June 1, 1967

To the Graduate Council:

I am submitting herewith a thesis written by James Blackburn McLaren entitled "Evaluation of Factors Affecting 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.

Harald J. Smith
Major Professor

We have read this thesis and recommend its acceptance:

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EVALUATION OF FACTORS AFFECTING 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

---

by

James Blackburn McLaren

June 1967

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TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

CHAPTER I

INTRODUCTION

Profit from a swine enterprise is dependent on the level of performance in the swine herd. Some of the factors affecting profit are size of litter farrowed, pig survival rate and gain from birth to market. Tennessee swine producers follow many practices in relation to breed and age of their breeding stock. Some producers depend largely on mature sows, whereas others use gilts almost exclusively. On most Tennessee farms both gilts and mature sows are used to produce pigs; however, the proportion of gilts to sows a producer keeps varies from farm to farm. Most swine producers do not have a definite plan for maintaining their sow herd, and there may be a large variation in the number of breeding sows and gilts on the same farm from year to year.

Usually, farmers select herd replacements as needed with little regard to any systematic breeding program. Some producers practice a program of farrowing gilts at about one year of age and market these gilts when their first litters are weaned. Replacement gilts are selected from the market hogs to produce the next year's pigs. Under this system many gilts are sold for slaughter before they reach the peak of performance.

On the average, the gross return from six market hogs is required to pay for the costs of carrying a sow and litter. A study of the various factors which affect performance traits of economic importance to swine producers can aid in the establishment of sound production programs.

The objectives of this study were: (1) to determine the effects of year, season of birth, age of dam, breed of dam and breed of pig on litter and pig performance traits; (2) to compare certain performance traits of straight and crossbred pigs; and (3) to evaluate the effects of various two- and three-breed rotational crosses on litter and pig performance traits.

CHAPTER II

REVIEW OF LITERATURE

I. SEASON OF BIRTH

Many workers have reported that season of birth influences many of the important litter and pig performance traits. Reports vary as to the degree of the difference due to the effects of various seasons. Survival rate has been observed to be affected by season of birth. Wilcox, Carrol and Hornung (1933) reported that late-farrowed spring pigs had an 8 per cent lower mortality rate than pigs farrowed in early spring and 2 per cent lower than fall pigs. Pomeroy (1960), who studied 17,015 pigs almost equally distributed with respect to farrowing time over all 12 months, found that litters farrowed from September to March had a higher mortality rate than pigs farrowed during the months of April through August. Comparisons by Korkman (1947) showed that spring- or summer-farrowed pigs had lower mortality rates than pigs farrowed in other seasons.

In contrast to these reports, Kernkamp (1965) states that 26.2 per cent of the fall-farrowed pigs and 30.5 per cent of the spring-farrowed pigs died before weaning. It was noted by Asdell and Willman (1941) that spring-farrowed litters had a mortality rate nearly twice that of fall-farrowed litters. Bradford, Chapman and Grummer (1953) reported survival rates to 154 days of age for early-, middle- and late-born spring groups as 73.6, 74.7 and 73.8 per cent, respectively. Work reported by

Robison (1948) showed spring-farrowed pigs to be heavier at birth and heavier at weaning than fall-farrowed pigs. These heavier weights were attributed to the availability of pasture during the spring season.

Sexual development of gilts of market weight, slaughtered at various seasons of the year, was investigated by Wiggins, Casida and Grummer (1950). The percentage of sexually mature animals at market weight was significantly lower for pigs farrowed in the early spring than in the gilts born later in the season. Seasonal differences in the percentage of pre-puberal animals were found to be highly significant. The lowest percentage was found in April and the highest in October.

II. AGE OF DAM

There is general agreement that mature sows farrow larger litters which contain more stillborn pigs than gilts. Age of the sow has been found by several workers to be directly related to the number of pigs farrowed per litter.

Litter size. Ovulation rate is one of the important factors governing fertility in mammals. Its importance was demonstrated by Squiers, Dickerson and Mayer (1952), who found that the number of ova shed was significantly correlated ($r = 0.47$) with litter size at the 25th day of gestation. Reports show a wide variation in the age at which a gilt reaches puberty. Phillips and Zeller (1943); Robertson *et al.* (1951); Self, Grummer and Casida (1955); Burger (1952); and

Foote et al. (1956) reported the range to be from 6 to 8 months of age. Rice and Andrews (1951) observed that gilts reached puberty at about 5 months of age.

Hammond (1914) found that a smaller number of ova were released during estrus by younger sows than by older sows. He offered this as an explanation for the smaller litters of young sows. Reports by Robertson et al. (1951) indicate that 1-year-old gilts produced an increasing number of ova at each succeeding heat period for the first three periods. Squiers, Dickerson and Mayer (1952) and Hammond (1914) and Newman (1963) observed a larger number of corpora lutea for mature sows than for gilts. Carlisle et al. (1945) found that litter size increased 0.5 pig in gilt litters for each month between 11 and 14 months of age at farrowing. Stewart (1954), in a study of 749 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 more pig than gilts farrowing at 12 months of age.

In work by Olbrycht (1943), 156 Large White sows were used to produce 10 litters each. Of the 1,560 litters produced, the maximum performance was reached with the third litter. Performance leveled off through the fifth litter and then declined beyond this point. Data of Lush and Molln (1942) showed that average litter size increased a little more than 0.5 pig from the first to the second litter. Litter size increased by one more pig per litter for 2-year-old sows and varied slightly between 2.0 and 4.5 years of age. However, average litter size tended to decline after sows reached 4.5 years of age.

Robison (1948) found that sows 1.5 to 3.5 years of age farrowed more pigs per litter than younger or older sows.

Birth weight. Many workers have observed that age of dam influences birth weight. Olbrycht (1943) reported that pigs from older sows tended to be heavier at birth than pigs from gilts. In studies by Vestal (1936) it was found that pigs from 2-year-old sows were considerably heavier than pigs from gilts and 3- to 5-year-old sows. Carmichael and Rice (1920) reported that 2-year-old sows farrowed pigs 0.17 lb. heavier at birth than those farrowed by gilts. In contrast, it was observed by Russell (1936) that there was no difference in birth weight of pigs from sows between 1 and 7 years of age.

Survival rate. Warwick (1928) found that crowding in the uterus caused prenatal deaths. He concluded that uterine size had a large influence on the number of pigs farrowed. Sows with large reproductive tracts tended to farrow more live pigs. Gilts farrowed fewer pigs, and these pigs had a lower mortality rate than pigs from older sows, according to Pomeroy (1960). A pre-weaning mortality rate of 27.4 per cent for the first litter was followed by a gradual increase up to the eighth litter in which an average mortality rate of 32.5 was observed. This greater mortality rate accompanied the increase in litter size observed from older sows.

Robison (1948) found that gilts and 1.5-year-old sows had fewer stillborn pigs and saved a larger per cent of their pigs than older sows. In contrast, Korkman (1947) noted that when equal numbers of pigs were born in each litter, the survival rate declined steadily as the age of the dam increased.

Robertson (1965) found that 2-year-old sows farrowed larger litters than sows of any other age. However, there was no significant difference in the number of pigs per litter at 56 days of age among sows from 1.5 to 3 years of age. The number of pigs per litter at weaning was significantly less for gilts than for older sows.

Braude, Clarke and Mitchell (1954) observed pre-weaning mortality to be 23.0 per cent in litters farrowed by gilts and 31.0 per cent in litters farrowed by mature sows. Pre-weaning mortality rate increased from the first through the sixth litter, then declined through the eighth litter in studies reported by Kernkamp (1965).

Weaning weight. Influence of milk production on weaning weight was observed by Donald (1939) and Zeller, Johnson and Craft (1937). Sows were observed to be heavier milkers and weaned heavier litters than gilts. Smith and Donald (1937) found that very fertile females were heavy milkers.

Sinclair and Syrotuck (1928) and Nordskog, Comstock and Winters (1944) reported that gilts produced pigs that were 4.0 to 4.5 lb. lighter at weaning than pigs from sows 2 to 5 years of age. The heaviest litter weaning weights were reached by litters farrowed by sows 4 years of age. In reports by Vestal (1936) and Lush and Molln (1942), 2-year-old sows produced larger and heavier litters at weaning than sows of younger or older ages. Individual pigs in the litters farrowed by 2-year-old sows were heavier at weaning than pigs from other age dams. Carlisle et al. (1964) studied gilts of various ages at farrowing. Pigs weaned at 42 days of age were 1.3 lb. heavier for each additional month of age of gilts that farrowed between 11 and 14 months of age. In this study, the average 56-day weight of pigs from gilts was 35 lb. compared to 40 lb. for pigs weaned from sows.

It is generally agreed by research workers (Wilson, Whatley and Harington, 1961; Winters, Cummings and Stewart, 1947; Weaver and Bogart, 1943; and Russell and Hutton, 1938) that the age of dam influences weaning weight and that gilts wean the lightest litters.

154-day and 180-day weight. Baker, Hazel and Reinmiller (1943) concluded that litters farrowed by mature sows maintained a distinct advantage up to 112 days of age and thereafter the advantage decreased. In contrast, Hetzer (1942) and Russell and Hutton (1938) found that pigs from gilts were lighter at 154 days than pigs farrowed by sows. Robison (1946) reported that pigs produced by gilts weighed 32.9 lb. less at 180 days of age than pigs from older sows. Whatley, Chambers and Stephens (1954) also found that age of dam affected pig weight at 180 days of age but suggested the effect was small.

Lasley (1963) demonstrated that the weight at 154 days of age is an economic trait. He suggested that a weight taken at this time can be used as an evaluation of all gains from birth. Further observations were made that older sows milked heavier during the nursing period and had heavier pigs at 154 days of age. Pigs from 2-year-old sows were heavier at 154 days of age than pigs from older sows in studies by Vestal (1936).

Reporting on total litter weight at 154 and 190 days of age, Russell and Hutton (1938) found that gilt litters had a slight weight disadvantage compared to mature sow litters at 154 days of age. Gilts produced litters averaging 1260 lb. and mature sows produced litters averaging 1322 lb. Whatley et al. (1952) failed to observe significant differences among various ages of dam for 180-day weight of pigs.

III. BREED

Hybrid vigor resulting from crossbreeding has been used by many swine producers to increase efficiency in the production of market hogs. The pork producer who desires larger litters, stronger pigs at birth, fewer death losses, faster gain and less feed per lb. of gain should consider all breeding methods which will give these results.

Purebred versus crossbred. Roberts and Carroll (1939) used a double mating system to produce purebred and crossbred pigs in the same litter. The crossbred pigs were stronger at birth and had a higher survival rate to weaning than the purebred pigs.

A number of workers have reported that litter size is influenced most by the breed of the dam. Lush and Molln (1942) found the average litter size at birth for Duroc, Hampshire and Tamworth sows was 9.78, 8.66 and 7.43 pigs, respectively. Carlisle et al. (1964) reported an advantage for first-cross pigs over purebred pigs for each trait studied. These advantages were: litter size at birth, 1 per cent; litter size at weaning, 7 per cent; weaning weight, 14 per cent; and litter weight at 154 days of age, 12 per cent.

Two-breed, three-breed and backcrosses. 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. Gaines and Hazel (1957) indicated that crossbred sows were superior to purebred sows in litter size at all ages. Three types of crossbreds (first-cross, three-breed-cross and back-cross) used by Winters et al. (1936) were superior to purebreds for producing market hogs. Two- and three-breed crosses had an advantage of 1.00 and 1.67 pigs per litter, respectively, over purebred litters. They noted that the three-breed-cross litters possessed the greatest advantage in most performance traits.

In a study by Carlisle et al. (1964), the four-breed-cross litters were larger at farrowing than litters of purebreds and other crosses. The performance of each breed group was evaluated with respect to the average purebred performance. When the purebred performance was expressed as 100 per cent, the performance in the crosses were: first cross, 101 per cent; three-breed cross, 111 per cent; and four-breed cross, 113 per cent. Nance (1959) reported the largest advantage (26.0 to 30.0 per cent) in litter weight at 180 days of age for the three-breed cross over straightbreds. Although the two- and four-breed crosses produced significantly heavier litters at 180 days of age than the purebreds, the three-breed-cross litters were heavier than either the two- or four-breed-cross litters.

