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Title: The Influences of Heredity and Some Environmental Components on Occurrence of Puberty in Gilts in Confinement

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In a swine production and breeding experiment, Yorkshire gilts were evaluated for the influences of heredity and some environmental components on occurrence of puberty in gilts in confinement. In the first experiment, 186 Yorkshire gilts reared and maintained in total confinement were used in a study to assess effects of several environmental variables on occurrence of puberty and subsequent estrus periods. The four social combination groups were: reared-together and exposed-together (RT-ET), reared-together and exposed-separately (RT-ES), reared-separately and exposed-together (RS-ET), and reared-separately and exposed-separately (RS-ES). The percentage expressing puberty and days to puberty were not significantly different among the four social groups nor was regularity of estrus cycles.

Based on these findings there appears to be no added benefit

of allotting gilts in the various social groups used beyond the effects resulting from mixing to provide unfamiliar penmates and providing boar exposure. Secondly, it appears that gilts which achieved pubertal estrus promptly continued to have high cyclic adequacy.

In the second experiment 438 Yorkshire gilts reared and housed in total confinement were used to determine hereditary influence on occurrence of puberty and days from commencing of experiment to puberty. Line-of-sire effect was significant ($P = .10$) for percentage occurrence of puberty. Difference among line-of-sire for days to puberty were not significant ($P > .05$). Maternal variance components were significantly larger than the sire's variance components for both traits ($P < .05$). Paternal half-sib estimate of heritability was $.05 \pm .11$ for occurrence of puberty and was $-.11 \pm .10$ for days to puberty. Maternal half-sib analysis gave $1.06 \pm .22$ and $1.18 \pm .36$ for percentage occurrence of puberty and days to puberty. Based on these findings there appears to be a basis for modest expectation of improvement in performance of the two traits through selection based on differences in performance among lines-of-sires and among litters effects. There is indication that the ability to achieve occurrence of puberty and the number of days to puberty within a given time period are relatively independent of each other.

The Influence of Heredity and Some Environmental Components on Occurrence of Puberty in Gilts in Confinement

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To all of mankind, I claim to be no more than the average man with less than average ability. I cannot claim any special merit for such attainment I shall, or hope to, receive through dedication and continuance, as I have been able to reach through laborious study, work and mentors' belief in and aiding me in my quest for knowledge and understanding. I have not a shadow of a doubt that any man or woman can achieve that I have if he or she would make the same dedicated effort and cultivate the same hope and faith in oneself and others.

AMEN

TABLE OF CONTENTS

APPENDIX (continued)

LIST OF FIGURES

LIST OF TABLES

THE INFLUENCE OF HEREDITY AND SOME ENVIRONMENTAL COMPONENTS ON OCCURRENCE OF PUBERTY IN GILTS IN CONFINEMENT

CHAPTER 1

GENERAL INTRODUCTION

Successful swine breeding programs require reproductive efficiency by both the sow and by the gilts added to the breeding herd. Level of reproductive efficiency is influenced by the proportion of potential replacement gilts which achieve puberty and also by the number of days to occurrence of puberty after incorporation into breeding herd. Regularity of occurrence of succeeding estrus periods also has an influence on the level of reproductive efficiency.

Research reported by Christenson and Ford [1979] pointed out that rearing of gilts in total confinement, in many instances, places the gilts in an environment different from their natural habitat. This change in the environment, along with genetic changes of swine as a result of selection for faster growth, leanness and improvement in other traits, may have altered the physiological and behavioral patterns of the gilts. Length of time to first estrus and regularity of occurrence of successive estrual periods is variable among and within breeds. Delayed occurrence of puberty and longer intervals between estrual periods have adverse economic effects on production efficiency through increased feed costs and production delays.

Delayed puberty and subsequently anoestrus are major and often causally unexplained reproductive disorders of gilts. Producers and researchers have attempted to circumvent these problems by manipulation of various aspects of the environment. Procedures such as choosing the selection of replacement gilts during the season of highest percent occurrence of estrus, use of boar exposure as a stimulus, providng adequate pen space to avoid possible deterrent to estrus and regrouping of gilts with unfamiliar penmates and in unfamiliar environments have been reported to be of varying degrees of usefulness.

Because prompt occurrence of puberty and regular occurring succeeding estrual period is economically important, they should receive attention in both selection among and within breeds if those are hereditarily determined. Attention should also be given to provide the kind of environment that tends to enhance occurrence of these traits. The experiments reported here attempt to evaluate the influence of social grouping as an environmental influence and within breed genetic effects on occurrence of puberty and occurrence of subsequent estrual periods.

Running Head: Environmental influences on puberty

CHAPTER 2

INFLUENCE OF SOCIAL ENVIRONMENTS, AGE AND SEASONS ON ATTAINMENT OF PUBERTY BY GILTS[1]

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SUMMARY

One hundred and eighty-six Yorkshire gilts reared and maintained in total confinement were used in this study. Initiation of the experiment commenced by transferring gilts from rearing groups in the growing unit to pens in the nearby brood stock unit. Pairs of gilts were allotted for estrus occurrence in four social groupings based on togetherness-separateness combinations during rearing and exposure. All gilts were observed daily for behavioral indications of puberty and were exposed daily to one or more Yorkshire boars in a breeding pen until occurrence of puberty or for 42 days. After puberty the procedure was continued until occurrence of second estrus or for a maximum of 30 additional days, and similarly until occurrence of third estrus or for a maximum of an additional 30 days following second estrus.

Percentage expressing puberty and days to puberty in this study were not significantly different among the four rearing-and-exposure combination groups. Likewise, regularity of estrus cycles was similar for the four social groups. Seasonal effects of spring, summer and fall were not significantly different on gilt responses; percentages occurrence of puberty among exposed gilts were 73, 62 and 63, respectively. Differences in age on test were not significant between pubertal and non-pubertal gilts. Weight on test was significantly higher for non-pubertal gilts (80 vs. 81.8 kg) but from an operational or biological point of view this difference is negligible and does not appear to be a meaningful component of failure of occurrence of puberty.

INTRODUCTION

Anoestrus, delayed puberty, repeat breeding and irregular occurrence of postweaning estrus are often encountered in swine production. The management of gilts in total confinement has increased these breeding problems in gilts. Delayed puberty and anoestrus are major and generally causally unexplained reproductive disorders of gilts. Anoestrus is reported to be associated to variable extents with deficiencies in housing, nutrition, genetic background and various aspects of management procedures. Within the anoestrus parameter, inactive ovaries, undetected estrus cycles, and irregular estrus cycles have been some of the major defined components of reproductive problems in gilts [Rentzel and Sumption, 1968; George and England, 1974; Aherne et al., 1976; Christenson and Ford, 1979].

Producers and researchers have attempted to circumvent these problems by manipulation of various environmental factors. Procedures such as choosing the most favorable season for selection of replacement gilts, use of boar exposure, providing adequate pen space and regrouping of gilts with unfamiliar penmates and in unfamiliar environments have been reported to be of varying usefulness [Robertson et al., 1951; Mavrogenis and Robison, 1976; Schiemann et al., 1976; Ford and Teague, 1978; Christenson and Ford, 1979]. Response to these practices is not uniform; some gilts respond more readily than others.

