--	6	9	6	--	--	--	26
HxD	4	4	5	5	4	9	8	7	46
DxH	-	--	1	10	4	10	6	5	36
LxH	-	--	--	3	5	9	8	6	31
LxD	-	--	--	4	5	9	8	7	33
LxP	-	--	--	--	5	4	2	--	11
HxP	-	--	--	--	4	3	--	--	7
DxP	-	--	3	--	--	5	1	--	9
HxLD	-	--	--	--	--	--	7	7	14
DxLH	-	--	--	--	--	--	7	6	13
LxHD	-	--	3	2	--	--	7	5	17
LxDH	-	--	--	--	--	--	7	8	15
YxHD	-	--	5	4	--	--	--	--	9
HxPL	4	7	--	--	--	--	--	--	11
DxHPL	-	--	7	3	--	--	--	--	10
Total	37	37	64	67	61	80	96	89	531

[a]Breed code: first letter in crosses denotes sire breed. H - Hampshire; D - Duroc; L - Landrace; P - Poland China; and Y - Yorkshire.

[b]Season code: S - spring; F - fall.

the farrowing stall. Twice daily, the sows were allowed out of their farrowing crates for feed and water both pre- and post-parturition.

Once each year sows were vaccinated for erysipelas, cholera and leptospirosis. Twice yearly a brucellosis test was run. Sows were wormed twice more each year in addition to worming before farrowing, and rung as needed to prevent excessive rooting in the pasture lots.

Boars were managed in the same general manner as the sows in regard to vaccination and general management.

At farrowing pigs were ear notched for identification and weighed to the nearest 0.1 pound. After ear notching, ears and umbilical cords were treated with tincture of iodine. Needle teeth were clipped at this time and each pig was injected with 3 cc. of swine erysipelas antiserum.

When pigs were 3 to 5 days of age, they were injected with an iron compound to prevent anemia, and at 7 to 10 days of age sows and their litters were moved to 4-acre pasture lots. About eight sows and their litters were placed in each lot. Shelter and shade was made available by portable hog houses in each lot.

At 4 weeks of age, male purebred pigs were graded and pigs which showed no promise as future herd sires were castrated. All crossbred male pigs were castrated.

About 8 weeks of age, the sows were removed from the lots and the pigs were weaned and weighed. At this time, the remaining purebred boar pigs were graded and the undesirable ones castrated. At 10 weeks of age, pigs were wormed with piperazine.

When pigs reached 154 days of age, they were weighed and divided into the four following groups: 200 pounds and over; 185 to 200 pounds; 165 to 185 pounds; and 165 pounds or less. At 180 days of age, pigs were weighed and those weighing 220 pounds or more were sold as market hogs or as breeding stock. At market time, a live-animal backfat probe was taken at the seventh rib, 2 inches off center of the back, using an official backfat probe ruler.

IV. FEEDS AND RATIONS

Ground ear corn and a protein supplement were fed to the sows, the amount of each depending on the condition of the pasture. When sows were on "good" pasture, they were fed a supplement consisting of a mixture of 100 pounds of tankage and 100 pounds of soybean oil meal. One hundred pounds of alfalfa leaf meal was added to the supplement mixture if the pasture was classified as "poor." Ten pounds of dicalcium phosphate and 2 pounds of salt were added per 100 pounds of either mixture.

Sows were fed daily 2 to 5 pounds of ground ear corn and 0.5 to 1 pound of supplement between weaning and rebreeding, depending on the age and condition of the sow and on the pasture condition. Sows were flushed at breeding time by increasing the ground ear corn about 2 pounds and the supplement 0.5 to 1 pound. They were fed at this level for about a month after breeding and later the amount was reduced to prevent them from becoming excessively fat.

During the last third of the gestation period, the supplement was increased to 1.5 to 2 pounds and the corn was also increased. When the sows farrowed, they received a small amount of corn and the supplement containing the alfalfa leaf meal. After sows were placed on pasture they were self-fed ear corn and supplement until the pigs were weaned.

Boars were fed the same rations as the sows and were fed in a manner to keep them thrifty and in good breeding condition.

From weaning until market age, pigs were self-fed ear corn and supplement free-choice. During the period from weaning to 4 months of age, pigs on "good" pasture were self-fed a supplement mixture consisting of 100 pounds of soybean oil meal and 100 pounds of tankage. Pigs 4 months and older in age were fed a supplement containing an additional 100 pounds of soybean meal added to the mixture. Pigs up to 4 months of age on "poor" pasture were self-fed a supplement mixture consisting of 150 pounds of soybean oil meal, 150 pounds of tankage and 50 pounds of alfalfa leaf meal. Pigs 4 months of age and older were fed a supplement in which the soybean oil meal was increased by 50 pounds and the tankage was decreased by 50 pounds. Two pounds of salt and 10 pounds of dicalcium phosphate were added per 100 pounds of supplement. Four grams of antibiotics were added to each 100 pounds of supplement mixture.