Birth weight. Most data suggest that little if any advantage to birth weight is obtained through crossbreeding. Hazel, Baker and Reinmiller (1943) obtained a correlation of 0.84 between birth weight and weaning weight. A correlation of 0.71 between these traits was noted by Blunn, Baker and Hanson (1953). Vestal (1936) found a high correlation between birth weight and survival rate. Less than 50 per cent of the pigs weighing 2 lb. or less at birth survived to weaning age.

Freedeen and Plank (1963) observed that 42 per cent of the pigs weighing less than 1.4 lb., 11 per cent of the pigs weighing 1.5 to 1.9 lb. and 7 per cent of those weighing over 2.0 lb. at birth were stillborn. Whatley, Chambers and Stephens (1954) and Pani et al. (1963) found Duroc pigs similar to crossbred pigs in birth weight.

Survival rate. Crossbred litters have been shown (Winters, Cummings and Stewart, 1947; Lush, Shearer and Culbertson, 1939; Carroll and Roberts, 1942; and Robison, 1946) to have a lower percentage of stillborn pigs and a greater survival rate at weaning than purebreds. Smith, Moorman and McLaren (1960) stated that pigs in the three- and four-breed-cross litters had greater survival ability than purebreds. Lush, Shearer and Culbertson (1939) reported that crossbred pigs were more vigorous at birth. Wilson, Whatley and Harington (1961) suggested that decreased birth weight and inability of the sow to produce sufficient milk resulted in increased pre-weaning pig losses.

Litter size. Carroll and Roberts (1942) reported that the number of pigs farrowed per litter was related to the number of eggs produced and fertilized and to the prenatal mortality. They found that crossbreeding did not increase the number of eggs produced and fertilized but prenatal mortality was lower in crossbred litters than in purebred litters. Bradford, Chapman and Grummer (1953); Whatley, Chambers and Stephens (1954) and Pani et al. (1963) found no significant difference in litter size at birth between purebred and crossbred litters; however, they suggested that the genotype of the dam had a marked influence on litter size and weight at birth.

In work reported by England and Winters (1953), rotational crosses had a larger number of pigs born alive than either criss-cross or single-cross litters. Nance (1959) concluded that purebred sows farrowed smaller litters than crossbred sows. Pani et al. (1963) suggested, to obtain maximum expression of hybrid vigor in pigs, a crossbreeding program should include at least three breeds.

Weaning weight. Vogt, Comstock and Rempel (1963) and Ward, Rempel and Enfield (1964) found high genetic correlations of 0.88 and 0.69, respectively, between weaning weight and post-weaning weights, whereas, Blunn, Baker and Hanson (1953) showed a correlation of 0.12. Hazel, Baker and Reinmiller (1943) and Forshaw et al. (1953) noted intermediate correlations of 0.45 and 0.46, respectively.

Winters et al. (1936) reported that crossbred sows produced litters of from 0.66 to 2.00 more pigs at weaning, and each crossbred pig weighed from 5 to 7 lb. more than purebred pigs at weaning. Many workers (Russell, 1936; Robison, 1946; Sherrit et al., 1954; Nance, 1959; and Smith, Moorman and McLaren, 1960) have reported that crossbred litters were larger at weaning and that the pigs in crossbred litters were heavier than purebreds. Crossbred litters in studies by Whatley, Chambers and Stephens (1954) were 38 per cent heavier at 56 days of age than straightbred litters.

Weight at 154 and 180 days. The 56-day weight was the best indicator of 154-day weights of pigs (Yorkshire, Duroc and crosses of these breeds) in studies conducted by MacDonald, Maxley and Hamilton (1959). Crossbreds were superior in litter size and litter weight at 154 days of age in reports by Smith and Moorman (1959); Bradford, Chapman and Grummer (1953); MacDonald, Maxley and Hamilton (1959) and Nance (1959). It was suggested by Nance (1959) that the advantage in litter size at 154 and 180 days of age was due to the increased number of pigs farrowed and higher survival in crossbred litters compared to purebred litters.

Smith, Moorman and McLaren (1960) reported that at market age 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 litters were from 203 to 206 lb. heavier and had from 0.7 to 1.4 more pigs per litter than purebred litters at 180 days of age in work by Robison (1948). Nance stated that crossbred pigs were about 8 to 10 per cent heavier than purebreds at 180 days of age.

<u>Backfat thickness</u>. Whiteman, Hillier and Whatley (1951) observed that crossbred Poland-Duroc and Landrace-Poland carcasses were leaner and possessed less backfat than purebred Duroc carcasses.

Smith and Moorman (1959) found that purebred Landrace market hogs had significantly lower backfat thickness than other purebreds and that including Landrace in a crossbreeding program was very effective in reducing backfat thickness in the crossbred pigs. This is in agreement with the reports by Nance (1959).

CHAPTER III

EXPERIMENTAL PROCEDURE

I. SOURCE OF DATA

The data for this study are some of those collected in a swine breeding project conducted by the University of Tennessee, Animal Husbandry-Veterinary Science Department, at Ames Plantation, Grand Junction, Tennessee. This study includes data from eight farrowing seasons during the years of 1960 through 1963.

Data were obtained for the following pig and litter performance traits: number of pigs farrowed (both alive and stillborn); litter size at 56, 154 days and market age; pig and litter weight at birth, 56, 154 and 180 days of age; survival rate; average daily gain from birth to market; and live backfat probe at market weight.

II. EXPERIMENTAL ANIMALS

The animals used in this study were litters of purebred Hampshire, Duroc and various two- and three-breed repeat crosses. Purebred Hampshire (H), Duroc (D), Landrace (L) and Yorkshire (Y) boars were used in the various crosses and rotational crosses. The number of litters produced by each type of mating in this study are shown by year and season in Table I. The number of litters produced in the various breeding groups varied from season to season.

TABLE I

DISTRIBUTION OF LITTERS BY YEAR, SEASON AND BREEDING GROUPS
1960 THROUGH 1963

	Number of Litters								
	1960		1961		1962		1963		
	S	F	S	F	S	F	S	F	Total
H x H[a,b]	12	7	17	17	19	15	17	21	125
D x D	14	14	13	12	15	16	20	21	125
H x D	8	5	6	6	6	4	6	7	47
D x H			6						6
L x H	6	6	6	3	6	6	8	8	49
L x D	8	7	6	5	5	6	6	6	49
Y x H	6	7	5	5	6	4	8	7	48
Y x D	8	6	6	5	5	5	4	4	43
L x HD	10	10	8	6				1	35
Y x HD	10	10	8	7				2	37
H x LD	7	7	8	5	6	6	6	3	48
D x LH	7	6	8	5	5	7	7	7	50
H x YD			6	6	7	6	6	8	39
D x YH			4	3	5	3	7	2	24
D x HD	5	8							13
H x DHD			5	5					10
D x HDHD					11	9	2	1	23
H x DHDHD							7	3	10
D x YHD			4	5					9
H x DYHD					6	7	2		15
Y x HDYHD							5		5
D x LHD			9	7					16
H x DLHD					11	10	2		23
L x HDLHD							4	8	12
Totals									
Seasons	101	93	123	102	113	104	117	108	861
Years	194		225		217		225		

[a]Breed code: H-Hampshire; D-Duroc; L-Landrace; Y-Yorkshire.

[b]First letter denotes breed of sire. Second and additional letters denote breed of dam.

Three rotational crossbreeding programs were included in the mating plans. These rotational programs, originating with purebred Duroc sows, were continued through the sixth generation of each rotational cross. They were:

1. Duroc-Hampshire rotation.
2. Duroc-Hampshire-Landrace rotation.
3. Duroc-Hampshire-Yorkshire rotation.

Each phase in the rotational program was followed for two successive breeding seasons. Gilts produced in the second breeding season of each cross were selected for use in the succeeding cross. The breed of pig produced in each of the rotations were:

1. Purebred Duroc, H x D, D x HD, H x DHD, D x HDHD and H x DHDHD
2. Purebred Duroc, H x D, L x HD, D x LHD, H x DLHD and L x HDLHD
3. Purebred Duroc, H x D, Y x HD, D x YHD, H x DYHD and Y x HDYHD.

Sows of similar breeding were randomly assigned to breeding groups. The sows were reallotted to breeding groups each season on the basis of breed, age and previous performance.

III. HERD MANAGEMENT

The spring farrowing season began about April 1 and the fall season about October 1, with each sow producing two litters per year. Pasture mating was practiced using approximately 2-acre breeding lots for each boar group. Sows allotted to each of the breeding groups were divided into three subgroups and approximately one-third of the sows were put with the boars at 2-week intervals. This practice spread the farrowing dates over a period of 8 to 10 weeks and allowed time to confine the sows to the farrowing stalls a few days prior to farrowing and for steam cleaning and disinfecting the stalls between sows.

Breeding groups were checked daily for estrus so that approximate farrowing dates could be predicted. Gilts were bred to farrow initially at 10 to 14 months of age, depending upon their development.

A pole type central farrowing house was used. Sows were brought to the farrowing barn a few days prior to the expected farrowing date, washed thoroughly, wormed with piperazine, and placed in the farrowing stalls. The sows were turned out of the stalls twice daily for feed and water before and after parturition.

The breeding herd, both sows and boars, were blood-tested annually for brucellosis and herd accreditation was maintained. The herd was vaccinated once each year for erysipelas and cholera and twice yearly for leptospirosis. Both sows and boars were rung as needed to prevent excessive rooting. Sows were wormed during late gestation in addition to the worming at farrowing time. Between breeding seasons the boars were run together in groups according to size and age. They were wormed and tusked as needed.

At farrowing the pigs were ear notched for identification, weighed and injected with 3 cc. of swine erysipelas antiserum. The needle teeth of the pigs were clipped at this time and umbilical cords were treated with tincture of iodine. At birth a teat count was made on all pigs, both live and stillborn.

The pigs were injected at 3 days of age with an iron compound for the prevention of anemia. The sows and their litters were moved to pasture lots when the pigs were 7 to 14 days of age. About eight sows and their litters were placed in each 4-acre pasture lot. Shelter and shade were provided in each pasture lot by portable hog houses and straw-covered shades. Allotment was planned so that a stocking rate of approximately 15 to 20 pigs per acre would be in effect at later ages.

At 4 weeks of age, all crossbred male pigs and purebred male pigs not saved for potential breeding stock were castrated. All pigs were vaccinated for erysipelas at this time.

Weaning weights were taken and the sows were removed when the pigs in each lot reached an average age of 8 weeks. All pigs were rung, vaccinated for cholera and a second evaluation of purebred boar pigs was made at this time. Pigs were wormed with piperazine after weaning and again approximately 18 days later.

When the pigs were approximately 154 days of age they were weighed and sorted into groups according to weight range. The groups were routinely reweighed and any of the pigs weighing 200 lb. or more were marketed. At this time a backfat probe was taken at the seventh rib, 2 in. off the center of the back.

IV. FEEDS AND RATIONS

The sows were fed ground ear corn and a protein supplement during the breeding season and during gestation. The amount fed depended on the condition of the pasture, stage of production and the condition of the sows. The sows were flushed during the first 2 weeks of the breeding season. The flushing ration generally consisted of 7 lb. of corn and cob meal and 1 lb. of supplement per sow per day. The amount of feed was gradually reduced after 2 weeks to 3 lb. corn and cob meal and 1 lb. supplement per sow per day. The sows were fed at this level until approximately 3 weeks before farrowing, at this time the daily ration was increased to 6 or 7 lb. Sows were fed once daily, 6 days a week during the breeding and gestation periods.

When the sows were brought to the farrowing barn, they were placed on a bulky ration containing approximately 33 per cent alfalfa leaf meal until approximately 5 days after parturition.

Corn grown on Ames Plantation or purchased in the local area was used for all rations. Protein supplements were either purchased commercially or mixed on the Plantation. Corn was fed as ground ear corn, whole ear corn or shelled corn, depending on the age of the animals and the availability of the corn. The amount and proportion of tankage, soybean oil meal and alfalfa leaf meal fed varied according to the quality and amount of pasture available as shown in Table II.

Sows nursing pigs and pigs being grown and finished on pasture were self-fed either ear corn or shelled corn and supplemented free

TABLE II

PROTEIN SUPPLEMENT MIXTURES[a] FED

	Soybean oil meal (lb.)	Tankage (lb.)	Alfalfa leaf meal (lb.)
Sows, nursing pigs			
on "good" pasture	100	100	---
on "poor" pasture	100	100	100
Pigs, weaning to 4 months of age			
on "good" pasture	100	100	---
on "poor" pasture	150	150	50
Pigs, 4 months old to market			
on "good" pasture	200	100	---
on "poor" pasture	200	100	50

[a]Ten lb. dicalcium phosphate, 2 lb. salt and 4 grams of antibiotic activity per 100 lb. were added to each of the various supplement mixtures.

