REPRODUCTIVE AND TESTES CHARACTERISTICS OF PUREBRED AND CROSSBRED BOARS

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Bachelor of Science

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Brookings, South Dakota

1971

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1976

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ACKNOWLEDGMENTS

The author would like to thank Dr. R. K. Johnson, Assistant Professor of Animal Science, for his help and advice during the collection of the data and preparation of the thesis.

The author also expresses appreciation to Dr. Joe Whiteman and Dr. Charles Maxwell for their help and contributions.

Special thanks is given to Steve Welty for his assistance in the collection of the data.

The author wishes also to thank his parents and brother for encouragement during this study.

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CHAPTER I

INTRODUCTION

"The proportionate contribution of offspring to the next generation is called the fitness of the individual" (Falconer, 1960, p. 23). Individuals may differ in viability and fertility; however, characters most closely associated with reproductive fitness generally have low heritabilities (Falconer, 1960).

Swine reproductive efficiency has been studied almost exclusively from the aspect of the female and her contribution to litter size. Few reports are available characterizing breeds and breed differences relative to male reproductive performance.

Recent crossbreeding studies have demonstrated significant differences among breeds of boar for conception rate and litter size. Observations made by researchers and swine producers suggest differences among boars in sexual behavior. Also documented is the advantage of crossbred females for litter size. Crossbred boars have not been evaluated. If crossbred males exhibit similar levels of heterosis as crossbred females, the swine industry can realize a significant improvement in net efficiency by specific crossing sequences of crossbred males and females.

In order to make recommendations to swine producers on combining breeds for maximum efficiency, reproductive performance of purebreed and crossbred boars needs to be evaluated. The objectives of this study are to evaluate the testicular and epididymal characteristics of seven and

one-half month old purebred and crossbred boars and the differences between purebred and crossbred boars in litter size, conception rate and mating behavior.

CHAPTER II

REVIEW OF LITERATURE

This review is concerned with studies of different components of male reproductive fitness. It is divided into testicular evaluation, characterization of testicular components, male mating behavior and the sire effect on reproductive efficiency.

The process of spermatogenesis is similar for all mammals. Courot, Hochereau-de Reviers, and Ortvant (1970, p. 339-340) defined the spermatogenic process in the following manner.

> The primordial germ cells migrate toward the germinal crests and occupy the gonad space some time before sexual differentiation. In the fetus and the young male, the gonocytes issuing from these primordial germ cells are contained within the sex cords.
>
> The gonocytes multiply and give rise to spermatogonia. The later, after several mitotic divisions and the differentiation of most of the daughter cells thus obtained (the others remaining in the state of stem cells) form a group of germ cells contained in the parietal layer of the seminiferous tubule. Their last generation gives rise to primary spermatocytes.
>
> The primary spermatocytes (tetraploid nuclei) are the germ cells which undergo meiosis. This comprises an extremely long prophase with pairing of the chromosomes and possible exchange of chromosome material. The reduction in number of chromosomes takes place in the course of two sucessive divisions (maturation divisions) giving, first, secondary spermatocytes (diploid nuclei), and then spermatids (haploid nuclei).
>
> The spermatids are the postmeiotic germ cells of the seminiferous epithelium. They undergo a series of transformations during spermiogenesis, ending in the formation of spermatozoa.

Swierstra (1968a) studied the seminiferous cycle in boars by injecting ten Yorkshire and ten Lacombe boars with thymidine-methyl-H^3. This cycle is the series of changes occurring in a given area of the seminiferous epithileum between two successive appearances of the same cellular association.

Testis tissue was taken from these boars at intervals over a 50 day period and analyzed for stage of the cylce of the seminiferous epithelium. Within five hours after injection, primary spermatocytes were labeled. He concluded that one cycle of the seminiferous epithelium was about 8.5 days. The life cycles which were calculated are: primary spermatocytes, 12.3 days; secondary spermatocytes, 0.4 days; spermatids with round nuclei, 3.6 days; spermatids with elongated nuclei, 1.5 days; and spermatozoa, 6.2 days. These are summarized in Figure 1. Twenty-five days after injection, the labeled spermatozoa were leaving the testis. The mean epididymal transport time was 10.2 days with a range from 9 to 12 days. He assumed that spermatogenesis extends over four consecutive cycles of the seminiferous epithelium and based on this assumption concluded that spermatogenesis has a duration of 34.4 days in boars.

Testicular Evaluation

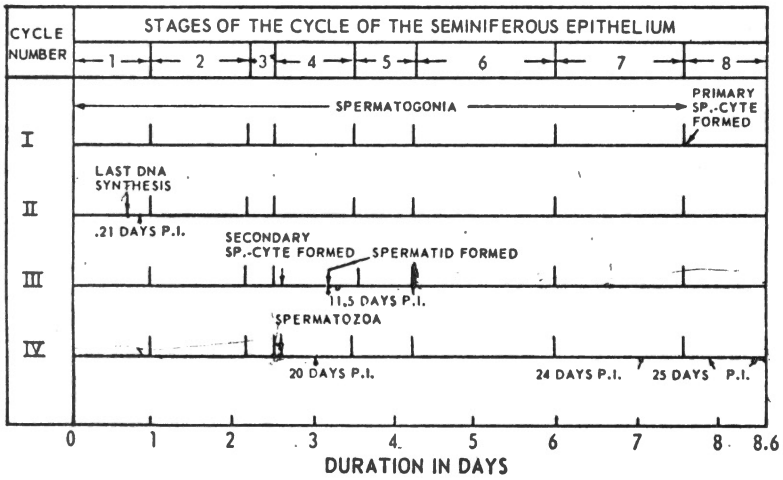
Homogenization of testicular and epididymal parts has been used for estimation of spermatozoa reserves in rabbits, mice, bulls, rams and boars. Amann (1970) states that for large-scale investigations, determination of rate of sperm production from testicular homogenates appears to be the method of choice. Much less time is required, larger

testis samples can be analyzed and values obtained seemed to be as accurate as for testicular histology. Data on spermatid reserves may be useful for studying treatment or seasonal differences in spermatogenesis. For reference, labeled diagram of the testis is shown in Figure 2.

Kennelly and Foote (1964) castrated six, 2-year-old Yorkshire boars and analyzed the testis for intratestis differences in volumetric proportions of testicular structures. They evaluated four areas in a midsagitally cut testis and concluded that the area close to the mediastinum differed from the other areas. The difference was probably due to the increased connective tissue, which reduced the percentage of seminiferous tubules in the mediastinum. Left and right testis did not differ, indicating that boar evaluation can be done by properly sampling one testis.

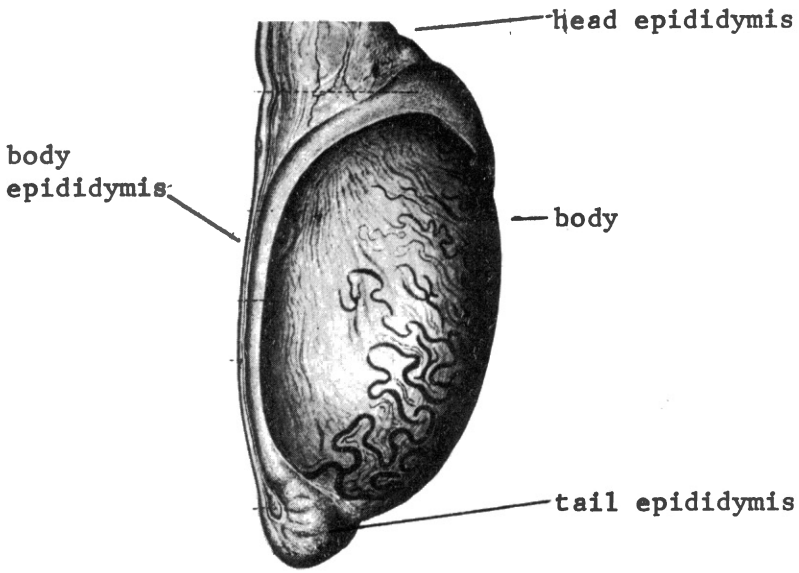
Swierstra (1968b) used quantitative testicular histology to measure daily spermatozoa production of ten Yorkshire and ten Lacombe boars which averaged approximately 11 months of age. The testis were cut midsagitally and tissue was removed from three locations. Locus A was near the caput epididymis, locus B midway between the poles of the testis and locus C near the cauda epidiymis. Right and left testis and the three locations did not differ significantly in percentages of round spermatid nuclei.