Spring-born litters were pastured on Ladino clover, alfalfa and orchardgrass. Fall-born litters were provided a temporary pasture of oats and crimson clover. Approximately 20 growing-finishing pigs were pastured per acre.

V. METHODS AND ANALYSIS

A permanent record was kept of individual straightbred and crossbred pig weights. These weights 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 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.

A weight of 200 pounds was used as a standard for adjusting backfat measurements. An adjustment table devised by H. W. Bean of the University of Illinois was used in adjusting backfat probes.

All pigs farrowed, either live or dead, were included in the number of pigs farrowed.

It was necessary to obtain estimates of the effects of season of birth, breed and age of dam on total number of pigs born, birth weight,

number born alive, weight and number alive at 154 days of age, 180-day weight, market age, number alive at market, total gain from birth to market, average daily gain from birth to market and average adjusted backfat thickness at market weight. Disproportionate subclass numbers caused effects to be nonorthogonal and necessitated the use of the method of least squares (Harvey, 1960).

A mathematical model was constructed so that estimates of the effects due to age of dam, season of birth and breed of pig could be obtained. An additive model was considered appropriate for the analysis of dependent variables.

This model was:

$$Y_{ijklm} = \alpha + y_i + s_j + a_k + g_l + e_{ijklm}$$

i = 1956, 1957, 1958 and 1959

j = spring and fall

k = 1, 1.5, 2, 2.5 and 3-year and older sows

l = D, H, L, P, HD, DH, LH, LD, LP, HP, DP, HLD, DLH, LHD, LDH, YHD, HPL and DHPL.

When:

Y_{ijklm} = the value of the dependent variable for the observed traits

α = the theoretical population mean when equal numbers exist in the subclasses (adsorbed)

y_i = the effect of the ith year (adsorbed)

s_j = the effect of the jth season

a_k = the effect of the kth age of dam

g_l = the effect of the lth breed of pig

e_{ijklm} = random errors.

Duncan's multiple range test (1955) as modified by Kramer (1957) was used for mean separation when significant differences were detected.

CHAPTER IV

RESULTS AND DISCUSSION

I. GENERAL

The effects of season, age of dam and breed on average litter and pig performance traits from 531 litters were analyzed by least squares methods. The data for litter and pig performance traits were separated into pre-weaning and post-weaning traits. Duncan's multiple range test was used for mean separation when significant differences were detected in effects for age of dam and breed of pig.

Means and standard errors by years for the various traits are presented in Table IV. Overall means and standard errors for traits studied are shown in Table V.

II. SEASON OF BIRTH

Season of birth effects as shown in Tables VI and VII were significant for birth weight, 56-day weight, 154-day weight, 180-day weight and average daily gain from birth to market. Differences between spring and fall seasons for number of pigs per litter were not significant at any period. In general, season of birth effects as shown by least squares constants presented in Tables VIII and IX were positive for spring-farrowed pigs and negative for fall-farrowed pigs.

TABLE IV

MEANS AND THEIR STANDARD ERRORS FOR VARIABLES STUDIED IN 1956, 1957, 1958 AND 1959

Variables	1956		1957		1958		1959	
	Mean	Standard error	Mean	Standard error	Mean	Standard error	Mean	Standard error
Birth weight, lb.	3.09	0.068	3.28	0.050	2.98	0.040	3.17	0.036
Number at birth	8.89	0.375	9.95	0.255	10.48	0.230	11.16	0.205
56-day weight, lb.	37.01	0.881	34.99	0.598	32.40	0.564	32.64	0.608
Number at 56 days	7.61	0.355	7.99	0.205	7.87	0.222	7.95	0.203
154-day weight, lb.	167.56	2.483	167.16	1.816	160.57	2.023	158.16	1.913
Number at 154 days	7.41	0.355	7.44	0.216	7.44	0.219	7.42	0.213
Market weight, lb.	213,32	2.039	208.56	1.134	210.31	1.011	212.19	0.796
Number at market	7.39	0.355	7.27	0.222	7.38	0.221	7.26	0.213
Litter size total	8.89	0.375	9.95	0.255	10.48	0.230	11.16	0.205
Litter size alive	8.49	0.376	9.53	0.242	9.82	0.226	10.56	0.203
Number of males/litter	4.24	0.247	4.58	0.177	4.81	0.186	5.22	0.158
Market age, days	183.94	1.218	181.77	0.926	188.00	1.309	195.00	1.730
Total gain, birth - market, lb.	210.22	2.020	205.10	1.124	207.21	0.990	208.58	0.796
Average daily gain, birth - market, lb.	1.15	0.015	1.14	0.010	1.12	0.010	1.09	0.010
180-day weight, lb.	208.91	3.082	207.61	2.103	199.93	2.387	194.27	2.397
Backfat probe, in.	1.68	0.030	1.58	0.016	1.50	0.012	1.47	0.012
Adjusted backfat probe, in.	1.58	0.025	1.51	0.014	1.41	0.011	1.38	0.079