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

Spring-farrowed litters were pastured on Ladino clover and orchardgrass. Temporary pastures of oats and crimson clover were provided for fall-farrowed litters. Pastures were grazed at the rate of approximately 20 growing-finishing pigs per acre. During the breeding and gestation periods, the sows were pastured on orchardgrass and Ladino clover.

Death losses and health problems encountered were recorded and evaluated with respect to their effect on the various breed groups. During the period of this study, atrophic rhinitis was diagnosed as a serious disease problem in the swine herd. This disease is apparently transmitted by direct contact between an infected sow and young pigs. The period of highest susceptibility appears to be from birth to about 6 to 8 weeks.

The effects of the disease on the growth rate and thriftiness of the pigs may not be evident until weaning or later in the growth period. There was no evidence in the study to indicate that the incidence of the disease differed among the groups.

V. METHODS AND ANALYSIS

Weight records were kept for all straightbred and crossbred pigs. These weights were adjusted to a 56-, 154- and 180-day basis to allow for mean comparisons between litters and breeding groups. The following linear formulas were used for adjusting individual pig weights:

$$\text{Adjusted 56-day weight} = 56\left(\frac{W_w - W_b}{A_w}\right) + W_b$$

$$\text{Adjusted 154-day weight} = W_w + (154 - A_w)\left(\frac{W_{154} - W_w}{A_{154} - A_w}\right)$$

$$\text{Adjusted 180-day weight} = W_{154} + (180 - A_{154})\left(\frac{W_{180} - W_{154}}{A_{180} - A_{154}}\right)$$

when: W_b = Birth weight

W_w = Weaning weight

A_w = Weaning age

W_{154} = Actual 154-day weight

W_{180} = Actual 180-day weight

A_{154} = Actual age at 154-day weight

A_{180} = Actual age at 180-day weight

Backfat probes taken on the pigs at market weight were adjusted to a 200 lb. basis 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.

Least-squares constants were fitted for the dependent variables as a means of studying the effects of year, season of birth, breed of dam, age of dam, breed of sire and breed of pig on the number of pigs per litter at birth, 56, 154 days of age and at market; average pig weight at birth, 56, 154, 180 days of age and at market; market age;

total and average daily gain from birth to market and average backfat thickness at market weight. Disproportionate subclass numbers necessitated the use of least-square methods (Harvey, 1960).

The following linear additive mathematical models were assumed for the least-squares analysis of the dependent variables. These models were:

(1). $Y_{ijklno} = u + y_i + s_j + a_k + g_l + d_n + e_{ijklno}$

where: Y_{ijklno} = The total number of pigs farrowed, number farrowed alive, average birth weight, number at 56 days, 56-day weight, number at 154 days, 154-day weight, number at market, 180-day weight or adjusted backfat probe at market for the o^{th} litter of the n^{th} breed of dam, the l^{th} breed of sire, the k^{th} age of dam, the j^{th} season of birth and the i^{th} year.

(2). $Y_{ijklno} = u + b_1 (X_1 - \bar{X}_1) + y_i + s_j + a_k + g_l + d_n + e_{ijklno}$

where:

Y_{ijklno} = The average market weight or total gain from birth to market at a constant market age for the o^{th} litter of the n^{th} breed of dam, the l^{th} breed of sire, the k^{th} age of dam, the j^{th} season of birth and the i^{th} year.

(3). $Y_{ijklno} = u + b_2(X_2 - \bar{X}_2) + y_i + s_j + a_k + g_l + d_n + e_{ijklno}$

where:

Y_{ijklno} = The average market age, average daily gain from birth to market or actual backfat probe at a constant market weight for the o^{th} litter of the n^{th} breed of dam, the l^{th} breed of sire, the k^{th} age of dam, the j^{th} season of birth and the i^{th} year.

(4). $Y_{ijkto} = u + y_i + s_j + a_k + p_t + e_{ijkto}$

where:

Y_{ijkto} = The total number of pigs farrowed, number farrowed alive, average birth weight, number at 56 days, 56-day weight, number at 154 days, 154-day weight, number at market, 180-day weight or adjusted backfat probe at market for the o^{th} litter of the t^{th} breed of pig, the k^{th} age of dam, the j^{th} season of birth and the i^{th} year.

(5). $Y_{ijkto} = u + b_1(X_1 - \bar{X}_1) + y_i + s_j + a_k + p_t + e_{ijkto}$

where:

Y_{ijkto} = The average market weight or total gain from birth to market at a constant market age for the o^{th} litter of the t^{th} breed of pig, the k^{th} age of dam, the j^{th} season of birth and the i^{th} year.

(6). $Y_{ijkto} = u + b_2(X_2 - \bar{X}_2) + y_i + s_j + a_k + p_t + e_{ijkto}$

where:

Y_{ijkto} = The average market age, average daily gain from birth to market or actual backfat probe at a constant market weight for the o^{th} litter of the t^{th} breed of pig, the k^{th} age of dam, the j^{th} season of birth and the i^{th} year.

where:

u = The theoretical population mean when equal numbers exist in subclasses (absorbed).

y_i = The effect of year of birth with i classification, when i = 1, 2, 3, 4 as follows:

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

s_j = The effect of season of birth with j classification, when j = 1, 2 as follows:

1. Spring 2. Fall

a_k = The effect of age of dam with k classification, when k = 1, 2, 3, 4, 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 sow

g_l = The effect of breed of sire with l classification, when l = 1, 2, 3, 4 as follows:

1. Hampshire 3. Landrace
2. Duroc 4. Yorkshire

d_n = The effect of breed of dam with n classification, when n = 1, 2, 3, ...16 as follows:

1. H 3. HD
2. D 4. LD

5.	LH	11.	YHD
6.	YD	12.	DYHD
7.	YH	13.	HDYHD
8.	DHD	14.	LHD
9.	HDHD	15.	DLHD
10.	DHDHD	16.	HDLHD

p_t = The effect of breed of pig with t classification, when t = 1, 2, 3, ...24 as follows:

1. H		9. LHD		17. DHDHD	
2. D		10. YHD		18. HDHDHD	
3. HD		11. HLD		19. DYHD	
4. DH		12. DLH		20. HDYHD	
5. LH		13. HYD		21. YHDYHD	
6. LD		14. DYH		22. DLHD	
7. YH		15. DHD		23. HDLHD	
8. YD		16. HDHD		24. LHDLHD	

$b_1 (X_1-\bar{X}_1)$ = Term for regression of market weight on market age (X_1 = market age).

$b_2 (X_2-\bar{X}_2)$ = Term for regression of market age on market weight (X_2 = market weight).

e_{ijklno} and e_{ijkto} = 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

Data from 861 litters consisting of 8,980 pigs were analyzed by least-squares methods to determine the effects of year, season of birth, age of dam, breed of sire and breed of pig on average litter and pig performance traits. Duncan's Multiple Range Test (1955) as modified by Kramer (1957) was used for mean separation where significant differences were detected in the effects of a variable.

Overall means and their standard errors for the various traits are shown in Table III.

II. CORRELATIONS AMONG TRAITS

Correlations between the members of various pairs of performance traits studied are shown in Table IV. The "t" test as described by Snedecor (1956) was used to test the significance of the correlation coefficients. The highest correlation between a trait at birth and at subsequent periods was between the number of live pigs born per litter and the number of pigs per litter at 56, 154 days and market age. These correlations were 0.68, 0.63 and 0.61, respectively, and were highly significant. These results are in agreement with Black (1965), Pomeroy (1960) and Kernkamp (1965), who reported that the

TABLE III

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

Variables	Mean	Standard Error
Number farrowed	10.43	0.099
Number farrowed alive	9.75	0.094
Birth weight, lb.	2.98	0.016
Number at 56 days	7.90	0.089
56-day weight, lb.	29.44	0.233
Number at 154 days	7.51	0.091
154-day weight, lb.	139.10	0.840
180-day weight	174.99	0.968
Number at market	7.21	0.093
Market age, days	207.53	0.728
Market weight, lb.	209.46	0.432
Total gain, birth-market, lb.	206.30	0.428
Average daily gain, birth-market, lb.	1.01	0.004
Backfat probe, in.	1.45	0.006
Adjusted backfat probe, in.	1.38	0.005

[a]Overall means as referred to in the tables and discussion in this presentation are the simple arithmetic averages for the various traits.

TABLE IV

CORRELATIONS AMONG LITTER AND PIG PERFORMANCE TRAITS

	No. pigs born	No. born alive	Av. birth wt.	No. at 56 days	56-day wt.	No. at 154 days	154-day wt.	No. at mkt.	180-day wt.	Adj. back-fat probe	Mkt. wt.	Mkt. age	A.D.G., birth-market
No. pigs born	1.00	0.92	-.21	0.59	-.02	0.54	0.08	0.52	0.07	0.00	0.03	-.11	0.08
No. born alive		1.00	0.18	0.68	-.03	0.63	0.07	0.61	0.06	0.01	0.02	-.09	0.07
Av. birth wt.			1.00	-.03	0.38	-.01	0.34	0.02	0.36	-.10	0.20	-.32	0.36
No. at 56 days				1.00	0.10	0.95	0.17	0.92	0.16	0.02	0.03	-.17	0.15
56-day wt.					1.00	0.20	0.79	0.24	0.76	-.16	0.30	-.70	0.72
No. at 154 days						1.00	0.24	0.97	0.22	0.01	0.06	-.21	0.20
154-day wt.							1.00	0.31	0.95	-.17	0.35	-.87	0.88
No. at market								1.00	0.27	0.01	0.09	-.26	0.26
180-day wt.									1.00	-.15	0.40	-.91	0.94
Adj. backfat probe										1.00	0.02	0.09	-.07
Market wt.											1.00	-.16	0.59
Market age												1.00	-.86
A.D.G., birth-market													1.00

Correlation coefficients ≥ 0.07 are significant ($P < .05$).

Correlation coefficients ≥ 0.09 are highly significant ($P < .01$).

highest death losses in pigs occurred in the nursing period. The correlations between the number of pigs at birth (both total and born alive) and 56-, 154-, 180-day weights, market weight and average daily gain were not significant. There were highly significant negative correlations between birth weight and the total number of pigs born per litters ($r = -.21$) and between birth weight and market age ($r = -.32$). However, highly significant positive correlations were found between birth weight and 56-day weight, ($r = 0.38$); 180-day weight, ($r = 0.36$); market weight, ($r = 0.20$); and average daily gain from birth to market ($r = 0.36$).

These results indicate that pigs farrowed in the larger litters were lighter at birth and at subsequent ages and reached market weight at an older age than pigs from smaller or average-sized litters. This is in partial agreement with Wilson, Whatley and Harington (1961), who observed an almost linear relationship between the number of pigs farrowed and litter weight at farrowing. Reports by other workers (Kuhlman, 1928; Baker, 1939; Weaver and Bogart, 1943; and Forshaw _et al._, 1953) suggest that an additional 1 lb. of birth weight accounts for a 7 lb. to 8 lb. advantage at weaning. The high correlation between the number of live pigs per litter at birth and the average litter size at later ages supports the report by Weaver and Bogart (1943) that, within limits, large litters were superior to small litters in number of pigs weaned. They report a slight advantage in birth weight and a lower per cent mortality for smaller litters.

Correlations were 0.79, 0.76 and -.70, respectively, between average 56-day weight and 154-day weight, 180-day weight and market age. The correlations between litter size at 56 days of age and litter size at 154 days and market were 0.95 and 0.92, respectively. These results indicate the importance of pre-weaning survival rate on post-weaning litter performance.

Negative correlations ($P < .01$) were found between market age and average weights at various ages. These correlations were: birth weight, -.32; 56-day weight, -.70; 154-day weight, -.87; and average daily gain from birth to market, -.86. This indicates that the heavier pigs at birth tended to reach market weights at a younger age. However, any factor that increased average daily gain during one or all periods of growth reduced the age at which the pigs reached market weight.

Correlations among various performance traits indicate that the number of pigs born alive per litter and the number per litter at 56 days were important factors in post-weaning litter size. Increases in average birth weight tended to be accompanied by increases in subsequent rate of gain and decreases in the age at which market weight was reached. Factors positively correlated with litter size and pig weight at birth and 56 days were also positively correlated with most other traits studied.

