A STUDY OF THE HERITABILITIES AND CORRELATIONS AMONG MEASURES OF PERFORMANCE AND PRODUCTIVITY IN GILTS

By

PETTER INGE BERGHEIM

Agricultural Degree

Agricultural University of Norway

Aas-NLH, Norway

1973

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, 1975

A STUDY OF THE HERITABILITIES AND CORRELATIONS

AMONG MEASURES OF PERFORMANCE

AND PRODUCTIVITY IN GILTS

Thesis Approved:

Rodger K. Johnson
Thesis Adviser

Joe Whiteman

Robert P. Wettemann

N N Durham
Dean of the Graduate College

ACKNOWLEDGEMENTS

The author would like to express his sincere appreciation to Dr. R. K. Johnson, Assistant Professor of Animal Science for his excellent guidance and counsel during the preparation of this thesis and throughout our aquaintance.

Thanks goes also to Dr. J. V. Whiteman and Dr. R. P. Wettemann for assistance in proofing this manuscript and for serving as members of my committee. Appreciation goes to fellow graduate students, especially Larry Young for help and advice with regard to the statistical treatment of the data.

Special thanks goes to the authors parents, family and wife, Solfrid, who through their moral support made this study possible.

TABLE OF CONTENTS

Chapter | Page

I. INTRODUCTION 1

II. REVIEW OF LITERATURE 3

General Breeding Principles 3
Genetic Correlations 4
Heritabilities for Some of the Important Traits in Swine 8
Correlations between a Females Own Performance and Productivity in Swine 11
Summary of Literature Review 14

III. MATERIALS AND METHODS 15

Management and Husbandry 18
Data Used and Traits Considered 20
Statistical Treatment of the Data 21

IV. RESULTS AND DISCUSSION 34

Discussion of the Separate Analyses 34
Estimates of Heritability 42
Phenotypic Correlations between Performance and Productivity 45
Genetic Correlations between Performance and Productivity 49

V. SUMMARY 57

LITERATURE CITED 61

APPENDIX 65

LIST OF TABLES

Table		Page
I.	Mating System in the Different Seasons	17
II.	Number of Litters Farrowed in Each Season and Breed-Group in Seasons with Purebred and 2-Breed Cross Litters	22
III.	Number of Litters Farrowed in Each Season and Breed-Group in Seasons with 2-Breed Cross and 3-Breed Cross Litters	23
IV.	Observed and Expected Mean Squares and Mean Cross Products for Pooled Analyses	30
V.	Observational and Causal Components of Variance and Covariance	31
VI.	Explanation of Symbols Used	32
VII.	Breed Group Means for Gilts Growth Performance Traits in Seasons with Purebred and 2-Breed Cross Litters	35
VIII.	Breed Group Means for Gilts Reproductive Performance in Seasons with Purebred and 2-Breed Cross Litters	36
IX.	Breed Group Means for Gilts Growth Performance Traits in Seasons with 2-Breed Cross and 3-Breed Cross Litters	37
X.	Breed Group Means for Gilts Reproductive Performance in Seasons with 2-Breed Cross and 3-Breed Cross Litters	38
XI.	Heritabilities and Standard Errors from Pooled Analysis	43
XII.	Phenotypic Correlations Between the Gilts Growth Performance Traits and Her Reproductive Performance Based on Pooled Analyses	46

Table		Page
XIII.	Genetic Correlations from Pooled Analyses	51
XIV.	Genetic Correlations from Pooled Analyses	52
XV.	Heritability Estimates for Purebred Gilts with Purebred Litters	66
XVI.	Heritability Estimates for Purebred Gilts with Crossbred Litters	67
XVII.	Heritability Estimates for Crossbred Gilts with 3-Breed Cross Litters	68
XVIII.	Phenotypic Correlations for Purebred Gilts with Purebred Litters	69
XIX.	Phenotypic Correlations for Purebred Gilts with Crossbred Litters	70
XX.	Phenotypic Correlations for Crossbred Gilts with 3-Breed Cross Litters	71
XXI.	a. Genetic Correlations for Purebred Gilts with Purebred Litters	72
XXI.	b. Genetic Correlations for Purebred Gilts with Purebred Litters	73
XXII.	a. Genetic Correlations for Purebred Gilts with Crossbred Litters	74
XXII.	b. Genetic Correlations for Purebred Gilts with Crossbred Litters	75
XXIII.	a. Genetic Correlations for Crossbred Gilts with 3-Breed Cross Litters	76
XXIII.	b. Genetic Correlations for Crossbred Gilts with 3-Breed Cross Litters	77

CHAPTER I

INTRODUCTION

Swine production is an important part of agriculture in many parts of the world. Economically, where concentrates are available at a reasonable price and where land area is the limiting factor, it is a well fitted solution as the main production or as an additional source of income for many farmers. In total energy, swine is one of the more efficient species commonly used in converting plant products to animal protein for human consumption.

The economically important traits that have been emphasized in most swine breeding programs have been carcass traits and growth rate which are moderate to highly heritable. Reproductive traits are lowly heritable, and consequently little progress is expected from direct selection for reproductive performance. However, improving reproductive efficiency offers tremendous potential for improving overall efficiency of the swine industry and further investigation of the genetic factors influencing reproductive efficiency are justified.

Knowledge of genetic correlations between highly heritable performance traits and reproductive efficiency will aid in evaluating the effectiveness of indirect selection for a trait like litter size. Knowledge of this relationship will also assist in evaluating the correlated response in fitness traits when selecting directly for other more highly heritable traits. Genetic correlations between reproductive traits and traits expressed early in life are helpful in accurately selecting the replacement females for the herd at an early age. These correlations are necessary in the development of selection indexes with the appropriate traits included and the appropriate weight on the different traits. Phenotypic correlations are also of interest to the producer because these help him in predicting future performance on a particular animal.

The objectives of this study were to look at some genetic as well as phenotypic relationships between a young gilt's growth performance and her performance as a reproducing individual. Thus, providing information to evaluate the effectiveness of indirect selection for reproductive performance.

CHAPTER II

REVIEW OF LITERATURE

General Breeding Principles

For any population of animals, if we define the desirable traits to select for, we can say that the aim of all work in animal breeding is to make improvement with regard to these traits. The principles of population genetics used in animal breeding were mainly developed in the 1920's. Through the work of J.L. Lush and others the population genetic theory has been applied and animal breeding has become a science based on genetic and statistical principles. Descriptions of these principles refered to here are based on books by Falconer (1960) and Pirchner (1969).

Basically, genetic improvement can be made in two ways:

1. By selection, which allows individuals with desirable traits to leave more offspring than others, and in this way change the gene frequency in the population and the population mean.
2. By mating systems, which are some non-random way of deciding matings, that produce desirable offspring.

There are different methods of selection. Individuals can be selected based on their own performance, pedigree, offspring, half-sibs or full-sibs. The phenotype is determined by the genotype and the environment. The genotype expresses itself through additive dominance and epistatic gene effects. Selection on individual performance is based on phenotypic superiority in the individuals selected compared to the rest of the population (SD). The heritability (h^2) gives a measure of to what extent phenotypic differences are passed on to the offspring, and consequently expected progress is: $\Delta G = h^2 \cdot SD$. For this reason, it is of interest to know the heritabilities for the economically important traits. For traits with low heritabilities, it is difficult to make very much progress by selecting only on an individual's performance, or mass-selection, because the environmental and the non-additive genetic factors mask differences due to additive genetic effects.

Genetic Correlations

To aid in selection it is of benefit to know the correlations or covariances between traits. Correlations of interest are phenotypic correlations, which are the correlations between phenotypic values; the genetic correlations which are the correlations of breeding values; and the environmental correlations which usually contain the correlations of environmental deviations together with non-additive genetic deviations.

A correlation is basically the ratio of the appropriate covariance to the product of the two standard deviations. The relation between phenotypic, genetic and environmental correlation is given by Falconer (1960):

$$r_p = \frac{cov_p}{\sigma_{px} \cdot \sigma_{py}} \qquad \text{or} \qquad r_p = \frac{cov_A + cov_E}{\sigma_{px} \cdot \sigma_{py}}$$

where cov_p = phenotypic covariance between the two characters x and y.

cov_A = additive covariance between the two characters x and y.

cov_E = non-additive covariance between the two characters x and y.

σ_{px} and σ_{py} = standard deviations for phenotypes with regard to x and y respectively

When substituting $\sigma_A^2 = e^2\sigma_p^2$ and $\sigma_E^2 = \sigma_p^2$ in the formula above, it derives to $r_p = h_x h_y r_A + e_x e_y r_E$

where h_x and h_y = the square root of the heritability for x and y respectively,

$e_x = \sqrt{1 - h_x^2}$

$e_y = \sqrt{1 - h_y^2}$

r_A = the genetic correlation between x and y

r_E = the environmental correlation between x and y

σ_A^2 = the additive genetic variance

σ_E^2 = the environmental variance + all non additive genetic variance.

When the heritability estimates for a trait are low it might be better to select for a correlated trait and in this way obtain an indirect response. The relation between direct and indirect selection is given by Falconer (1960):

The response of character X directly selected for is

$$R_x = i_x h_x \sigma_{AX}.$$

The expected correlated response in character X when selecting for character Y is

$$CR_x = i_y h_y r_A \sigma_{AX}$$

where i_x and i_y = the selection intensity for x and y, respectively;

h_x and h_y = the square root of heritability for x and y, respectively;

σ_{AX} = the additive genetic standard deviation for X; and

r_A = the genetic correlation between trait X and Y.

From the above we find:

$$\frac{CR_x}{R_x} = r_A \cdot \frac{i_y}{i_x} \cdot \frac{h_y}{h_x},$$

and assuming $i_y = i_x$ we see that when $r_A h_y > h_x$ we get: $CR_x > R_x$ and consequently indirect selection is more efficient than direct selection for trait X.

Selection studies with mice (Bradford, 1968, 1969, 1971; Meyer and Bradford, 1974) produced the following observation on correlated responses:

1. Selection for litter size resulted in a marked increase in ovulation rate.

2. A positive genetic correlation between body weight and ovulation rate, but prenatal loss was not predictably associated with body weight.

3. No evidence that selection for litter size following superovulation resulted in any increase in genetic merit for litter size, even though this permitted selection differentials nearly double those obtained in the absence of superovulation.

4. A line selected for rapid growth during three to six weeks of age had a considerable higher ovulation rate than both the unselected control line and the line selected for ovulation rate. Thus, the correlated response in ovulation rate was higher than the response when selecting directly for ovulation rate.

Results from experiments with laboratory species have been a significant aid in breeding of farm animals and there have been no obvious inconsistencies between results from laboratory species and genetic theory (Chapman, 1951; Roberts, 1965). Correlations between individual growth performance and reproductive performance have been observed in poultry (Lush et al. 1948; Hogsett and Nordskog, 1958; King, 1961; Kolstad, 1972) and sheep (Turnes, 1969; Cunningham and Gjedrem 1970).

Genetic correlations are caused primarily by pleiotropy, which is one gene influencing more than one trait, but also to some extent by linkage. Genetic correlations caused by linkage occur most frequently in early generations of crosses between populations or strains. However, through the crossing over and recombination that occurs during random mating, linkage groups tend to be broken up. The usefulness as well as the values of genetic correlations may change over time, and after many generations of selection their values tend to be negative. This is because of fixation of these genes affecting two traits in the same direction, and these genes contribute little to the variance or the covariance of the two traits. Genes acting favorably on one trait and unfavorably on another will remain unfixed, and will contribute relatively more to the variance and covariance. The genes working in different directions for different traits will remain at intermediate frequencies for a longer time because on the average, selection is for the heterozygous individuals with respect to these genes. Economic value is usually determined by a number of traits, so it is important to know correlations between traits, and how selection for one trait affects others. This aids in determining weighting factors for the traits to be selected for and to develop indexes for breeding purposes.

Heritabilities for Some of the Important Traits in Swine

Even if this study mainly was meant to deal with correlations among traits it is natural also to look at the heritabilities for some of the economically important performance and productivity traits that have been studied, because of the close relationship between heritabilities and correlation coefficients.

As indicated before, heritability estimates for reproductive traits are low. Lush and Molln (1942) used 7415 litters from 2560 different sows and estimated the heritability (h^2) of litter size at birth to be 0.17. With so many individuals involved this should prove to be a realistic estimate even, if some later studies have indicated it might be lower. Stewart (1945b) got estimates that ranged from 0.088 to 0.176 for h^2 of litter size while Cummings et al. (1947) arrived at a value of 0.22 and Blunn and Baker (1949) observed $h^2 = 0.24$ and $h^2 = 0.25$ for litter size at birth.

Louca and Robison (1967) used 8039 records of individual pigs from 1396 litters and 76 sires to look at variance components and covariance components obtained from contemporary purebred and crossbred offspring of Durocs and Yorkshires. Using daughter-dam regression, h^2 for litter size was estimated to be 0.05. Using the same technique, Revelle and Robison (1973) got $h^2 = 0.13$. However, by regressing granddaughter on granddam an estimate of 0.28 was obtained for litter size. An explanation for this was that the stress of being raised in a large litter is removed by using granddam-granddaughter regression when estimating heritabilities. Using sire components of variance, Dickerson et al. (1974) got $h^2 = 0.02$ for litter size while the use of both sire and dam components gave $h^2 = 0.10$. This corresponds to the results obtained by Polyanichko (1972) who reported h^2 for litter size to be effectively zero.