TABLE V

OVERALL MEANS AND THEIR STANDARD ERRORS FOR ALL VARIABLES STUDIED FROM 1956 THROUGH 1959

Variables	Mean	Standard error
Birth weight, lb.	3.13	0.023
Number at birth	10.36	0.125
56-day weight, lb.	33.76	0.323
Number at 56 days	7.88	0.116
154-day weight, lb.	162.33	1.026
Number at 154 days	7.42	0.119
Market weight, lb.	210.95	0.555
Number at market	7.31	0.120
Litter size total	10.36	0.125
Litter size alive	9.82	0.122
Number of males/litter	4.82	0.092
Market age, days	188.36	0.752
Total gain, birth - market, lb.	207.58	0.549
Average daily gain, birth - market, lb.	1.12	0.006
180-day weight, lb.	201.10	1.246
Backfat probe, in.	1.53	0.008
Adjusted backfat probe, in.	1.46	0.007

TABLE VI

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

Source	d.f.	Mean squares				
		Average birth weight	Number of pigs at birth	56-day weight	Number of pigs at 56 days	Litter size alive at birth
Season	1	1.544*	2.406	3318.947**	8.280	5.172
Age of dam	4	3.232**	86.781**	731.573**	32.968**	49.630**
Breed	17	0.626**	19.434**	250.388**	16.743**	17.295**
Residual	505	0.238	7.111	41.577	6.683	7.172

*P<.05.

**P<.01.

TABLE VII

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

Source	d.f.	Mean squares									
		154-day weight	Number of pigs at 154 days	Market weight	Number of pigs at market	Market age	Total gain birth - market	Average daily gain birth - market	180-day weight	Backfat probe	Adjusted backfat probe
Season	1	38972.848**	22.723	1583.554*	22.391	28378.257**	1788.196**	1.097**	62639.553**	0.167	0.272
Age of dam	4	8334.672**	36.905**	535.179**	40.240**	4280.413**	478.049**	0.187**	11474.048**	0.043	0.026
Breed	17	4323.917**	29.363**	1139.333**	33.388**	2067.172**	1118.767**	0.162**	7281.791**	0.358**	0.224**
Residual	505	350.097	6.587	126.375	6.579	186.419	123.820	0.009	479.395	0.020	0.017

*P<.05.

**P<.01.

TABLE VIII

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

Source	No. litters	Average birth weight (lb.)	Number of pigs at birth	56-day weight (lb.)	Number at 56 days	Litter size alive at birth
Season						
Spring	258	0.064[b]	-.080[b]	2.974[b]	0.149[b]	-.117[b]
Fall	273	-.064[c]	0.080[b]	-2.974[c]	-.149[b]	0.117[b]
Age of dam						
1 year	235	-.280[c]	-1.444[c]	-5.009[c]	-.694[c]	-.914[c]
1.5 years	173	0.066[b]	-.466[bc]	-.016[b]	-.042[b]	-.011[bc]
2 years	75	0.105[b]	0.986[b]	-.236[b]	0.721[b]	0.896[b]
2.5 years	40	0.077[b]	0.796[b]	2.427[b]	0.739[b]	0.645[b]
3 years[d]	8	0.033[bc]	0.128[bc]	2.834[b]	-.724[b]	-.617[c]

[a]Constants are deviations from the overall mean.

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

[d]Sows 3 years and older are included.