III. YEAR OF BIRTH

The effects of year of birth on the various production traits were shown in Tables V, VI and VII. The effects of year of birth were highly significant ($P < .01$) on the total number of pigs born, number of

TABLE V

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

		Mean Squares				
Source	df	Number farrowed	Number farrowed alive	Average birth weight	Number at 56 days	56-day weight
Year	3	26.84**	29.50**	1.57**	5.94	638.24**
Season	1	31.44*	32.42*	.68	182.20**	20.68
Age of dam	4	386.97**	260.50**	4.02**	103.03**	1105.95**
Breed of sire	3	5.22	7.60	.36	7.58	119.09*
Breed of dam	15	25.49**	30.75**	.31	30.37**	173.80**
Residual	834	5.90	5.61	.20	5.72	36.80

$^{*}P < .05$.

$^{**}P < .01$.

TABLE VI

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

		Mean Square				
Source	df	Number at 154 days	154-day weight	Number at market	180-day weight	Adjusted backfat probe
Year	3	12.39	28337.60**	6.58	41584.63**	.61**
Season	1	175.52**	2622.91**	163.55**	4506.67**	.49**
Age of dam	4	111.48**	12915.98**	124.17**	18688.77**	.01
Breed of sire	3	10.26	3777.41**	15.45	4335.10**	.63**
Breed of dam	15	37.27**	1912.62**	39.84**	2807.75**	.03
Residual	834	5.97	381.91	6.20	476.84	.02

*P < .05.

**P < .01.

TABLE VII

ANALYSIS OF VARIANCE OF YEAR, SEASON-OF-BIRTH, AGE-OF-DAM, BREED-OF-SIRE AND BREED-OF-DAM EFFECTS ON LITTER AND PIG PERFORMANCE TRAITS AT MARKET

		Mean Square				
Source	df	Market[a] weight	Total[a] gain birth-market	Market[b] age	Average[b] daily gain birth-market	Actual[b] backfat probe
Regression	1	1180.06**	926.59*	2347.32**	3.11**	3.10**
Year	3	1738.44**	1699.42**	21267.11**	.46**	.77**
Season	1	2203.22**	2151.54**	1020.69	.01	.69**
Age of dam	4	526.78*	491.98*	9768.18**	.19**	.01
Breed of sire	3	711.36**	675.24**	1775.39**	.05**	.71**
Breed of dam	15	277.66	223.35	1196.25**	.03**	.04**
Residual	833	143.99	141.53	286.42	.01	.02

[a]Market age held constant.

[b]Market weight held constant.

*P < .05.

**P < .01.

pigs born alive, birth weight, 56-day weight, 154-day weight, 180-day weight, average daily gain from birth to market, actual backfat probe and adjusted backfat probe. The year effects were significant ($P < .05$) for market weight, total gain from birth to market and market age. Least-squares constants for the various production traits for the different years are presented in Tables VIII, IX and X. There was a wide variation in the level of performance of the pigs during the various years. The highest production was in 1960 and the lowest in 1963.

Pigs farrowed in 1960 were 3.7 lb. heavier at 56 days of age, 24.5 lb. heavier at 154 days of age and 31.5 lb. heavier at 180 days of age than pigs farrowed in 1963. Average birth weight was less ($P < .05$) in 1962 than in any other years. The total number of pigs farrowed and the number farrowed alive per litter were significantly greater in 1960 than in the other years. Average pig weight at any given age was significantly less in 1963 than in any other year. Pigs farrowed in 1962 were heavier at 56, 154 and 180 days of age than pigs farrowed in 1961 ($P < .05$). These differences were 1.3, 4.7 and 7.7 lb., respectively.

Differences of 24.5 and 31.5 lb. in average weight at 154 and 180 days of age, respectively, between 1960 and 1963, were due in part to the effects of atrophic rhinitis. The severity of this disease was considered greatest in 1963 when a higher per cent of the pigs expressed visual symptoms of the disease. Birth weight or litter size at birth, 56 days or market age did not appear to be associated with the incidence of atrophic rhinitis.

TABLE VIII

LEAST-SQUARES CONSTANTS[a] OF YEAR AND SEASON-OF-BIRTH EFFECTS ON PRE-WEANING LITTER AND PIG PERFORMANCE TRAITS

Source	No. of litters	No. of pigs born	No. of pigs born alive	Average birth weight (lb.)	No. at 56 days	56-day weight (lb.)
Overall mean		10.430	9.754	2.976	7.897	29.443
Year						
1960	194	0.595^{d}	0.605^{d}	0.089^{e}	-.073	1.014^{ef}
1961	225	$-.179^{e}$	$-.213^{e}$	0.043^{e}	-.168	0.184^{e}
1962	217	$-.300^{e}$	$-.345^{e}$	$-.140^{d}$	-.014	1.471^{f}
1963	225	$-.116^{e}$	$-.047^{e}$	0.008^{e}	0.255	-2.669^{d}
Season						
Spring	454	0.196^{d}	0.199^{d}	0.029	0.472^{d}	-.159
Fall	407	$-.196^{e}$	$-.199^{e}$	-.029	$-.472^{e}$	0.159

[a]Constants are deviations from the least-squares means.

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

TABLE IX

LEAST-SQUARES CONSTANTS[a] OF YEAR AND SEASON-OF-BIRTH EFFECTS ON POST-WEANING LITTER AND PIG PERFORMANCE TRAITS

Source	No. of litters	No. at 154 days	154-day weight (lb.)	No. at market	180-day weight (lb.)	Adjusted backfat probe (in.)
Overall mean		7.509	139.096	7.206	174.993	1.378
Year						
1960	194	-.192	6.126^{ef}	-.112	9.521^{f}	0.020^{e}
1961	225	-.258	3.763^{e}	-.215	2.376^{e}	$-.050^{f}$
1962	217	0.133	8.462^{f}	0.117	10.051^{f}	$-.041^{f}$
1963	225	0.317	-18.351^{d}	0.210	-21.948^{d}	0.071^{d}
Season						
Spring	454	0.463^{d}	1.791^{d}	0.447^{d}	2.348^{d}	$-.024^{d}$
Fall	407	$-.463^{e}$	-1.791^{e}	$-.447^{e}$	-2.348^{e}	0.024^{e}

[a]Constants are deviations from the least-squares means.

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

TABLE X

LEAST SQUARES CONSTANTS[a] OF YEAR AND SEASON-OF-BIRTH EFFECTS ON LITTER AND PIG PERFORMANCE TRAITS AT MARKET

Source	No. of litters	Market[b] weight (lb.)	Total[b] gain birth-market (lb.)	Market[c] age (days)	Average[c] daily gain birth-market (lb.)	Actual[c] backfat probe (in.)
Overall mean		209.461	206.297	207.531	1.012	1.453
Year						
1960	194	2.416^{f}	2.424^{f}	-6.905^{d}	0.029^{e}	0.018^{f}
1961	225	-4.064^{d}	-4.077^{d}	-2.020^{e}	0.009^{e}	$-.055^{e}$
1962	217	$-.692^{e}$	$-.534^{e}$	-6.860^{d}	0.036^{e}	$-.047^{e}$
1963	225	2.340^{f}	2.187^{f}	15.785^{f}	$-.074^{d}$	0.084^{d}
Season						
Spring	454	1.644^{d}	1.625^{d}	1.127^{d}	$-.003^{d}$	$-.029^{d}$
Fall	407	-1.644^{e}	-1.625^{e}	-1.127^{d}	0.003^{d}	0.029^{e}
Regression		-1.070	-.062	-.139	0.005	0.005

[a]Constants are deviations from the least-squares means.

[b]Market age held constant. [c]Market weight held constant.

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

IV. SEASON OF BIRTH

Season of birth had a significant effect on the performance traits studied except birth weight, 56-day weight, market age and average daily gain (Tables V, VI and VII, pages 33, 34, and 35).

Spring-farrowed litters were significantly larger at birth, 56 days, 154 days and market age (Tables VIII, IX and X, pages 37, 38 and 39). The differences in average litter size were 0.4 pig at 56 days of age and 0.9 pig at 154 days and market age. This is in agreement with Lush and Molln (1942), who found that spring-farrowed litters had a higher number of pigs weaned per litter. Kernkamp (1943) and Black (1965) also reported higher pre-weaning mortality in fall-farrowed litters.

There were no significant differences in birth or 56-day weights between the spring- and fall-farrowed litters. However, the spring-farrowed litters were significantly heavier at 154 and 180 days of age (3.5 and 5.0 lb., respectively). An advantage in average pig weight at 154 and 180 days of age was observed for spring-farrowed pigs by Daniel (1965) and Robertson (1965) which is in agreement with these data. However, Lush and Molln (1942) and Robison (1946) reported a significant difference in average birth weight and 56-day weight in favor of spring-farrowed litters.

Generally, spring-farrowed litters were superior in performance when compared to fall litters. Variations between seasons were probably influenced in part by the availability of pasture. Spring pigs had access to pasture during most of the growing period, whereas less pasture was available for the fall-farrowed litters during the post-weaning period.

V. AGE OF DAM

Age of dam had a significant effect on all of the litter and pig performance traits studied except backfat probe. Least-squares constants for age-of-dam effects are presented in Tables XI, XII and XIII. These constants were generally negative for 1-year-old gilts and positive for 2-year-old sows.

Gilts farrowed significantly fewer total pigs per litter and fewer live pigs than sows. These advantages in litter size were 2.8, 3.0, 3.3 and 3.5 more total pigs and 1.9, 2.7, 2.5 and 2.4 more live pigs farrowed per litter by 1.5-, 2-, 2.5- and 3-year-old or older sows, respectively. Sows 1.5 years of age farrowed fewer pigs than sows 2, 2.5 and 3 years old or older. These differences were 1.3, 1.5 and 1.6 pigs, respectively. There were no significant differences in the total number of pigs born or the number of pigs born alive from sows 2, 2.5 and 3 years old or older. Olbyrcht (1943) reported consistently smaller litters from gilts than from older sows. Robison (1946) and Carmichael and Rice (1920) made similar observations in which they reported that 1.5- and 2-year-old sows farrowed significantly larger litters than gilts.

Litters farrowed by gilts contained significantly fewer pigs at 56, 154 days and at market age than those farrowed by older sows. The pigs farrowed by sows 1.5 years old and older were 0.3, 4.2, 15.8 and

TABLE XI

LEAST-SQUARES CONSTANTS[a] OF AGE-OF-DAM AND BREED-OF-SIRE EFFECTS ON PRE-WEANING LITTER AND PIG PERFORMANCE TRAITS

Source	No. of litters	No. of pigs born	No. of pigs born alive	Average birth weight (lb.)	No. at 56 days	56-day weight (lb.)
Overall mean		10.430	9.754	2.976	7.897	29.443
Age of dam						
1 year	425	-2.287[d]	-1.878[d]	-.233[d]	-1.136[d]	-3.751[d]
1.5 years	164	-.534[e]	-.069[e]	-.017[e]	0.212[e]	0.450[e]
2 years	107	0.741[f]	0.832[f]	0.110[ef]	0.605[e]	0.600[ef]
2.5 years	71	0.977[f]	0.621[f]	0.080[ef]	0.367[e]	0.193[e]
3 years[b]	94	1.103[f]	0.492[f]	0.060[f]	-.048[e]	2.508[f]
Breed[c] of sire						
H	317	0.236	0.339	-.048	-.007	-1.241[d]
D	266	0.079	-.256	0.000	-.353	0.043[e]
L	145	-.233	-.109	-.026	0.086	1.104[e]
Y	133	-.082	0.026	0.074	0.274	0.094[e]

[a]Constants are deviations from the least-squares means.

[b]Sows 3 years old and older are included. [c]Breed code as described on page 16.

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

TABLE XII

LEAST-SQUARES CONSTANTS[a] OF AGE-OF-DAM AND BREED-OF-SIRE EFFECTS ON ON POST-WEANING LITTER AND PIG PERFORMANCE TRAITS

Source	No. of litters	No. at 154 days	154-day weight (lb.)	No. at market	180-day weight (lb.)	Adjusted backfat probe (in.)
Overall mean		7.509	139.096	7.206	174.993	1.378
Age of dam						
1 year	425	-1.193[d]	-12.989[d]	-1.256[d]	-15.714[d]	-.004
1.5 years	164	0.224[e]	2.992[e]	0.233[e]	1.857[e]	0.002
2 years	107	0.570[e]	3.265[e]	0.632[e]	4.805[e]	-.013
2.5 years	71	0.409[e]	1.836[e]	0.371[e]	1.919[e]	0.000
3 years[b]	94	-.010[e]	4.896[e]	0.020[e]	7.133[e]	0.015
Breed[c] of sire						
H	317	-.045	-6.975[d]	-.123	-7.537[d]	-.070[d]
D	266	-.406	-.112[de]	-.466	-.729[e]	-.032[e]
L	145	0.054	6.201[f]	0.338	6.351[f]	0.007[f]
Y	133	0.297	0.886[e]	0.251	1.915[ef]	0.095[g]

[a]Constants are deviations from the least-squares means.