Litter birth weight was found to have a heritability of 0.36 by Cummings _et al._ (1947), while h^2 for average pig weight at birth has estimates ranging from 0.00 to 0.40 (Louca and Robison, 1967; Standal, 1968; Polyanichko, 1972; Dickerson _et al._, 1974).

The traits observed during the lactation period are expected to be influenced to a high degree by maternal effects. However, estimates as high as 0.36 for litter weight at 21 days and 0.16 and 0.19 for litter size at 21 days are reported by Dickerson _et al._ (1974). In this experiment all traits were looked at as traits of the dam, and the result corresponds fairly well to $h^2 = 0.27$ for litter size at 21 days obtained by Blunn and Baker (1949). Standal (1968) did a study based on 2701 records of purebred and crossbred pigs sired by 39 purebred boars of Yorkshire and Norwegian Landrace breeds with contemporary purebred and crossbred progeny. The heritability estimates for crossbred pigs were, on the average, higher than for purebreds. For average pig weight at 21 days, h^2 was found to be 0.69 for crossbreds and 0.22 for purebreds.

For litter size at weaning, heritability estimates of about 0.2 to 0.3 were observed in most of the works reviewed (Cummings _et al._, 1947; Blunn and Baker, 1949; and Louca and Robison, 1967.) Dickerson _et al._ (1974) reported $h^2 = 0.18$ and $h^2 = 0.13$ using sire and sire and dam components, respectively.

Litter weight at weaning has been found to be low to moderately heritable, h^2 ranging from 0.07 to 0.37, while h^2 estimates for average pig weight at weaning are low to moderate (Cummings *et al*., 1947; Blunn and Baker, 1949; Siers and Thomson, 1972; Dickerson, *et al*., 1974). The heritability for survival percentage until weaning at 42 days was estimated to be 0.40 (Cummings *et al*., 1947).

Heritabilities for postweaning daily gain and probe backfat at 200 or 220 pounds, have generally been higher than for reproductive traits. Lush (1936) arrived at $h^2 = 0.24$ and $h^2 = 0.47$ for rate of gain and backfat probe, respectively. Johansson and Korkmann (1951), using 3036 tested groups of 4 pigs each from Large White and Swedish Landrace representing four experiment stations, estimated h^2 for average daily gain to be from 0.12 to 0.26.

Based on 5996 Danish Landrace pigs obtained in a four year period, Johnsson and King (1962) estimated several heritabilities. To give a closer approach to an unselected population only litters that completed the test (90 kg) with two gilts and two boars, that had sires less than 20 months old when litters were born and had dams with no more than three previous litters were used. For average daily gain h^2 was estimated to be 0.45 and h^2 for probe backfat was reported to be 0.47. Heritabilities of 0.14 to 0.35 for backfat probe were reported by Louca and Robison (1967), while Dickerson *et al*. (1974) got $h^2 = 0.48$ for backfat and $h^2 = -0.40$ for gain from 98 to 140 days.

Heritability estimates of carcass traits are high, with most of them ranging from 0.25 to 0.60 (Lush, 1936; Johansson and Korkmann, 1951; Johnsson and King, 1962; Langholz, 1966).

<u>Correlations between a Females Own Performance and Productivity in Swine</u>

It was realized early that knowledge of the genetic and phenotypic correlations among traits would be of importance for the prediction and description of genetic change over time. Many of the same workers that have been previously cited have also studied correlation coefficients and the description of their experimental designs are not repeated here.

Zeller *et al.* (1937), using data on 658 sows, found that the heaviest sows at farrowing had the largest litters and weaned more and heavier pigs, and these sows also gained most weight during gestation and lost most weight during the suckling period. Donald and Flemming (1938) found that the weight increase of sow from mating until just after farrowing had a negative phenotypic correlation with the variability between pig birth weight within a litter, and also that total birth weight was not affected by the weight increase of the sow during pregnancy. Three-week litter weight was not affected by either weight increase from mating till just before farrowing, weight increase during the last month of pregnancy, total weight of the sow just before farrowing or weight increase of the sow from mating till just after farrowing.

Based on records of 749 gilts, Steward (1945a) concluded that age and weight at time of breeding, and gain in weight during gestation were significantly associated with number of pigs farrowed. Size of first litter increased curvelinearly with age of dam up to about 15 months; most increase took place between nine and twelve months. With inbreeding of both dams and litters held constant, Steward (1945a) calculated the partial regression of total litter size at birth on age of dam in months to be 0.609. Similarly, Olbryecht (1943) found that sows farrowing at twelve months produced 1.07 pigs less than those farrowing at seventeen months.

Squiers et al. (1952) studied some relations between sexual maturity, ovulation rate, effectiveness of the fertilization process and embryonic survival to the 25th day of gestation. Two-hundred seventy nine gilts and sows of two inbred Poland China, one inbred Hampshire and one non-inbred Duroc strains and gilts of the six crosses were used. Inbreeding of both the litter and dam reduced litter size at the 25th day of gestation. Phenotypically, the number of ova shed was significantly correlated with age at which estrus was observed (r = 0.31). An increase in age of ten days gave a linear increase of 0.35 ova shed. Age was also found positively correlated with litter size at twenty-five days, with an increase in age of ten days giving 0.5 more embryos at twenty five days. Crosses averaged twenty-eight days younger at breeding than the parent lines.

Rathnasabapathy et al. (1956) observed that 154 day weight, age at breeding, and average backfat thickness all had significant positive correlations with ovulation rate, and were negatively correlated, but not significant with litter size. Gilt's birth weight and postweaning daily gain had positive but not significant correlations with ovulation rate. Backfat thickness was positively correlated with mortality (r = 0.365). Length of uterus was also positively correlated with litter size (r = 0.406), but here it might be questioned which of the factors is causing the other.

Omtvedt et al. (1965) found that gestation length was correlated phenotypically ($p < .01$) to litter size at birth ($r = -0.16$), pig weight at birth ($r = 0.12$) and litter birth weight ($r = -0.12$). Age at breeding had a significant and positive correlation with breeding weight, litter size, pig weight and litter birth weight (0.55, 0.12, 0.16, 0.19 respectively). Breeding weight was positively correlated to litter size ($r = 0.19$) and litter birth weight ($r = 0.24$), while gestation gain was negatively correlated to litter size at birth ($r = -0.14$) and positively correlated to pig weight at birth ($r = 0.16$).

One-hundred seventy-six first litter gilts of three breed groups (Beltsville Number 1, Duroc and a multicross line) were used (Young and Omtvedt, 1973) to study possible phenotypic relations between the litter in which a gilt was raised and the performance of her own litter. Although not significant, size of the litter in which a gilt was farrowed was negatively correlated to the size of her first litter, while the size of the litter that the gilt was weaned from was not correlated to the number of pigs she farrowed. Neither the gilt's 42-day weight or backfat were significantly correlated with size of her first litter. Faster growing gilts, those reaching 200 pounds at a younger age, farrowed larger litters ($r = -0.13$). Revelle and Robison (1973) found that gilts from litters of six to eight pigs reached puberty at about the same age while gilts from litters of more than twelve pigs were progressively older at puberty.

Dickerson et al. (1974) reported no significant genetic correlations of litter size with backfat probe at 92 kg live weight or with postweaning growth, but postweaning gain was genetically correlated with shorter gestations ($r = -0.45$) and with pig birth ($r = 0.42$) and pig weaning weights (r = 0.77). It was found that effects of maternal environment were important for preweaning and postweaning growth but not for backfat probe. Effects of sire of progeny were important for numbers of stillborn pigs as well as preweaning growth, postweaning growth and backfat thickness.

Summary of Literature Review

Estimates of heritabilities are low for reproductive traits, moderate to high for feed efficiency and daily gain and relatively high for carcass traits.

Few phenotypic and genetic correlations between performance traits and reproductive traits have been reported. There is, however, some evidence that gestation gain, gilts 110-day weight and gilts postweaning daily gain have positive phenotypic correlations with litter size at birth, 21 days and 42 days. Age at farrowing and breeding weight have been found to be positively correlated to litter size at birth and total litter weight at weaning. Lactation gain is negatively correlated to litter size at birth and weaning as well as average pig weight at weaning. Little evidence exists for phenotypic relationships between a gilt's birth weight, weaning weight, probe of backfat and weight when weaning her litter and her productivity.

Correlation coefficients between performance and productivity are low and varying. But since the heritability estimates of reproductive traits are so low, even low correlations between performance and productivity traits can be a significant aid in obtaining correlated responses in the reproductive traits. Therefore, it is necessary to investigate this area and to estimate these correlation coefficients.

CHAPTER III

MATERIALS AND METHODS

This study includes data from 397 purebred and 191 crossbred gilts and their litters from phase I and II of the Oklahoma swine crossbreeding project (Project 1444) carried out at the Ft. Reno Experiment Station. The original objectives of this project were to (1) evaluate the purebred performance and the combining ability of Duroc, Hampshire and Yorkshire breeds of swine in 2-breed and in 3-breed crosses, (2) investigate the importance of maternal influence in terms of crossbred sow productivity and pig performance, and (3) develop methods of selection for performance traits. Results from investigations of these objectives are reported by Johnson and Omtvedt (1973), Johnson et al. (1973) and Johnson and Omtvedt (1975). Also, Young et al. (1974) reported the relationships between various performance measurements and ovulation rate and number of embryos 30 days after breeding in gilts.

Foundation purebred herds of each breed were maintained at Stillwater and all crossbreeding was done at Fort Reno. The purebred Duroc (D), Hampshire (H) and Yorkshire (Y) herds were formed in 1969 from crosses between several lines within a breed, to give the breeds a wide genetic base. Each year, two boars from outside sources were introduced into each purebred herd to maintain the broad genetic base.

The primary purpose of this study is to estimate phenotypic and genetic correlations among performance traits and productivity of gilts.

Thus, it is important to clearly define how the gilts that produced litters were selected, how they were managed and the traits measured.

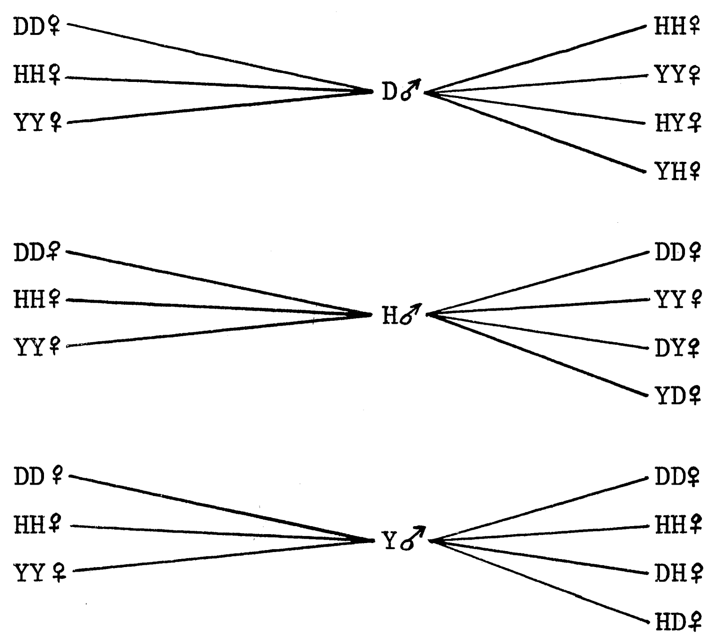
The overall mating scheme for each season of the project from which data were obtained for this study is shown in Table I. The gilts that produced the litters in each of these seasons were investigated. There are two basic mating systems (Table I). The first of these, shown in the left hand column of the table, used only purebred gilts. In each season, all purebred gilts were born in the Stillwater herd and approximately 50 per breed were randomly selected and transferred to Fort Reno prior to the breeding season. They were mated at random to boars produced at Stillwater according to the system shown in Table I. Thus, in the spring and fall farrowing seasons of 1971 and 1973, purebred gilts of each breed that were born at Stillwater produced purebred or crossbred litters at Fort Reno.

The second mating system, shown in the right hand column of Table I, involved mating purebred and crossbred gilts to a boar of a third breed. All the gilts that produced these litters were purebred or crossbred gilts born in the previous season shown in the left column of Table I. These gilts were selected at random as they reached 220 pounds from those available in each breed group.

TABLE I

MATING SYSTEM IN THE DIFFERENT SEASONS[a]

Season of Farrowing	
1971 Spring	1972 Spring
1971 Fall	1972 Fall
1973 Spring	1974 Spring
1973 Fall	1974 Fall



[a]D = Duroc, H = Hampshire, Y = Yorkshire; the first letter indicates breed of sire and the second is the breed of dam.

Table I illustrates the type of problem which is involved in estimating correlations from these data. Gilts were born and raised in two different locations and were mated in several different combinations. Thus, statistical analyses, to be discussed later, had to be employed that considered all these sources of variation.