To reduce the amount of particulate matter in homogenates, Amann and Lambiase (1969) added 0.05% Triton X-100 to a 0.9% saline and 100 ppm Merthiolate solution for homogenization of rabbit testes and epidymides. They found that up to 28% of the sperm cells counted from



Source: Swierstra (1968a, p. 176).

Figure 1. The Spermatogenic Cycle of the Boar



Source: Hafez (1968, Plate 1).

Figure 2. Diagram of Testis

a solution containing Triton X-100 might have been obscured by debris when saline and merthiolate were used without the addition of Triton X-100.

Testicular Characteristics

Little work has been reported which has evaluated testicular development in swine. Several reports are available on testicular development and line differences in laboratory animals and chickens.

Hauser, et al. (1952) crossed two inbred lines of Poland China swine and inbred line of Hampshires and non-inbred line of Durocs to study testicular, epididymal and spermatozoa development. Five boars per breed group were evaluated. Testis weight, at the mean age of 150 days was significantly different between the crossbred and linecross boars from the fall farrowing. Testis weight of crosses in 1948 fall averaged about 25% above that for the corresponding parent lines in 1948 spring. In general, the crosses surpassed the parent lines in weight of epididymis and in the ratio of testis to epididymis size. On the average, crosses exceeded parent lines by 28% in body weight, 30% in testis weight, 27% in epididymis weight and 20% in stage of spermatogenesis. The crossbred boars were above the corresponding parent strains in body, testis and epididymis weight but the curvilinear regression of testis weight on body weight for crossbreds was intermediate to the curves for the two parent strains. This suggests that testicular development is merely part of the general growth stimulus from crossing. Rate of testicular development was also more closely associated with body size than with age. All crosses except one were superior to the average of the two parent strains for estimated age at first sperm production.

Swierstra (1968b) found that the mean testis weight at 11 months was 349.1 g for Yorkshire boars and 389.1 g for Lacombe boars. The differences between breeds was not significant. Paired testes weight was correlated ($r = 0.90$, $P < .01$) with Daily Sperm Production (DSP). There was no difference between breeds for DSP/gram net testis weight. The relative volume of the testis occupied by spermatids with round nuclei did not differ significantly between testes, among boars within breeds or between breeds. Within a testis, there generally is a consistancy of the relative frequencies of the stages of the seminiferous epithelium; "thus, since the duration of spermatogenesis is a constant within a species, DSP is primarily a function of testis size in normal boars" (Swierstra, 1968b, p. 468).

Swierstra and Rahnefeld (1967) castrated 17 Yorkshire and 18 Lacombe boars after they had been on a semen collection trial. The left testis was significantly heavier than the right testis. Yorkshire right and left testis weighed 331.1 g and 342.5 g respectively, while the Lacombe right and left testis weighed 370.5 g and 382.5 respectively. The sperm output per gram of testis did not differ significantly between breeds. Sperm output was correlated (0.51, $P < .01$) with gross testis weight.

Most of the evidence regarding heterosis for testes growth is available from small animals. Johnson and Eisen (1975) measured testicular development in crosses of two lines of mice. One line (M16) had been selected for gain for 33 generations and the fertility of this line had diminished until approximately 30% of the matings were infertile. The other line (IGR) was a random bred control line which averaged 7% infertile matings. Accompanying the increase in M16 body weight were significant increases in reproductive organ

(testes. tunica, parenchyma, epididymides, and seminal vesicles) weights. However, testes, epididymides and seminal vesicles weights expressed per gram body weight actually decreased significantly. Reciprocal crosses differed significantly in actual and relative weights of the testes, parenchyma and epididymides. Testicular sperm counts were significantly higher in the M16 male x 1CR female crosses than in the reciprocal crosses but when adjusted for organ weights, no significant differences were detected. Heterosis was significant for testes epididymides and parenchyma weights. Percent heterosis varied from 5.2 to 7.1%. Heterosis levels for number of testicular and epididymal sperm was about 8.5%. Adjustments for organ weights, however, essentially eliminated all heterosis.

Kamar and Mostageer (1960) studied 105 cockrels of three pure breeds and for reciprocal crosses. Cockrels were killed at 10, 12, 16, 20 and 24 weeks of age. They concluded that when early and late sexually maturing breeds are crossed, the offspring attain sexual maturity at an earlier age and have larger reproductive organs than the average of the parents.

Male Mating Behavior

Male mating behavior encompasses several behavioral functions which are difficult to describe and quantify. If mating behavior is a fitness trait it would appear that it would be influenced more by non-additive gene action than by additive gene action. Parsons (1974) has suggested that in Drosophila, male mating speed or male virility is usually an important component of fitness and that mating speed is associated with fertility and the number of offspring.

Siegel (1972) reported a selection experiement with chickens in which he selected for total number of completed matings (CNCM) in eight 10-minute observation periods. After 11 generations, realized heritability estimates were 0.16 $\pm$ 0.02 in the high mating line and 0.32 $\pm$ 0.07 in the low line. In the last generation, 7, 18, and 31% of the males failed to mate in the high, control and low lines, respectively. Two genetically controlled systems for CNCM were hypothesized; one neural and one endocrine. The neural system may be the primary system to behavior and when its threshold is reached, the endocrine influences are brought into play. This implies that the endocrine effects, while under genetic control, are not behaviorally expressed until the neural threshold is reached.

Dewsbury (1975) crossed four strains of inbred rats to study mating behavior. In the male parent strains 13.8% failed to complete a series of five ejaculatory tests while only 1% of the F_1 failed. The F_1 rats tended to initiate copulation sooner, require fewer mounts and intromissions to ejaculate, ejaculate sooner, have shorter intervals between intromissions, and have shorter intervals to resume copulation after ejaculation.

In an attempt to relate libido tests to mating behavior, Mattner, Braden and George (1973) tested seventy-five 1 1/2 year-old Merino rams in three 20 minute libido tests. Seventeen of the rams showed no sexual activity. These rams were joined in pairs (Active-Active, A-A; Active-Inactive, A-I; Inactive-Inactive, I-I) and placed in ewe flocks for five weeks. Although the effect of ram combination on the number of ewes marked by the rams was not significant, the proportion of marked ewes that lambed was higher ($P < 0.05$) in flocks

joined with A-A pairs than in those joined with A-I or I-I ram pairs. The proportion of marked ewes that did not lamb to their first marking was lower ($P < 0.001$) in A-A than in A-I or I-I matings. The lower fertility in the flocks joined with A-I or I-I ram pairs could be attributed to poor mating dexterity and lower libido in the I (inactive) rams.

Swierstra and Rahnefeld (1967) reported that there was a significant difference between Yorkshire and Lacombe boars in ejaculation time for semen collection. Yorkshire boars averaged 5.7 minutes and Lacombe boars 7.2 minutes. There was also a difference among boars within a breed with respect to ejaculation time. There was no significant differences between the breeds for semen characteristics.

Fertility and Breed of Sire

Much of the evidence reported to date is inconclusive relative to evaluating breed of sire for litter effects such as number of pigs born or differences in levels of boar fertility.

Hauser, Dickerson and Mayer (1952) observed that although the differences between breeding groups of boars in age at first fertile mating were large and agreed well with other indications of sexual maturity, they were not significant. This was very probably due to relatively few gilts that could be mated to each boar and the rather long interval between matings. Inbreeding of sire had no effect on size of litter. Bereskin et al. (1968) summarized records from 2,878 litters and also found that the inbreeding of the sire did not significantly effect the size of litter at farrowing.

O'Ferrall, Hetzer and Gaines (1968) reported that the breed of sire was not significant for litter size or weight at birth, 21 days

or 56 days for crossbred litters. Reddy et al. (1958) were in agreement and reported that the boar did not influence the prenatal death loss or the litter size of the litters he sires.

Johnson and Omtvedt (1973) reported that breed of sire of litter was not significant for litter size 30-day postbreeding or at birth but was significant for number of pigs per litter at 21 and 42 days. Rahnefeld and Swierstra (1970) found that Yorkshire and Lacombe mated at 250 days of age differed significantly for total number of pigs born, the number born alive and the number weaned per litter. Also in this study, sires with a high conception rate produced the largest litters. Baker (1973) in a nutrition study, observed that crossbred boars settled 10% more sows than purebred boars with approximately 80 sows in each group. There were no differences in number of pigs farrowed.

Koh et al. (1976) during 1883 estrous cycles inseminated purebred and crossbred gilts and sows with liquid semen containing 5×10^9 spermatozoa. Inseminations with Landrace, Minnestoa No. 2 and Duroc semen resulted in higher ($P < 0.05$) farrowing rates (74.3 to 71.3%) than Yorkshire semen (63.3%). Pietrain and Hampshire boars were not different from any of the other breeds. Breed of male did not affect the number of pigs born alive per litter.