[b]Sows 3 years old and older are included. [c]Breed code as described in page 16.

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

TABLE XIII

LEAST-SQUARES CONSTANTS[a] OF AGE-OF-DAM AND BREED-OF-SIRE EFFECTS ON LITTER AND PIG PERFORMANCE TRAITS AT MARKET

Source	No. of litters	Market[b] weight (lb.)	Total[b] gain birth-market (lb.)	Market[c] age (days)	Average[c] daily gain birth-market (lb.)	Actual[c] backfat probe (in.)
Overall mean		209.461	206.297	207.531	1.012	1.453
Age of dam						
1 year	425	-1.487[d]	-1.328[d]	11.617[f]	-.050[d]	-.002
1.5 years	164	2.468[e]	2.463[e]	-.011[e]	-.002[e]	0.005
2 years	107	1.278[de]	1.196[de]	-3.456[de]	0.017[e]	-.010
2.5 years	71	-2.063[d]	-2.108[d]	-2.786[de]	0.009[de]	-.005
3 years[g]	94	-.196[d]	-.223[de]	-5.364[d]	0.026[e]	0.012
Breed[h] of sire						
H	317	-3.558[d]	-3.477[d]	3.921[f]	-.018	-.077[d]
D	266	1.148[e]	1.169[e]	1.432[ef]	-.010	-.034[de]
L	145	0.701[e]	0.705[e]	-4.920[d]	0.027	0.009[de]
Y	133	1.709[e]	1.603[e]	-.433[e]	0.001	0.102[e]

[a]Constants are deviations from the least-squares means.

[b]Market age held constant. [c]Market weight held constant.

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

[g]Sows 3 years old and older are included.

[h]Breed code as described on page 16.

17.6 lb. heavier at birth, 56, 154 and 180 days of age, respectively, than pigs farrowed by gilts.

Litters from 2-year-old sows contained 2.7, 1.7, 1.8 and 1.9 more pigs at birth, 56 days, 154 days and at market age, respectively, than litters raised by gilts. The average weight advantage at birth, 56, 154 and 180 days for pigs raised by 2-year-old sows over pigs raised by gilts was 0.3, 4.4, 16.2 and 20.5 lb., respectively.

Two-year-old sows were superior to either younger or older sows for the number of live pigs born and litter size at 56, 154 days and market age.

Sows 2.5 and 3 years of age or older farrowed more total pigs per litter than 2-year-old sows. However, the litters of the 2-year-sows contained more live pigs. Reports by most workers (Vestal, 1936; Gaines and Hazel, 1957; Weaver and Bogart, 1943; and Donald, 1939) are in general agreement that age of dam affects total litter performance.

Some workers have reported greater post-weaning gains of pigs farrowed by gilts as compared to pigs from mature sows. Baker, Hazel and Reinmiller (1943) concluded that mature sow litters maintained a distinct advantage in weight up to 112 days; thereafter the advantage decreased. These data indicate that mature sows produce heavier pigs than gilts and that the advantage continues to market age. These results are in agreement with reports by Robinson (1946) and Russell and Hutton (1938).

No significant differences were observed among age-of-dam groups for average backfat probes.

Litters farrowed by 2-year-old sows contained 1.9 more pigs at market, and the average 180-day pig weight was 21.5 lb. more than in litters farrowed by gilts ($P < .05$). When expressed as total litter performance, this was a difference of approximately 440 lb. more pork marketed per litter. These differences would suggest an advantage of a breeding plan in which 2-year-old sows could be kept in the herd. If only gilts are used, as is practiced by some producers, the average production per litter will be lower.

VI. BREED OF SIRE

Differences in the various performance traits among the breed-of-sire groups do not indicate the true effects of breed of sire since approximately 40 to 50 per cent of the litters sired by the Hampshire and Duroc boars were purebred while all the litters sired by the Landrace and Yorkshire boars were crossbred. Hence, these data have to be evaluated in view of the fact that the effect of crossbreeding in the pigs sired by the Yorkshire and Landrace boars was confounded with breed-of-sire effects. Winters _et_ _al_. (1936), Smith and Moorman (1959) and Carlisle _et_ _al_. (1964) indicated an advantage in both litter size and weight from crossbreeding. Comparisons may be made between the pigs sired by the Duroc and Hampshire boars and between those sired by the Yorkshire and Landrace boars.

These data show that the pigs sired by the Duroc boars were 1.2 lb. heavier at 56 days of age and 6.8 lb. heavier at 154 days of age than the pigs sired by the Hampshire boars. Pigs sired by the

Landrace boars were 5.4 lb. heavier at 154 days of age and had 0.09 in. less backfat at market weight than those sired by Yorkshire boars.

VII. BREED OF DAM

Breed of dam had a highly significant effect upon most of the litter and pig performance traits (Tables V, VI and VII, pages 33, 34 and 35). Least-squares constants for breed-of-dam effects on litter and pig performance traits are shown in Table XIV, XV and XVI.

Generally, the least-squares constants were negative for the purebred and two-breed-cross dams and positive or near the mean for the three-breed and rotational-cross dams.

Hampshire and YD dams farrowed significantly fewer total and live pigs than LH, LD, LHD, DYHD or HD sows. Litters from Hampshire dams contained significantly fewer pigs at 56 and 154 days than litters farrowed by most of the other groups. All other groups had significantly larger litters at market than Hampshire dams.

The DHD, DLDH, YH and HDHD dams raised pigs that were significantly heavier at 56 days than those raised by LH, D, HD or H dams. At 154 and 180 days of age, pigs in most of the groups were significantly heavier than pigs raised by the Hampshire dams. These data indicate that the Hampshire dams were not equal to either the purebred Duroc or the crossbred sows in maternal ability. No significant differences were detected for breed-of-dam effects on average birth weight or total gain from birth to market. The breed-of-dam effects were highly significant for number of pigs farrowed; number of pigs farrowed

TABLE XIV

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

Breed[b]	No. of litters	No. of pigs born	No. of pigs born alive	Average birth weight (lb.)	No. at 56 days	56-day weight (lb.)
Overall mean		10.430	9.754	2.976	7.897	29.443
H	228	-1.207^{d}	-1.512^{dk}	-.052	-1.752^{d}	-3.623^{d}
D	264	$-.276^{defg}$	$-.427^{efhi}$	-.085	$-.373^{eh}$	-2.546^{de}
HD	85	0.880^{h}	0.824^{hj}	-.196	$-.010^{ej}$	-3.221^{de}
LD	48	0.449^{eh}	0.229^{fij}	0.133	0.023^{ej}	$-.343^{h}$
LH	50	0.251^{fh}	0.594^{ghj}	0.009	0.847^{fij}	-2.165^{def}
YD	39	-1.239^{dg}	-1.072^{de}	0.090	$-.890^{e}$	1.815^{gh}
YH	24	$-.981^{dfg}$	$-.632^{def}$	-.097	$-.421^{ehi}$	0.416^{fh}
DHD	10	0.642^{gh}	$-.004^{fijk}$	0.007	0.304^{ej}	5.129^{gh}
HDHD	23	$-.044^{dh}$	0.293^{dj}	0.057	$-.177^{ej}$	0.930^{gh}
DHDHD	10	0.126^{dh}	0.294^{ej}	0.197	0.296^{ej}	$-.471^{dh}$
YHD	9	0.136^{dh}	0.721^{ej}	0.094	1.397^{fhj}	-1.010^{defg}
DYHD	15	0.749^{fh}	0.613^{ej}	0.016	0.731^{ej}	0.417^{eh}
HDYHD	15	0.627^{dh}	0.586^{dj}	-.263	0.633^{dej}	$-.051^{dh}$
LHD	16	0.591^{fh}	0.844^{fj}	0.117	0.900^{fghj}	1.401^{fh}
DLHD	23	$-.659^{dfeg}$	$-.872^{def}$	0.105	$-.723^{deg}$	3.447^{h}
HDLHD	12	$-.045^{dh}$	$-.479^{defgh}$	-.132	$-.785^{def}$	$-.125^{dh}$

[a]Constants are deviations from the least-squares means.

[b]Breed code as described on page 16.

[c,d,e,f,g,h,i,j,k]Constants in this class of effects not superscripted with the same letter are significantly different ($P < .05$).

TABLE XV

LEAST-SQUARES CONSTANTS[a] OF BREED-OF-DAM EFFECTS ON POST-WEANING LITTER AND PIG PERFORMANCE TRAITS

Breed[b]	No. of litters	No. at 154 days	154-day weight (lb.)	No. at market	180-day weight (lb.)	Adjusted backfat probe (in.)
Overall mean		7.509	139.036	7.206	174.993	1.378
H	228	-2.007^{d}	-12.154^{d}	-2.104^{d}	-14.996^{d}	0.004
D	264	$-.506^{e}$	-4.433^{e}	$-.563^{ef}$	-5.309^{eh}	-.017
HD	85	$-.201^{eh}$	-6.371^{e}	$-.312^{ef}$	-8.802^{eg}	-.049
LD	48	0.104^{ei}	4.905^{fh}	0.060^{efi}	4.314^{fi}	-.005
LH	50	0.815^{fhi}	-1.610^{eh}	0.773^{hgik}	-2.274^{ef}	-.036
YD	39	$-.786^{de}$	7.771^{gh}	$-.733^{efg}$	8.487^{fi}	0.037
YH	24	$-.310^{e}$	-4.690^{def}	$-.289^{efi}$	$-.251^{ei}$	0.028
DHD	10	0.405^{ei}	10.870^{fh}	0.580^{fk}	10.545^{fhi}	0.009
HDHD	23	$-.249^{eh}$	-2.627^{deh}	$-.198^{efij}$	2.207^{ei}	0.044
DHDHD	10	0.369^{ei}	6.412^{eh}	0.521^{ek}	7.537^{fghi}	0.026
YHD	9	1.706^{fhi}	-8.627^{egf}	1.744^{jk}	-9.671^{def}	0.058
DYHD	15	0.633^{ei}	4.636^{eh}	0.697^{fk}	3.648^{ei}	0.049
HDYHD	15	0.650^{ei}	-2.258^{deh}	0.880^{ek}	-9.079^{def}	-.037
LHD	16	0.941^{fghi}	2.104^{eh}	0.761^{ek}	4.810^{fhi}	-.050
DLHD	23	$-.772^{deg}$	9.202^{h}	$-.872^{ef}$	14.010^{i}	-.008
HDLHD	12	$-.792^{def}$	-3.130^{deh}	$-.945^{eh}$	-5.176^{def}	-.058

[a]Constants are deviations from the least-squares means.

[b]Breed code as described on page 16.

[c,d,e,f,g,h,i,j,k]Constants in this class of effects not superscripted with the same letter are significantly different ($P < .05$).

TABLE XVI

LEAST-SQUARES CONSTANTS[a] OF BREED-OF-DAM EFFECTS ON LITTER AND PIG PERFORMANCE TRAITS AT MARKET

Breed[b]	No. of litters	Market[c] weight (lb.)	Total[c] gain birth-market (lb.)	Market[d] age (days)	Average[d] daily gain birth-market (lb.)	Actual[d] backfat probe (in.)
Overall mean		209.461	206.297	207.531	1.012	1.453
H	228	-2.270	-2.396	10.591^{e}	-.054^{e}	0.008^{fikl}
D	264	-.628	-.574	3.107^{h}	-.013^{fgh}	-.019^{ej}
HD	85	0.062	0.129	7.019^{efg}	-.034^{f}	-.049^{eh}
LD	48	4.776	4.555	-.899^{hk}	0.000^{gj}	0.004^{ek}
LH	50	0.767	0.744	0.451^{hk}	0.001^{gj}	-.039^{ei}
YD	39	2.205	2.164	-4.414^{ijk}	0.022^{hij}	0.048^{fk}
YH	24	-3.271	-3.110	-2.957^{hk}	0.020^{gj}	0.036^{fijkl}
DHD	10	5.013	4.895	-4.656^{ihk}	0.023^{fj}	0.013^{ek}
HDHD	23	0.149	0.132	-2.743^{hk}	0.013^{gj}	0.049^{fjkl}
DHDHD	10	2.235	2.097	-5.086^{ghi}	0.019^{fj}	0.028^{ek}
YHD	9	0.406	0.287	6.696^{efhi}	-.031^{gi}	0.063^{fghjkl}
DYHD	15	3.155	3.159	-2.319^{ghk}	0.005^{fj}	0.048^{ghijkl}
HDYHD	15	-11.176	-10.819	3.822^{efhj}	-.014^{fgh}	-.066^{el}
LHD	16	1.077	0.982	-4.344^{hk}	0.022^{gj}	-.060^{ef}
DLHD	23	2.763	2.764	-6.680^{ijk}	0.035^{hj}	-.006^{ek}
HDLHD	12	-5.263	-5.009	2.402^{eghk}	-.014^{fgh}	-.058^{eg}

[a]Constants are deviations from the least-squares means. [b]Breed code as described on page 16.