Management and Husbandry

The following is as described by Johnson (1973) and Young (1973). The breeding season started December 1 for the spring farrowings and June 1 for the fall farrowings, and lasted for eight weeks. After reaching an age of 220 days, gilts were hand mated. The gilts were limited fed during gestation in dry lots with 16 in each pen and were allotted to pens at random. About 110 days after breeding the gilts were moved to the farrowing barn, and three to seven days after farrowing the gilts were moved with their litters to a nursery barn where they remained until the litters were weaned (42 days of age).

The litters remained in the pen after weaning, while the sows were removed. The pigs remained for two weeks in the pen and were then moved to the finishing floor, and started on test after another week, at an age of nine weeks. There were about 15 pigs per pen arranged according to breed group. The pigs were self-fed a 16% protein ration of milo, corn, or wheat and soybean meal until 220 pounds. The pigs were taken off test once a week, and adjustments made in age at 220 pounds and probe backfat at 220 pounds for those which were not exactly 220 pounds. Additive adjustment factors of two pounds of gain per day and 0.004 in. per pound live weight were used.

The gilts born at Stillwater were subjected to slightly different management than those born at Fort Reno. The litters in which the gilts were born were farrowed in crates in a central farrowing house very similar to that at Fort Reno. Three to five days after farrowing, about one third of the litters were placed in individual pens open to the south and with solid concrete floors. The remaining litters were kept in pasture lots, two litters per lot, until weaning. All litters were weaned at 42 days and a sample of the pigs were placed on the test floor at eight weeks of age and growth, as at Fort Reno, was measured from nine weeks of age to 220 pounds. The gilts that were taken to Fort Reno were transferred after they came off the test floor at 220 pounds.

The measurements of individual growth performance of the gilts were very similar at both locations for all traits except weaning weight. In Stillwater some pigs were weaned on pasture and others in concrete pens while at Fort Reno all pigs went from the farrowing barn to the nursery and then to the finishing barn. No attempt was made to adjust for method of handling prior to weaning.

In addition, in the seasons in which 2-breed and 3-breed cross litters were farrowed at Fort Reno, some of the purebred dams that produced 2-breed cross litters were born at Stillwater. These gilts were transferred to Fort Reno after weaning and placed on the feeding floor at Fort Reno at eight weeks of age at the same time as the gilts born at Fort Reno. Preweaning data on these gilts were recorded at Stillwater while postweaning information was recorded at Fort Reno.

Data Used and Traits Considered

Only data from gilts with purebred, 2-breed cross and 3-breed cross litters were used. Litters farrowed outside, litters with serious illness or disease and litters from which a minimum of one pig was not weaned were not used in the analyses. Number of litters used in each season and breed-group are shown in Tables II and III.

All the traits were considered as traits of the gilt. The traits considered were:

Individual growth performance of the gilt:

Gilts birth weight (BW)

Gilts weaning weight (WW)

Postweaning daily gain (PDG)

Age at 220 pounds (AGE)

Probe backfat at 220 pounds (PBF)

Breeding weight (SBRWT)

110-day post breeding weight (S110WT)

Weight of gilt when weaning her litter (SWNWT)

Gestation gain = S110WT - SBRWT (GESGAN)

Lactation gain = SWNWT - S110WT (LACGAN)

Reproductive performance:

Number of pigs at birth (NOBIR)

Litter weight at birth (LITBIR)

Average pig weight at birth (PIGBIR)

Number of pigs at 21 days (NO21)

Litter weight at 21 days (LIT21)

Average pig weight at 21 days (PIG21)

Number of pigs at 42 days (NO42)

Litter weight at 42 days (LIT42)

Average pig weight at 42 days (PIG42)

Survival percentage = number at 42 days as % of number born alive (SURV%)

Statistical Treatment of the Data

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

For each of the 20 traits considered, the means were computed within season and breed of litter combination, and the breed group means were averaged over the four seasons.

The missing information for the HY (Hamp x York) type of litter in the fall 1971 (Table II), were estimated. The traits for the gilt's individual performance were estimated by the average of the other Yorkshire gilts used that season, and the reproductive performance was estimated by taking the average for the HY - litters in the three other seasons with purebred and crossbred litters.

To analyze the data, the data set was divided into three subsets as follows:

1. Purebred gilts with purebred litters
2. Purebred gilts with crossbred litters
3. Crossbred gilts with 3-breed cross litters.

The three subsets were then pooled and some adjustments, to be discussed later, were made and the adjusted data set was used to obtain estimates of phenotypic and genetic correlations.

TABLE II

NUMBER OF LITTERS FARROWED IN EACH SEASON AND BREED-GROUP IN SEASONS WITH PUREBRED AND 2-BREED CROSS LITTERS

	DD[a]	DH	DY	HD	HH	HY	YD	YH	YY	
1971 Spring	10	10	9	10	7	8	10	11	9	84
1971 Fall	7	5	1	3	5	-	6	4	3	34
1973 Spring	9	8	7	9	10	10	10	8	10	81
1973 Fall	4	4	2	3	7	3	4	6	6	39
Total	30	27	19	25	29	21	30	29	28	238

[a]First letter indicates breed of sire of litter, last letter indicates breed of dam of litter.

TABLE III

NUMBER OF LITTERS FARROWED IN EACH SEASON AND BREED-GROUP IN SEASONS WITH 2-BREED CROSS AND 3-BREED CROSS LITTERS

	DH[a]	DY	HD	HY	YD	YH	D(HxY[b])	D(YxH)	H(DxY)	H(YxD)	Y(DxH)	Y(HxD)	
1972 Spring	8	8	8	8	9	9	8	9	9	8	8	9	101
1972 Fall	7	4	7	8	9	6	7	8	9	6	7	8	86
1974 Spring	7	4	4	3	3	5	6	3	10	6	6	8	65
1974 Fall	7	6	6	7	8	9	9	10	9	7	12	8	98
Total	29	22	25	26	29	29	30	30	37	27	33	33	350

[a]See Table I for explanation

[b]First letter indicates breed of sire of litter, letters in parenthesis indicates breed of the crossbred dam of litter.

The three subsets were analyzed on a within season and within breed of gilt bases without adjustments for breed of sire of litter in the seasons with 2-breed cross and 3-breed cross litters. Breed of service sire when a purebred gilt produced a crossbred litter was considered unimportant for litter productivity traits (i.e. DxY litters were considered to have the same expectation as HxY litters). If breed of service sire influences litter performance, this will increase the sampling error in subsets two and three.

In the pooled analyses, two kinds of adjustments were made. All gilts were sired by a purebred sire. Therefore, in the seasons in which purebred and crossbred gilts were used, there were purebred and crossbred paternal half sibs. For this reason it was felt necessary to adjust all individual performance records for crossbred gilts to the basis of the purebred sire breed of the gilt. Adjustments were made from the overall breed group means. A HxY cross gilt (a gilt with a Hampshire sire and Yorkshire dam) was adjusted to the equivalent of a purebred Hampshire gilt. Each gilts record was adjusted by subtracting the difference in breed group means (HxY - HxH) from each HxY cross gilt. A YxH gilt however, was adjusted to a purebred Yorkshire basis by subtracting the difference in means (YxH - YxY) from each YxH gilt's record. Adjustments for other crosses were made similarly. This adjustment attempts to make the expected value for each crossbred equal to the expected value for its purebred half-sib. It also attempts to remove breed of dam differences and heterosis effects between purebred and crossbred half-sibs.

For all traits of gilt expressed post farrowing, a further adjustment of the data was considered necessary. In some seasons half and full-sib purebred gilts farrowed both purebred and crossbred litters while in other seasons purebred gilts, with 2-breed cross litters had crossbred half-sibs that produced 3-breed cross litters. Since post farrowing litter traits were also considered as traits of the gilts, some of the variation between sibs was due to the heterosis of the litter for pig liveability and growth, to breed of sire of litter effects and to maternal heterosis of crossbred females. These sources of variation should not be included as causal components of variation in estimating phenotypic and genetic correlations from sib data. Adjustments were again made by using differences in breed group means. For example, in seasons in which there were purebred and crossbred litters, crossbred litter records were adjusted to the basis of the pure breed of the sire of the gilt that produced the litter. This adjustment was made as described above for individual records of crossbred gilts. However, in seasons in which there were 2-breed and 3-breed cross litters, 3-breed cross litters were adjusted to the basis of 2-breed cross litters from breed group means. For example, litters of breeding DxY, D(YxH), HxY and H(YxD) were all produced by gilts that could have been either half or full sibs since the dam of each litter has a Yorkshire sire. Thus, one of the 2-breed cross litter types; DxY for example, was chosen as a base and the post farrowing litter traits for the other three litter breed types were adjusted to this base from the differences in breed group means as described above.

Since the described adjustments were done for all three breeds of sire of gilt, it also made each sire contribute only 1 degree of freedom in each season in the analyses. The adjustments were done for the seasons with purebred and 2-breed cross litters and for seasons with

2-breed and 3-breed cross litters separately. In this way all gilts by one sire, whether purebred or crossbred and regardless of the type of litter they produced, should have a common expected mean. Assuming that variances in traits and covariances between traits are the same in the different breeds and breed combinations these adjustments make it possible to do one analysis on the entire data set.

The model assumed for each subset and for the entire adjusted data set was as follows:

$Y_{ijkl} = \mu + a_i + s_j + d_k + e_{ijkl}$ where:

Y_{ijkl} = actual or adjusted record depending on the data set, for the trait.

μ = the overall mean of the breed type chosen as the base in each data set.

a_i = the effect of the i^{th} season-breed of sire of gilt combination

s_j = effect of the j^{th} sire in the i^{th} season-breed combination

d_k = effect of the k^{th} dam mated to the j^{th} sire in the i^{th} season-breed combination

e_{ijkl} = effect of the l^{th} gilt from the litter of the k^{th} dam mated to the j^{th} sire in the i^{th} season-breed combination.

a_i is considered a fixed effect while s_j, d_k and e_{ijkl} are considered to be independent normally distributed random variables with mean zero and variances σ_s^2, σ_d^2 and σ_w^2, respectively.

Since every trait was considered as a trait of the gilt that produced the litter, this is a typical analyses for full sib data and, statistically, can be described as a hierarchical or nested design. This model, using the SAS METHOD procedure, was fit separately for each data subset and for the pooled adjusted data set. In this way mean squares for each trait were calculated for each effect in the model. These mean squares were then equated to the expected values of the mean squares and solved for estimates of the observational components of variance, σ_s^2, σ_d^2, and σ_w^2. Also, the mean crossproduct between each pair of traits was obtained and equated to the expected crossproduct and solved for observational estimates of covariances. An example of the form of the analyses for two traits from the pooled analyses and the observed and expected Mean Squares and Mean Cross Products are shown in Table IV.

Observational and causal components of Variance as given by Falconer (1960) are given in Table V. Symbols used are defined in Table VI.

Heritabilities were calculated for each of the 20 traits considered in three different ways as given by Falconer (1960), using:

sire of gilt components of variance:

$$h_s^2 = \frac{4\sigma_s^2}{\sigma_p^2} \quad ;$$

dam of gilt components of variance:

$$h_d^2 = \frac{4\sigma_d^2}{\sigma_p^2}$$

and a combination of both:

$$h^2 = \frac{2(\sigma_s^2 + \sigma_d^2)}{\sigma_p^2}$$

The standard errors for the heritabilities were estimated as:

$$s_h^2 = \sqrt{16\ V(t)}$$

where V(t) is approximated as given by Sweiger et al. (1964):

$$V(t) \simeq \frac{2(N-1)\ (1-t)^2\ [1 + (k-1)t]^2}{k^2\ (N-s)\ (s-1)}$$

N = total number of observations

s = number of groups

$$k = \frac{1}{s-1}\ (N - \frac{\Sigma\ n_i^2}{N}\ )$$

n_i = number of observations in the i^{th} group

t = intraclass correlation

V(t) = the variance of intraclass correlation

From these analyses, genetic and phenotypic correlations were also calculated. Correlations were estimated only between individual growth performance of the gilt and reproductive traits of gilt.

Genetic correlations were calculated three different ways (Pirchner, 1969; Dickerson et al., 1974), using:

sire components:

$$r_{s_{12}} = \frac{cov_{s_1 s_2}}{\sigma_{s_1} \cdot \sigma_{s_2}} \quad ;$$

dam components:

$$r_{d_{12}} = \frac{cov_{d_1 d_2}}{\sigma_{d_1} \cdot \sigma_{d_2}} \quad ;$$

and both sire and dam conponents:

$$r_{(s + d)} = \frac{cov_{s_1 s_2} + cov_{d_1 d_2}}{\sqrt{\sigma^2_{s_1} + \sigma^2_{d_1}} \cdot \sqrt{\sigma^2_{s_2} + \sigma^2_{d_2}}}$$

Phenotypic correlations were calculated according to the formula:

$$r_{p_{12}} = \frac{cov_{s_1 s_2} + cov_{d_1 d_2} + cov_{w_1 w_2}}{\sigma_{p_1} \cdot \sigma_{p_2}}$$

Standard errors for genetic correlation coefficients were obtained by the method of Dickerson (1969).