TABLE IX

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.)
Season										
Spring	10.192[b]	0.246[b]	2.054[b]	0.244[b]	-8.697[b]	2.183[b]	0.054[b]	12.921[b]	-.021[b]	-.027[b]
Fall	-10.192[c]	-.246[b]	-2.054[c]	-.244[b]	8.697[c]	-2.183[c]	-.054[c]	-12.921[c]	0.021[b]	0.027[b]
Age of dam										
1 year	-16.268[c]	-.863[c]	-3.514[c]	-.916[c]	11.043[b]	-3.405[c]	-.073[c]	-17.887[c]	-.017[b]	-.003[b]
1.5 years	2.223[b]	-.110[bc]	-.342[b]	-.133[bc]	-2.598[c]	-.583[b]	0.012[b]	3.656[b]	0.026[b]	0.025[b]
2 years	-2.555[b]	0.713[b]	1.161[b]	0.717[b]	2.720[c]	0.930[b]	-.009[b]	-2.486[b]	0.007[b]	0.003[b]
2.5 years	6.903[b]	0.529[b]	3.797[b]	0.580[b]	-5.670[c]	3.706[b]	0.049[b]	11.413[b]	-.016[b]	-.025[b]
3 years[d]	9.698[b]	-.269[bc]	-1.102[b]	-.247[bc]	-5.496[c]	-.648[b]	0.021[b]	5.304[b]	-.001[b]	0.000[b]

[a]Constants are deviations from the overall mean.

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

[d]Sows 3 years and older are included.

Spring-farrowed pigs were heavier at birth ($P<.05$) than fall-farrowed pigs although there was no significant difference in the number of pigs per litter at birth between seasons. The significant seasonal difference in weaning weight was in favor of spring pigs. These results are in close agreement with those of Robison (1948), who observed spring-born pigs were heavier at birth and heavier at weaning. Lush and Molln (1942) also noted a significant difference in weaning weight between seasons. They found, however, that season influenced the number of pigs weaned per litter, which is not in agreement with the results obtained in this study.

An advantage for average pig weight at 154 and 180 days of age and for average daily gain from birth to market was observed for spring-born pigs ($P<.05$). No significant differences due to season of birth were found for number of pigs at birth, litter size alive at birth, number of pigs at 56 days, 154 days and at market, and actual backfat probe or adjusted backfat probe (Tables VI and VII, pages 34 and 35).

III. AGE OF DAM

As shown in Tables VI and VII, pages 34 and 35, all litter and pig performance traits except backfat were significantly influenced by age of dam.

Average birth weights of pigs from 1-year-old sows were less than birth weights of pigs from 1.5-year-old to 2.5-year-old sows ($P<.05$) but did not differ significantly from that of 3-year and older sows. The birth weights of pigs from 1.5-year-old to 3-year-old and older sows did

not differ significantly although the average birth weight of pigs from 2-year-old sows was heavier than those among other ages of dam. This is in agreement with the results of Vestal (1936), who found that 2-year-old sows produced heavier pigs at birth than any other sow age group.

Two-year-old sows farrowed a larger number of pigs at birth than did sows of other ages (Table VIII, page 36). Sows 2 and 2.5 years of age farrowed significantly more pigs than 1-year-old sows. Olbrycht (1943) found 1-year-old sows consistently farrowed fewer pigs than older sows. Robison (1946) and Carmichael and Rice (1920) made similar observations in which they noted that 1.5- and 2-year-old sows significantly farrowed larger litters than 1-year-old sows.

Weaning weight (56-day weight) was significantly affected by age of dam (Table VIII, page 36). Pigs from 3-year-old and older sows were the heaviest at weaning. Pigs from 1-year-old sows were significantly lighter at 56 days than pigs from 1.5- to 3-year-old sows. There were no differences among weaning weights of pigs from 1.5- to 3-year-old sows. Sinclair and Syrotuck (1928) observed that 1-year-old sows produced pigs that were 4 to 4.5 pounds lighter at weaning than did sows 2 to 5 years of age. Donald (1939) noted that older sows weaned heavier pigs due to higher milk production.

Differences in number of pigs per litter at 56 days among sows 1.5 to 3 years of age were not significant. The number of pigs per litter at weaning (56 days) was significantly less for 1-year-old sows as compared with all ages from 1.5 to 3 years (Table VIII, page 36).

Sows 2 and 2.5 years of age produced more live pigs at birth than 1-year-old sows ($P<.05$). Sows 2 years of age farrowed the largest number of live pigs, followed by 2.5-, 3-, 1.5- and 1-year-old sows. No significant differences were found among sows 1.5 through 3 years of age. Pigs from 3-year-old sows were heavier at 154 days, but differences among sows ranging in age from 1.5 to 3 years were not significant. This is in agreement with the results of Russell (1936) who noted that pigs from 4-year-old sows were heavier at 154 days than pigs from sows of other ages.