Expression of puberty is of special economic importance because of added feed costs and production delays resulting from failure of prompt and regular occurrence of estrus. No reports of experiments in the literature were found concerning influence of social groups among gilts prior to and during exposure except for the influence of providing unfamiliar penmates during the exposure period and providing board presence. In the present experiment, specific social environments were applied as experimental procedures to determine pubertal and subsequent estrual responses by gilts to the imposed social environments.

The objectives of the present research were to evaluate: (1) the influence of social grouping on percentage of gilts reaching puberty and days to occurrence of subsequent estrus within the specified experimental period; (2) seasonal effects on occurrence of puberty; and (3) difference in age and weight of gilts which did or did not reach puberty within the experimental period.

EXPERIMENTAL PROCEDURE

One hundred and eighty-six Yorkshire gilts reared and maintained in total confinement were used in this study. The study was initiated by transferring gilts from rearing groups in the growing unit to pens in the nearby brood stock unit. Prior to movement of gilts to the brood stock unit, each had been observed at least once weekly for indications of estrus; no occurrence of estrus was observed. At the time of movement of gilts to the brood stock unit, mixing of gilts was accomplished to achieve four designed social groups during the allotted puberty-attainment period of 42 days. These social groups are shown in Figure 1. Each pen group consisted of 8 to 12 gilts. In essence, each gilt was exposed as a pairmate with a gilt which was or was not a penmate prior to beginning of the puberty-attainment experimental period. While on experiment, gilts were fed 2.3 to 2.7 kg per day of a 14% crude protein ration composed of the ingredients as shown in Table 1.

Beginning with the day of initiation of the experiment. each gilt was observed daily for physical and behavioral indications of estrus. In addition, all gilts were exposed daily to one or more Yorkshire boars in a breeding pen. This estrus-stimulating and detection procedure was continued until occurrence of estrus or for 42 days for gilts not reaching puberty. For gilts reaching puberty, this procedure was continued until second estrus or a maximum of 30 additional days, and similarly for an additional 30 days following second estrus. Gilts reaching third estrus were bred at that time.

Natural daylength or intensity of lighting was not altered other than by use of artificial lighting as use in normal swine husbandry. Analysis of data for the influence of social groupings on gilts was by analysis of variance with unequal cell frequencies [Nie and Hull, 1975]. Seasonal effects on percentage expressing estrus were assessed by analysis binomial of proportion [Snedecor and Cochran, 1969]. Seasonal effect on days to puberty was determined by analysis of variance.

RESULTS AND DISCUSSION

Influence of Social Grouping

It has been experimentally established that application of some kinds of environmental changes, such as mixing unfamiliar gilts and exposure to boar presence stimulates occurrence of estrus [Robertson *et al*., 1951; Brooks and Cole, 1970; George and England, 1974; Zimmerman *et al*., 1974; Marvogenis and Robison, 1976; Christenson and Ford, 1979]. In the present experiment, such environmental changes were applied as a constant to all social groups. The social groups *per se* (Figure 1) were an experimental environmental variable. Of the 186 gilts in the experiment, 119 (64%) attained puberty within the allotted 42 days. Data show in Table 2 that there is no significant influence of the social grouping combinations on percentage of gilts expressing puberty or on days to puberty. No significant differences were observed for percentage expressing puberty or for days to puberty between gilts reared together-exposed together (RT-ET) vs. gilts reared together-exposed separately (RT-ES); values were 56 vs. 63%, respectively. Difference between gilts reared together-exposed together (RT-ET) vs. gilts reared separately-exposed separately (RS-ES), 56 vs. 73%, respectively, were not statistically significant. Differences in days to puberty among the social groupings were also not statistically significant.

These findings indicate that there was no added benefit of allotting gilts in the various social groups used in this experiment beyond the effects resulting from mixing to provide unfamiliar penmates and providing boar exposure.

Regularity of Estrus Cycles

A high percentage of gilts showing regular estrous cycles is desirable. For our study, puberty was considered as the first day of first observed standing estrus. Occurrence of succeeding estrous in the range 18 to 30 days, including duration of the previous estrous period, was considered normal. Data in Table 3 indicate that estrus cycles occurred within the expected time period for most gilts after puberty. Of the 119 gilts which reached puberty within the allotted 42 days, 98 and 92% expressed second and third estrus, respectively, within the allotted 30 days for each additional estrous period. Mean combined intervals for all social groups were 21.4 and 21.3 from first to second and second to third estrus period, respectively. These data indicate that the gilts which achieved pubertal estrus promptly continued to have high cyclic adequacy.

Seasonal Effect

Seasonal effects on age at puberty have been reported. In our experiment, seasonal effects are defined as season in which the gilts were allotted for estrus stimulation. Some reports relate season of birth to age at puberty [Robertson *et al*., 1951;

Marvogenis and Robison, 1976], whereas others use time of year when the gilt is approaching sexual maturity as seasonal effect [Bane et al., 1976; Christenson and Ford, 1979; Christenson, 1981]. Marvogenis and Robison [1976] reported that gilts born in the fall and thus reaching puberty during winter and early spring reached puberty at a younger age than gilts born in the spring and thus reaching puberty during summer and early fall.

Figure 2 shows seasonal effects on percentage expressing puberty and days to puberty in this experiment. Gilts exposed for estrus stimulation during the fall had a nonsignificantly higher percentage expression of puberty than those exposed during spring and summer; percentages were 73, 62 and 63, respectively. Days to puberty were not significantly affected by season of exposure ($P > .05$). Temperature during the seasons involved in the locale of this experiment are generally mild and not subject to frequent or prolonged occurrence of high temperature-high humidity combinations.

Comparison of Pubertal and Non-pubertal Gilts

Data contained in Table 4 indicate that age at initiation did not differ significantly between gilts which did or did not express puberty; ages were 183 vs. 185 days, respectively. Weight on test was 80 vs. 818 kg for the two groups, respectively. The average weight of 80 kg and average age of 183 days for gilts in our study have previously been shown at this station to result in normal levels of pubertal response within 42 days [Schiemann, 1976; Knott, 1980]. These differences in weight were significant ($P < .05$). It is difficult, however, to impute any biological significance to this small difference in weight. Within the population of 119 gilts which reached puberty, weight was not significantly associated ($r = .01$) with days to puberty ($P > .05$). Knott [1980] reported no effect of age on either percentage of gilts reaching puberty or in days to puberty for gilts varying in weight from 70 to 114 kg.