Swierstra (1974) grouped boars according to high, medium and low numbers of motile sperm per ejaculate. Semen collections were started at an average age of 198 days. Age associations with semen characteristics were pronounced from 6.5 to 8.5 months of age on these boars. The low repeatabilities indicated that boars having low numbers of

total and motile sperm per ejaculate at 6.5 to 8.0 months of age do not necessarily have low numbers of toal and motile sperm per ejaculate when they reach 10 months of age.

Sellier (1973) used 20 young boars from five groups (Yorkshire, Landrace, Landrace x Yorkshire, Hampshire x Yorkshire, and Hampshire x Landrace) in a breeding test. He found that genetic groups were significant for age and weight at first collection and for a few semen characteristics, the data suggests that toal spermatozoa/ejaculate are somewhat increased in crossbred boars.

Summary of Literature Review

This review shows the importance of the male in reproductive efficiency and that there are individual and line differences for measures of reproduction. It points out a need for more information evaluating breeds and breed crosses for reproductive efficiency in meat animals and its impact on livestock production.

Researchers agree that, with the exception of the mediastinum, normal boar testis are homogonous and samples are representative of the entire testis. Homogenization of testis and epididymal parts appears to be the choice for evaluation of large numbers of testes where only an estimate of sperm reserves is desired. Addition of Triton X-100 to the homogenization solution has reduced particulate matter in homogenates and increased the number of observed spermatogonia.

Boar testes development appears to be closely related with body growth. Information available in crosses in swine, mice, and chickens suggest that there is significant heterosis for testicular growth. Several researchers have found a difference between lines and breeds

for daily sperm production or sperm reserves but not when expressed as sperm/gram of testis. As testis weight is a part of the computation of daily sperm production, testis weight is highly correlated with daily sperm production. In mice and chickens there appears to be heterosis for increased epididymal weights and sperm numbers in the same magnitude as for testis weight and sperm numbers.

Mating behavior is very complex and difficult to quantify. It appears that mating behavior is a fitness trait and is basically controlled by non-additive gene action. If this is the case, heterosis should be expressed when two lines or breeds are crossed.

Some evidence exists in sheep that pen testing of young rams can give an indication of future mating performance and fertility when rams are pasture mated.

The data reported in the literature is inconclusive regarding effect of breed of sire on fertility and litter size. The effect of breed of sire on number of pigs at 21 or 42 days has been established (Young, Johnson and Omtvedt, unpublished data); however, little evidence has yet been shown for the breed-of-sire to greatly influence the size of a litter at birth. There are some indications that breed of sire may have an effect on conception rate.

There is a lack of information about the evaluation of breeds of swine for differences in male reproduction. The physiological process of male reproduction has been investigated but the extent to which it is under genetic control is not known. This study will evaluate two breeds of boars and their reciprocal crosses for reproductive traits.

CHAPTER III

MATERIALS AND METHODS

Animal and Laboratory Procedure

The boars used in this study were raised from the purebred Duroc and Hampshire lines maintained at the Stillwater Experimental Swine Farm. These herds were formed in 1969 from crosses among several lines within each breed to ensure a wide genetic base. Since that time at least two new sires have been introduced into each herd per year. The boars were farrowed in fall 1973, spring and fall 1974 and spring 1975. The crossbred boars were produced from reciprocal matings between randomly selected individuals from the purebred Duroc and Hampshire herds.

The pigs were farrowed in crates in a central farrowing house. About three to five days after farrowing, one-third of the litters were moved to individual pens, open to the south, with solid concrete floors. The remaining litters were moved to pasture lots with two litters to a lot until weaning. All litters were weaned at six weeks of age. One hundred sixteen boars were castrated. These included 31 Durocs, 35 Duroc x Hampshire (D x H), 23 Hampshire x Duroc (H x D) and 27 Hampshires. Twenty boars of each of the Duroc, D x H, H x D breed groups and 19 Hampshire boars were mated in the breeding portion of the study.

The boars were placed on an open front concrete test floor at eight weeks of age and weighed on a growth test at nine weeks. Boars

were weighed off test weekly as they reached 220 pounds at which time they were probed for backfat and penned in dirt lots with ten to twelve boars per lot. Table I shows the growth rate and backfat probe of the 195 boars.

TABLE I

GROWTH PERFORMANCE AND BACKFAT PROBE AT 220 POUNDS OF ALL BOARS

	No. of Boars	Gain lbs. per day	Age at 220 lbs.	Backfat Probe, in.
Duroc	51	1.79 ± 0.03	167.7 ± 1.5	1.03 ± 0.02
Duroc x Hampshire	55	1.92 ± 0.03	156.9 ± 1.5	0.97 ± 0.02
Hampshire x Duroc	43	1.93 ± 0.03	160.7 ± 1.7	0.94 ± 0.02
Hampshire	46	1.66 ± 0.03	174.1 ± 1.6	0.86 ± 0.02

Each season as the boars reached 7 1/2 months of age, six boars from each breed group were randomly selected to be kept for breeding and the remaining boars were castrated. Table II shows the distribution of the boars which were castrated.

The boars which were castrated were selected as near to 225 days of age as possible (Table III). Normally, one group was castrated per week except when there were more than ten boars and then two groups were castrated in a week.

The boars were bilaterally castrated with a scalpel and the right testis was retained. Upon removal, the testis was placed in a plastic bag and kept in ice until it was processed in the laboratory two to eight hours later.

TABLE II

DISTRIBUTION OF BOARS WHICH WERE CASTRATED BY SEASON AND BREED GROUP

	Spring '74	Fall '74	Spring '75	Fall '75	Total by Breed
Duroc	9	6	8	8	31
Duroc x Hampshire[a]	8	10	9	8	35
Hampshire x Duroc[a]	3	6	7	7	23
Hampshire	4	7	8	8	27
Total	24	29	32	31	116

[a]Breed of sire listed first.

The following laboratory procedure was used. The tunica was removed from the testis and the epididymis was separated. The head and body epididymis (capita-corpora epididymidis) were cut from the tail (cauda epididymidis)of the epididymis as shown in Figure 2. The testis and epididymal parts were weighed. The testis was cut transversely and approximately 20g of parenchyma were sampled by cutting away with a scalpel. Care was taken to avoid the mediastinum when sampling.

TABLE III

AVERAGE AGE AT CASTRATION FOR BOARS
OF EACH BREED GROUP IN EACH SEASON

	Spring 1974	Fall 1974	Spring 1975	Fall 1975	Average by Breed
Duroc	239.2	230.0	225.1	226.3	230.5
Duroc x Hampshire	241.6	231.0	225.2	226.3	230.9
Hampshire x Duroc	235.3	231.0	226.0	225.4	228.3
Hampshire	231.0	227.9	223.9	226.5	226.7
Average by Season	236.8	230.0	225.1	226.1	

Each sample was homogenized in a commercial Waring Blender for two minutes with physiological saline (STM) which contained 0.9 percent NaCL, 0.05 percent Triton X-100 and 100 ppm methiolate. Triton X-100 reduces the particulate matter while methiolate is added to retard bacterial growth (Amann and Lambiase, 1969). The 20g of testis parenchyma was homogenized in 200 ml of STM and both the head and body epididymis and tail epididymis were homogenized in 250 ml STM. The homogenate was strained twice in a single layer of cheesecloth. A sample of approximately 50 ml of the homogenate was stored overnight at 4°C. The following day the homogenate was stirred with a magnetic stirrer and sampled. The following dilutions were performed. Two ml of the head and body epididymis sample were added to 50 ml STM. One ml of the tail epididymis sample was added to 50 ml STM and 10 ml testis sample was added to 30 ml STM.

Each sample was again stirred and a sample taken with a micropipette for microscopic evaluation of sperm numbers. Two readings were made from a 0.1 mm hemacytometer (a slide partioned into 25, 5 x 5 grids) under a phase contrast microscope. Each reading, five diagonal squares were counted. The next day the sampling process was repeated and an additional two readings were made. Countings on the second day were made by a different person than the first day. Within a season, all first day readings were made by the same person and all second day readings by the same person.

Computation of sperm numbers was done in the following manner.