One-year-old sows had significantly fewer pigs per litter at 154 days and market than sows 2 and 2.5 years of age (Table IX, page 37). Differences among other sow ages were not significant. Robison (1948) found that 1.5- to 3.5-year-old sows saved more pigs to weaning, thus increasing the number of pigs per litter at 154 days.

Average pig weights at 180 days and at market time from 1-year-old sows were lighter ($P<.05$) when compared with average pig weights from 1.5- to 3-year-old sows (Table IX, page 37). No significant differences were found among average pig weights of 1.5- to 3-year-old sows. Russell and Hutton (1938) found that pigs from mature sows were heavier at 180 days than pigs from first-litter gilts.

Pigs from 1-year-old sows were about 8 to 16 days older at market weight than pigs from the older sows and all differences were significant. Sows 1.5 to 3 years of age produced pigs which did not differ significantly in age at market weight.

Sows 1.5- to 3-years-old produced pigs with a faster growth rate from birth to market weight than did 1-year-old sows ($P<.05$). Sows 2.5 years old produced the fastest growing pigs.

Age of dam did not significantly influence actual backfat probe at market weight or adjusted backfat probe (Table IX, page 37).

IV. BREED OF PIG

The breed of pig had a highly significant effect on all litter and pig performance traits as shown in Tables VI and VII, pages 34 and 35. Least squares effects of breed of pig on pre-weaning and post-weaning litter and pig performance traits are presented in Tables X and XI.

H vs. D. Although differences were not significant, purebred Duroc litters were larger than Hampshire litters at birth, 56, 154 days and at market time as shown by least squares constants in Table X. Greater survival ability in the Duroc pigs is indicated by the difference of about 0.74 pigs per litter at market time as compared with a difference of only 0.38 pigs at birth. Duroc pigs gained significantly faster from birth to market and were heavier at 154 and 180 days of age ($P<.05$) than Hampshire pigs. The difference between pigs of these breeds in adjusted backfat was not significant.

H vs. L. Hampshire litters had significantly more pigs per litter at 154 days and market time as compared with Landrace litters.

TABLE X

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

Breed*	No. litters	Average birth weight (lb.)	Number of pigs at birth	56-day weight (lb.)	Number at 56 days	Litter size alive at birth
H	82	0.018	-.123	-3.514	-.901	-.201
D	104	-.162	0.261	-2.020	-.321	0.029
L	57	0.057	-.050	-4.280	-1.526	-.224
P	26	-.086	-1.231	-3.659	-1.228	-1.260
HD	46	-.306	1.345	-1.174	0.459	1.326
DH	36	0.006	-.635	1.656	-.244	-.708
LH	31	0.089	0.124	1.213	-.497	-.207
LD	33	-.037	-.590	-.381	-.632	-.502
LP	11	-.177	-1.108	1.219	-.378	-.523
HP	7	-.025	-1.294	-5.746	-.321	-.902
DP	9	0.337	-2.378	3.554	-.869	-1.875
HLD	13	0.236	0.124	4.737	0.899	-.193
DLH	14	0.154	-.812	5.404	0.812	-.881
LHD	17	0.112	0.597	3.613	0.721	0.461
LDH	15	-.306	1.582	-4.685	0.540	1.409
YHD	9	0.165	1.803	-4.423	1.626	1.550
HPL	11	-.049	1.749	4.923	1.261	1.976
DHPL	10	-.024	0.636	3.563	0.598	0.725

[a]Constants are deviations from the overall mean.

*Breed code as described on page 24.