[c]Market age held constant. [d]Market weight held constant.

[e,f,g,h,i,j,k,l]Constants in this class of effects not superscripted with the same letter are significantly different ($P < .05$).

alive; and litter size and average weight of the pigs at 56, 154 and 180 days of age.

The general pattern of the least-squares constants for breed of dam indicates that the level of performance for most traits increased as the number of breeds in the crossbreeding program increased up to three- and four-breed crosses. Crossbreeding in the sows beyond three- and four-breed crosses did not result in further increases in average litter and pig performance with respect to most traits. Results from these data are supported by reports of several workers who noted that hybrid vigor may be obtained if three or four breeds are used in producing crossbred pigs. Winters et al. (1936) compared three types of crossbreds and found that the three-breed crosses had the greatest advantage in most performance traits. Carlisle et al. (1964) noted that the four-breed crosses produced the largest litters at farrowing.

VIII. BREED OF PIG

The effects of breed of pig were significant for all traits studied as shown in Tables XVII, XVIII and XIX. Least-squares constants of breed-of-pig effects on litter and pig performance traits are presented in Tables XX, XXI and XXII.

Hampshire versus Duroc. Purebred Duroc litters were superior to Hampshire litters for most performance traits studied ($P < .05$). Purebred Duroc litters were 1.1 pig larger than Hampshire litters at 56 days of age and 1.3 pigs larger at market age. The Duroc pigs were

TABLE XVII

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

Source	df	Mean Square				
		Number farrowed	Number farrowed alive	Average birth weight	Number at 56 days	56-day weight
Year	3	26.34**	29.28**	1.47**	7.45	624.34**
Season	1	33.47*	32.33*	.56	169.70**	34.18
Age of dam	4	376.66**	252.95**	3.79**	89.21**	1082.94**
Breed of pig	23	18.95**	21.03**	.32*	24.03**	144.54**
Residual	829	5.91	5.63	.20	5.68	36.41

*$p < .05$.

**$p < .01$.

TABLE XVIII

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

		Mean Square				
Source	df	Number at 154 days	154-day weight	Number at market	180-day weight	Adjusted backfat probe
Year	3	14.38	27885.72**	8.88	41086.34**	.59**
Season	1	162.48**	2297.38*	150.13**	3998.59**	.50**
Age of dam	4	97.13**	12834.40**	109.38**	18331.28**	.01
Breed of pig	23	29.32**	2069.20**	31.48**	2846.37**	.12**
Residual	829	5.91	370.96	6.13	462.52	.02

*$P < .05$.

**$P < .01$.

TABLE XIX

ANALYSIS OF VARIANCE OF YEAR, SEASON-OF-BIRTH, AGE-OF-DAM AND BREED-OF-PIG EFFECTS ON LITTER AND PIG PERFORMANCE TRAITS AT MARKET

		Mean Square				
Source	df	Market[a] weight	Total[a] gain birth-market	Market[b] age	Average[b] daily gain birth-market	Actual[b] backfat probe
Regression	1	801.86*	604.68*	1570.51*	2.93**	2.91**
Year	3	1622.30**	1589.67**	21009.96**	.46**	.75**
Season	1	2032.17**	1982.51**	1109.60*	.01	.70**
Age of dam	4	458.96**	422.19*	9648.75**	.19**	.01
Breed of pig	23	299.15**	259.72**	1234.30**	.03**	.13**
Residual	828	143.17	140.73	280.40	.01	.02

[a]Market age held constant.

[b]Market weight held constant.

$*P < .05$.

$**P < .01$.

TABLE XX

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

Breed[b]	No. of litters	No. of pigs born	No. of pigs born alive	Average birth weight (lb.)	No. at 56 days	56-day weight (lb.)
Overall mean		10.430	9.754	2.976	7.897	29.443
H	125	$-.734^{eif}$	$-.964^{deg}$	$-.105^{de}$	-1.543^{d}	-4.480^{h}
D	125	$-.073^{ijl}$	$-.527^{df}$	$-.082^{def}$	$-.394^{egi}$	-2.126^{gh}
H x D	47	$-.310^{ifj}$	$-.056^{gf}$	$-.035^{def}$	0.152^{fhik}	-1.666^{efh}
D x H	6	-1.745^{dig}	-1.457^{deghm}	0.332^{ef}	0.151^{dhik}	4.334^{de}
L x H	49	-1.467^{d}	-1.574^{d}	0.019^{ef}	-1.241^{dg}	$-.778^{efh}$
L x D	49	$-.097^{ijl}$	$-.119^{gfj}$	$-.128^{def}$	$-.144^{fgik}$	$-.853^{efh}$
Y x H	48	-1.335^{df}	-1.356^{de}	$-.003^{ef}$	-1.369^{de}	-3.213^{h}
Y x D	43	$-.289^{ifj}$	$-.380^{defj}$	0.034^{ef}	$-.030^{fhik}$	-1.281^{efh}
L x HD	35	0.456^{ghjl}	0.663^{hfi}	$-.240^{d}$	0.345^{fhik}	-1.932^{efh}
Y x HD	37	1.086^{kl}	1.207^{jim}	$-.054^{def}$	1.020^{jk}	-1.742^{efh}
H x LD	48	0.778^{jlg}	0.726^{hfi}	0.110^{f}	0.305^{fhik}	$-.681^{efh}$
D x LH	50	0.421^{ijl}	0.494^{hfi}	0.035^{ef}	0.779^{jk}	-1.226^{efh}

TABLE XX (continued)

Breed[b]	No. of litters	No. of pigs born	No. of pigs born alive	Average birth weight (lb.)	No. at 56 days	56-day weight (lb.)
H x YD	39	$-.905^{di}$	$-.527^{def}$	0.066^{ef}	$-.598^{egk}$	1.438^{df}
D x YH	24	$-.813^{dhi}$	$-.730^{degh}$	$-.070^{def}$	$-.474^{dhig}$	1.368^{df}
D x HD	13	1.186^{hjl}	0.708^{gfi}	$-.154^{def}$	-1.364^{def}	1.240^{dfh}
H x DHD	10	0.958^{ijl}	0.499^{defi}	$-.010^{def}$	0.634^{egik}	4.914^{d}
D x HDHD	23	0.133^{ijl}	0.193^{efi}	0.080^{ef}	$-.262^{egik}$	1.833^{df}
H x DHDHD	10	0.465^{djl}	0.790^{gfi}	0.169^{ef}	0.545^{egik}	$-.903^{dfh}$
D x YHD	9	0.298^{djl}	0.629^{efi}	0.125^{ef}	1.375^{hik}	0.043^{dfh}
H x DYHD	15	1.084^{hjlg}	1.108^{ifh}	$-.009^{def}$	0.987^{hik}	0.031^{dfh}
Y x HDYHD	5	0.643^{dejl}	0.771^{defi}	$-.167^{def}$	1.170^{egik}	0.880^{dfh}
D x LHD	16	0.748^{ijl}	0.752^{gfi}	0.149^{ef}	0.885^{hik}	2.478^{df}
H x DLHD	23	$-.320^{djl}$	$-.376^{def}$	0.079^{ef}	$-.474^{dhij}$	3.049^{d}
L x HDLHD	12	$-.169^{dejkl}$	$-.429^{def}$	$-.141^{def}$	$-.455^{dhij}$	1.753^{dfg}

[a]Constants are deviations from the least-squares means.

[b]Breed code as described on page 16.

[d,e,f,g,h,i,j,k,l]Constants in this class of effects not superscripted with the same letter are significantly different ($P<.05$).

TABLE XXI

LEAST-SQUARES CONSTANTS[a] OF BREED-OF-PIG EFFECTS ON POST-WEANING LITTER AND PIG PERFORMANCE TRAITS

Breed[b]	No. of litters	No. at 154 days	154-day weight (lb.)	No. at market	180-day weight (lb.)	Adjusted backfat probe (in.)
Overall mean		7.509	139.096	7.206	174.993	1.378
H	125	-1.837^{dl}	-19.765^{d}	-2.010^{d}	-23.075^{e}	-.058^{ij}
D	125	-.562^{fgl}	-4.486^{ef}	-.697^{fi}	-5.151^{df}	-.024^{gj}
H x D	47	0.179^{fgk}	-1.580^{eh}	0.133^{ik}	-.386^{dh}	-.026^{gj}
D x H	6	0.234^{dgk}	11.254^{fh}	0.405^{dfk}	11.138^{fh}	0.004^{efj}
L x H	49	-1.312^{dgh}	1.419^{fh}	-1.148^{df}	0.668^{fh}	0.043^{ef}
L x D	49	-.080^{fgk}	3.948^{gh}	0.117^{ik}	2.888^{fh}	-.017^{gj}
Y x H	48	-1.506^{de}	-9.264^{e}	-1.645^{de}	-10.030^{d}	0.150^{d}
Y x D	43	-.215^{fgk}	-2.932^{eh}	-.283^{fk}	-2.905^{dh}	0.085^{e}
L x HD	35	0.105^{fgk}	-3.881^{efg}	0.883^{gk}	-5.455^{df}	0.009^{fj}
Y x HD	37	1.027^{hk}	0.191^{eh}	0.936^{k}	0.322^{dh}	0.056^{ef}
H x LD	48	0.407^{fgk}	0.409^{fh}	0.314^{ik}	0.040^{dh}	-.053^{hj}
D x LH	50	0.752^{hik}	0.773^{fh}	0.681^{gk}	0.283^{fh}	-.046^{gj}

TABLE XXI (continued)

Breed[b]	No. of litters	No. at 154 days	154-day weight (lb.)	No. at market	180-day weight (lb.)	Adjusted backfat probe (in.)
H x YD	39	$-.478^{egi}$	3.049^{fh}	$-.477^{efk}$	3.985^{fh}	$-.011^{fj}$
D x YH	24	$-.359^{egk}$	-2.349^{eh}	$-.369^{efk}$	2.272^{dh}	0.018^{efgh}
D x HD	13	-1.374^{def}	5.850^{fh}	-1.256^{dfi}	1.818^{dh}	$-.094^{j}$
H x DHD	10	0.757^{fgh}	6.592^{eh}	0.887^{fk}	6.516^{dh}	$-.039^{fj}$
D x HDHD	23	$-.332^{egk}$	$-.384^{eh}$	$-.311^{efk}$	4.585^{fh}	0.033^{efg}
H x DHDHD	10	0.636^{fgk}	1.735^{eh}	0.738^{fk}	3.051^{db}	$-.022^{fj}$
D x YHD	9	1.691^{hik}	-6.091^{efg}	1.702^{k}	-6.950^{dfg}	0.048^{defghi}
H x DYHD	15	0.905^{gk}	0.002^{eh}	0.921^{ik}	$-.812^{dh}$	0.011^{efj}
Y x HDYHD	5	1.268^{egk}	0.993^{deh}	1.480^{fk}	-4.035^{dh}	0.082^{defghi}
D x LHD	16	0.934^{gk}	4.708^{fh}	0.728^{ik}	7.613^{fh}	$-.060^{gj}$
H x DLHD	23	$-.506^{egh}$	4.521^{fh}	$-.655^{efig}$	9.487^{gh}	$-.057^{gj}$
L x HDLHD	12	$-.334^{dgk}$	5.288^{eh}	-1.074^{dfig}	4.133^{dh}	$-.022^{efj}$

[a]Constants are deviations from the least-squares means.

[b]Breed code as described on page 16.