For Head and Body Epididymis and Tail Epididymis:

$$\left(\begin{array}{l}\text{TOTAL SPERM CELLS}\\ \text{in 25 squares}\end{array}\right)\left(10000\right)\left(\begin{array}{l}\text{TISSUE WEIGHT}\\ \text{+ STM Volume}\end{array}\right)\left(\begin{array}{l}\text{dilution}\\ \text{total}\end{array}\right)\left(\frac{}{2}\right) = \text{Sperm Numbers}$$

For Testis:

$$\left(\begin{matrix}\text{TOTAL SPERM CELLS} \\ \text{in 25 squares}\end{matrix}\right)\left(10000\right)\left(\begin{matrix}\text{TISSUE WEIGHT} \\ \text{+ STM Volume}\end{matrix}\right)\left(\begin{matrix}\text{dilution} \\ \text{total}\end{matrix}\right)\left(\frac{\text{total testis wt.}}{\text{testis sample wt.}}\right)$$

$$\left(2\right) = \begin{matrix}\text{TESTES SPERM} \\ \text{Numbers}\end{matrix}$$

Both spermatids and spermatozoa were counted in the testis sample.

Total sperm cells in 25 squares were found by multiplying the mean of the four individual readings by five. The multiplicitive factor of 10,000 results from using a 0.1 mm hemacytometer. The hemacytometer is 1 mm x 1 mm x 0.1 so to convert to cc, multiply 10 x 10 x 100 = 10000 per ml or cc of sample.

The dilution total is the sum of the sample volume and the volume of STM dilutant:

Head and Body Epididymis	26	(25 ml STM + 1 ml sample)
Tail Epididymis	51	(50 ml STM + 1 ml sample)
Testis	4	(3 ml STM + 1 ml sample)

The values in the equation were multiplied by two to place the sperm numbers on a boar basis since only one testis was analyzed per boar.

The reproductive efficiency portion of the study began as the last boars reached 7 1/2 months of age and the last castrations had been completed. The breeding season began approximately November 10 for the fall season and May 1 for the spring season. Six boars, which were littermates to the castrated boars, were available per breed group. All six boars per breed group were individually exposed to a gilt until five boars had successfully mated with one gilt. These five boars were mated to a second gilt. Boars were randomly chosen across breed groups to mate with Yorkshire gilts. When a boar mated with his first gilt he was given a second opportunity with her the

following day. When the boar was mated to the second gilt the same procedure was followed. No boar was given an opportunity for his second gilt until all boars had completed their first mating. These boars had no mating experience prior to this study.

The 7 1/2 - 9 month old Yorkshire gilts were checked daily with a teaser boar to detect gilts in estrus. When a gilt was found in estrus, she was brought from the dirt lot to the breeding pen. Gilts were bred on the day they were detected in estrus and given an opportunity to mate again on the following day. All matings were made in a 15 foot square concrete floor pen.

A stop watch was used to record three periods during each mating. Period 1 was the time from the boar entered the pen until he made a mount. Period 2 was from mount to intromission and Period 3 was from intromission until the end of ejaculation. The boars were helped only when it appeared that the mating would not be completed if assistance was not given. The first season the only times obtained were time until mount and from mount to completion of ejaculation.

Approximately 30 days postbreeding the gilts which had not returned to estrus were slaughtered. The reproductive tracts were retained and the number of embryos in the uterine horns were counted. The ovaries were examined to count the number of active corpus lutea (CL) to obtain an estimate of ovulation rate.

Statistical Analysis

The "SAS" computer program developed by Barr and Goodnight (1972) was used for statistical analyses.

The linear model used in the analysis for each trait was:

$$Y_{ijkl} = \quad + A_i + S_j + D_k + (AS)_{ij} + (AD)_{ik} + (SD)_{jk} + (ASD)_{ijk} + e_{ijkl}$$

where:

Y_{ijkl} = the observed trait of the l^{th} boar from the i^{th} season, j^{th} breed of sire and k^{th} breed of dam.

u = population mean

A = fixed effect of the i^{th} season; i 1, 2, 3, 4.

S = fixed effect of the j^{th} breed of sire; j = 1, 2.

D = fixed effect of the k^{th} breed of dam; k = 1, 2.

$(AS)_{ij}$ = interaction between the i^{th} season and the j^{th} breed of sire.

$(AD)_{ik}$ = interaction between the i^{th} season and the k^{th} breed of dam.

$(SD)_{jk}$ = interaction between the j^{th} breed of sire and the k^{th} breed of dam.

$(ASD)_{ijk}$ = interaction between the i^{th} season, the j^{th} breed of sire, and the k^{th} breed of dam.

e_{ijkl} = the random error associated with the $ijkl^{th}$ observation.

The general analysis of variance for testis characteristics is shown in Table IV. The general model is the same for the reproductive efficiency analyses; however, the number of observations change and for "ejaculation time" the number of seasons and seasons interactions is reduced by one. In analyzing embryo number per gilt, embryo number was regressed on the number of corpus lutea in order to obtain a correction factor to adjust number of embryo to a constant ovulation rate. Error is the boar to boar variation within season and breed group pooled across subclasses.

Correlations among all traits were obtained from simple correlations from within season and breed group pooled across subclasses.

Conception rate was analyzed by Chi-square analysis as described by Steel and Torrie (1960, p. 370).

TABLE IV

SOURCES OF VARIATION, DEGRESS OF FREEDOM AND EXPECTED MEAN SQUARES

Source	d.f.	Expected Mean Squares
Total	115	
Season	3	$\sigma^2 + K_7 \sigma^2$ (Season)
BOS	1	$\sigma^2 + K_6 \sigma^2$ (BOS)
BOS x Season	3	$\sigma^2 + K_5 \sigma^2$ (BOS x Season)
BOD	1	$\sigma^2 + K_4 \sigma^2$ (BOD)
BOD x Season	3	$\sigma^2 + K_3 \sigma^2$ (BOD x Season)
BOS x BOD	1	$\sigma^2 + K_2 \sigma^2$ (BOS x BOD)
BOS x BOD x Season	3	$\sigma^2 + K_1 \sigma^2$ (BOSxBODxSeason)
Error	100	σ^2

CHAPTER IV

RESULTS AND DISCUSSION

The Testicular and Epididymal Development of Seven and One-Half Month Old Purebred and Crossbred Boars

The breed group means for testes characteristics are shown in Table V. The crossbred mean for testes weight of 685.00g was significantly heavier ($P < .01$) than the purebred mean of 589.67g. Hampshire boars testes weighed 614.87g compared to 564.47g for Durocs. This difference, however, was not significant. Swiertstra (1968b) reported mean testis weights of 349.1g and 389.1g for 11-month old Yorkshire and Lacombe boars, respectively. Kennelly (1960) found the testes weight of 12 one-year old Yorkshire and Bershire boars to be 427 g.

Testes sperm reserves, which include spermatids and spermatozoa, were greater in the crossbred boars than the purebred boars by 14.4×10^9 sperm ($P < .01$). This is 25.1% heterosis for number of testes sperm. There was no significant difference between the Durocs and the Hampshires for number of testes sperm. Kennelly (1960) used testicular homogenates and estimated that one-year old Yorkshire and Berkshire boars had 45.1×10^9 spermatid reserves per testes. These estimates are difficult to compare to this study because he counted spermatids.

TABLE V

BREED GROUP LEAST SQUARES MEANS AND STANDARD ERRORS FOR TESTES CHARACTERISTICS

	No. of boars	Weight in grams	Spermatozoa no.[a]	Concentration[b]
Duroc	31	564.47 ± 21.32	54.35 ± 3.66	0.1064 ± 0.0078
Duroc x Hampshire	35	652.31 ± 19.92	67.86 ± 3.42	0.1028 ± 0.0073
Hampshire x Duroc	23	717.70 ± 26.00	75.94 ± 4.46	0.1082 ± 0.0095
Hampshire	27	614.87 ± 23.53	60.62 ± 4.04	0.0983 ± 0.0086
Purebred $\bar{X}$		589.67 ± 15.87	57.49 ± 2.73	0.1024 ± 0.0058
Crossbred $\bar{X}$		685.00 ± 15.87	71.90 ± 3.18	0.1055 ± 0.0067
Crossbred - Purebred		95.33 ± 22.81**	14.41 ± 3.92**	0.0031 ± 0.0084
Duroc - Hampshire		-50.40 ± 31.75	-6.27 ± 5.45	0.0081 ± 0.0116

[a] $\times 10^9$

[b] $\frac{\text{sperm number}}{\text{testes weight}}$

**significantly different from zero, $P < .01$

Table XIX shows the analysis of variance for testes characteristics. Season effects were significant for testes weight and testes sperm members. There were no apparant explanations for season effects. Breed of sire effects were significant for testes weight and approached significance for testes sperm number. Hampshire sired boars had heavier testes and tended to have greater testes sperm numbers.