The percentage of gilts expressing puberty in this study is consistent with reports by Rampacek and Kraeling [1978], Christenson and Young [1978], Christenson and Ford [1979], and Christenson [1981]. Results reported here were lower for percentage occurrence of puberty than those reported by George and England [1974] in which 85% of the gilts exhibited pubertal estrus. Difference in percentage expressing puberty with a specified time period in total confinement may be due to age difference at exposure for estrus stimulation. Reports in the literature can be found for experimental allotment for estrus stimulation at ages ranging from 103 to 215 days. Maximum allowed time for expression of puberty varies among reports. Cunningham et al. [1974], George and England [1974], and Christenson [1981] reported maximum allowable times of 105, 42 and 270 days, respectively. Increased percentages of occurrence of puberty would be expected to occur with somewhat larger time periods than in the 42 days allowed in the present experiment.

CHAPTER 3

THE INFLUENCES OF HEREDITY ON PERCENTAGE OCCURRENCE OF PUBERTY AND DAYS TO PUBERTY FOR GILTS IN CONFINEMENT[1]

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SUMMARY

Four hundred and thirty-eight Yorkshire gilts reared and maintained in total confinement were used in this study to determine influence of heredity on occurrence of puberty and on days from commencing of the experiment to puberty. Hereditary effects due to line-of-sire and to maternal effects, and heritability estimates were determined. The experiment commenced by transferring gilts from rearing groups in the growing unit to pens in the nearby brood stock unit. All gilts were observed daily for behavioral indications of puberty. In addition, they were exposed daily to one or more Yorkshire boars in a breeding pen.

Effect of line-of-sire was significant at $P < .10$ for percentage exhibiting puberty. Differences among lines for days to puberty were not significant. Line x year interaction for percentage occurrence of puberty and days to puberty were nonsignificant ($P > .05$ and $P > .05$, respectively). Maternal contributions to the variance components in the analyses of variance were 18.6% and 23% larger than the sire components for percentage occurrence of puberty and for days to puberty, respectively. Paternal half-sib estimate of heritability was $.05 \pm .11$ for occurrence of puberty and was $-.11 \pm .10$ for days to puberty. Estimates based on maternal half-sib analysis were $1.06 \pm .22$ and $1.18 \pm .36$ for percentage occurrence of puberty and days to puberty.

Based on these findings there appears to be a basis for these two traits through selection based on differences in performance among sires and among litters. There is indication that ability to achieve occurrence of puberty and the number of days required to reach puberty within a given time are relatively independent of each other.

INTRODUCTION

Gilts normally reach puberty between 5 and 8 months of age. Cross-bred gilts generally express first estrus earlier than the average of their parental breeds and thus exhibit heterosis for this trait. Breed differences in mean age at puberty exist. Ramirez [1973] stated that the occurrence of puberty is genetically determined for each breed, but that the normal rate of maturation can be altered by the environment. Breed and crossbreeding effects on age at puberty in pigs have been reported [Phillips and Zellar, 1943; Self *et al*., 1955; Christenson, 1981; Rampacek and Kraeling, 1978; Hutchens *et al*., 1982]. Foote *et al*. [1956], studying Chester White, Yorkshire, and Chester White x Yorkshire gilts, reported that the average days of age at puberty were significantly lower for linecross gilts when compared to inbred gilts (194 vs. 228 days, respectively).

Maternal effects influence reproductive performance of gilts. Evidence for maternal environmental effects on first parity litter size of daughters in swine, consisting of size of nursing group, has been reported [Ahlschwede and Robison, 1971; Revelle and Robison, 1973; Nelson and Robison, 1976; Toelle and Robison, 1982]. It is not known if such influences also have an effect on attainment of puberty by gilts.

Reports were not found in the literature on the role of heredity, within a breed population, as a cause variation in percentage of gilts reaching puberty in a given time period or by a given age. The genetic base of percentage expressing estrus warrants attention because failure of prompt attainment of puberty is presently a widely prevalent problem in the swine industry. Increased knowledge of hereditary influences is needed in order to improve selection precision for high performance for timely occurrence of puberty.

The objectives of this study were to determine hereditary influences on percentages of gilts attaining puberty as shown in (1) differences due to line-of-sire, (2) maternal effects, and (3) heritability estimates for this trait. Similar determinations of hereditary influences were made for days from initiation of a puberty-stimulating regimen to occurrence of pubertal estrus.

EXPERIMENTAL PROCEDURE

During a two-year period, 438 prepubertal Yorkshire gilts were used to determine influences of heredity on percentage reaching puberty during a 42-day test period and number of days to puberty after beginning of the test period. The gilts were sired by boars of three Yorkshire sire-lines maintained without recent common pedigree ancestry. A total of 19 different sires were used during the two years combined. Eleven sires were used during year 1; 7 of these plus 8 additional sires were used during year 2. The experimental design for number of sires, dams and progeny by line within years are contained in Table 5. Dams of the gilts were mated to boars of the line least related to them in a three-line within-breed rotational cross.

From initial weights of about 27 kg to weights ranging from 73 to 95 kg, gilts were reared in confinement groups of about 10 per pen in a grower unit which is separate from the brood stock unit. Gilts were moved from the growing unit to the breeding herd unit at weights ranging from 73 to 95 kg. Prior to movement, each gilt was observed at least once weekly; none was seen to be in estrus. At movement of gilts to the breeding herd unit they were regrouped 8 to 12 per pen in groups consisting of familiar and unfamiliar penmates.

While on experiment gilts were fed 2.3 to 3.2 kg per day of a 14% crude protein finisher ration (see Table 1 in Chapter 2). Boars were housed in the same building as the gilts but were not visible or in direct contact except during daily heat check. Each gilt was observed daily for signs of approaching estrus and all gilts were exposed daily in a breeding pen to one or more boars. Exposure of gilts in this manner continued for 42 days unless standing estrus occurred sooner. Gilts which did not come in heat within 42 days were removed from the experiment; gilts which expressed first estrus were kept for another 30 days with daily check for occurrence of second estrus; those which exhibited second estrus were kept for an additional 30 days for occurrence of third estrus. Dates of each estrus were recorded for each gilt. Days to puberty are defined in this study as the number of days from initiation of the experimental period to first estrus.

Statistical analyses for percentage occurrence of and days to puberty were by least squares procedures for data with unequal subclass numbers [Harvey, 1977]. The sum of squared deviations of the observations around their expected values were used to minimize the sum of squared deviations to obtain the least squares estimator. The following model was used to determine paternal and maternal half-sib estimates of heritability:

$$Y_{ijklm} = U + A_i + B_{ij} + C_{ijk} + (AF)_{ie} + F_e + E_{ijklm}$$

where: U is the overall mean.

A_i is the fixed effect for line-of-sire (i = 1, 2, 3).

B_{ij} is the random nested effect of the j^{th} sire in the i^{th} line.

C_{ijk} is the random nested effect of the k^{th} dam within the j^{th} sire and i^{th} line.

F_e is the fixed effect of the e^{th} year (e = 1, 2).

$(AF)_{ie}$ is the line by year interaction.

E_{ijklm} is the random error.