TABLE XI

LEAST SQUARES CONSTANTS[a] FOR BREED OF PIG ON POST-WEANING PERFORMANCE TRAITS

Breed*	154-day weight (lb.)	Number 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.)
H	-18.719	-1.041	-5.885	-1.135	12.803	-5.825	-.102	-23.420	0.018	0.043
D	-8.527	-.372	-.160	-.409	4.607	-.285	-.029	-8.796	0.050	0.046
L	-27.813	-2.378	-16.766	-2.576	19.509	-16.615	-.187	-37.856	-.312	-.217
P	-17.868	-1.296	-7.098	-1.325	9.713	-6.900	-.094	-20.792	0.031	0.080
HD	2.215	0.510	0.243	0.552	0.250	0.701	0.001	-1.529	0.025	0.016
DH	1.086	0.117	-2.350	0.158	-3.450	-2.087	0.005	1.735	0.029	0.041
LH	2.087	-.275	0.195	-.282	-.774	0.209	0.011	1.960	0.011	0.010
LD	2.605	-.508	-1.413	-.425	-4.064	-1.263	0.016	3.745	0.034	0.030
LP	7.385	-.691	1.888	-.831	-6.276	2.068	0.050	11.705	0.031	0.025
HP	-7.152	-.324	-2.714	-.300	3.358	-2.623	-.036	-7.873	0.033	0.050
DP	8.988	-.781	5.858	-.708	-4.975	5.494	0.056	12.241	0.054	0.013
HLD	10.216	1.336	1.540	1.343	-8.967	1.753	0.045	10.157	0.052	0.050
DLH	16.124	1.122	2.526	1.141	-13.884	1.295	0.072	18.654	0.007	-.002
LHD	7.317	0.933	0.568	0.974	-5.685	0.317	0.030	7.585	-.019	-.015
LDH	1.831	-.280	1.663	-.258	1.918	1.701	-.006	-.898	0.096	0.085
YHD	-3.904	2.036	1.733	2.191	3.573	1.665	-.010	-2.245	0.052	0.042
HPL	16.340	1.188	11.633	1.126	-5.677	11.699	0.110	23.377	-.119	-.192
DHPL	12.221	0.705	8.540	0.765	-1.980	8.697	0.069	12.249	-.071	-.105

[a]Constants are deviations from the overall mean.

*Breed code as described on page 24.

The greater mortality rate in the Landrace pigs is indicated by differences in litter size of 0.06, 0.77, 1.34 and 1.44 pigs at birth, 56, 154 days and market time, respectively. In addition to the advantage in livability, the Hampshire pigs had a faster growth rate from birth to market weight ($P<.05$) and were significantly heavier at 154 and 180 days by about 9.1 and 14.4 pounds, respectively. Landrace pigs had, however, less backfat at 200 pounds than Hampshire pigs ($P<.05$).

H vs. P. For most litter and pig performance traits, differences between the Hampshire and Poland breeds were not significant. Differences in litter size at birth, 56, 154 days and at market time were in favor of the Hampshires. However, the difference was only about 0.10 pigs at market time as compared to a difference of 1.11 pigs at birth, indicating a greater mortality rate among the Hampshire pigs. Average daily gain and weight at all ages were similar for pigs of both breeds.

D vs. L. Average litter size in the Durocs was greater ($P<.05$) at all ages than in the Landrace litters with the exception of number of pigs per litter farrowed where the difference was 0.31 pigs in favor of the Durocs. At market time, however, the Durocs had about 2.16 more pigs per litter than the Landrace. Average litter pig weight at 154 and 180 days was significant and in favor of the Durocs with a difference of 29.1 pounds at 180 days. Landrace pigs had less backfat at 200 pounds ($P<.05$), however, as compared with the Duroc pigs.

D vs. P. Duroc sows farrowed significantly more pigs than Poland China sows, the difference being about 1.49 pigs per litter. Differences in litter size at weaning (56 days), 154 days and market time were 0.91, 0.93 and 0.91 pigs, respectively, in favor of the Duroc sows. Duroc pigs gained faster and were heavier at 154 and 180 days by 9.5 and 12.0 pounds, respectively.

P vs. L. Landrace sows farrowed larger litters by 1.18 pigs than Poland China sows but the difference in litter size at market time was 1.25 pigs in favor of the Poland China sows ($P<.05$). The mortality rate of pigs in Landrace litters was very high, averaging about 2.6 pigs per litter as compared with a loss of 1.24 pigs in Poland China litters. Poland China pigs were significantly heavier at 154 and 180 days by 10.0 and 17.1 pounds, respectively. Landrace pigs had 0.30 inch less backfat than Poland China pigs ($P<.05$).

Two-breed crosses. Least squares constants for the effects of breed of pig on the various traits (Tables X and XI, pages 42 and 43) indicate the performance of the two-breed crosses included in this study (HD, DH, LH, LD, LP, HP and DP) was similar for most traits. A comparison of the least squares effects for litter size at birth, 56, 154 days and at market age show that the HD litters were larger than all other two-breed cross litters. The least squares constants for the HD cross, which measure deviations from the overall mean litter size, at these ages were 1.345, 0.459, 0.510 and 0.552 pigs, respectively. Least squares constants for litter size in all other two-breed crosses, except

the reciprocal DH cross, were negative at all ages of pigs. Litter size of two-breed crosses involving Landrace, Hampshire and Duroc boars mated to Poland China sows (LP, HP and DP) were smaller at birth, 154 days and at market time than other two-breed crosses where Duroc and Hampshire dams were used (DH, HD, LH and LD).