If testes weight and sperm reserves are fitness traits which are influenced by non-additive gene action, then when two breeds are crossed, heterosis would be expected. The crossbred boars had 16.2% heavier testes and 25.1% more testes sperm than purebred boars. Hauser, Dickerson and Mayer (1952) also found that crossbred boars testis were heaver than the average of the parental lines. Increased testis weight was attributed to increased body weight of the crossbred boars. Johnson and Eisen (1975) reported for mice a 7.4% heterosis for testes weight and 8.5% heterosis for testes sperm reserves, which was nonsignificant.

When testes sperm numbers are expressed as testis concentration $\frac{\text{sperm number}}{\text{testes weight}}$, there are no significant differences among breed groups (Table V). Kennelly (1960) reported 0.113×10^9 spermatids per gram of parenchyma. This is similar to testis sperm concentration reported in this study.

Since there are no significant differences among breed groups for testis sperm concentration, it appears that the increased sperm reserves in crossbred boar testes is due to heavier testes weight and is not heterosis for increased spermatozoa production by the seminferous epithelium. When Johnson and Eisen (1975) adjusted sperm count for organ weight, all heterosis for number of sperm was eliminated.

There were no significant differences among breed groups for the head and body epididymis (caput and corpus epididymidis) characteristics shown in Table VI. There were three statistically significant differences in the tail epididymis (cauda epididymidis) measurements. The tail epididymis is 6.74 g heavier in crossbred boars than purebreds. Duroc boars have 24.55 x 10^9 more sperm numbers and significantly more sperm per gram of tissue than Hampshires.

Appendix Table XVIII shows the analysis of variance for head and body epididymis characteristics. Season was a significant source of variation for spermatozoa numbers and concentration. Breed of sire is significant for head and body sperm concentration. Hampshire-sired boars had the greatest concentration. Season is also a significant source of variation for all three tail epididymis measurements (appendix table XIX). There is no apparent explanation for the season variation.

Crossbred boars had significantly more sperm in the testes than purebred boars. They also had more total sperm in the head and body and in the tail of the epididymis, although not significant. Perhaps real differences do exist in epididymis sperm numbers but were not detected in this experiement. However, it is possible that real differences exist in testes sperm numbers but not in epididymal numbers.

Possible explanations for thse differences were developed by Amann (1970). Since these are young boars that are still maturing, they may be at different sperm production rates. If this is the case, the crossbred boars may be increasing sperm production and these spermatozoa have not arrived in the epididymis. This may also explain

TABLE VI

BREED GROUP LEAST SQUARES MEANS AND STANDARD ERRORS FOR EPIDIDYMAL CHARACTERISTICS

		Head and Body Epididymis			Tail Epididymis		
		Weight, g	No. of Spermatozoa[a]	Concentration[b]	Weight, g	No. of Spermatozoa[a]	Concentration[b]
Duroc	31	119.83±15.14	44.44±4.02	0.4748±0.0400	85.65±3.07	88.64±8.16	0.9891±0.0771
Duroc x Hampshire	35	99.67±14.15	51.07±3.75	0.5237±0.0374	94.55±2.87	92.29±7.63	0.9324±0.0721
Hampshire x Duroc	23	89.05±18.46	55.52±4.90	0.6253±0.0488	84.29±3.75	85.17±9.95	0.9814±0.0941
Hampshire	27	86.05±16.51	51.59±4.43	0.5829±0.442	79.71±3.39	64.09±9.01	0.7582±0.0851
Purebred $\bar{X}$		102.94±11.27	48.02±2.99	0.5289±0.0298	82.68±2.30	76.37±6.08	0.8736±0.0574
Crossbred $\bar{X}$		94.36±13.13	53.30±3.48	0.5745±0.0347	89.42±2.67	88.73±7.08	0.9569±0.0669
Crossbred - Purebred		-8.58±16.20	5.28±4.30	0.0456±0.0428	6.74±3.29*	12.36±8.73	0.0833±0.0825
Duroc - Hampshire		33.78±22.54	-7.15±5.98	0.1081±0.0596	5.94±4.60	24.55±12.16*	0.2309±0.1149*

[a] $\times 10^9$

[b] $\frac{\text{spermatozoa number}}{\text{weight}}$

*significantly different from zero, $P < .05$

the differences in the Duroc and Hampshire comparisons. The Hampshires tend to have more sperm reserves in the testes but the Durocs have significantly more tail epididymis spermatozoa. This seems plausible since the epididymal transit time is appoximately 10 days (Swierstra, 1968a).

Another explanation may be that the epididymis has the capacity to store the same number of spermatozoa regardless of breed and that excess spermatozoa are reabsorbed in the epididymis or are excreted through the urine. Amann and Almquist (1962) suggest that in dairy bulls the tail (cauda) epididymis is the site of spermatozoa reabsorption. They estimate that more than 57% of sperm produced are reabsorbed in bulls which were ejaculated eight times per week and 97% of sperm production is reabsorbed in bulls at sexual rest. Orgebin-Crist (1968) found that in sexually rested rabbits, 50% of the sperm production is reabsorbed. Another potential loss of sperm according to Koefoed-Johnson (1964) is that large number of spermatozoa are excreted through the urine in bulls which have been at sexual rest.

Table VII shows the correlations between testes and epididymal characteristics. The correlation between testes sperm number and the epididymal spermatozoa number in the head and body epididymis and tail epididymis are $r = 0.45$ and 0.51 ($P < .01$), respectively. These are pooled within season, breed group correlations. Testes weight is significantly correlated with all testes and epididymal characteristics except testes concentration and head and body epididymis weight. The correlation of testes weight ($r = 0.65$) with testes sperm number is expected since sperm number is partially a function of testes weight due to the formula used to calculate sperm numbers. This correlation

TABLE VII

CORRELATIONS BETWEEN TESTES AND EPIDIDYMAL CHARACTERISTICS

	Testes Sperm No. (1)	Testes Concentration (2)	Head and Body Epididymis Weight (3)	Head and Body Epididymis Sperm No. (4)	Head and Body Epididymis Concentration (5)	Tail Epididymis Weight (6)	Tail Epididymis Sperm No. (7)	Tail Epididymis Concentration (8)
Testes Weight	0.65**	-0.03	0.00	0.51***	0.36**	0.51***	0.49***	0.36**
(1)		0.38***	-0.09	0.45***	0.40***	0.28***	0.51***	0.51***
(2)			0.77***	0.09	0.12	-0.02	0.13	0.21
(3)				0.04	-0.06	0.09	0.01	-0.01
(4)					0.89***	0.34**	0.47**	0.42**
(5)						0.15	0.43***	0.47***
(6)							0.57**	0.28*
(7)								0.91***

* $P < .01$
** $P < .001$
*** $P < .0001$

is in agreement with Almquist and Amann (1961) who found a correlation of 0.65 between testes weight and testes sperm number in mature, sexually-rested dairy bulls. In rabbits a correlation of 0.61 for the same variables was reported by Orgebin-Crist (1968).

Testes sperm number was significantly correlated with head and body epididymis spermatozoa number ($r = 0.45$) and tail epididymis spermatozoa number ($r = 0.51$). Almquist and Amann (1961), working with dairy bulls, found a correlation of 0.560 for testis sperm and head and body spermatozoa but a nonsignificant correlation of -0.155 between testes sperm and tail epididymis spermatozoa. Testis sperm and sperm in epididymis had a nonsignificant correlation of 0.14. In sexually rested rabbits a significant correlation of 0.64 between epididymal spermatozoa reserve and gonadal sperm reserve has been reported. (Orgebin-Crist, 1968).

The correlations of boar growth rates and backfat probe with testes and epididymal characteristics are shown in Table VIII. Few of these correlations are significant and the significant correlations between weaning weight and head and body epididymis spermatozoa ($r = 0.25$), tail epididymis weight ($r = 0.40$) and tail epididymis spermatozoa ($r = 0.25$), tail epididymis weight ($r = 0.40$) and tail epididymis spermatozoa ($r = 0.32$) are small. All of the correlations between average daily gain and age at 220 pounds with testes and epididymal characteristics are nonsignificant. Reports in bulls, rabbits and mice all show a small and nonsignificant correlation between body weight and testes weight (Almquist and Amann, 1961; Orgebin-Crist, 1968; and Johnson and Eisen, 1975).