RESULTS AND DISCUSSION

Influence of Line-of-Sire

Line-of-sire influence on percentage occurrence of puberty was not significant at $P > .05$ but was at $P < .10$ (Table 6) for the two years combined. Within year 1, percentages were significantly different ($P < .05$) among the three lines (Table 6 and Figure 3). Line x year interaction was not significant ($P > .05$). Significant year differences in percentage attaining puberty (Table 7) are attributed to the relatively larger variation among sire lines in year 1; 94, 22 and 68% for the three lines, respectively. Reasons for large differences between years are unclear; designed experimental and routine management procedures were the same and genetic bases of the herd were not augmented or designedly reduced. Least squares means for the percentages reaching puberty during the two years were 58, 47 and 41 for lines 1, 2 and 3, respectively ($P < .10$).

Line differences in percentage of gilts reaching puberty were significant at $P < .10$ but not at $P < .05$. These results suggest that line differences may be important, especially during conditions which are conducive to reasonable percentages of occurrence of puberty such as occurred in year 1. It may be concluded that line-of-sire within breed, as well as reported differences among breeds, can have an influence on the percentages of gilts expressing puberty. It appears that the variation in occurrence of puberty is partially genetically determined among breeds and within breed.

Differences in days to puberty among sire lines were not significant ($P > .05$). A line x year interaction ($P < .02$) was found for days to puberty (Tables 8 and 9). Figure 4 is a graphic display of days to puberty, expressed as deviations from the overall population mean, for each line-of-sire during each of the two years. Mean days to puberty are very similar and not significantly different ($P > .05$). It is interesting to note this similarity in days to puberty in the two years in contrast to the differences in percentages reaching puberty in the 2 years. This relationship suggests that variations in the 2 traits are not due largely to the same causes.

Influence Due to Dams

Effects due to dams were significant ($P < .01$) for percentage of daughters reaching puberty and for days to puberty (Tables 6 and 8). Variance and covariance components for percentage exhibiting first puberty are shown in Table 10. The dam (σ^2_d) component of the variance is approximately 14% more than the sire component (σ^2_s). These differences in magnitude of sire and dam components indicate that percentage of gilts expressing puberty is influenced markedly more by maternal effects than by parental heredity. Several factors may contribute to this difference. It may be due in part to the prenatal and/or postnatal environment provided by the dam. Robison [1972] stated that the cause can possibly be due to the cytoplasm of the egg. Rio [1957] reported results from cross-fostering between Yorkshires and Hampshires in which ovulation rate differences between gilts of the same breed reared by the two different purebred dams were small and nonsignificant. However, there was a larger and significant difference (2.06) between first-generation reciprocal cross-gilts (Yorkshire-Hampshire and Hampshire-Yorkshire) nursing their respective dams. The Yorkshire-sired crossbred gilts farrowed and nursed by Hampshire dams were the superior cross for ovulation. These data indicate a large prenatal effect of breed of dam but no distinct postnatal effect of dam on ovulation. Squires, Dickerson and Mayer [1952] also reported a significant difference between reciprocal crosses for ovulation rate.

Days to puberty in this report showed a similar trend for maternal effects (Table 11). The proportion of the total variance due to maternal effects was 23 times as large as the sire component. Thus for both traits, maternal effects contributed more to the variation than did paternal effects. Robison [1972] indicated that behavior of the dam and/or an individual's penmates and study of biological effect of different management systems may be important in assessing maternal effects.

Heritability Estimates

Reports were not found in the literature of heritability for percentage of gilts which reach puberty or for days from allotment to puberty. Additional knowledge of heritability estimates in the 2 traits is needed to increase precision of selection for the occurrence of puberty.

Data contained in Table 12 show the heritability estimate for percentage occurrence of puberty and days to puberty. Paternal half-sib estimates for percentage occurrence of puberty was .05 ± .11 and was -.11 ± .10 for days to puberty; both are nonsignificant. Maternal half-sib (MHS) are used less frequently than paternal half-sibs (PHS) to estimate heritability. The main problem of using maternal half-sibs is that it overestimates heritability due to any permanent non-genetic influence of the dams. The MHS share a prenatal and postnatal environment which can contribute to resemblance among sibs that is not shared by paternal half-sibs. MHS estimates of h^2 were 1.06 ± .22 and 1.19 ± .36 for percentage occurrence of puberty and days to puberty, respectively. A definitive reason for the MHS estimate of h^2 being greater than 1 is unclear. The magnitude of estimate of h^2 by use of MHS analysis should be higher than PHS if prenatal and/or postnatal maternal influences have an effect on occurrence of puberty.

TABLE 1. COMPOSITION OF DIET FED TO GILTS DURING EXPERIMENT ON ATTAINMENT OF PUBERTY[1]

Ingredient	International Ref. No.	Percent
Wheat or Barley	4-05-247 or 1-00-515	68.50
Soybean Oil Meal	5-04-612	13.50
Suncured Alfalfa	1-00-078	15.00
Dicalcium Phosphate	6-01-080	1.50
Limestone	6-02-632	<.01
Trace Mineral Salt		<.01
Zinc Sulphate		340 g
Shamrock Vitamin Mix		<.01

[1] Each diet was supplemented with 2.5 g of vitamin-mineral premix/kg. Composition of the premix per kilogram was: 1,320,000 IU vitamin A, 440,000 IU vitamin D_3, 440 IU vitamin E, 880 mg vitamin K, 4.4 mg vitamin B_{12}, 1,760 mg riboflavin, 3,238 mg pantothenic acid, 8.8 g niacin, 110 g choline chloride, 25 g Mn, 40 g Zn, 8 g Fe, .8 g Cu, 118 mg I, 80 mg Co, 39.6 mg Se.

TABLE 2. PERCENTAGE ATTAINMENT OF PUBERTY AND DAYS TO PUBERTY BY GILTS ALLOTTED IN VARIOUS SOCIAL GROUPS

Group	Number of gilts	% reaching puberty[5]	Days to puberty[5]
RT-ET[1]	48	$56^{a} \pm .073$[6]	$26.4^{a} \pm 1.93$
RT-ES[2]	48	$63^{a} \pm .071$	$24.6^{a} \pm 1.47$
RS-ET[3]	44	$73^{a} \pm .069$	$25.6^{a} \pm 1.96$
RS-ES[4]	46	$67^{a} \pm .070$	$25.3^{a} \pm 1.55$

[1]Denotes pairs of gilts reared together-exposed together.

[2]Denotes pairs of gilts reared together-exposed separately.

[3]Denotes pairs of gilts reared separately-exposed together.

[4]Denotes pairs of gilts reared separately-exposed separately.

[5]Unless data in columns contain different superscripts, differences are not significant at $P < .05$.

[6]Data presented in this fashion refer to means and standard errors.

TABLE 3. LENGTH OF ESTRUS CYCLES AND PROPORTIONS CYCLING FOR GILTS IN VARIOUS SOCIAL GROUPINGS

Social group	First to Second Estrus			Second to Third Estrus		
	Sample size	Proportion cycled (%)	Cycle Length (days)[5]	Sample size	Proportion cycled (%)	Cycle length (days)[5]
RT-ET[1]	27	100	21.6[a] ± .88[6]	26	97	20.0[a] ± .89[6]
RT-ES	29	97	21.4[a] ± .64	24	83	22.5[a] ± .82
RS-ET	30	97	22.1[a] ± .65	29	97	22.9[a] ± .78
RS-ES	31	100	20.5[a] ± .58	29	94	19.6[a] ± .49

[1]Denotes pairs of gilts reared together-exposed together.