TABLE IV

OBSERVED AND EXPECTED MEAN SQUARES AND MEAN CROSS PRODUCTS FOR POOLED ANALYSES

Source	df	M.S. Trait 1	M.S. Trait 2	MCP	EMS	ECP
Season-Breed Comb	23					
Sires/ws-B.C.	148	18.565	7.425	14.183	$\sigma_w^2 + 1.477\sigma_d^2 + 3.198\sigma_s^2$	$\sigma_{w_1w_2} + 1.477\sigma_{d_1d_2} + 3.198\sigma_{s_1s_2}$
Dams/w sires/w s-BC	241	11.415	7.486	8.145	$\sigma_w^2 + 1.355\sigma_d^2$	$\sigma_{w_1w_2} + 1.355\sigma_{d_1d_2}$
Progeny/w Dam	175	762.244	6.873	5.433	σ_w^2	$\sigma_{w_1w_2}$

TABLE V

OBSERVATIONAL AND CAUSAL COMPONENTS OF VARIANCE AND COVARIANCE
(Falconer, 1960)[a]

Observational Components of Variance	Causal Components of Variance	Observational Components of Covariance	Causal Components of Covariance
σ_s^2	¼ V(A)	$\sigma_{s_1 s_2}$	¼ Cov(A)
σ_d^2	¼ V(A) + ¼ V(D) + V(Ec)	$\sigma_{d_1 d_2}$	¼ Cov(A) + ¼ Cov(D) + Cov(Ec)
$\sigma_s^2 + \sigma_d^2$	½ V(A) + ¼ V(D) + V(Ec)	$\sigma_{s_1 s_2} + \sigma_{d_1 d_2}$	½ Cov(A) + ¼ Cov(D) + Cov(Ec)
σ_w^2	½ V(A) + 3/4 V(D) + V(Ew)	$\sigma_{w_1 w_2}$	½ Cov(A) + 3/4 Cov(D) + Cov (Ew)

[a]The epistatic variance is assumed to be zero.

TABLE VI

EXPLANATION OF SYMBOLS USED

σ^2_w = variance between full-sibs

σ^2_d = dam component of variance

σ^2_s = sire component of variance

$\sigma^2_p = \sigma^2_s + \sigma^2_d + \sigma^2_w$ = total phenotypic variance

$\sigma^2_{w_1}$ & $\sigma^2_{w_2}$ = the within litter variance for trait 1 and 2

$\sigma^2_{s_1}$ & $\sigma^2_{s_2}$ = the sire component of variance for trait 1 and 2

$\sigma^2_{d_1}$ & $\sigma^2_{d_2}$ = the dam component of variance for trait 1 and 2

$\sigma_{w_1w_2} = cov_{w_1w_2}$ = the within full-sib group component of covariance between trait 1 and 2

$\sigma_{d_1d_2} = cov_{d_1d_2}$ = the dam component of covariance between trait 1 and 2

$\sigma_{s_1s_2} = cov_{s_1s_2}$ = the sire component of covariance between trait 1 and 2

$r_{s_{12}}$ = genetic correlation between trait 1 and 2 using sire components

$r_{d_{12}}$ = genetic correlation between trait 1 and 2 using dam components

$r_{(s+d)_{12}}$ = genetic correlation between trait 1 and 2 using dam and sire components

TABLE VI (Continued)

$r_{p_{12}}$ = phenotypic correlation between 1 and 2

$h^2_{s_1}$, $h^2_{d_1}$ and $h^2_{(s+d)_1}$ = the heritability for trait 1 estimated by sire, dam and sire plus dam components, respectively.

V(A) = Variance due to additive effects of genes

V(D) = Variance due to dominance effects of genes

V(Ec) = Variance due to common environment

V(Ew) = Variance within litter due to environment

Cov (A) = Covariance due to additive effects of genes

Cov (D) = Covariance due to dominance effects of genes

Cov (Ec) = Covariance due to common environment

Cov (Ew) = Covariance within litter due to environment

CHAPTER IV

RESULTS AND DISCUSSION

The means and standard deviations for the 20 traits considered are given in Table VII, VIII, IX and X. All traits are considered as trait of the gilt, but they are classified according to the breed of litter the gilt raises. The reason for this classification is that breed of sire of litter also influences the reproductive traits of the gilt, and this arrangement makes it possible to estimate differences due to service sire, which is used as adjustment factors in the analyses. The standard deviations given are the square root of total phenotypic variance from the pooled analyses.

Discussion of the Separate Analyses

As described before the statistical analyses of this data were done in four separate parts, for purebred gilts with purebred litters, purebred gilts with crossbred litters, 2-breed cross gilts with 3-breed cross litters and a pooled analyses. The main part of the following discussion is based on the pooled analyses. To justify the pooling of the data, however, a careful examination and comparison of the separate analyses is needed.

The heritabilities for each of the first three analyses are given in Appendix Tables XV, XVI, and XVII. For notation purposes, heritabilities obtained from sire components will be referred to as (S)

TABLE VII

BREED GROUP MEANS FOR GILTS GROWTH PERFORMANCE TRAITS[a] IN SEASONS WITH PUREBRED AND 2-BREED CROSS LITTERS

Breed group	No of gilts	BW	WW	PDG	AGE	PBF	SBRWT	S110WT	SWNWT	GESGAN	LACGAN
DD	30	3.06	22.52	1.41	184.2	1.28	264.27	350.58	366.32	83.82	22.16
DH	27	3.22	25.68	1.34	186.4	1.11	252.70	354.61	329.31	89.42	-19.46
DY	19	2.35	22.47	1.26	200.4	1.13	253.81	430.78	295.86	66.98	-19.15
HD	25	3.47	25.23	1.41	178.6	1.20	275.62	375.60	368.75	99.98	0.19
HH	29	3.21	24.32	1.35	187.0	1.10	263.13	352.85	328.75	89.73	-13.91
HY	21	2.82	23.49	1.28	195.9	1.13	251.11	335.86	326.26	84.71	-4.10
YD	30	3.18	25.44	1.42	180.7	1.28	267.49	366106	350.06	98.00	-6.18
YH	29	3.15	26.37	1.34	187.6	1.09	266.19	357.13	334.83	90.94	-16.40
YY	28	2.80	23.29	1.32	192.6	1.14	260.20	357.83	328.72	97.64	-23.36
Std. Dev.[b]		0.57	5.12	0.15	13.45	0.14	28.36	38.73	37.99	28.15	32.96

[b] Based on pooled analyses

[a]BW= Gilts birth weight, WW=Gilts weaning weight, PDG = Postweaning daily gain, AGE = Age at 220 lbs. PBF = Probe backfat, SBRWT = Gilts breeding weight, S110WT = Gilts 110-day post breeding weight, SWNWT = Gilt weight when her litter was weaned, GESGAN = Gestation gain, LACGAN = Lactation gain.

TABLE VIII

BREED GROUP MEANS FOR GILTS REPRODUCTIVE PERFORMANCE IN SEASONS WITH PUREBRED AND 2-BREED CROSS LITTERS[a]

Breed group	No. of gilts	Litter size			Litter weight lbs.			Average Pig Weight Per Litter lb.			
		Birth	21 days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	Surv.%
DD	30	9.61	5.32	4.97	25.80	51.16	106.11	2.78	9.45	21.34	55.74
DH	27	8.33	6.06	5.96	22.99	70.22	150.95	2.85	11.52	2[illegible].28	76.11
DY	19	11.05	8.08	8.05	22.08	82.31	172.14	2.06	10.43	21.48	72.97
HD	25	9.33	7.49	7.22	25.52	71.37	165.57	2.77	9.59	23.18	79.48
HH	29	8.39	6.03	5.81	22.98	66.51	136.30	2.78	11.03	23.43	71.88
HY	21	10.27	7.58	7.13	25.94	82.84	171.30	2.53	11.25	24.87	71.71
YD	30	10.03	6.96	6.87	26.55	72.46	165.82	2.79	10.61	23.94	72.18
YH	29	8.03	6.87	6.77	22.96	74.69	162.76	2.90	10.89	24.02	86.11
YY	28	9.87	8.33	8.10	23.54	88.82	186.07	2.43	10.82	23.30	82.95
Std. Dev.[b]		2.70	2.29	2.24	6.87	25.44	52.95	0.45	1.89	4.07	18.83

[a] This includes 1971 spring and fall and 1973 spring and fall.

[b] See Table VII.

TABLE IX

BREED GROUP MEANS FOR GILTS GROWTH PERFORMANCE TRAITS IN SEASONS WITH 2-BREED CROSS AND 3-BREED CROSS LITTERS

Breed group	No of gilts	BW[a]	WW	PDG	AGE	PBF	SBRWT	S110WT	SWNWT	GESGAN	LACGAN
DH	29	3.21	24.48	1.43	189.0	1.06	281.82	373.29	343.62	91.12	-30.89
D(HxY)	30	2.52	24.56	1.50	183.9	1.07	245.08	343.06	309.87	97.99	-32.86
D(YxH)	30	3.07	27.16	1.48	184.6	1.19	257.44	350.35	317.19	92.90	-31.25
DY	22	2.74	24.35	1.47	184.3	1.16	269.80	377.13	329.02	96.74	-33.92
HD	26	3.08	24.18	1.51	181.9	1.24	269.28	374.11	358.69	104.84	-14.93
H(DxY)	37	2.43	25.59	1.59	178.4	1.15	270.40	372.21	352.58	101.81	-19.63
H(YxD)	27	2.84	25.72	1.56	176.3	1.22	263.76	356.14	335.01	92.38	-21.14
HY	26	2.61	23.95	1.38	189.8	1.09	257.60	366.72	318.67	109.12	-37.21
YD	29	2.93	22.46	1.52	183.0	1.25	288.49	377.69	378.58	89.29	0.89
Y(DxH)	34	3.14	30.04	1.63	173.5	1.20	284.99	386.46	354.07	101.47	-26.21
Y(HxD)	33	3.02	22.83	1.53	185.1	1.10	261.87	369.54	349.57	107.67	-16.87
YH	28	3.23	25.78	1.46	182.3	1.09	281.65	379.15	351.36	97.50	-23.22
Std. Dev.[b]		0.57	5.12	0.15	13.45	0.14	28.36	38.73	37.99	28.15	32.96

[a,b] See Table VII

TABLE X

BREED GROUP MEANS FOR GILTS REPRODUCTIVE PERFORMANCE IN SEASONS WITH 2-BREED CROSS AND 3-BREED CROSS LITTERS[a]

Breed group	No. of gilts	Litter size Birth	Litter size 21 days	Litter size 42 days	Litter weight lbs Birth	Litter weight lbs 21 days	Litter weight lbs 42 days	Average Pig Weight per Litter lb. Birth	Average Pig Weight per Litter lb. 21 days	Average Pig Weight per Litter lb. 42 days	Surv%
DH	29	8.19	6.92	6.63	22.44	76.45	156.66	2.82	11.60	24.37	80.58
D(HxY)	30	10.03	8.57	8.33	26.36	96.54	197.49	2.64	11.19	23.74	84.07
D(YxH)	30	10.33	9.19	8.94	26.76	98.40	201.93	2.59	10.76	22.83	87.10
DY	22	9.56	7.50	7.38	24.95	84.02	178.32	2.67	11.52	24.88	80.15
HD	26	9.16	6.75	6.47	26.70	71.57	152.81	2.99	11.02	23.97	73.91
H(DxY)	37	9.39	7.08	6.94	26.11	78.19	164.43	2.85	11.11	24.23	77.95
H(YxD)	27	9.67	7.77	7.69	26.27	83.08	184.77	2.77	10.83	24.16	79.15
HY	26	10.28	7.11	6.80	26.58	74.71	155.83	2.61	10.50	23.01	69.00
YD	29	8.91	7.32	7.32	25.36	73.54	177.61	2.85	10.45	24.41	83.76
Y(DxH)	34	9.86	7.94	7.81	27.97	89.00	194.53	2.90	11.08	25.41	81.24
Y(HxD)	33	9.23	7.91	7.48	26.40	88.91	185.64	2.96	11.62	25.16	83.03
YH	28	8.84	6.61	6.47	23.78	73.64	158.05	2.83	11.34	25.26	76.98
Std. Dev.[b]		2.70	2.29	2.24	6.87	25.44	52.95	0.45	1.89	4.08	18.83

[a] This includes 1972 spring and fall and 1974 spring and fall.

[b] See Table VII

estimates of heritability, estimates obtained from dam components will be referred to as (D) estimates and heritabilities obtained from both sire and dam components will be noted (S + D) estimates. Generally, the heritability estimates from the preliminary analyses are quite variable. The approximated standard errors of (S) estimates ranged from 0.7 to 0.8, for the 87 purebred gilts with purebred litters, 0.25 to 0.35 for the 311 purebred gilts with crossbred litters and 0.35 to 0.45 for the 190 crossbred gilts with 3-breed cross litters respectively. With standard errors this large, few of the estimates from the three data subsets are significantly different. Also, the fact that no adjustments were made for breed of sire of litter in the seasons with 2-breed cross and 3-breed cross litters or for heterosis in gilt in seasons with crossbred gilts could contribute to the existing variability between the estimates. Even though h^2 are generally higher estimated from 2- and 3-breed crosses, most of these differences would not be judged significant with this large standard errors. Work supporting that a pooling of the data can be done is given in the literature. Standal (1968) found that the effects of sire on purebred and crossbred progeny were essentially the same. Dickerson et al. (1974) found no differences in heritabilities and genetic correlations between crossbred and purebred litters. On the contrary Robison et al. (1964) reported genetic correlations between purebred and crossbred performance to be -0.74 and (<-1.00 for number farrowed and number raised respectively).