TABLE VIII

CORRELATIONS BETWEEN BOAR GROWTH AND TESTES AND EPIDIDYMAL CHARACTERISTICS

	Testes Weight	Testes Sperm no.	Testes Concentration	Head and Body Epididymis Weight	Head and Body Epididymis Sperm no.	Head and Body Epididymis Concentration	Tail Epididymis Weight	Tail Epididymis Sperm no.	Tail Epididymis concentration
Birth Weight	0.11	0.17	0.09	0.06	0.11	-0.01	0.27**	0.16	0.06
Weaning Weight	0.19	0.14	0.04	0.11	0.25**	0.08	0.40**	0.32**	0.23*
Daily Gain	0.17	-0.04	-0.01	0.07	-0.08	-0.16	0.04	-0.14	-0.19
Age at 220 lbs.	-0.16	-0.11	-0.07	-0.13	-0.13	-0.01	-0.18	-0.03	0.03
Back Fat Probe	-0.12	-0.07	0.03	-0.02	-0.04	0.07	-0.14	-0.09	-0.02

* $P < .05$
** $P < .01$

Previous research (Almquist and Amann, 1961; Amann and Almquist, 1962; and Orgebin-Crist, 1968) showed differences between sperm production and epididymal reserves due in part to sperm reabsorption in the epididymis. Although there is a relationship between the number of testes sperm and head and body epididymis spermatozoa and tail epididymis spermatozoa, it is not strong enough for predictive value and therefore the best estimate of sperm production would be testes sperm reserves. As a result it can be concluded that these crossbred boars were producing more sperm than purebred boars at 7 1/2 months of age.

The Reproductive Efficiency and Mating Behavior of 7 1/2 to 9 Month Old Purebred and Crossbred Boars

Reproductive efficiency of a sire is measured by conception rate and number of embryos or pigs born per dam exposed. Table IX shows the number of Yorkshire gilts exposed to boars of each breed and the number of pregnant gilts per sire breed group. There was no significant difference between breed groups for the percent of gilts pregnant (Table IX). The crossbreds had a 7.9% higher conception rate than purebreds however, this was due mainly to the 14.6% lower conception rate for Hampshire boars compared to Duroc boars. The overall conception rate of 60% is low but when considering that there were no rebreeds of gilts found to be open, it is more realistic. Baker (1973) reported that crossbred boars settled 10% more ($P < .07$) sows than purebred Yorkshire boars.

TABLE IX

AVERAGE CONCEPTION RATE BY BREED GROUP

	No. Boars	No. Gilts Exposed	No. Gilts Pregnant	% Pregnant[a]
Duroc	20	38	24	63.2 ± 15.3
Duroc x Hampshire	20	40	27	67.5 ± 14.5
Hampshire x Duroc	20	40	24	60.0 ± 15.2
Hampshire	19	35	17	48.6 ± 16.6
Purebred $\bar{X}$		73	41	55.9 ± 11.4
Crossbred $\bar{X}$		80	51	63.8 ± 10.5
Crossbred - Purebred				7.9 ± 15.5
Duroc - Hampshire				14.6 ± 22.6

[a]includes .95 confidence interval

TABLE X

LEAST SQUARES MEANS AND STANDARD ERRORS FOR EMBRYO NUMBER AND PERCENT EMBRYOS OF CORPUS LUTEA BY SIRE BREED GROUP

Breed of Boar	No. of Gilts	Number of Corpus Lutea	Embryo Number[a]	Percent Embryos of Corpus Lutea
Duroc	24	16.08	10.72 ± 0.67	70.14 ± 4.33
Duroc x Hampshire	27	14.81	11.57 ± 0.59	78.24 ± 4.17
Hampshire x Duroc	24	14.58	11.17 ± 0.60	75.30 ± 3.94
Hampshire	17	15.29	10.48 ± 0.76	69.57 ± 4.95
Purebred $\bar{X}$			10.60 ± 0.50	69.86 ± 3.29
Crossbred $\bar{X}$			11.37 ± 0.44	76.77 ± 2.87
Crossbred-Purebred			0.77 ± 0.67	6.91 ± 4.36
Duroc - Hampshire			0.24 ± 1.01	0.37 ± 6.58

[a]adjusted to a mean ovulation rate

The number of embryos, 30 days postbreeding, adjusted for rate of ovulation are shown in table XX. Since the partial regression of corpus lutea was significant, the number of embryos was adjusted to a mean ovulation rate. Although it was non-significant, the crossbred boars sired litters which had 0.77 more embryos. If this difference is real, it would be of practical significance. None of the sources of variation, season, breed of sire of boar, breed of dam of boar or interactions were significant. (Appendix table XX).

The failure of breed of sire to be significant for embryo numbers is in agreement with Reddy et al. (1958) and O'Ferral et al. (1968) who reported that breed of sire was not significant for litter size at farrowing. No reports could be found on survival rate of embryos from crossbred sires. Johnson and Omtvedt (1973) reported a significant specific breed of sire effect for number of pigs in a litter at 21 and 42 days. In the same report they found no difference between breed of sire groups for number of embryos at 30 days postbreeding. This suggests that these litters may have to be carried to term or to weaning to detect any breed of sire effect on number of pigs per litter.

The crossbred boars had a higher percent (6.91%) of live embryos per corpus lutea ($p = .12$) This may be due to fewer corpus lutea per gilt in the crossbred groups; however, there were no differences in dead embryos between breed groups (Appendix Table XX). The crossbred boar mean (76.8%) and the purebred boar mean (69.9%) are both below the values of about 84% when Durocs and Hampshires were mated to Yorkshire gilts. (Johnson and Omtvedt, 1973).

The number of failures of a boar to mate when exposed to an estrus gilt is shown in Table XI. The median test, illustrated in Appendix Table XXII, (Conover, 1971) was used to analyze the data. The crossbred boars were significantly different from the purebred boars ($P < .001$). Twenty-eight of the crossbreds mated every time they were exposed and eight failed one time. Only three of the Durocs and eight of the Hampshires mated every time. No crossbred boar had more than two failures while 15 purebred boars had two or more failures. Dewsbury (1975) reported that with rats the proportion of inbred parental males that failed to mate in a series of four consecutive tests was much smaller than the proportion of the F_1 males that failed the test.

Table XII reports the breed group means for mating times which were analyzed without considering whether it was the first or second gilt mated to the boars. Each of these traits, and those discussed later, were analyzed individually in order to have the maximum number of observations for each measurement. The reasons for the unequal numbers are that mount times were taken for all four seasons and ejaculation time was taken only the last three seasons. Also, several gilts would not mate on the second day and occassionally a second gilt was not available for a boar.

It is evident that there is little measurable difference among breed groups for time it takes to mount or for ejaculation time. Duroc boars had a significantly longer ejaculation time than Hampshire on the second service. Overall trends are that both purebred and crossbred boars mount faster on the second day. Ejaculation time appeared to be longer on the second mating.

TABLE XI

MATING BEHAVIOR FOR BOARS OF EACH BREED WHEN EXPOSED TO A GILT SHOWING ESTRUS

Breed Group	Total No. Boars	No. of Boars That				
		Mated a Gilt Each Time Exposed	Had 1 Failure to Mate	Had 2 Failures to Mate	Had 3 Failures to Mate	Had 4 or More Failures to Mate
Duroc	18	3	7	5	1	2
Duroc x Hampshire	18	16	2	0	0	0
Hampshire x Duroc	18	12	6	0	0	0
Hampshire	18	8	3	4	0	3

TABLE XII

BREED GROUP LEAST SQUARES MEANS AND STANDARD ERRORS FOR MATING TIME

Breed	No. of Boars	First Day Mount[a]	No. of Boars	First Day Ejaculation[a]	No. of Boars	Second Day Mount[a]	No. of Boars	Second Day Ejaculation[a]
Duroc	39	127.4 ± 14.4	32	165.2 ± 11.1	27	70.7 ± 15.7	22	216.2 ± 17.0
Duroc x Hampshire	40	105.9 ± 14.1	30	176.8 ± 11.1	26	58.0 ± 16.1	18	178.9 ± 19.2
Hampshire x Duroc	40	115.4 ± 13.8	30	160.3 ± 11.1	25	106.3 ± 16.3	19	204.9 ± 18.3
Hampshire	35	126.4 ± 15.0	26	152.4 ± 12.0	28	94.4 ± 15.2	21	162.0 ± 17.3
Purebred $\bar{X}$		126.9 ± 10.4		158.8 ± 8.1		82.6 ± 10.9		189.1 ± 12.1
Crossbred $\bar{X}$		110.7 ± 9.8		168.6 ± 7.8		82.2 ± 11.4		191.9 ± 12.1
Crossbred - Purebred		-16.2 ± 14.3		9.8 ± 11.2		-0.4 ± 15.8		2.8 ± 18.0
Duroc - Hampshire		1.0 ± 20.8		12.8 ± 16.1		-23.7 ± 21.9		54.2 ± 24.3*

[a]measurement in seconds

*Significantly different from zero, $P < .05$

Tables XIII and XIV partition the overall means into the means for mount 1 on gilt 1 (M11), mount 2 on gilt 1 (M21), mount 1 on gilt 2 (M12), mount 2 on gilt 2 (M22) and the corresponding ejaculation times, ejaculation 1 for gilt 1 (E11), ejaculation 2 for gilt 1 (E21), ejaculation 1 for gilt 2 (E12) and ejaculation 2 for gilt 2 (E22). The analyses of variance for thse times are in Table XXIII and Table XXIV. The crossbred boar advantage of 38 seconds for faster first mount (M11) approached significance ($P < .10$). However, there is no difference in M21, M12 or M22 between purebreds and crossbreds or Duroc and Hampshires. Integrating the difference between the crossbreds and purebreds for failing to mate and the crossbred boar advantage for mounting faster on the first mount, it appeared that the crossbred boars learn to mount quicker, but once the purebred boars have made one mount, there is no significant difference in mounting time.