[2]Denotes pairs of gilts reared together-exposed separately.

[3]Denotes pairs of gilts reared separately-exposed together.

[4]Denotes pairs of gilts reared separately-exposed separately.

[5]Unless data in columns contain different superscripts, differences are not significant at $P < .05$.

[6]Data presented in this fashion refer to means and standard errors.

TABLE 4. ON-TEST WEIGHT AND AGE OF SUBSEQUENTLY PUBERTAL OR NON-PUBERTAL GILTS

Traits	Pubertal	Non-perbutal
Weight on test	$80.0^{1} \pm 0.49$	$81.8^{2} \pm 0.81$
Age on test	182.5 ± 1.70	185.3 ± 2.47

[1,2]Significantly different at $P < .05$.

TABLE 5. NUMBER OF SIRES, DAMS, AND PROGENY WITHIN LINES BY YEARS USED IN A STUDY OF GENETIC EFFECTS ON PUBERTY IN GILTS

	Years					
	1			2		
Line	Number of sires	Number of dams	Number of progeny	Number of sires[1]	Number of dams	Number of progeny
1	5	34	79	5	28	66
2	3	23	50	4	35	88
3	3	18	43	6	42	112

[1]Seven of these were sires also used in year 1.

TABLE 6. ANALYSIS OF VARIANCE FOR PERCENTAGE OCCURRENCE OF PUBERTY AMONG GROUPS OF GILTS

Source	D.F.	Mean squares	P value
Line	2	.959	.10
Sire/line	17	.364	.26
Dam	133	.299	<.01
Year	1	3.321	<.01
LXY	2	.307	.17
Error	282	.172	

TABLE 7. LEAST SQUARES MEANS BY SIRE LINE WITHIN YEARS FOR PERCENTAGE OF GILTS ATTAINING PUBERTY

Line effects	Year 1	Year 2	Overall
1	.94[a] ± .18	.22[c] ± .19	.58[a] ± .05
2	.60[b] ± .11	.35[cd] ± .09	.47[a] ± .06
3	.68[b] ± .12	.14[ce] ± .10	.41[a] ± .06
Overall average	.74 ± .07	.24 ± .06	.49 ± .03

[a,b,c,d,e]Within years and overall, means having different superscripts are significant ($P < .05$).

[a,b,c,d,e]Between years values having different superscripts are significant ($P < .05$).

TABLE 8. ANALYSIS OF VARIANCE FOR DAYS TO ESTRUS OF PREPUBERTAL GILTS

Source	D.F.	Mean squares	P value
Line	2	175.7	.18
Sire/line	12	96.1	.61
Dam	69	117.9	.01
Year	1	11.7	.69
LXY	2	304.0	.02
Error	107	71.5	

TABLE 9. LEAST SQUARES MEANS BY SIRE LINE WITHIN YEARS FOR DAYS TO PUBERTY

Line effects	Year 1	Year 2	Overall
1	24.2[a] ± 1.84	26.6[a] ± 2.40	25.6[a] ± 1.14
2	24.3[a] ± 2.31	33.0[b] ± 2.30	28.7[a] ± 1.59
3	30.0[b] ± 3.30	21.6[c] ± 3.20	25.8[a] ± 1.53
Overall average	26.2 ± 1.40	27.1 ± 1.43	26.7 ± .87

[a,b,c,d,e]Within years and overall, means having different superscripts are significant ($P < .05$).

[a,b,c,d,e]Between years values having different superscripts are significant ($P < .05$).

TABLE 10. COMPONENTS OF THE TOTAL VARIANCE AND COVARIANCE FOR PERCENTAGE OCCURRENCE OF PUBERTY BY GILTS

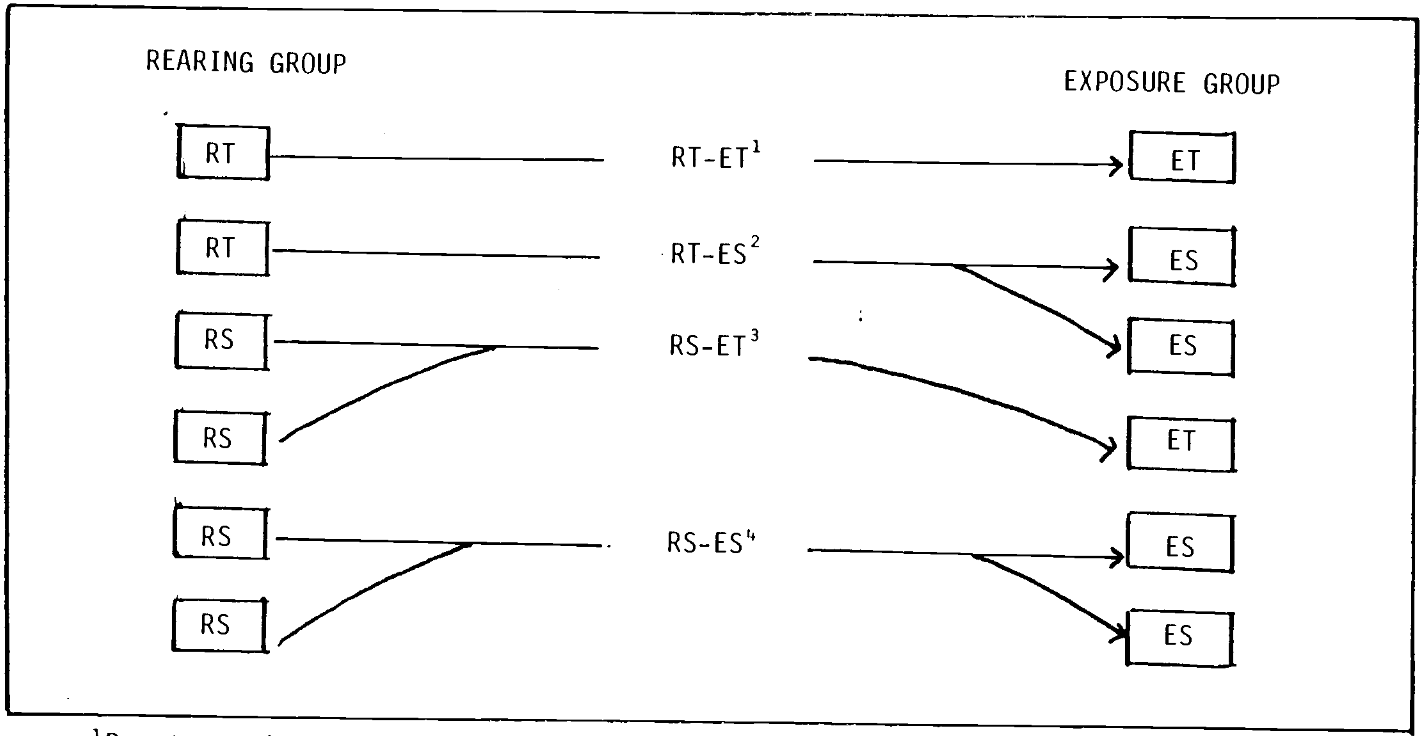
Source	Variance components	Covariance components	% of the total variance
Sires = σ_S^2	σ_S^2 = .003	COV (HS)	1.4
Dams = σ_D^2	$\sigma_{D/S}^2$ = .044	COV (FS)-COV (HS)	20.0
Within full-sibs = σ_u^2	σ_E^2 = .173	σ_T^2 - COV (FS)	78.6
Total = σ_F^2	σ_T^2 = .22		