[c,d,e,f,g,h,i,j,k,l]Constants in this class of effects not superscripted with the same letter are significantly different ($P < .05$).

TABLE XXII

LEAST-SQUARES CONSTANTS[a] OF BREED-OF-PIG EFFECTS ON LITTER AND PIG PERFORMANCE TRAITS AT MARKET

Breed[b]	No. of litters	Market[c] weight (lb.)	Total[c] gain birth-market (lb.)	Market[d] age (days)	Average[d] daily gain birth-market (lb.)	Actual[d] backfat probe (in.)
Overall mean		209.461	206.297	207.531	1.012	1.453
H	125	-7.084[e]	-7.119[e]	14.795[e]	-.072[e]	-.063[gjmp]
D	125	0.007[fg]	0.051[fg]	3.777[fg]	-.021[fg]	-.028[jkp]
H x D	47	-.537[fg]	-.491[fg]	-.967[g]	0.005[gi]	-.029[gjkp]
D x H	6	6.377[fg]	6.301[fg]	-7.210[fg]	0.042[gi]	0.019[fklm]
L x H	49	0.033[fg]	-.254[fg]	-.107[g]	-.002[gi]	0.049[fh]
L x D	49	-.649[fg]	-.500[fg]	-4.031[g]	0.028[gi]	-.018[kp]
Y x H	48	0.709[fg]	0.541[fg]	8.013[f]	-.045[f]	-.163[e]
Y x D	43	0.735[fg]	0.657[fg]	2.986[fg]	-.012[fi]	0.087[f]
L x HD	35	0.823[fg]	0.935[fg]	4.546[fg]	-.021[fi]	0.013[fkl]
Y x HD	37	1.619[fg]	1.476[fg]	0.795[fg]	-.004[gi]	0.061[fg]
H x LD	48	1.522[fg]	1.363[fg]	0.724[fg]	-.006[gi]	-.049[jkp]
D x LH	50	2.240[fg]	2.219[fg]	-.453[g]	0.002[gi]	-.050[jlp]

TABLE XXII (continued)

Breed[b]	No. of litters	Market weight[c] (lb.)	Total gain birth-market[c] (lb.)	Market age[d] (days)	Average daily gain birth-market[d] (lb.)	Actual backfat probe[d] (in.)
H x YD	39	-1.099^{fg}	-1.079^{fg}	-2.607^{g}	0.014^{fi}	-.006^{ghilo}
D x YH	24	-1.779^{eg}	-1.615^{fg}	-3.757^{g}	0.020^{gi}	0.025^{fkl}
D x HD	13	4.245^{fg}	4.418^{fg}	1.725^{fg}	-.008^{fi}	-.095^{imop}
H x DHD	10	1.889^{fg}	1.836^{eg}	-3.260^{fg}	0.018^{gi}	-.041^{ghkp}
D x HDHD	23	1.602^{eg}	1.587^{fg}	-3.506^{g}	0.013^{gi}	0.038^{fk}
H x DHDHD	10	-1.041^{eg}	-1.117^{eg}	-3.260^{g}	0.011^{fi}	-.026^{fkp}
H x YHD	9	1.860^{eg}	1.748^{eg}	5.658^{efg}	-.029^{efgh}	0.053^{fhj}
H x DYHD	15	-.136^{fg}	-.067^{eg}	-.524^{fg}	-.002^{fi}	-.006^{fghkp}
Y x HDYHD	5	-9.223^{ef}	-8.988^{ef}	1.449^{efg}	-.003^{efi}	0.058^{efhij}
D x LHD	16	2.694^{fg}	2.604^{fg}	-5.479^{g}	0.025^{gi}	-.070^{jlp}
H x DLHD	23	-.502^{eg}	-.438^{fg}	-4.839^{g}	0.027^{hi}	-.061^{jlp}
L x HDLHD	12	-4.306^{eg}	-4.068^{eg}	-4.469^{fg}	0.020^{gi}	-.024^{hkp}
Regression		-.059	-.051	-.115	0.005	0.005

[a]Constants are deviations from the least-squares means.

[b]Breed code as described on page 16.

[c]Market age held constant. [d]Market weight held constant.

[e,f,g,h,i,j,k,l,m,n,o,p]Constants in this class of effects not superscripted with the same letter are significantly different ($P < .05$).

15 lb. heavier at 154 days and 18 lb. heavier at 180 days of age. Duroc pigs gained faster and reached market weight 11 days younger than Hampshire pigs. Average backfat thickness was 0.03 in. less for the Hampshire pigs than for the Duroc pigs. Robertson (1965) and Daniel (1965) reported that Duroc sows were superior to Hampshire sows in maternal ability and that Duroc pigs were superior in growth rate to Hampshire pigs.

Two-breed crosses. Least-squares constants (Tables XX, XXI and XXII, pages 55, 57 and 59) show that the two-breed-cross pigs were significantly heavier at 154 and 180 days of age than the purebred Hampshire pigs. Pigs in the DH litters were 7.5 lb. heavier at 56 days of age than the YH pigs. The DH, LH and LD pigs were significantly heavier than the YH pigs at 154 and 180 days of age.

The litters of HD, YD and LD pigs were larger at 56, 154 days and at market age than the Hampshire litters ($P < .05$). Considerable variation in litter size was observed among the two-breed crosses at various ages. The HD litters were significantly larger than LH and LD litters at birth, 56 days and market age. The LD, YH and HD litters were larger than the YH litters at 154 days of age.

Average backfat thickness of the HD pigs was significantly less than that of the YH, YD and LH pigs.

Least-squares constants for the two-breed cross performance traits indicate Duroc, Landrace and Hampshire boars used in this study were superior to the Yorkshire boars when mated to purebred Hampshire and Duroc sows. Considering the number of pigs and their weight at 154 and 180 days, all other two-breed crosses exceeded YH pigs in total performance.

Three-breed crosses. Average pig weight for each of the three-breed-cross groups was greater at 56, 154 and 180 days of age than weights of the purebred Hampshire pigs ($P<.05$). The HYD and DYH pigs were 3.5 lb. heavier than the purebred Duroc pigs at 56 days of age.

The pre-weaning mortality rate of the DHD litters was 52 per cent. This is extremely high when compared to the other breed-of-pig groups. The YHD litters contained 1.9 more pigs at birth than the HYD or DYH litters and 2.2 more pigs than the DHD litters at market.

Backfat thickness of the DHD pigs was significantly less than that of the YHD and DYH pigs.

Differences in average daily gain from birth to market and differences in average weight at 56, 154 and 180 days between the various three-breed crosses were not significant.

Generally, the least-squares constants indicate that the three-breed crosses exceeded the purebreds and two-breed crosses in litter and pig performance. Least-squares constants were negative for most traits for the purebred litters and positive for most of the three-breed crosses.

The results of this study are in close agreement with those reported by Smith, Moorman and McLaren (1960), Winters et al. (1936), Daniel (1965) and Robertson (1965), who reported that the performance of the three-breed generation exceeded the performance of the purebreds and the two-breed crosses in litter size and average pig weight at market age.

Four-way crosses. Differences between the four-way crosses (HDHD, HLHD and HYHD) with respect to the various litter and pig performance traits were not significant. Litters of DYHD were 1.0 pigs larger than the purebred Hampshire litters at birth. The HDHD and DYHD litters were significantly larger at 56 days and market age than either the purebred Hampshire or purebred Duroc litters. The four-way cross litters reached market weight from 11.2 to 17.0 days younger than Hampshire litters.

Generally, the differences in market age, average daily gain and litter size at market between the four-way-cross litters and the two- or three-breed cross litters were not significant.

Five-way crosses. Three five-way crosses (HDYHD, DHDHD and HDLHD) were compared. Least squares constants presented in Tables XX, XXI and XXII, pages 55, 57 and 59 indicate that the performance of the five-way crosses were similar for most traits. A comparison of these constants shows that differences with respect to various performance traits, except backfat thickness, were not significant. The average backfat thickness of the HDLHD pigs was significantly less than that of the DHDHD pigs. The various five-way-cross litters reached market weight from 15.3 to 19.6 days younger than the purebred Hampshire litters.

Six-way crosses. Little variation was observed between the three six-way crosses (YHDYHD, HDHDHD and LHDLHD) for any of the traits studied. Differences in least-squares constants with respect to the various traits were not significant.

Comparison of these constants for the six-way crosses with the constants for the purebreds, two-breed, three-breed and four-way crosses indicate that the six-way-cross litters were superior to the purebred and the two-breed-cross litters with respect to most performance traits and that the advantage of crossbreeding tended to decline after three- or four-way crosses were reached.

IX. ROTATIONAL CROSSES

Litters of the breed crosses in the rotational crossbreeding part of this study were included in the least-squares analysis of breed-of-pig effects. The least-squares constants for each breed of pig in the rotational crosses were arranged in order of their sequence in the various rotations and presented in Tables XXIII through XXXI. These least-squares constants represent the deviation from the overall mean (Table III, page 29).

Hampshire-Duroc rotational cross. Least-squares constants for the performance traits of all crosses in the Hampshire-Duroc rotational cross are presented in Tables XXIII, XXIV and XXV, pages 65, 66 and 67. There was very little difference in the performance traits between the various crosses in the rotation. The HDHD cross litters had more pigs

TABLE XXIII

LEAST-SQUARES CONSTANTS[a] OF HAMPSHIRE-DUROC, TWO-BREED ROTATIONAL-CROSS EFFECTS ON PRE-WEANING LITTER AND PIG PERFORMANCE TRAITS

Breed[b]	Number of pigs born	Number born alive	Average birth wt. (lb.)	Number at 56 days	56-day weight (lb.)
Overall mean	10.430	9.754	2.976	7.897	29.443
D	$-.073^{c}$	$-.527^{c}$	$-.082^{c}$	$-.394^{c}$	-2.126^{cd}
H x D	$-.310^{c}$	$-.056^{c}$	$-.035^{c}$	0.152^{c}	-1.666^{cd}
D x HD	1.186^{d}	0.708^{c}	$-.154^{c}$	-1.364^{c}	-1.240^{ce}
H x DHD	0.958^{cd}	0.499^{c}	$-.010^{c}$	0.634^{c}	4.914^{e}
D x HDHD	0.133^{cd}	0.193^{c}	0.080^{c}	$-.262^{c}$	1.833^{de}
H x DHDHD	0.465^{cd}	0.790^{c}	0.169^{c}	0.545^{c}	$-.903^{de}$

[a]Constants are deviations from the least-squares means.

[b]Breed code as described on page 16.

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

TABLE XXIV

LEAST-SQUARES CONSTANTS[a] OF HAMPSHIRE-DUROC, TWO-BREED ROTATIONAL-CROSS EFFECTS ON POST-WEANING LITTER AND PIG PERFORMANCE TRAITS

Breed[b]	Number at 154 days	154-day weight (lb.)	Number at market	180-day weight (lb.)	Adjusted backfat probe (in.)
Overall mean	7.509	139.096	7.206	174.993	1.378
D	$-.562^{c}$	-4.486^{c}	$-.697^{c}$	-5.151^{c}	$-.024^{cd}$
H x D	0.179^{c}	-1.580^{c}	0.133^{c}	$-.386^{c}$	$-.026^{cd}$
D x HD	-1.374^{c}	5.850^{c}	-1.256^{c}	1.818^{c}	$-.094^{c}$
H x DHD	0.757^{c}	6.592^{c}	0.887^{c}	6.516^{c}	$-.039^{cd}$
D x HDHD	$-.332^{c}$	$-.384^{c}$	$-.311^{c}$	4.585^{c}	0.033^{d}
H x DHDHD	0.636^{c}	1.735^{c}	0.738^{c}	3.051^{c}	$-.022^{cd}$

[a]Constants are deviations from the least-squares means.

[b]Breed code as described on page 16.

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

TABLE XXV

LEAST-SQUARES CONSTANTS[a] OF HAMPSHIRE-DUROC, TWO-BREED ROTATIONAL CROSS EFFECTS ON LITTER AND PIG PERFORMANCE TRAITS AT MARKET

Breed[b]	Market[c] weight (lb.)	Total[c] gain birth-market (lb.)	Market[d] age (days)	Average[d] daily gain birth-market (lb.)	Actual[d] backfat probe (in.)
Overall mean	209.461	206.297	207.531	1.012	1.453
D	0.007[e]	0.051[e]	3.777[e]	-.021[e]	-.028[ef]
H x D	-.537[e]	-.491[e]	-0.967[e]	0.005[e]	-.029[ef]
D x HD	4.245[e]	4.418[e]	1.725[e]	-.008[e]	-.095[e]
H x DHD	1.889[e]	1.836[e]	-3.260[e]	0.018[e]	-.041[ef]
D x HDHD	1.602[e]	1.587[e]	-3.506[e]	0.013[e]	0.038[f]
H x DHDHD	-1.041[e]	-1.117[e]	-3.260[e]	0.011[e]	-.026[ef]

[a]Constants are deviations from the least-squares means.