Differences in the growth rate of pigs among the various two-breed crosses as shown by average daily gain from birth to weaning were not significant although the daily gains of LP and DP pigs were greater than those of pigs of other crosses. The rank of crosses for average 180-day pig weight was DP, LP, LD, LH, DH, HD and HP; however, only the difference between LP and HP pigs was significant.

The backfat thickness of the pigs from the various two-breed crosses was similar as shown by the least squares constants in Table XI, page 43, and differences were not significant.

Three-breed crosses. Least squares constants for number of pigs farrowed per litter for the three-breed crosses included in this study (HLD, DLH, LHD, LDH, YHD and HPL) were 0.124, -.812, 0.597, 1.582, 1.803 and 1.749, respectively. At market time the constants were 1.343, 1.141, 0.974, -.258, 2.191 and 1.126, respectively. None of the differences, however, between the various crosses were significant.

Considerable variation was found in 180-day average pig weight as shown by the constants in Table XI, page 43. These constants were: LDH, -.898; YHD, -2.245; LHD, 7.585; HLD, 10.157; DLH, 18.654; and HPL, 23.377. HPL and DLH pigs were significantly heavier than LDH and YHD

pigs at 180 days. HPL pigs had significantly less backfat than pigs of other three-breed crosses.

Four-breed cross. Only one four-breed cross, DHPL, was included in the study. Litters in this cross averaged 0.636, 0.598, 0.705 and 0.765 pigs above the overall mean litter size at birth, 56 days, 154 days and at market time, respectively. Least squares constants for pig weight at 56, 154 and 180 days were 3.563, 12.221 and 12.249 pounds, respectively (Tables X and XI, pages 42 and 43).

Comparison of the performance of this cross with the purebreds (H, D, L and P) shows that litter size was consistently greater at all ages for the four-breed cross as indicated by least squares constants in Tables X and XI, pages 42 and 43; however, differences were significant between this cross and Landrace only. DHPL pigs gained faster ($P<.05$) and were heavier ($P<.05$) at 56, 154 and 180 days than purebred pigs of all four breeds.

Differences between this four-breed cross and the two-breed crosses were mostly nonsignificant for both litter size and average litter pig weight at various ages. However, constants for the effects of breed of pig were positive for the DHPL cross and negative in the majority of cases for the two-breed crosses.

There were very few significant differences among comparisons of DHPL and the six three-breed crosses for litter size, average litter pig weight and other traits. Except for the LDH cross, the performance of the three-breed crosses in the more important traits was superior to that of the DHPL cross.

Purebreds vs. two-breed crosses. The two-breed cross HD litters contained significantly more pigs at birth, 56, and 154 days and at market time than purebred Hampshire, Landrace and Poland litters, but litter size between the HD cross and purebred Durocs did not differ significantly. Average litter pig weight was generally in favor of the two-breed cross pigs at various ages from birth to market. Differences were significant and in favor of two-breed crosses at both 154 and 180 days of age except for comparisons involving HP pigs with purebred Duroc, Hampshire and Poland pigs. The least squares constants for the effects of breed of pig for 180-day average litter pig weight were: H, -23.420; D, -8.796; L, -37.856; P, -20.792; HD, -1.529; DH, 1.735; LH, 1.960; LD, 3.745; LP, 11.705; HP, -7.873; and DP, 12.241 pounds.

Purebred Landrace pigs had less backfat ($P<.05$) as compared with all other purebred and all two-breed cross pigs.

These results are in agreement with the findings of Bradford, Chapman and Grummer (1953), Smith, Moorman and McLaren (1959), Nance (1959), Sherrit et al. (1954) and Daniel (1965) who found that cross-bred pigs were superior in performance in most traits as compared with straightbred or purebred pigs.

Three-breed crosses vs. purebreds and two-breed crosses. Litter size at birth was consistently in favor of three-breed crosses compared with the purebreds as shown by constants in Table X, page 42, but only differences among LDH, YHD and HPL and purebred Poland China litters were significant. Three-breed cross litters were larger ($P<.05$) at 154

days and at market time except for comparisons between all three-breed crosses and Durocs and between the LDH cross and purebred Hampshire and Poland China.

Pigs of all three-breed crosses gained significantly faster from birth to market and were heavier ($P<.05$) at 154 and 180 days than pigs in all purebred groups.