TABLE 11. COMPONENTS OF TOTAL VARIANCE AND COVARIANCE FOR DAYS TO PUBERTY

Source	Variance components	Covariance components	% of the total variance
Sires = σ^2_S	σ^2_S = -2.37	COV (HS)	0
Dams = σ^2_D	$\sigma^2_{D/S}$ = 21.1	COV (FS)-COV (HS)	23.0
Within full-sibs = σ^2_u	σ^2_E = 71.5	$\frac{2}{T}$ - COV (FS)	77.0
Total = σ^2_P	σ^2_T = 90.2		

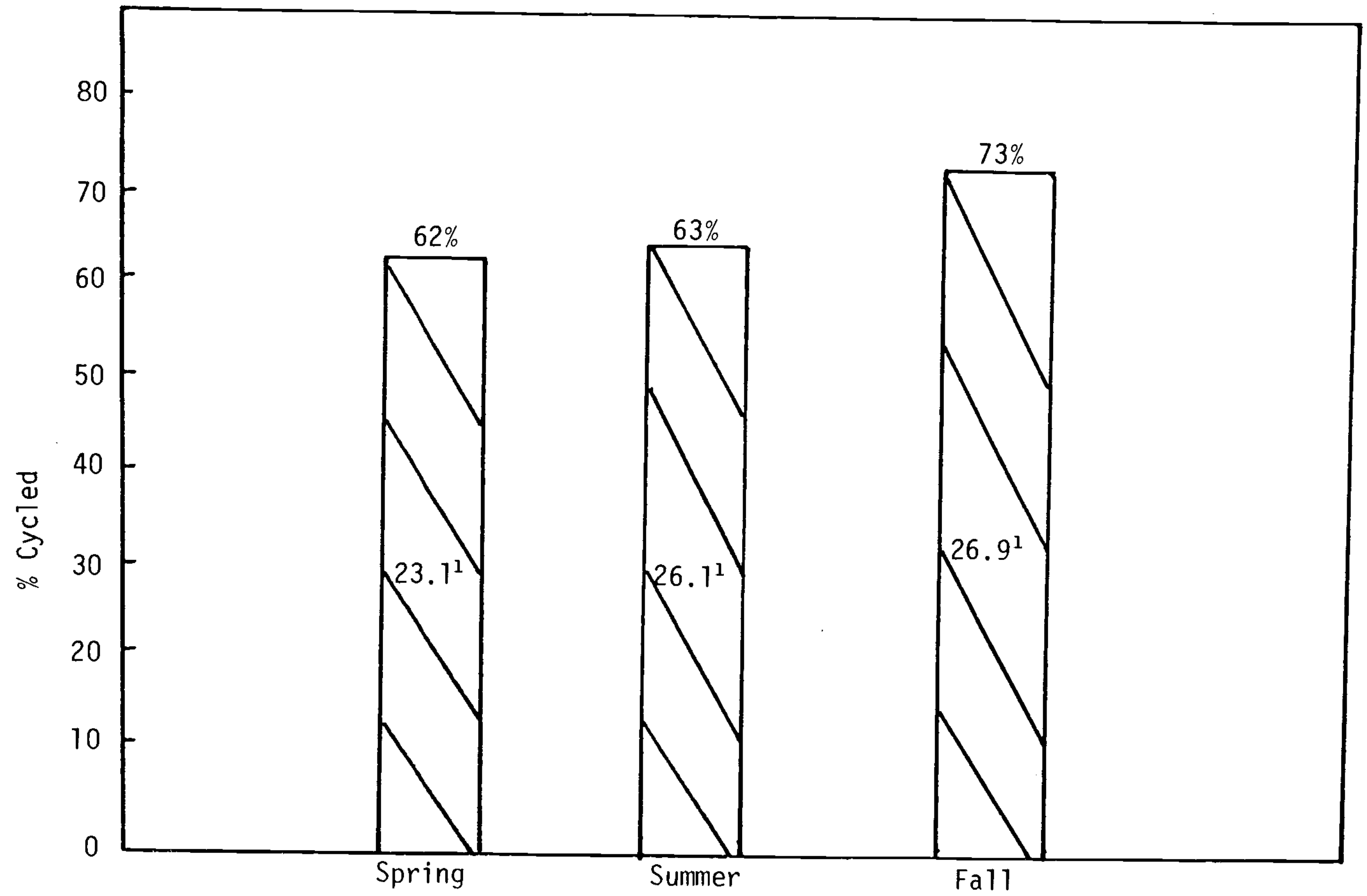
TABLE 12. HERITABILITY ESTIMATES FOR PERCENTAGE OCCURRENCE OF PUBERTY AND DAYS TO PUBERTY FOR GILTS

Traits	PHS	MHS	FS
% cycled	.05 ± .11	1.06 ± .22	.50 ± .11
Days to puberty	-.11 ± .10	1.18 ± .36	.52 ± .18



[1]Denotes pairs of gilts reared together and exposed together.
[2]Denotes pairs of gilts reared together and exposed separately.
[3]Denotes pairs of gilts reared separately and exposed together.
[4]Denotes pairs of gilts reared separately and exposed separately.

FIGURE 1. Schematic diagram of social groupings for pairs of gilts during rearing and exposure for occurrence of puberty



[1]Denotes mean days to puberty.