For purebred gilts with purebred litters, 17 out of the 20 traits had higher h^2 estimates using (D) and (D + S) than using (S). The (D) component contains a portion of the variance due to dominance effects and all the variance due to maternal effects. Thus, there appears to be considerable non-additive genetic variance and maternal variance for these traits. For heritabilities obtained from crossbred gilts with 3-breed cross litters, most (S) estimates were higher than (D) estimates. This could be due to chance since genetic expectations for heritabilities from the (D) component are greater than or equal to those obtained from (S) components. Another possible explanation could be that the data are not adjusted for breed of service sire or for heterosis or breed of dam of gilt. If full-sibs are mated to a boar of the same breed, variation between full-sibs groups will be smaller than between paternal half-sib groups, since both variances would tend to be calculated from deviations about a common mean. The variance component calculated for dams could then appear smaller than for sire.

Phenotypic correlations between measures of a gilts own growth performance and her productivity for the three preliminary analyses are given in Tables XVIII, XIX, and XX. Most of the obtained phenotypic correlation coefficients are close to zero and there are no obvious inconsistencies between the three analyses, however, some generalizations can still be made. The gilts breeding weight, 110-day weight and gestation gain are generally positively correlated to the fitness traits of the litter with the exception of survival percentage. Lactation gain and weight of gilt when weaning her litter were negatively correlated to the fitness of the litter, and postweaning daily gair is also generally positively correlated to fitness traits. Weaning weight was positively correlated with fitness traits for purebred gilts with purebred litters and for 2-breed cross gilts with 3-breed cross litters, while the same correlation was negative for purebred gilts with 2-breed cross litters. This might be due to the fact that weaning weight and offspring fitness are correlated in purebred pigs, but heterosis in the litter and specific combining ability tend to reduce the relative importance of maternal effects from the purebred gilt in the 2-breed cross litters. In the 3-breed cross litter, however, the effect of service sire does not cover up the effects of maternal heterosis in the gilt, consequently a positive correlation between weaning weight and litter performance was obtained. This is also in agreement with the accepted theory that the effect of heterosis is largest in the first cross.

Genetic correlations for the three preliminary analyses are given in the tables XXI, XXII, and XXIII. Particularly for the analyses for purebred gilts with purebred litters and 2-breed cross gilts with 3-breed cross litters, there were many negative estimates of the variance components that made it impossible to estimate the genetic correlation coefficients. In general, the correlations for the different breed groups were in agreement even though estimates of variation are high. Sampling error associated with estimates of genetic correlations from small numbers of observations are generally quite large.

Based on the above observations and the literature cited, it was found appropriate to pool the data into one data set to reduce sampling error. For the pooled analyses the data were adjusted as described before.

The following is based on the pooled data.

Estimates of Heritability

Heritabilities and standard errors from the pooled analyses are given in Table XI.

For gilts birth weight, weaning weight, postweaning daily gain, age at 220 pounds, probe of backfat and breeding weight, which are traits not influenced by the service sire, it was found that the (D) and (S + D) estimates were larger than the (S) estimates. This is as expected because the heritabilities obtained using (D) and (S + D) are usually overestimated due to non additive genetic and maternal effects. Using sire components of variance the heritability estimates for birth weight (0.72) and for weaning weight (0.75) are higher than those reported by others. Part of the explanation for this might be the fact that some of the data for these traits came from two different herds, as explained earlier. No attempt was made to fit a model with effects of different herds included. Consequently, variation between different sires in different herds contributed to variation between sires. This could lead to an overestimation of the sire component of variance and the (S) estimates of heritability. Laugholz (1966) also indicates that many of the heritability estimates reported might be too high due to the fitting of too simple a model. The (S) heritabilities for daily gain (0.32), age at 220 pounds (0.45), backfat probe (0.34) and gilts breeding weight (0.46) corresponds to what has been previously reported (Lush, 1936; Johnsson and King, 1962; Louca and Robison, 1967; Dickerson, et al., 1974).

TABLE XI

HERITABILITIES AND STANDARD ERRORS FROM POOLED ANALYSES[ab]

Trait[c]	Heritability		
	$\frac{4S}{S+D+W}$	$\frac{4D}{S+D+W}$	$\frac{2(S+D)}{S+D+W}$
BW	0.72± .18	1.60± .25	1.16± .28
WW	0.75± .18	1.23± .28	0.99± .29
PDG	0.32± .16	1.06± .29	0.69± .32
AGE	0.45± .17	1.15± .28	0.80± .31
PBF	0.34± .16	0.60± .32	0.47± .33
SBRWT	0.46± .17	0.66± .32	0.56± .32
S110WT	0.57± .17	0.10± .35	0.34± .34
SWNWT	0.38± .17	0.18± .35	0.28± .34
GESGAN	0.09± .15	0.06± .35	0.08± .35
LACGAN	0.27± .16	0.05± .35	0.16± .35
NoBIR	-0.02± .15	0.25± .34	0.11± .35
No21	-0.22± .18	-0.54± .38	-0.38± .37
No42	-0.30± .13	-0.54± .38	-0.42± .37
LITBIR	0.03± .15	0.27± .34	0.15± .35
LIT21	0.01± .15	-0.38± .37	-0.18± .36
LIT42	-0.23± .14	-0.34± .37	0.28± .34
PIGBIR	0.22± .16	0.52± .33	0.37± .34
PIG21	0.36± .17	0.89± .30	0.63± .32
PIG42	0.20± .16	0.73± .31	0.46± .32
SURV%	0.21± .16	-0.48± .33	-0.13± .36

[a]Based on 588 gilts in 8 seasons

[b]Standard errors are approximated as given by Sweiger, et al. (1964)

[c]All traits are considered as trait of the gilt

One-hundred and ten day weight of gilt, gilts weight when litter weaned, gestation gain and lactation gain had lower heritability estimates using (D) and (S + D) components than using (S) components of variance. This is difficult to explain, except that it is quite likely that there are little if any maternal effects for these traits. The estimated heritability for gestation gain (0.06 - 0.09) is much lower than the values of 0.27 (S) and 0.47 (S + D) arrived at by Dickerson et al., (1974).

Using the (S) components of variance, the estimates for litter size at birth, 21-days and 42-days were -0.02, -0.22 and -.30, respectively. This indicates that litter size is determined primarily by specific combining ability and environmental factors. This corresponds fairly well to non-significant positive estimates for these traits reported by Dickerson et al. (1974). Polyanichko (1972) also found h^2 for litter size to be effectively zero. However, most estimates in the literature range from 0.05 to 0.30 (Lush and Molln, 1942; Stewart, 1945b; Cummings et al., 1947; Blunn and Baker, 1949; Louca and Robison, 1967; Pivnyak, 1971; Revelle and Robison, 1973). For litter size at birth the estimate from sire components was smallest, while for litter size at 21 and 42 days using sire components gave the largest estimate. This tendency corresponds also to the results obtained by Dickerson et al. (1974), although not significant in either study.

None of the estimates for litter weight at birth, 21-days and 42 days were significantly different from zero ($P > .05$). Dickerson et al. (1974) however, reported (S + D) estimates for litter weight at 21 and 56 days to be significantly positive.

Of the reproductive performance traits on the gilt, the average pig weight of her litter at birth, 21-days, and 42-days had the highest heritabilities. Using sire of gilt components estimates were 0.22, 0.36 and 0.20 respectively for the three traits. Particularly the estimates of 0.22 (S) and 0.37 (S + D) for pig birth weight are similar to the respective 0.23 and 0.40 estimates obtained by Dickerson et al. (1974). For these three traits, it also appears that thegranddam of a litter has more influence on the average pigweights than has the grandsire since all the estimates based on (D) and (S + D) are larger than those based on (S).

The heritabilities for survival percentage were 0.21 (S), -0.48 (D) and -0.13 (S + D). The fact that (D) and (D + S) estimates are lower than (S) and that even the latter is low probably indicates that the heritability for this trait is low.

Phenotypic Correlations between Performance and Productivity

The phenotypic correlations between the gilts own performance and reproductive traits are given in Table XII. All correlations between reproductive traits and gilts birth weight, weaning weight, postweaning daily gain, age at 220 pounds and probe backfat were between -0.07 and 0.10. This indicates little relationship between these traits, and subbests that gilts reproductive merit cannot be very accurately predicted by her performance to 220 pounds. Birth weight of gilt was negatively correlated with litter size at birth, 21-and 42 days; and positively related to average pig weight at the three ages; however, most of these correlations were significantly different from zero.

TABLE XII

PHENOTYPIC CORRELATIONS BETWEEN THE GILTS GROWTH PERFORMANCE AND HER REPRODUCTIVE PERFORMANCE BASED ON POOLED ANALYSIS

	Litter size			Litter weight			Average Pig weight in litter			
	Birth	21-days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	Surv %
BW [a]	-0.02	-0.04	-0.05	0.02	-0.02	-0.01	0.05	0.07	0.09	0.05
WW	0.04	0.04	0.03	0.04	0.04	0.07	0.00	0.02	0.10	-0.02
PDG	0.08	0.04	0.02	0.09	0.04	0.02	0.02	0.01	0.00	0.09
AGE	0.07	-0.03	-0.01	-0.07	-0.02	-0.03	-0.02	0.00	-0.06	0.10
PBF	0.05	0.06	0.07	0.06	0.05	0.06	0.02	-0.06	-0.04	0.02
SBRWT	0.14	0.09	0.09	0.09	0.11	0.09	0.07	0.08	0.03	-0.08
S110WT	0.20	0.13	0.12	0.33	0.20	0.14	0.22	0.14	0.03	-0.08
SWNWT	-0.10	-0.24	-0.24	-0.07	-0.22	-0.23	0.13	0.01	0.04	-0.17
G ESGAN	0.12	0.09	0.09	0.27	0.16	0.11	0.24	0.10	0.02	-0.03
LACGAN	-0.30	-0.40	-0.40	-0.42	-0.47	-0.41	-0.15	-0.16	-0.01	-0.11

[a]See Table VII

Standard errors of z for these correlations are about 0.04

Young and Omtvedt (1973) found a non-significant correlation of 0.10 between a gilts weaning weight and size of her first litter at birth, while in this study the estimate of this parameter was 0.04. The gilts weaning weight was not significantly correlated to any of the reproductive traits, except 42 day pig weight. Postweaning daily gain had a small positive correlation to all reproductive traits. Rathnasabapathy (1956) reported a positive, but not significant correlation between postweaning daily gain and ovulation rate. Age at 220 pounds was slightly positively correlated to litter size at birth ($r = 0.07$) and survival percentage ($r = 0.10$), the latter being significantly different from zero ($P < .05$). The positive correlation with litter size contradicts the report by Young and Omtvedt (1973), where the correlation between age at 200 pounds and litter size was negative ($r = -0.13$). However, age at 220 pounds was found slightly negatively correlated to most of the reproductive traits, but the sizes of the correlation coefficients were small and not significantly different from zero ($P > 0.05$). But if this tendency is real, it means that gilts that grow fast and reach 220 pounds early will raise more and heavier pigs than slower growing gilt. Backfat probe was found to be positively, but not significantly correlated to all reproductive traits except average pig weight at 21 and 42 days. Previously, Young and Omtvedt (1973) reported no consistent correlations between backfat probe and litter size at birth.

With the exception of survival percentage, all productivity traits had positive, but small correlations with gilts weight at breeding, ranging from 0.03 to 0.14. Stewart (1945a) reported a positive relationship between breeding weight and size of litter, and Omtvedt *et al.*

(1965) found that breeding weight phenotypically was positively correlated to litter size (r = 0.19) and to litter birth weight (r = 0.24). Positive correlations were found between gilts 110 day weight and the reproductive traits except survival percentage, which indicates that on the average gilts heavy at day 110 of gestation will farrow and raise, more and heavier pigs than lighter gilts. The gestation gain was also positively correlated to the same traits, but the correlation coefficients here were smaller. The results obtained corresponds to those reported by Zeller et al. (1937) and Stewart (1945a), while Donald and Flemming (1938) found no correlations between birth weight and three week litter weight was not correlated to sows weight just before farrowing. Omtvedt et al. (1965) found that gestation gain was negatively correlated to litter size at birth (r = -0.14) and positively to pig birth weight (r = 0.16); the same correlation coefficients from this analyses were 0.12 and 0.24, respectively.

It is generally accepted that a highly productive sow or gilt loses weight during lactation. The results obtained from this study support this conclusion. The correlations between lactation gain and litter size at birth, 21-days and 42-days were -0.30, -0.40 and -0.40 respectively. For total litter weight, the correlations of lactation gain were -0.42 (birth), -0.47 (21 days) and -0.41 (42 days), while the relationships to the respective pig weights and survival percentage were not so strong, but all negative. The gilts weight when the litter was weaned was negatively correlated to litter size and litter weight at weaning, but positively to the pig weights; 0.13; 0.01, and 0.04. As can be seen, the correlation of gilts weight when the litter was weaned to average pig weight at 21 and 42 days are essentially zero. The positive correlation between gilts weaning weight and pig weight at birth can be explained if the gilts that farrow few pigs are those that lose the least weight during gestation; and when few pigs are farrowed there might be a tendency to heavier birth weights and weaning weights.