[b]Breed code as described on page 16. [c]Market age held constant.

[d]Market weight held constant.

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

TABLE XXVI

LEAST-SQUARES CONSTANTS[a] OF YORKSHIRE-HAMPSHIRE-DUROC, THREE-BREED ROTATIONAL-CROSS EFFECTS ON PRE-WEANING LITTER AND PIG PERFORMANCE TRAITS

Breed[b]	Number of pigs born	Number born alive	Average birth weight (lb.)	Number at 56 days	56-day weight (lb.)
Overall mean	10.430	9.754	2.976	7.897	29.443
D	-.073[cd]	-.527[c]	-.082[c]	-.394[c]	-2.126[c]
H x D	-.310[c]	-.056[c]	-.035[c]	0.152[cd]	-1.666[c]
Y x HD	1.086[d]	1.207[d]	-.054[c]	1.020[d]	-1.742[c]
D x YHD	0.298[cd]	0.629[cd]	0.125[c]	1.375[cd]	0.043[c]
H x DYHD	1.084[cd]	1.108[cd]	-.009[c]	0.987[cd]	0.031[c]
Y x HDYHD	0.643[cd]	0.771[cd]	-.167[c]	1.170[cd]	0.880[c]

[a]Constants are deviations from the least-squares means.

[b]Breed code as described on page 16.

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

TABLE XXVII

LEAST-SQUARES CONSTANTS[a] OF YORKSHIRE-HAMPSHIRE-DUROC, THREE-BREED ROTATIONAL-CROSS EFFECTS ON POST-WEANING LITTER AND PIG PERFORMANCE TRAITS

Breed[b]	Number at 154 days	154-day weight (lb.)	Number at market	180-day weight (lb.)	Adjusted backfat probe (in.)
Overall mean	7.509	139.096	7.206	114.993	1.378
D	-.562[c]	-4.486[c]	-.697[c]	-5.151[c]	-.024[c]
H x D	0.179[cd]	-1.580[c]	0.133[cd]	-.386[c]	-.026[c]
Y x HD	1.027[d]	0.191[c]	0.936[d]	0.322[c]	0.056[d]
D x YHD	1.691[d]	-6.091[c]	1.702[d]	-6.950[c]	0.048[cd]
H x DYHD	0.905[cd]	0.002[c]	0.921[cd]	-.812[c]	0.011[cd]
Y x HDYHD	1.268[cd]	0.933[c]	1.480[cd]	-4.035[c]	0.082[cd]

[a]Constants are deviations from the least-squares means.

[b]Breed code as described on page 16.

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

TABLE XXVIII

LEAST-SQUARES CONSTANTS[a] OF YORKSHIRE-HAMPSHIRE-DUROC, THREE-BREED ROTATIONAL CROSS EFFECTS ON LITTER AND PIG PERFORMANCE TRAITS AT MARKET

Breed[b]	Market[c] weight (lb.)	Total[c] gain birth-market (lb.)	Market[d] age (days)	Average[d] daily gain birth-market (lb.)	Actual[d] backfat probe (in.)
Overall mean	209.461	206.297	207.531	1.012	1.453
D	0.007[e]	0.051[e]	3.777[e]	-.021[e]	-.028[e]
H x D	-.537[e]	-.491[e]	-.967[e]	0.005[e]	-.029[ef]
Y x HD	1.619[e]	1.476[e]	0.794[e]	-.004[e]	0.061[f]
D x YHD	1.860[e]	1.748[e]	5.658[e]	-.029[e]	0.053[ef]
H x DYHD	-.136[e]	-.067[e]	-.524[e]	-.002[e]	-.006[ef]
Y x HDYHD	-9.223[e]	-8.988[e]	1.449[e]	-.003[e]	0.058[ef]

[a]Constants are deviations from the least-squares means.

[b]Breed code as described on page 16.

[c]Market age held constant. [d]Market weight held constant.

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

TABLE XXIX

LEAST-SQUARES CONSTANTS[a] OF LANDRACE-HAMPSHIRE-DUROC, THREE-BREED ROTATIONAL-CROSS EFFECTS ON PRE-WEANING LITTER AND PIG PERFORMANCE TRAITS

Breed[b]	Number of pigs born	Number born alive	Average birth weight (lb.)	Number at 56 days	56-day weight (lb.)
Overall mean	10.430	9.754	2.976	7.897	29.443
D	-.073[c]	-.527[c]	-.082[cd]	-.394[c]	-2.126[c]
H x D	-.310[c]	-.056[c]	-.035[cd]	0.152[c]	-1.666[cd]
L x HD	0.456[c]	0.663[c]	-.240[c]	0.345[c]	-1.932[cd]
D x LHD	0.748[c]	0.752[c]	0.149[d]	0.885[c]	2.478[de]
H x DLHD	-.320[c]	-.376[c]	0.079[d]	-.474[c]	3.049[e]
L x HDLHD	-.169[c]	-.429[c]	-.141[cd]	-.455[c]	1.753[cde]

[a]Constants are deviations from the least-squares means.

[b]Breed code as described on page 16.

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

TABLE XXX

LEAST-SQUARES CONSTANTS[a] OF LANDRACE-HAMPSHIRE-DUROC, THREE-BREED ROTATIONAL-CROSS EFFECTS ON POST-WEANING LITTER AND PIG PERFORMANCE TRAITS

Breed[b]	Number at 154 days	154-day weight (lb.)	Number at market	180-day weight (lb.)	Adjusted backfat probe (in.)
Overall mean	7.509	139.096	7.206	174.993	1.378
D	-.562[c]	-4.486[c]	-.697[c]	-5.151[c]	-.024[c]
H x D	0.179[c]	-1.580[c]	0.133[cd]	-.386[cd]	-.026[c]
L x HD	0.105[c]	-3.881[c]	0.883[d]	-5.455[c]	0.009[c]
D x LHD	0.934[c]	4.708[c]	0.728[cd]	7.613[cd]	-.060[c]
H x DLHD	-.506[c]	4.521[c]	-.665[cd]	9.487[d]	-.057[c]
L x HDLHD	-.334	5.288[c]	-1.074[cd]	4.133[cd]	-.022[c]

[a]Constants are deviations from the least-squares means.

[b]Breed code as described on page 16.

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

TABLE XXXI

LEAST-SQUARES CONSTANTS[a] OF LANDRACE-HAMPSHIRE-DUROC, THREE-BREED ROTATIONAL-CROSS EFFECTS ON LITTER AND PIG PERFORMANCE TRAITS AT MARKET

Breed[b]	Market[c] weight (lb.)	Total[c] gain birth-market (lb.)	Market[d] age (days)	Average[d] daily gain birth-market (lb.)	Actual[d] backfat probe (in.)
Overall mean	209.461	206.297	207.531	1.012	1.453
D	0.007[e]	0.051[e]	3.777[e]	-.021[e]	-.028[e]
H x D	-.537[e]	-.491[e]	-.967[e]	0.005[e]	-.029[e]
L x HD	0.823[e]	0.935[e]	4.546[e]	-.021[e]	0.013[e]
D x LHD	2.694[e]	2.604[e]	-5.479[e]	0.025[e]	-.070[e]
H x DLHD	-.502[e]	-.438[e]	-4.839[e]	0.027[e]	-.061[e]
L x HDLHD	-4.306[e]	-4.068[e]	-4.469[e]	0.020[e]	-.024[e]

[a]Constants are deviations from the least-squares means.

[b]Breed code as described on page 16.

[c]Market age held constant. [d]Market weight held constant.

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

per litter at 56, 154 days and market age than the other groups. Least-squares constants indicate that the purebred Duroc litters were the lowest of all breed groups in litter size and growth rate. The HDHD cross was the highest in total performance as compared to the other crosses in the rotation.

Yorkshire-Hampshire-Duroc rotational cross. The least-square constants for the various performance traits are presented in Tables XXVI, XXVII and XXVIII, pages 68, 69 and 70. The YHD litters were the largest at birth and the DYHD litters were the largest at market age. Considerable variation was observed among the crosses in this rotation for the various traits. The same pattern was observed as in the Hampshire-Duroc rotation. Purebred Duroc litters were the lowest in total performance and the YHD and DYHD litters were the highest.

Landrace-Hampshire-Duroc rotational cross. Least-squares constants for the various performance traits of the crosses in this rotation are presented in Tables XXIX, XXX and XXXI, pages 71, 72 and 73. Purebred Duroc litters were lower than any of the other crosses in the rotation for total litter weight at market age. The DLHD litters were larger than litters of the other breed-of-pig groups at 154 days of age, and the LHD litters were the largest at market age. The HDLHD pigs were heavier than those in the other crosses at 56 and 180 days of age. Total litter weight at market age of the DLHD cross was greater than that of the other crosses in the rotation.

Comparison of the two-breed and three-breed rotational crosses. Performance was similar for the Hampshire-Duroc, Yorkshire-Hampshire-Duroc and Landrace-Hampshire-Duroc rotational crosses. Significant differences between the three rotational crosses were observed for litter size at 56, 154 days and market age in the three-way-cross generation. The YHD litters were 2.5, 2.4 and 2.2 pigs larger than the DHD litters at these ages, respectively. Pigs sired by the Landrace boars had significantly less backfat than those of the other crosses in the three- and six-way cross generations. Least-squares constants for litter size at market and 180-day weight indicates that the Yorkshire-Hampshire-Duroc rotational cross had an advantage in total litter performance over the other two rotations.

These data indicate that by rotational crossbreeding a swine herd with total performance (litter weight at market) superior to the parental purebred breed can be maintained at least through the sixth generation cross. Increased performance efficiency due to crossbreeding was observed up to the third or fourth cross. At this point the peak in total performance was reached and a slight decline in crossbreeding advantage was observed in the subsequent crosses. This is supported in part by reports of Carlisle et al. (1964), who found that three- and four-breed crosses were superior to straightbreds and other crosses with respect to most performance traits.

CHAPTER V

SUMMARY AND CONCLUSIONS

A 4-year study was conducted at Ames Plantation involving 8,980 pigs from 861 litters. The breed groups were purebred Hampshire, purebred Duroc and combinations of Duroc, Hampshire, Landrace and Yorkshire breeds in crosses through the sixth generation of rotational crossing.

This study was conducted to (1) evaluate the effects of year, season of birth, age of dam, breed of sire, breed of dam and breed of pig on various litter and pig performance traits, (2) to evaluate the effects of two- and three-breed repeat crosses on these litter and pig performance traits, (3) to study the effects of various two- and three-breed rotational crosses on total litter performance and (4) to determine at what point in a rotational crossbreeding program hybrid vigor exerts the maximum influence on the performance traits.

Correlations among the various traits show that litter size and average pig weight at weaning are important economic traits. The relationship between average litter size at 56 days and at market were highly significant ($r = 0.92$). Likewise, there was a high average correlation ($r = 0.72$) between average pig weight at 56 days and average daily gain from birth to market ($P < .01$). High correlations between the number of live pigs farrowed per litter and litter size at later ages indicates the importance of large litters of live pigs on total performance.

The level of performance of the spring-farrowed litters was significantly greater than for the fall-farrowed litters.

Age of dam had a significant effect on all litter and pig performance traits except backfat thickness. Mature sows produced larger litters at weaning and market than gilts. Average litter size at birth increased 1.8 pigs from the first to the second litter and 0.9 pigs from the second to the third litter.

Two- and three-breed cross dams were generally superior to the purebred dams. Results from the rotational dams, beyond the two- and three-breed cross, generally, indicated a decline in the level of performance.

Average performance was greater for the crossbred pigs than for the purebred pigs. Purebred Duroc litters were approximately 314 lb. heavier at 180 days of age than the Hampshire litters.

Data from this study indicates that two- and three-breed rotational crossbreeding programs resulted in increased performance with respect to most traits up to a point of maximum performance in the three- and four-cross generation.

These data indicate that total litter performance greater than that of the parental purebred breed can be maintained through at least the sixth generation by a planned two- or three-breed rotational crossbreeding program.

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