FIGURE 2. Seasonal effects on percentage occurrence of puberty and days to puberty for Yorkshire pre-pubertal gilts

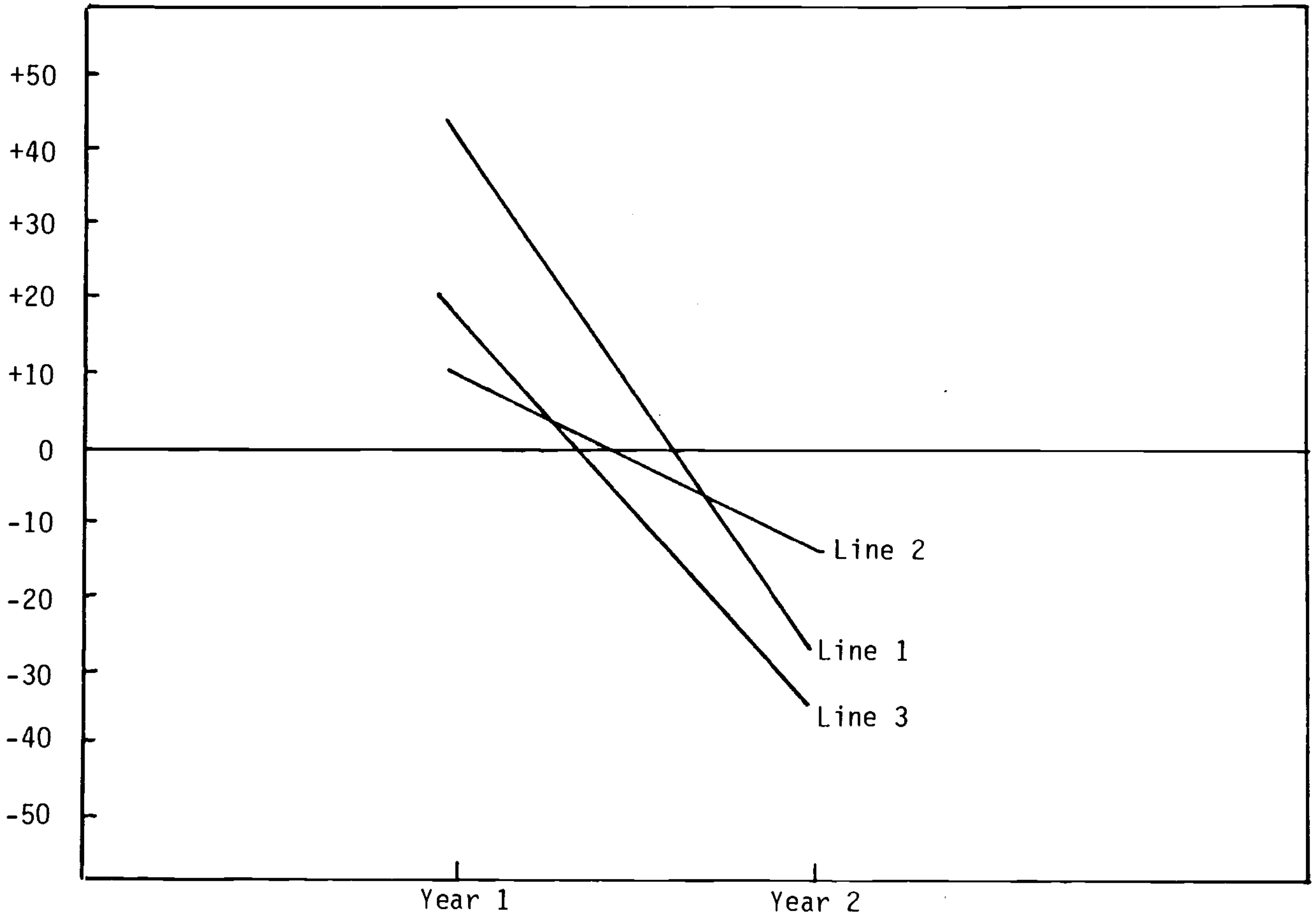


FIGURE 3. Mean percentage for attainment of puberty for sire line groups expressed as deviations from the population mean

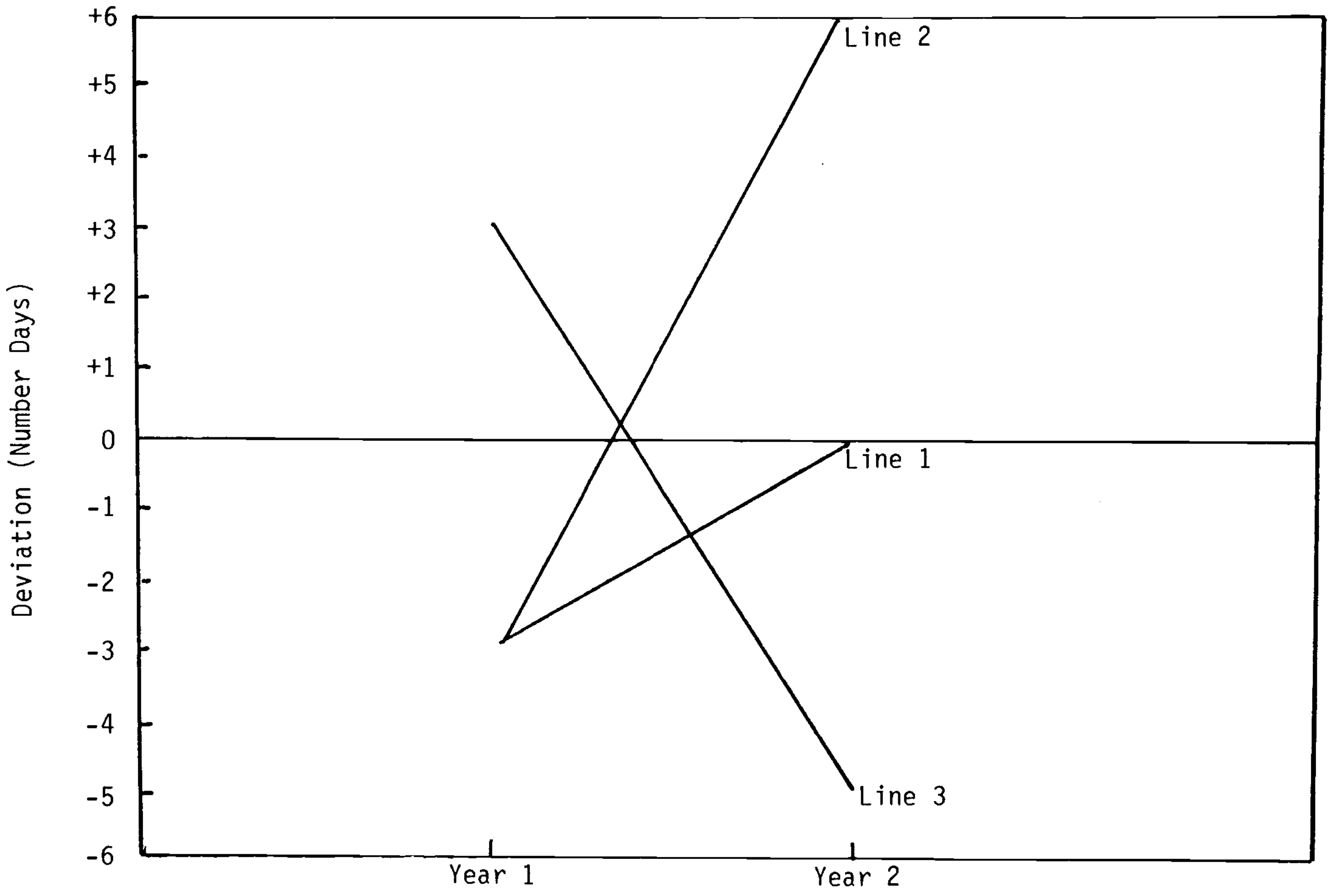


FIGURE 4. Mean days to puberty by sire line groups expressed as deviations from the population average

BIBLIOGRAPHY

Aherne, F. X., R. J. Christopherson, J. R. Thompson and T. T. Hardin. 1976. Factors affecting the onset of puberty, post-weaning oestrus and blood hormone levels of Lacombe gilts. Can. J. Anim. Sci. 56:681.