From the phenotypic relations obtained it looks like the most reproductive efficient gilts on the average are those that have a high weaning weight, gain fast, reach 220 pounds at an early age, high breeding weight and 110 day weight and gestation gain and lose the most weight during the lactation period. However, the phenotypic associations are so small that accurate prediction of the probably producing ability of a gilt cannot be made.

Genetic Correlations between Performance and Productivity

The genetic correlations obtained from the pooled analyses are given in Table XIII and XIV. For those traits where the estimated components of variance were negative and therefore the genetic correlations could not be calculated, the signs of the components of covariance are given. The signs indicated in Table XIII and XIV give the signs of the correlation coefficients, even if the values as such cannot be estimated. All genetic correlations had large standard errors, and only three of them were significantly different from zero, consequently very little can be concluded about the genetic relationships. This might be kept in mind in the following discussion.

Most correlations or covariances between litter size and litter weight at the three ages and gilts birth weight were negative (-1.06 to 0.07). Using sire components (S) the genetic correlations were -0.15

and -1.06 between gilts birth weight and litter birth weight and litter 21 day weight, respectively. This means that gilts that are light at birth tend to farrow and raise litters that are heavier than those which are heavy at birth. However, for average pig weight, it seems like the gilts with the highest birth weight farrowed and raised the heaviest pigs; correlations ranging from 0.05 to 0.63. The high correlation of 0.63 (S) between gilts birth weight and pig birth weight corresponds well with the high heritabilities arrived at for birth weight in this analyses as well as in the literature previously cited.

The correlation coefficients between gilts weaning weight and litter size at birth were -0.23 and -0.52 using dam (D) and sire + dam (S + D) components, respectively. Using (S) components the correlations between gilts weaning weight and litter weight at birth and 21 days were -1.30 and -2.20, respectively. Even if the high values in magnitude are partly due to sampling error, this might indicate that gilts that are light at weaning farrow and raise the heaviest litters. For average pig weight the relations are different. From (S) components the correlation coefficients between gilts weaning weight and average pig weight at birth, 21 days and 42 days were -0.05, -0.22 and 0.35 respectively. Using (D) the same correlations were estimated to be 0.44, 0.51 and 0.77 with the (S + D) being intermediate between (S) and (D) estimates. This suggests that there is a "maternal" effect of granddam on grand-progenies birth, 21 day and 42 day weight, because of the higher estimates of genetic correlations using (D) and (D + S) that when using (S) components of variance and covariance. A positive correlation of 0.19 was obtained between gilts weaning weight and

TABLE XIII

GENETIC CORRELATIONS FROM POOLED ANALYSES

	Var. comp. used	Litter Size			Litter Weight			Average Pig Weight			
		Birth	21 days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	Surv%
BW[a]	S	-[b]	-	-	-0.15±.36	-1.06±5.26	-	0.63±.34	0.11±.29	0.43±.39	0.05±.36
	D	0.01	-	-	0.01	-	-	0.05	0.27	0.28	-
	S+D	-0.24	-	-	0.07	-	-	0.22	0.23	0.32	-
WW	S	-	-	-	-1.30±3.13	-2.20±10.80	-	-0.05±.34	-0.22±.28	0.35±.35	0.19±.33
	D	-0.23	-	-	-0.22	+	+	0.44	0.51	0.77	-
	S+D	-0.52	-	-	-0.34	-	+	0.28	0.27	0.64	+
PDG	S	-	-	-	-0.16±1.33	-1.34±6.87	-	0.08±.55	0.45±.40	0.67±.58	-0.80±.50
	D	-0.34	+	+	0.32	+	+	-0.08	-0.07	0.05	+
	S+D	-0.23	+	+	0.24	+	+	-0.04	0.07	0.19	-
AGE	S	+	+	+	1.50±3.72	1.64±8.14	+	0.002±.46	-0.18±.34	-0.66±.47	0.05±.39
	D	-0.31	+	-	-0.21	-	-	0.15	-0.12	-0.28	+
	S+D	0.02	+	+	0.09	+	-	0.11	-0.13	-0.38	+
PBF	S	+	+	-	-0.20±3.67	-0.78±6.78	+	-0.20±1.55	-0.14±1.23	0.43±1.94	-0.11±1.42
	D	-0.13	-	-	-0.81	-	-	-0.81	-0.19	-0.24	-
	S+D	-0.07	-	-	-0.65	-	-	-0.65	-0.17	-0.05	-

[a]See Table VII for explanations.

[b]- The covariance is negative, but one or both of the variances are negative and makes it impossible to estimate the correlation coefficients.

+ The covariance is positive, and correlation coefficient not possible to estimate.

*Significant different from zero, P. $\leq$ .05.

TABLE XIV

GENETIC CORRELATIONS FROM POOLED ANALYSIS

	Var. comp. used	Litter Size			Litter Weight			Average Pig Weight			
		Birth	21 days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	Surv%
SBRWT[a]	S	+[b]	-	-	0.24±1.01	-0.83±4.65	-	-0.26±.43	0.64±.33	0.06±.43	-0.84±6.85
	D	0.25	+	+	0.76	+	+	0.68	0.24	0.38	+
	S+D	0.36	-	+	0.60	+	+	0.35	0.37	0.28	+
S110WT	S	+	-	-	1.39±4.40	-0.44±2.82	-	0.24±.34	0.62±.28*	0.08±.38	-0.95±.42*
	D	0.72	+	+	1.10	+	+	0.35	0.31	0.61	+
	S+D	0.64	+	+	0.81	+	+	0.23	0.41	0.24	+
SWNWT	S	+	-	-	1.03±2.67	-1.70±8.01	-	-0.01±.43	-0.29±.35	-0.63±.52	-0.70±.40
	D	1.03	+	+	0.81	+	+	-0.34	-0.56	-0.21	+
	S+D	0.93	+	+	0.71	+	+	-0.16	-0.40	-0.35	+
GESGAN	S	+	-	-	3.21±7.27	-0.93±5.81	-	0.87±.72	0.62±.64	-0.05±.76	-1.67±1.24
	D	0.88	-	-	-0.07	-	-	-1.44	-0.02	-0.56	-
	S+D	1.08	-	-	0.77	-	-	-0.37	0.25	-0.32	-
LACGAN	S	-	+	+	-1.38±2.70	-2.06±8.80	-	-0.62±.63	-1.44±.49*	-1.20±.70	0.64±.58
	D	1.55	+	+	1.28	+	+	-0.75	-0.94	-1.20	-
	S+D	0.59	+	+	0.07	+	+	-0.56	-1.03	-0.93	+

[a]See Table VII for explanations.

[b]See Table XIII for explanations.

*Significant different from zero, P $\leq$ .05.

survival percentage in her first litter, which means that gilts that are genetically superior for weaning weight also are genetically superior for percentage of survival. However, if those gilts also are the ones farrowing small and light litters as indicated before, this cannot be looked at isolated, as a measure of reproductive efficiency.

Based on (S) postweaning daily gain was negatively correlated to litter weight at birth (r = -0.16) and 21 days (r = -1.34), and the covariances between postweaning daily gain and litter size as well as 42 day litter weight were negative. The correlations for daily gain estimated by (D) and (S + D) were negative with litter size at birth, and positive with litter weight at birth. All the covariance components (D and D + S) between daily gain and litter size and litter weight at 21 days and 42 days were positive. If this relation between covariances estimated using (S) and (D) is real, it suggests that there might be a pleiotropic effect of some non-additive genes affecting growth and maternal ability in the gilt. Correlation coefficients of 0.45 and 0.67 were obtained by (S) between daily gain and average pig weight at 21 and 42 days, respectively, while the other estimates for this relationship were close to zero. Also from (S) components a correlation of -0.80 was estimated between daily gain and survival percentage. Age at 220 pounds was found positively correlated (S) to litter weight at birth and 21 days, 1.50 and 1.64, respectively. This indicates that genes improving daily gain decreases total litter weight. All estimates of correlations between age at 220 pounds and average pig weight at 21 and 42 days were negative, which indicates that fast growing gilts are genetically superior with regard to raising heavy pigs.

Probe backfat did not seem to be genetically correlated to litter size, based on the obtained estimates. All correlations obtained between backfat probe and litter weight and average pig weight at birth and 21 days were negative, while for the correlation between backfat probe and pig weight at 42 days 0.43, -0.24 and -0.05 were obtained using (S), (D) and (S + D), respectively. This suggests that some of the same genes that make a gilt lean also make her have heavy litters with heavy pigs at birth and 21 days while the relationship at 42 days are more uncertain.

As can be seen from Table XIV the gilts weight at breeding and 110 days were positively correlated to litter size and litter weight at birth, but a negative correlation of -0.83 was estimated between breeding weight and 21 day litter weight. Average pig weights at birth, 21 and 42 days were positively correlated (r = 0.06 - 0.68) to breeding weight, and 110 day weight except for birth weight with breeding weight using (S) components. Breeding weight as well as 110 day weight were negatively correlated with survival percentage using (S) components (-0.84 and -0.95) but the respective (D) and (D + S) covariances were positive. Using sire components gestation gain was found to be positively correlated to litter weight at birth and average pig weight at birth and 21 days, and negatively correlated to litter weight at 21 days and slightly negatively to pig weight at 42-days. However, from dam components the correlations between gestation gain and litter birth weight, and average pig weight at birth, 21 days and 42 days were all lower than those obtained from sire components. This might partly be due to sampling error and partly due to non-additive genes that work in opposite directions on gestation gain and maternal ability of the gilt. The estimate obtained for the correlation between gestation gain and survival percentage, indicates that those gilts that gain most weight during gestation are those who raise fewest of the pigs they farrow.

Lactation gain was found to have positive covariances with litter size at birth, 21 days and 42 days, with exception for the intr-sire covariance between litter size at birth and lactation gain. This indicates that gilts raising many pigs also have the genetic ability to gain most weight during lactation. Table XIV also indicates that these gilts are those which raise the lightest pigs and most pigs of those farrowed. With regard to litter weight at birth, 21 days and 42 days the correlations or covariances with lactation gain were negative based on (S) and positive based on (D) and (S + D). This suggests that the genes involved in determining litter weight at different stages and lactation gain are partly the same and non-additive.

The gilts weight when weaning her litter is partly an automatic effect caused by breeding weight, gestation gain, 110-day weight and lactation gain, and the signs for the correlation coefficients obtained are in most cases identical to those for lactation gain. Positive correlations were found between gilts weight when weaning of litter and litter weight and litter size at birth, while negative correlations were found between gilts weight at weaning of litter and litter weight at 21 days and average pig weight at all ages, as well as between gilts weight at weaning of litter and survival percentage. For litter size and litter weight at 21 and 42 days, however, the (D) and (S + D) components of covariance were found to be positive in opposite to the (S) components. From this it can be seen that the genetic relationship between lactation gain and productivity for the most part is due to maternal effects and effects of non-additive genes in the gilt. However, there are some genetic relationships which are fairly consistant, for example the negative genetic correlation between average pig weight at all ages and lactation gain as well as gilts weight when weaning her litter.

CHAPTER V

SUMMARY

The objectives of this study were (1) to estimate phenotypic and genetic correlations between growth performance and reproductive performance in gilts, considering all traits as traits of the gilt; and (2) to estimate the heritabilities for the traits in question, also considering all traits as traits of the gilt.

The data were collected from eight farrowing seasons from 1971 to 1974 and came from phase I and II of the Oklahoma swine crossbreeding project. Purebred foundation herds of Duroc, Hampshire and Yorkshire were maintained at Stillwater and the crossbreeding work was done at the Ft. Reno Experiment Station. The data contain information on 397 purebred gilts with purebred and 2-breed cross litters from 1971 and 1973 spring and fall, and 191 crossbred gilts with 2-breed cross and 3-breed cross litters from 1972 and 1974 spring and fall.

The data were evaluated for purebred gilts with purebred litters, purebred gilts with 2-breed cross litters and crossbred gilts with 3-breed cross litters separately. Finally a pooled analyses was done, where adjustments were made for effects of different breeds and effects of heterosis. Heritabilities and phenotypic and genetic correlations were estimated using sire of gilt components, dam of gilt components and a combination of both. The variability among estimates from the separate analyses was high, but no obvious inconsistencies

were observed. To reduce sampling error the data therefore were pooled, and most attention was paid to the pooled analyses.

Heritabilities for gilt's birth weight and weaning weight obtained from sire components were 0.72± .18 and 0.75± .18, respectively. Post-weaning daily gain, age at 220 pounds and backfat probe had heritabilities of 0.32± .16, 0.45± .17 and 0.34± .16 respectively, using sire components. Also, breeding weight, 110-day weight and gilts weight when her litter was weaned had fairly high heritability estimates (S). Using (S) gestation gain and lactation gain were estimated to have heritabilities of 0.09± .15 and 0.27± .16 respectively. Of the reproductive traits only h^2 for average pig weight at 21 days were significantly positive (0.36± .17) at the 0.05 level. The higher estimates obtained using (D) components for many of these traits indicates that maternal effects are important.