From observation during the collection of the data, it is apparent that many environmental factors influence the mating behavior of the boar. These include handling of the boar prior to going into the breeding pen, activity of the boar, and receptivity of the gilt. A time measurement as taken in this study, does not adequately measure libido of a boar. Mattner et al. (1971) have suggested that for young rams a simple form of libido test based on a count of services performed in a pen test may provide a useful indication of the subsequent service activity of young rams under flock mating conditions. They found that if a ram failed in a pen test he was likely to perform poorly in flock mating.

The means (Table XIV) and analyses of variance (Appendix Table XXIV) indicate that there is a large amount of boar variation for

TABLE XIII

BREED GROUP MEANS AND STANDARD ERRORS FOR MOUNT TIME

	No. of Boars	Mount #1[a] Gilt #1 (M11)	No. of Boars	Mount #2[a] Gilt #1 (M21)	No. of Boars	Mount #1 Gilt #2 (M12)	No. of Boars	Mount #2 Gilt #2 (M22)
Duroc	19	168.05±24.00	12	69.50±17.69	19	108.84±14.30	16	68.44±24.36
Duroc x Hampshire	20	139.50±23.39	12	67.58±17.69	20	72.20±13.94	14	45.86±26.04
Hampshire x Duroc	20	129.25±23.39	11	91.73±18.48	20	101.55±13.94	14	118.57±26.04
Hampshire	16	176.69±26.15	15	93.27±15.83	16	75.38±15.59	13	94.00±27.02
Purebred $\bar{X}$		172.37±17.68		81.39±11.80		92.11±10.54		81.22±18.09
Crossbred $\bar{X}$		134.38±16.54		79.66±12.78		86.88± 9.86		82.22±18.41
Crossbred - Purebred		-37.99±24.21		-1.73±17.39		-5.24±14.43		1.00±25.81
Duroc - Hampshire		-8.64±35.49		-23.77±23.74		33.46±21.15		-25.56±36.38

[a]Measurement in Seconds

TABLE XIV
BREED GROUP MEANS AND STANDARD
ERRORS FOR EJACULATION TIME

	No. of Boars	Ejaculation #1[a] Gilt #1 (E11)	No. of Boars	Ejaculation #2[a] Gilt #1 (E21)	No. of Boars	Ejaculation #1 Gilt #2 (E12)	No. of Boars	Ejaculation #2 Gilt #2 (E22)
Duroc	16	167.75±16.05	8	202.25±23.12	16	153.25±19.14	14	223.00±23.05
Duroc x Hampshire	15	174.80±16.58	7	155.14±24.72	15	188.40±19.77	11	194.27±26.00
Hampshire x Duroc	15	160.33±16.58	8	218.88±23.12	15	202.27±19.77	11	207.45±26.00
Hampshire	12	163.25±18.53	11	171.00±19.72	12	141.25±22.10	10	155.50±27.27
Purebred $\bar{X}$		165.50±12.13		186.63±15.00		147.25±14.47		189.25±17.60
Crossbred $\bar{X}$		167.57±11.72		187.01±16.89		195.34±13.98		200.86±18.39
Crossbred - Purebred		2.07±16.87		0.38±22.59		48.09±20.12*		11.61±25.45
Duroc - Hampshire		4.50±24.52		31.25±30.39		12.00±29.24		67.50±35.70

[a]Measurement in Seconds
*Significantly different from zero, $P < .05$

ejaculation time. Ejaculation time tends to increase after the first service of a boar for the crossbreds and Durocs. Hampshire boars varied little in length of ejaculation over the four services. Swierstra and Rahnefeld (1967) reported significantly different mean ejaculation times of 5.7 minutes for Yorkshire boars and 7.2 minutes for Lacombe boars collected for artificial insemination. These times cannot be compared to the results in this experiment but do show breed differences for ejaculation time.

Table XV shows the correlations between the mating times which were mostly small and nonsignificant. The correlation between ejaculation 1 and 2 on gilt 1 was 0.36, ($P < .10$) and 0.52 ($P < .01$) between ejaculation 1 and 2 on gilt 2. Apparently a boar's response is related to an individual gilt and does not remain the same between gilts as the correlation between measurements made on different gilts was very small.

The variability and inconclusiveness of results of the study of sexual behavior have been shown by several researchers with laboratory animals. Dewsberry (1975) in a diallel cross with four strains of rats found that the F_1 rats were more likely to mate and consistently ejaculated after fewer intromissions with fewer mounts than animals with parental genotypes. Jakeway (1959) described dominance of a lethargic strain of guinea pigs as the genetic mechanism for inheritance of measures such as nuzzling and mounting while a heterotic effect for intromission and ejaculation rate was apparent.

It is apparent from this study of boar mating behavior that unless a much more descriptive way to quantify the mating behavior is developed, the inherent and environmental causes of boar variation will make it very difficult to detect breed differences or to adequately relate male sexual activity to other measures of performance.

TABLE XV
CORRELATIONS BETWEEN MATING TIMES

	No. of Boars	Mount #1 Gilt #2	Mount #2 Gilt #2	Ejaculation #1 Gilt #2	Ejaculation #2 Gilt #2	Mount #2 Gilt #1	Mount #2 Gilt #2	Ejaculation #2 Gilt #1	Ejaculation #2 Gilt #2
Mount #1 Gilt #1	75	0.02							
Mount #2 Gilt #1	34		0.21						
Ejaculation #1 Gilt #1	58			0.11					
Ejaculation #2 Gilt #1	25				-0.08				
Mount #1 Gilt #1	50					0.23			
Mount #1 Gilt #2	57						0.01		
Ejaculation #1 Gilt #1	34							0.36*	
Ejaculation #1 Gilt #2	46								0.52**

*Significantly different from zero, P < .10
**Significnatly different from zero, P < .01

CHAPTER V

SUMMARY

The objectives of this study were to evaluate and compare:

(1) the testicular and epididymal development of seven and one-half month old purebred and crossbred boars and,

(2) the reproductive efficiency and mating behavior of 7 1/2 to 9 month old purebred and crossbred boars.

The crossbred boars testes were 95.3 g heavier ($P < .01$) and contained 14.4×10^9 greater sperm numbers than the mean of the purebred Duroc and Hampshire boars. Thus, heterosis estimates are 16.2% for testes weight and 25.1% for testes sperm numbers. There was no significant breed group difference when testes sperm numbers were expressed as sperm number per gram testes.

There were no significant differences among breed groups for head and body spididymis weight or sperm numbers. Crossbred boars had significantly heavier tail epididymis than did the purebreds. Duroc boars had 24.55×10^9 more sperm numbers in the tail epididymis ($P < .05$) and significantly more sperm numbers per gram of tail epididymis.

Testes weight was significantly correlated with testes sperm number ($r = 0.65$), Head and Body sperm number ($r = 0.51$) and tail epididymis sperm number ($r = 0.49$). Testes sperm number was correlated with head and body epididymis sperm number ($r = 0.45$) and

tail epididymis sperm number (0.51). In this study, testes weight and testes sperm number are probably the best indicators of differences between breed groups for sperm numbers. Weaning weight had a small significant correlation with head and body epididymis sperm numbers and tail epididymis sperm numbers. Average daily gain, age at 220 pounds and probe backfat at 220 pounds were not significantly correlated with any of the testicular or epididymal characteristics.