Three-breed cross litters were generally above the overall mean (positive least squares constants) for litter size at birth, 56 days, 154 days and at market time as compared with two-breed cross litters where least squares constants were mainly negative except for the HD and DH two-breed crosses which were above the mean in litter size at 154 days and market time. Three-breed cross pigs were heavier at 154 and 180 days but differences were significant in only a few comparisons including HPL with HD, DH, LD and HP pigs and DLH with HP pigs. Some of the more productive three-breed crosses in terms of number of pigs raised per litter and pig weight at 180 days were HLD, DLH, LHD and HPL. Backfat thickness of the HPL pigs was significantly less than that of pigs in all other three-breed and two-breed crosses.

The results of this study are in close agreement with those of Smith, Moorman and McLaren (1960), Winters et al. (1936) and Daniel (1965) who reported that performance of three-breed crosses exceeded the performance of two-breed crosses in the number of pigs farrowed and raised per litter and in pig weight at market age.

CHAPTER V

SUMMARY AND CONCLUSIONS

The records of 6,920 pigs were analyzed to determine the effects of season of birth, age of dam and breed of pig on pre-weaning and post-weaning litter and pig performance traits. The data were taken from the records of the swine breeding project at Ames Plantation and included eight farrowing seasons, beginning with the spring of 1956 and continuing through the fall of 1959.

Data from 531 litters were compiled representing 18 different breed groups including 4 purebred and 7 two-breed, 6 three-breed and 1 four-breed crosses. Hampshire, Duroc, Landrace, Poland China and Yorkshire breeds were used in the crosses. Two-breed cross litters were produced by breeding sows of one breed to boars of another breed. The three-breed crosses were produced by mating sows from two-breed crosses to boars of a third breed. The four-breed cross was made by mating three-breed cross sows to boars of a fourth breed.

The season of birth effects were significant for most growth performance traits. Spring-farrowed pigs were heavier at birth, 56, 154 and 180 days and at market than fall-farrowed pigs and had a higher average daily gain from birth to market. No seasonal differences were found for number of pigs born, number of pigs born alive, number of pigs at 56 days, 154 days and at market. Season did not significantly affect backfat probe measurements of pigs.

Age of dam significantly affected litter and pig performance traits. Pigs in litters from 1-year-old sows were lighter ($P<.05$) in weight at birth, 56, 154, 180 days of age and at market than pigs from older sows. Litters from 1-year-old gilts contained significantly fewer pigs at birth, 56 days, 154 days and at market than litters from older sows. Differences among sows from 2 to 3 years of age and above were non-significant for most of the litter and pig performance traits studied.

The breed of pig effect was significant for most litter and pig performance traits. In comparisons among purebreds, Durocs were generally superior in litter performance traits to Hampshires, Landrace and Poland China. Although Duroc pigs were lighter at birth, they were significantly heavier at market weight.

The HD two-breed cross had larger litter size at all ages of pigs as compared with other two-breed crosses. Litter size of two-breed crosses involving Landrace, Hampshire and Duroc boars mated to Poland China sows was smaller at birth, 154 days and market time than other two-breed crosses where Duroc and Hampshire dams were used. Differences in growth rate of pigs among the various two-breed crosses as shown by average daily gain from birth to weaning were not significant, although daily gains of the LP and DP pigs were greater than those of other crosses.

The two-breed cross HD litters had significantly more pigs at 56 and 154 days and at market time than purebred Hampshire, Landrace and Poland China litters, but litter size between the HD cross and purebred

Durocs did not differ significantly. Differences in average pig weight were significant and in favor of two-breed crosses at both 154 and 180 days except for comparisons involving HP pigs with purebred Duroc, Hampshire and Poland pigs. Purebred Landrace pigs had less backfat ($P<.05$) than all other purebred and two-breed cross pigs.

Litter size at birth was consistently in favor of three-breed crosses as compared with all purebreds. Most comparisons involving litter size at 154 days and market time were in favor of three-breed crosses ($P<.05$) except for those between the crosses and the Durocs and those between the LDH cross and purebred Hampshire and Poland China. Pigs of all three-breed crosses gained significantly faster and were heavier ($P<.05$) at 154 and 180 days than pigs in all purebred groups.

Three-breed cross litters were generally above the overall mean for litter size at birth, 56 and 154 days and at market time as compared with two-breed cross litters where effects were mainly negative except for the HD and DH crosses. Three-breed cross pigs were heavier at 154 and 180 days than two-breed cross pigs, but differences were significant in only a few comparisons including HPL with HD, DH, LD and HP pigs and DLH with HP pigs. Some of the most productive three-breed crosses in terms of number of pigs raised per litter and pig weight at 180 days were HLD, DLH, LHD and HPL.

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