Most of the phenotypic correlations estimated were low. However, gilts breeding weight, 110 day post breeding weight and gestation gain seem to be positively correlated to litter size, litter weight and average pig weight at birth, 21 days and 42 days. Weight of gilt when weaning of her litter seems to be negatively correlated to litter size and litter weight at birth, 21 days and 42 days. Lactation gain was negatively correlated to litter size at birth (r = -0.30), 21 days (r = -0.40) and 42 days (r = -0.40) as well as to litter weight at birth, 21 days and 42 days, the correlation coefficients being -0.42, -0.47 and -0.41 respectively. The relationships between lactation gain and survival percentage and average pig weights were also negative, but of smaller magnitude.

Genetic correlations were estimated using sire of gilt, dam of gilt and sire and dam of gilt components of variance and covariance where this was possible. Where the variance components were negative the signs of the covariances were used as an indicator of the sign of the genetic correlation. Most correlations and covariances between gilts birth weight and litter size and litter weight at the three ages were negative. Sire components gave genetic correlations of -1.30 and -2.20 between gilts weaning weight and litter weight at birth and 21 days, respectively; while (S + D) components gave r = -0.52 between weaning weight and litter size at birth. All (S) covariances between post weaning daily gain and litter size and litter weight were negative; the correlations between gain and litter weight at birth and 21 days were -0.16 and -1.34 respectively. Age at 220 pounds was positively correlated to litter weight (S) at birth and 21 days, 1.50 and 1.64 respectively. All estimates of genetic correlations between backfat probe and litter weight and average pig weight were negative. Breeding weight and 110 day weight were positively correlated to litter size and litter weight at birth and negatively to litter weight at 21 days and survival percentage. From (S + D) components a correlation of 1.08 was estimated between gestation gain and litter size at birth. Using (S) components correlations of -1.38 and -2.06 were obtained between lactation gain and litter weight at birth and 21 days respectively. By all methods it was found that average pig weight at all ages was positively correlated with gilts birth weight and gilts 110 day weight and negatively correlated with lactation gain and gilts weight when weaning of her litter. These data provide estimates of heritabilities in fairly close agreement with those found in the literature. Further evidence that most reproductive traits are lowly heritable and greatly influenced by maternal effects was found. Some of the genetic correlations between performance and productivity traits were fairly large, while most of the corresponding phenotypic correlations were essentially zero.

LITERATURE CITED

Barr, A. J. and J. H. Goodnight. 1972. A User's Guide to the Statistical Analyses System. Student Supply Stores, N. Carol. State Univ. Raleigh, N. Carolina.

Blunn, C. T. and M. L. Baker. 1949. Heritability estimates of sow productivity and litter performance. J. Anim. Sci. 8:89.

Bradford, G. E. 1968. Selection for litter size in mice in the presence and absence of gonadoptropin treatment. Genetics 58:283.

Bradford, G. E. 1969. Genetic control of ovulation rate and embryo survival in mice. I. Response to selection. Genetics 61:905.

Bradford, G. E. 1971. Growth and reproduction in mice selected for rapid body weight gain. Genetics 69:499.

Chapman, A. G. 1951. Effectiveness of selection in laboratory animals. J. Anim. Sci. 10:3.

Cummings, J. N., L. M. Winters and H. A. Stewart. 1947. The heritability of some factors affecting productivity of brood sows. J. Anim. Sci. 6:297.

Cunningham, E. P. and T. Gjedrem. 1970. Genetic control of Ewe Body Weight in Selection for Higher Wool and Lamb Output. Acta. Agr. Scand. Vol. 22:3. 194.

Dickerson, G. E. 1969. Techniques for research in quantitative animal genetics. Techniques and procedures in Animal Science Research. Amer. Soc. Anim. Sci. Champaign, Ill. 61820.

Dickerson, G. E., H. O. Hetzer, E. V. Krehbiel and A. E. Flower. 1974. Effectiveness of reciprocal selection for performance of crosses between Montana No 1 and Yorkshire swine. III. Expected and actual response. J. Anim. Sci. 39:24.

Donald, H.P. and I. Fleming. 1938. The effect of prenatal weight changes in breeding sows on the number and size of new born pigs. Empire Jour. Exp. Agr. 6:341.

Falconer, D. S. 1960. Introduction to Quantitative Genetics. Ronald Press Co., New York.

Hogsett, M. L. and A. W. Nordskog. 1958. Genetic-Economic Value in Selecting for Egg Production Rate, Body Weight and Egg Weight. Poul. Sci. 37:1404.

Johansson, I. and N. Korkman. 1951. A study of the variation in production traits of bacon pigs. Acta. Agr. Scand. 1:62.

Johnsson, P. and J. W. B. King. 1962. Sources of variation in Danish Landrace pigs at progeny testing stations. Acta. Agr. Scand. 12:68.

Johnson, R. K. 1973. Maternal heterosis for dam productivity and post-weaning feedlot performance in swine. Ph.D. Thesis. Oklahoma State University. Stillwater.

Johnson, R. K. and I. T. Omtvedt. 1973. Evaluation of purebreds and two-breed crosses in swine: Reproductive performance. J. Anim. Sci. 37:1279.

Johnson, R. K., I. T. Omtvedt and L. E. Walters. 1973. Evaluation of purebreds and two-breed crosses in swine: Feedlot performance and carcass merit. J. Anim. Sci. 37:18.

Johnson, R. K. and I. T. Omtvedt. 1975. Maternal heterosis in swine: Reproductive performance and dam productivity. J. Anim. Sci. 40:29.

King, S. C. 1961. Inheritance of economic traits in the Regional Cornell Control Population. Poul. Sci. 40:975.

Kolstad, N. 1972. Arvbarhet og korrelasjoner for økonomisk viktige egenskaper hos verpehøns. Meld. fra NLH 1972. 6.

Langholz, H-J. 1966. Das züchteriche Hilfsmittel der stationären Nachkommenprüfung beim Schwein. III. Heritabilitäten und genetische Korrelationen beim norwegischen Landschwein. Acta. Agr. Scand. 16:97.

Louca, A. and O. W. Robison. 1967. Components of variance and covariance in purebred and crossbred swine. J. Anim. Sci. 26:267.

Lush, J. L. 1936. Genetic aspects of the Danish system of progeny-testing swine. Research Bulletin No. 204. Ames, Iowa. 108.

Lush, J. L. and A. E. Molln. 1942. Littersize and weight as permanent characteristics of sows. USDA Tech. Bul. 836.

Lush, J. L., W. F. Lamereux, and L. N. Hazel. 1948. The heritability of resistance to death in the fowl. Poul. Sci. 27:375.

Meyer, H. H. and G. E. Bradford. 1974. Estrus, ovulation rate and body composition of selected strains of mice on ad libum and restricted feed intake. J. Anim. Sci. 38(2) 271.

Olbrycht, T. M. 1943. The statistical basis of selection in animal husbandry. Part I. Studies on life performance of brood sows: an analysis of variance and covariance of progeny born and reared. J. Agr. Sci. 33:28-43, 174-184.

Omtvedt, I. T., C. M. Stanislaw and J. A. Whatley. Jr. 1965. Relationship of gestation length, age and weight at breeding and gestation gain to sow productivity at farrowing. J. Anim. Sci. 24:531.

Pirchner. F. 1969. Population Genetics in Animal Breeding. W. H. Freeman and Co., San Francisco.

Pivnyak, N. V. 1971. Heritability and repeatability of litter size and milk production in pigs. In Genetika i selecktsiya na Ukraine, Ch. 2. Kiev: Nauk. Dumka. Pp. 21-22. Anim. Br. Abstra. 40:2123.

Polyanichko, YA.I. 1972. Variability and heritability of some economic traits in purebred pigs. In Genet. svinei i teoriya plemen. otbora v svinovodstve. Moscow, USSR, Kolos. (1972) 98. [An. Br. Abstracts No 4. 1973. 1711.]

Rathnasabapathy, V., J. E. Lasley and P. T. Mayer. 1956. Genetic and environmental factors affecting litter size in swine. Mo. Agr. Exp. Sta. Res. Bul. 615.

Revelle, T. J. and O. W. Robison, 1973. An explanation for the low heritability of litter size in swine. J. Anim. Sci. 36:195 [Abstract].

Roberts, R. C. 1965. Some contributions of the laboratory mouse to animal breeding research. Anim. Br. Abstract 33:339.

Robison, O. W., A. Louca and J. E. Legates, 1964. Purebred and crossbred performance of paternal half-sibs of swine. J. Anim. Sci. 23:853 [Abstract].

Siers, D. G. and G. M. Thomson, 1972. Heritabilities and genetic correlations of carcass and growth traits in swine. J. Anim. Sci. 35 (2) 311.

Squiers, C. D., G. E. Dickerson and D. T. Mayer. 1952. Influence of inbreeding, age and growth rate of sows on sexual maturity, rate of ovulation, fertilization and embryonic survival. Mo. Agr. Exp. Sta. Res. Bul. 494.

Standal, N. 1968. Selection on performance of purebred vs. crossbred progeny. Acta. Agr. Scand. 18:222.

Stewart, H. A. 1945a. An appraisal of factors affecting prolificacy in swine. J. Anim. Sci. 4:250.

Stewart, H. A. 1945b. Inheritance of prolificacy in swine. J. Anim. Sci. 4:359.

Sweiger, L. A., W. R. Harvey, D. O. Everson and K. E. Gregory. 1964. The variance of intraclass correlation involving groups with one observation. Biometrics 20:818.

Turnes, H. N. 1969. Genetic improvement of reproduction rate in sheep. Anim. Br. Abstr. 37:545.

Young, L. D. 1973. The influence of various factors on ovulation rate and the number of embryos 30 days after breeding in gilts. M.S. Thesis. Okla. State Univ. Stillwater.

Young, L. D. and I. T. Omtvedt. 1973. Influence of the litter in which a gilt is raised and her own performance on the subsequent reproductive performance. Okla. Agr. Exp. Sta. Res. Rept. MP - 90:177.

Young, L. D., I. T. Omtvedt and R. K. Johnson. 1974. Relationships of various measures of performance with ovulation rate and number of embryos 30 days after breeding in gilts. J. Anim. Sci. 39:480.

Zeller, J. H., T. C. Johnson and W. A. Craft. 1937. The significance of weight changes in sows during the gestation and suckling periods. Proc. Am. Soc. An. Prod. 121.

APPENDIXES

TABLE XV

HERITABILITY ESTIMATES FOR PUREBRED GILTS WITH PUREBRED LITTERS[a]

Trait	HERITABILITY		
	$\frac{4S}{S+D+W}$	$\frac{4D}{S+D+W}$	$\frac{2(S+D)}{S+D+W}$
BW	0.07	2.60	1.33
WW	-0.15	-0.11	-0.13
PDG	-1.29	4.08	-1.39
AGE	-0.32	2.01	0.85
PBF	1.02	-0.45	0.25
SBRWT	0.29	1.67	0.98
S110WT	-0.13	2.23	1.05
SWNWT	0.26	1.59	0.93
GESGAN	0.86	1.48	1.17
LACGAN	-1.36	3.80	1.22
NoBIR	-2.03	2.48	0.22
No21	-2.37	-1.60	-1.99
No42	-2.60	-0.86	-1.73
LITBIR	-1.30	0.34	-0.48
LIT21	-1.08	-1.25	-1.16
LIT42	-1.52	-1.06	-1.29
PIGBIR	-0.91	2.60	0.84
PIG21	0.75	1.98	1.37
PIG42	-0.04	1.77	0.86
SURV%	-0.50	-0.52	-0.51
Std. Dev.[b]	0.7-0.8		

[a]Based on 87 gilts in 4 seasons.

[b]Range of approximated standard deviations.

TABLE XVI

HERITABILITY ESTIMATES FOR PUREBRED GILTS WITH CROSSBRED LITTERS[a]

Trait	HERITABILITY		
	$\frac{4S}{S+D+W}$	$\frac{4D}{S+D+W}$	$\frac{2(S+D)}{S+D+W}$
BW	0.50	1.53	1.01
WW	1.20	0.28	0.74
PDG	0.25	1.15	0.70
AGE	0.61	0.89	0.75
PBF	0.34	0.80	0.57
SBRWT	0.39	1.39	0.89
S110WT	0.45	-0.53	-0.04
SWNWT	0.31	-0.25	0.03
GESGAN	0.20	-1.23	-0.51
LACGAN	0.10	0.45	0.28
NoBIR	0.30	0.49	0.40
No21	-0.27	-0.18	-0.23
No42	-0.41	-0.43	-0.42
LITBIR	0.49	-0.20	0.15
LIT21	-0.09	-0.08	-0.09
LIT42	-0.28	-0.38	-0.33
PIGBIR	0.44	0.24	0.34
PIG21	0.16	1.39	0.77
PIG42	0.08	1.62	0.85
SURV%	0.18	0.05	0.11
Std. Dev.[b]	.25-.35		

[a]Based on 311 in 8 seasons.

[b]Range of approximated standard deviations.