Crossbred boars had a nonsignificant greater conception rate by 7.9% than purebreds. Durocs were higher than Hampshires by 14.6%, however, this difference is not significant. The mean number of live embryos was 10.60 for purebred sired litters and 11.37 for crossbred sired litters. The crossbred boars had a nonsignificant higher percent embryos of corpus lutea (76.66%) than the purebred boars (69.85%).

Crossbred boars had fewer failures to mate as 28 to 36 boars mated every time as compared to 11 of 36 boars in the purebred groups. Crossbred boars tended to mount faster the first exposure; however, after the first mount, there were no significant difference among breed groups. This suggests that crossbred boars learn to mate quicker than do purebreds.

There were no significant differences between breed groups for length of ejaculation except that the crossbreds were longer for the first ejaculation with the second gilt by 48.09 seconds. A large amount of boar variation was present for each of these measurements making it difficult to determine if breed groups differ in sexual behavior.

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APPENDIX

TABLE XVI

GROWTH PERFORMANCE AND BACKFAT PROBE MEANS
AND STANDARD ERRORS FOR CASTRATED BOARS

	Gain	Age at 220 lbs	BF Probe at 220 lbs
Duroc	1.77 ± 0.04	168 ± 1.9	1.03 ± 0.03
Duroc x Hampshire	1.90 ± 0.03	158 ± 1.8	0.97 ± 0.02
Hampshire x Duroc	1.92 ± 0.04	163 ± 2.4	0.95 ± 0.03
Hampshire	1.60 ± 0.04	175 ± 2.1	0.85 ± 0.03
Purebred $\overline{X}$	1.69 ± 0.05	172 ± 2.9	0.94 ± 0.02
Crossbred $\overline{X}$	1.91 ± 0.04	161 ± 2.1	0.96 ± 0.02
Crossbred - Purebred	0.22 ± 0.03**	-11 ± 1.4**	0.02 ± 0.03
Duroc - Hampshire	0.17 ± 0.03*	-7 ± 1.7*	0.18 ± 0.04*

*Significnatly different from zero, P < .001
**Significantly different from zero, P < .0001

TABLE XVII

ANALYSIS OF VARIANCE TESTES WEIGHT, SPERM AND CONCENTRATION

Source	df	Testes Weight, g MS	No. Testes Sperm[a] MS	Testes Concentration[b] MS
Season	3	81489.7**	7297.5**	0.018168**
BOS	1	88725.0**	1364.1	0.000048
Season x BOS	3	18949.0	966.5	0.001326
BOD	1	1487.0	21.5	0.001206
Season x BOD	3	4313.6	92.1	0.000888
BOS x BOD	1	80208.8**	5496.4**	0.000258
Season x BOS x BOD	3	16076.8	262.2	0.003870
Error	100	13774.6	406.3	0.001850

**Significantly different from zero, $P < .01$

[a]Value analyzed was No. sperm $X\ 10^9$

[b]Value analyzed was No. sperm per gram of tissue $X\ 10^9$

TABLE XVIII

ANALYSIS OF VARIANCE FOR HEAD AND BODY EPIDIDYMIS WEIGHT, NUMBER OF SPERM AND SPERM CONCENTRATION

Source	df	Head and Body Epididymis Wt.,g MS	No. of Head and Body Epididymis Sperm[a] MS	Head and Body Epididymis Concentration[b] MS
Season	3	4581.7	11817.3*	1.2845*
BOS	1	13041.7	891.2	0.2729*
Season x BOS	3	5197.8	252.1	0.0394
BOD	1	3550.2	48.5	0.0012
Season x BOD	3	7717.8	909.3	0.0516
BOS x BOD	1	1948.8	738.1	0.0476
Season x BOS x BOD	3	7167.7	326.8	0.0140
Error	100	6945.9	488.8	0.0486

*Significantly different from zero, $P < .01$

[a]Value analyzed was No. sperm X 10^9

[b]Value analyzed was No. sperm per gram of tissue X 10^9

TABLE XIX

ANALYSIS OF VARIANCE FOR TAIL EPIDIDYMIS WEIGHT, NUMBER OF SPERM AND SPERM CONCENTRATION

Source	df	Tail Epididymis Wt.,g MS	No. of Tail Epididymis Sperm[a] MS	Tail Epididymis Concentration[b] MS
Season	3	1458.6**	54723.9**	5.7025**
BOS	1	1738.2*	6637.6	0.2192
Season x BOS	3	94.2	4361.9	0.2337
BOD	1	123.5	2009.5	0.5186
Season x BOD	3	104.6	1521.5	0.1109
BOS x BOD	1	1203.1*	4047.2	0.1832
Season x BOS x BOD	3	128.2	1526.3	0.1223
Error	100	286.6	2019.5	0.1804

*Significantly different from zero, $P < .05$
**Significantly different from zero, $P < .01$
[a]Value analyzed was No. sperm $\times 10^9$
[b]Value analyzed was No. sperm per gram of tissue $\times 10^9$

TABLE XX

ANALYSIS OF VARIANCE FOR NUMBER OF LIVE, DEAD AND TOTAL EMBRYOS

Source	df	No. Live Embryos MS	No. Dead Embryos MS	No. Total Embryos MS
Season	3	3.047	0.3668	3.304
BOS	1	2.132	0.0011	2.036
Season x BOS	3	7.88	0.0869	7.589
BOD	1	0.134	0.0058	0.084
Season x BOD	3	6.606	0.0980	7.372
BOS x BOD	1	12.329	0.5727	18.217
Season x BOS x BOD	3	15.257	0.5226	11.033
Corpus Lutea	1	114.705*	0.0089	116.734*
Error	76	9.286	0.2422	9.459

*Significantly different from zero, $P < .01$

TABLE XXI

CHI-SQUARE TEST FOR CONCEPTION RATE

	No. Gilts Pregnant	No. Gilts Open	Total	$\hat{P}$	$\hat{P}$ Pregnant
Duroc	24	14	33	.632	15.168
Duroc x Hampshire	27	13	40	.675	18.225
Hampshire x Duroc	24	16	40	.600	14.400
Hampshire	17	18	35	.486	8.262
Totals	92	61	153		56.055
				.601	55.292

$$X^2 = \frac{56.055 - 55.292}{(.601)(1-.601)} = 3.18$$

TABLE XXII

THE MEDIAN TEST FOR BREED OF BOAR FAILURE TO MATE

	Duroc	Duroc x Hampshire	Hampshire x Duroc	Hampshire	Total
> Median	15	2	6	10	33
≤ Median	3	16	12	8	39
Total	18	18	18	18	72

T = 20.76

Medians are different between groups (P < .001)

	Crossbred	Purebred	Total
> Median	8	25	33
≤ Median	28	11	39
Total	36	36	72

T = 16.17

Medians are different between breed groups (P < .001)

TABLE XXIII

ANALYSIS OF VARIANCE FOR BOAR MOUNT TIMES

Source	df	Mount #1 Gilt #1[b] MS	Mount #2 Gilt #1[b] MS	Mount #1 Gilt #2[b] MS	Mount #2 Gilt #2[b] MS
Season	3	7541.1	3181.4	15545.7*	5160.5
BOS	1	607.6	4586.4	235.8	26944.0
Season x BOS	3	12394.5	7423.0	5740.7	1452.7
BOD	1	60.0	48.5	12002.4	3346.2
Season x BOD	3	5245.7	989.5	774.5	427.7
BOS x BOD	1	34209.1	457.1	44.5	2.2
Season x BOS x BOD	3	5137.4	1239.0	5718.3	7051.4
Error[a]		10939.5	3757.1	3886.4	9493.2

[a]Error df = 59, 34, 59, 41, respectively

[b]Measurement in seconds

*significantly different from zero, $P < .05$

TABLE XXIV

ANALYSIS OF VARIANCE FOR BOAR EJACULATION TIMES

Source	df	Ejaculation #1 Gilt #1[b] MS	Ejaculation #2 Gilt #1[b] MS	Ejaculation #1 Gilt #2[b] MS	Ejaculation #2 Gilt #2[b] MS
Season	2	2602.3	12160.1	5020.3	4292.6
BOS	1	1830.3	4876.4	2.9	15564.1
Season x BOS	2	4754.1	14622.2*	7547.0	21664.9
BOD	1	134.0	20451.9*	2895.9	9396.4
Season x BOD	2	853.4	7605.2	433.5	1994.3
BOS x BOD	1	423.2	648.1	35498.3*	1587.5
Season x BOS x BOD	2	4944.3	1403.2	1403.2	1786.2
Error[a]		4121.6	4277.8	5862.8	7436.5

[a]Error df = 46, 22, 46, 34, respectively

[b]measurement in seconds

*significantly different from zero, $P < .05$

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