TABLE XVII

HERITABILITY ESTIMATES FOR CROSSBRED GILTS WITH 3-BREED CROSS LITTERS[a]

Traits	$\frac{4S}{S+D+W}$	$\frac{4D}{S+D+W}$	$\frac{2(S+D)}{S+D+W}$
BW	1.27	1.12	1.19
WW	1.23	1.58	1.40
PDG	0.52	0.64	0.58
AGE	0.56	1.18	0.87
PBF	0.20	-0.43	-0.11
SBRWT	-0.50	1.83	0.66
S110WT	0.89	-0.09	0.40
SWNWT	1.25	-1.10	0.07
GESGAN	0.04	0.00	0.02
LACGAN	0.65	-1.24	-0.29
NoBIR	0.87	-1.64	-0.39
No21	0.54	-1.96	-0.71
No42	0.43	-1.75	0.66
LITBIR	1.17	-1.13	0.02
LIT21	0.77	-1.13	-0.18
LIT42	0.47	-0.69	-0.11
PIGBIR	1.15	-0.39	0.38
PIG21	1.05	-0.58	0.24
PIG42	1.05	-1.06	0.00
SURV%	0.62	-1.99	-0.69
Std. dev.[b]	.35-.45		

[a]Based on 190 gilts in 4 seasons.

[b]Range of approximated standard deviations.

TABLE XVIII

PHENOTYPIC CORRELATIONS FOR PUREBRED
GILTS WITH PUREBRED LITTERS

	Litter Size			Litter Weight			Average Pig Weight			
	Birth	21 days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	Surv%
BW	0.10	0.07	-0.11	0.18	0.04	-0.07	0.05	-0.04	0.01	-0.19
WW	0.20	0.14	0.13	0.24	0.23	0.24	-0.01	0.19	0.22	-0.10
PDG	0.24	0.20	0.19	0.24	0.23	0.14	-0.02	0.14	-0.01	-0.08
AGE	-0.29	-0.17	-0.16	-0.32	-0.22	-0.21	0.01	0.14	-0.17	0.18
PBF	-0.06	-0.10	-0.07	-0.09	0.16	-0.16	-0.01	-0.05	-0.09	0.01
SBRWT	0.26	0.14	0.11	0.30	0.19	0.12	0.06	0.14	0.07	-0.18
S110WT	0.24	0.03	0.02	0.40	0.14	0.12	0.24	0.18	0.17	-0.24
SWNWT	0.02	-0.27	-0.25	0.13	-0.16	-0.15	0.26	0.15	0.15	-0.30
GESGAN	0.08	-0.10	-0.08	0.27	0.00	0.05	0.28	0.11	0.18	-0.16
LACGAN	-0.23	-0.39	-0.39	-0.28	-0.37	-0.35	0.03	-0.01	0.04	0.17

TABLE XIX

PHENOTYPIC CORRELATIONS FOR PUREBRED GILTS WITH CROSSBRED LITTERS

	Litter Size			Litter Weight			Average Pig Weight			
	Birth	21 days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	Surv%
BW	-0.13	-0.16	0.15	-0.08	-0.12	-0.07	0.08	0.09	0.17	-0.05
WW	-0.10	-0.11	-0.12	-0.08	-0.10	0.07	0.07	0.03	0.13	-0.03
PDG	0.04	0.02	0.00	0.03	0.01	0.01	0.00	0.01	0.03	-0.07
AGE	-0.02	0.07	0.07	-0.02	0.07	0.04	-0.02	-0.02	-0.08	0.11
PBF	0.01	0.31	0.07	0.04	0.09	0.09	0.07	-0.02	0.03	0.07
SBRWT	0.11	0.05	0.05	0.12	0.04	0.07	0.02	0.07	0.06	-0.08
S110WT	0.17	0.09	0.08	0.33	0.14	0.09	0.23	0.12	0.03	-0.09
SWNWT	-0.05	-0.21	-0.24	-0.04	-0.25	-0.23	0.04	-0.05	0.05	-0.20
GESGAN	0.11	0.04	0.03	0.31	0.11	0.03	0.28	0.07	-0.01	-0.06
LACGAN	-0.20	-0.33	-0.34	-0.38	-0.45	-0.36	-0.23	-0.22	-0.02	-0.15

TABLE XX

PHENOTYPIC CORRELATIONS FOR CROSSBRED GILTS
WITH 3-BREED CROSS LITTERS

	Litter Size			Litter Weight			Average Pig Weight			
	Birth	21 days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	Surv%
BW	0.04	0.01	0.01	0.04	0.04	0.05	0.00	0.08	0.06	-0.03
WW	0.09	0.11	0.12	0.02	0.37	-0.15	-0.12	-0.02	0.09	0.06
PDG	0.08	0.03	0.01	0.11	0.03	0.02	0.07	-0.02	0.01	-0.09
AGE	-0.04	-0.07	-0.04	-0.05	-0.04	-0.05	-0.02	0.06	-0.02	0.00
PBF	1.45	0.12	0.13	0.15	0.09	0.11	-0.05	-0.13	-0.13	-0.08
SBRWT	0.13	0.13	0.12	0.19	0.17	0.14	0.12	0.06	0.00	0.03
S110WT	0.22	0.21	0.19	0.33	0.30	0.21	0.21	0.16	0.00	-0.01
SWNWT	-0.23	-0.24	-0.26	-0.16	-0.19	-0.25	0.19	0.06	-0.02	0.02
GESGAN	0.18	0.17	0.14	0.28	0.25	0.16	0.16	0.17	0.00	-0.05
LACGAN	-0.45	0.45	-0.45	-0.49	-0.52	0.48	-0.03	-0.17	-0.07	0.03

TABLE XXI

a. GENETIC CORRELATIONS FOR PUREBRED GILTS WITH PUREBRED LITTERS

	Var. comp. used	Litter Size			Litter Weight			Average Pig Weight			Surv%
		Birth	21 days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	
BW	S	a							2.97		
	D	0.02			-0.35			-0.37	0.32	-0.32	
	S+D	-0.35						0.02	-0.02	0.05	
WW	S										
	D										
	S+D										
PDG	S										
	D	0.42			1.23			-0.03	0.01	-0.10	
	S+D	0.90						-0.28	0.15	0.10	
AGE	S										
	D	-0.25			-0.48			0.06	-0.20	-0.59	
	S+D	-0.71						0.37	-0.37	-0.77	
PBF	S								-0.32		
	D										
	S+D								-0.94		

[a] Empty cells means that one or both of the variances were negative and made it impossible to estimate the correlation coefficient.

TABLE XXI

b. GENETIC CORRELATIONS FOR PUREBRED GILTS WITH PUREBRED LITTERS

	Var. comp. used	Litter Size			Litter Weight			Average Pig Weight			Surv%
		Birth	21 days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	
	S	a							2.41		
SBRWT	D	0.78			1.76			-0.60	-0.26	0.09	
	S+D	1.21						-0.26	0.29	0.52	
	S										
S110WT	D	0.79			2.22			-0.49	-0.19	0.02	
	S+D	1.17						0.03	0.40	0.81	
	S								0.53		
SWNWT	D	-0.14			0.03			0.38	0.12	0.58	
	S+D	0.92						0.22	0.20	0.57	
	S								0.96		
GESGAN	D	0.54			2.02			0.21	-0.05	-0.05	
	S+D	0.46						0.17	0.27	0.71	
	S										
LACGAN	D	-0.70			-1.89			0.60	0.20	0.49	
	S+D	-0.17						0.29	-0.21	-0.20	

[a]See Table XXIa.

TABLE XXII

a. GENETIC CORRELATIONS FOR PUREBRED GILTS WITH CROSSBRED LITTERS

	Var. comp. used	Litter Size			Litter Weight			Average Pig Weight			Surv%
		Birth	21 days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	
	S	-0.48	a		-0.30			0.27	-0.60	-0.02	0.15
BW	D	-0.52						0.43	0.38	0.28	-0.63
	S+D	-0.50			-0.63			0.33	0.22	0.24	-0.19
	S	-0.00			-0.62			0.45	0.29	1.37	0.54
WW	D	0.70						0.39	0.00	0.44	-3.02
	S+D	-0.32			-0.34			0.43	0.08	0.53	-0.19
	S	-0.09			-0.60			-0.80	0.28	-0.88	-0.16
PDG	D	0.22						-0.39	0.01	-0.06	0.15
	S+D	0.13			0.07			-0.34	0.05	-0.13	0.01
	S	0.70			0.75			0.26	-0.20	-0.37	0.25
AGE	D	-0.57						0.74	-0.03	-0.03	0.49
	S+D	-0.07			0.26			0.47	-0.06	-0.07	0.32
	S	-0.47			-0.39			-0.05	0.04	1.05	-0.62
PBF	D	0.24						-0.31	-0.09	0.07	0.14
	S+D	0.00			-0.40			-0.17	-0.07	0.18	0.34

[a]See Table XXIa.

TABLE XXII

b. GENETIC CORRELATIONS FOR PUREBRED GILTS WITH CROSSBRED LITTERS

	Var. comp. used	Litter Size			Litter Weight			Average Pig Weight			Surv%
		Birth	21 days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	
SBRWT	S	0.38	a		-0.06			-0.70	1.20	-0.78	-1.83
	D	0.26						-0.28	-0.11	0.04	2.16
	S+D	0.29			0.08			-0.41	0.09	-0.04	0.14
S110WT	S	0.93			0.73			-0.04	0.75	-1.02	-1.91
	D										
	S+D										
SWNWT	S	-0.24			-0.26			0.33	-0.64	-2.27	-0.46
	D										
	S+D	2.17			1.61			-3.11	-1.55	-0.62	0.60
GESGAN	S	1.40			1.36			-0.16	-1.21	-2.16	-1.73
	D										
	S+D										
LACGAN	S	-2.05			-1.98			0.93	-3.22	-2.55	2.67
	D	1.16						-1.13	-0.13	0.26	-0.21
	S+D	0.03			0.45			-0.28	-0.56	0.00	0.93

[a]See Table XXIa.

TABLE XXIII

a. GENETIC CORRELATIONS FOR CROSSBRED GILTS WITH 3-BREED CROSS LITTERS

	Var. comp. used	Litter Size			Litter Weight			Average Pig Weight			Surv%
		Birth	21 days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	
BW	S	-0.42	-0.45	-0.48	-0.24	-0.08	-0.08	0.48	0.43	0.36	0.25
	D	[a]									
	S+D				0.56			0.07	0.35		
WW	S	-0.30	-0.12	-0.20	-0.18	-0.08	0.40	0.20	0.07	0.76	0.31
	D										
	S+D				-1.33			0.17	0.43		
PDG	S	0.21	0.69	0.87	0.29	0.83	1.54	0.17	0.52	1.09	0.90
	D										
	S+D				0.22			0.52	0.24		
AGE	S	0.03	-0.54	-0.69	0.13	-0.56	-1.33	0.02	-0.38	-1.07	-1.27
	D										
	S+D				0.77			-0.24	-0.19		
PBF	S	-0.09	0.77	1.20	0.58	0.32	1.33	0.51	-0.77	-0.03	0.96
	D										
	S+D										

[a]See Table XXIa.

TABLE XXIII

b. GENETIC CORRELATIONS FOR CROSSBRED GILTS WITH 3-BREED CROSS LITTERS

	Var. comp. used	Litter Size			Litter Weight			Average Pig Weight			Surv%
		Birth	21 days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	
	S										
SBRWT	D										
	S+D				1.14			0.97	0.62		
	S	0.38	-0.07	-0.09	0.48	0.24	-0.02	0.03	0.35	-0.06	-0.56
S110WT	D										
	S+D				0.23			0.47	1.11		
	S	-0.27	-0.31	-0.24	-0.22	-0.16	-0.34	0.04	0.02	-0.25	0.39
SWNWT	D										
	S+D				2.06			0.98	-0.88		
	S	1.40	0.02	0.19	1.99	1.31	-0.68	0.24	2.26	-1.00	-2.10
GESGAN	D										
	S+D				-5.95			-3.13	3.57		
	S	-0.67	-0.34	-0.22	-1.03	-0.70	-0.69	-0.47	-0.77	-0.68	1.05
LACGAN	D										
	S+D										

[a] See Table XXIa.

VITA

Petter Inge Bergheim

Candidate for the Degree of

Master of Science

Thesis: A STUDY OF THE HERITABILITIES AND CORRELATIONS AMONG MEASURES OF PERFORMANCE AND PRODUCTIVITY IN GILTS

Major Field: Animal Science

Biographical:

Personal Data: Born in Fiksdal, Romsdal, Norway, January 17, 1948, the son of Sigrid and Kristian Bergheim; married Solfrid Lindland July 27, 1974.

Education: Received Matriculation Certificate at Molde High School (Nor.) June, 1968. Received certificate from Gjermundnes Agricultural School (Nor.) March, 1970. Received an Agricultural Degree from the Agricultural University of Norway, Aas, Norway, August, 1973 with a major in General Agriculture.

Experience: Raised on general livestock farm in Western Norway; Norwegian Army 1968-69; Teaching secondary school and grade school for five months 1969 and 1970; Graduate Assistant at Oklahoma State University 1973-75.

Member: American Society of Animal Science.

Date of Degree: May, 1975