Ahlschwede, W. T. and O. W. Robison. 1971. Prenatal and post-natal influences on growth and backfat in swine. J. Anim. Sci. 32:10.

Bane, A., S. Einarsson and K. Larsson. 1976. Effect of season on age at puberty in crossbred gilts in Sweden. VIII. International Cong. on Anim. Reprod. and Artif. Insem. 3:117 (abst.).

Brooks, P. D. and D. J. A. Cole. 1970. The effect of the presence of a boar on the attainment of puberty in gilts. J. Reprod. Fertil. 23:435.

Christenson, R. K. 1981. Influence of confinement and season of the year on puberty and estrus activity of gilts. J. Anim. Sci. 52:821.

Christenson, R. K. and L. D. Young. 1978. Age at first estrus in five breeds of gilts reared in confinement. J. Anim. Sci. 47 (Suppl. 1):351.

Cunningham, P. J., C. H. Nabes, D. R. Zimmerman and E. R. Peo. 1974. Influence of nutritional regimen on age at puberty in gilts. J. Anim. Sci. 39:63.

Foote, W. C., D. P. Waldorf, A. B. Chapman, H. L. Self, R. H. Grummer and L. E. Casida. 1956. Age at puberty of gilts produced by different systems of matings. J. Anim. Sci. 15:959.

Ford, J. J. and H. S. Teague. 1978. Effects of floor space restriction on age at puberty in gilts and on performance of barrows and gilts. J. Anim. Sci. 47:828.

George, P. B. and D. C. England. 1974. Estrus and early pregnancy of gilts in confinement. Proc. West. Sect. Amer. Soc. Anim. Sci. 25:71.

Harvey, W. R. 1977. User's guide for LSML 76, mixed model least squares and maximum likelihood computer program. Ohio State University, Columbus (mimeo).

Hutchens, L. K., R. L. Hintz and R. K. Johnson. 1982. Breed comparisons for age and weight at puberty in gilts. J. Anim. Sci. 55:60.

Knott, R. E. 1980. Cycling and reproductive phenomena in gilts of three weight groups. M.S. Thesis, Oregon State Univ., Dept. of Anim. Sci., Corvallis.

Marvogenis, A. P. and O. W. Robison. 1976. Factors affecting puberty in swine. J. Anim. Sci. 42:1251.

Nelson, R. E. and O. W. Robison. 1976. Effects of postnatal - maternal environment on reproduction of gilts. J. Anim. Sci. 43:71.

Nie, N. H., C. H. Hull, J. G. Jenkins, K. Steinbrenner and D. H. Bent. 1975. SPSS - Statistical Package for the Social Sciences, 2nd edition, McGraw-Hill, Inc., New York, N.Y.

Phillips, R. W. and J. H. Zeldor. 1943. Sexual development in small and large types of swine. Anat. Rec. 85:387.

Ramirez, V. D. 1973. Endocrinology of puberty. Handbook of Physiology. Endocrinology 2:1.

Rampacek, G. B. and R. R. Kraeling. 1978. Delayed puberty in gilts in a total confinement system. J. Anim. Sci. 47 (Suppl. 1):384.

Rentzel, L. F. and L. J. Sumption. 1968. Genetic and phenotypic relationships involving age at puberty and growth rate in gilts. J. Anim. Sci. 27:27.

Revelle, T. J. and O. W. Robison. 1973. An explanation for the low heritability of litter size in swine. J. Anim. Sci. 37: 668.

Rio, P. R. 1957. Genetic interpretation of heterosis and maternal effects in reproduction and growth of swine. Unpublished Ph.D. thesis, University of Illinois, Urbana.

Robertson, G. L., L. E. Casida, R. H. Grummer and A. B. Chapman. 1951. Age at puberty and related phenomena in outbred Chester White and Poland China gilts. J. Anim. Sci. 10:647.

Robison, O. W. 1972. The role of maternal effects in animal breeding: V. Maternal effects in swine. J. Anim. Sci. 35: 1303.

Schiemann, C. A., D. C. England and W. H. Kennick. 1976. Initiating estrus in pre-pubertal confinement gilts. J. Anim. Sci. 43:210 (abst.).

Self, H. L., R. H. Grummer and L. E. Casida. 1955. The effects of various sequences of full and limited feeding on the reproductive phenomena in Chester White and Poland China gilts. J. Anim. Sci. 14:573.

Snedecor, G. W. and W. G. Cochran. 1969. Statistical Methods. The Iowa State Univ. Press, Ames, Iowa.

Squires, 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. Agric. Exp. Sta. Bull. 494.

Toelle, V. D. and O. W. Robison. 1982. Breed prenatal, breed postnatal and heterosis effects for preweaning traits in swine. J. Anim. Sci. 55:263.

Zimmerman, D. R., R. Carlson and B. Lantz. 1974. The influence of exposure to the boar and movement on pubertal development in the gilt. J. Anim. Sci. 39:230 (abst.).

APPENDIX

INFLUENCE OF PERCENTAGE COMMON PENMATES (PRIOR TO AND DURING EXPOSURE FOR PUBERTY) ON THE OCCURRENCE AND DAYS TO PUBERTY

Percentage common penmate	Number of gilts	% reaching puberty[1]	Days to puberty[1]
6.0 - 17.0	56	59 ± .07[a]	27.2 ± 1.92[a]
17.1 - 28.0	62	61 ± .06[a]	26.4 ± 1.81[a]
28.1 - 39.0	48	69 ± .07[a]	25.7 ± 2.16[a]
39.1 - 50.0	20	75 ± .10[a]	26.9 ± 3.13[a]

[1]Traits with different superscripts are significant at ($P < .05$).

RESPONSE MEASURED AS MEAN DAYS BY PAIRS OF LITTERMATE AND NON-LITTERMATE GILTS TO OPPORTUNITY TO ATTAIN PUBERTY DURING A 42-DAY TEST PERIOD IN CONFINEMENT

Group	Number of gilts	Days to puberty[1,2]
A. Littermates		
1. Reared together-exposed together	28	26.3[a]
2. Reared together-exposed separately	24	24.3[a]
3. Reared separately-exposed together	22	24.1[a]
4. Reared separately-exposed separately	24	24.7[a]
B. Non-littermates		
1. Reared together-exposed together	20	26.5[a]
2. Reared together-exposed separately	24	24.9[a]
3. Reared separately-exposed together	22	27.0[a]
4. Reared separately-exposed separately	22	25.8[a]

[1]From beginning of the experiment.

[2]Unless data in columns contain different superscipts, differences are not significant (P < .05).

PERCENTAGE OCCURRENCE OF PUBERTY RESPONSE, MEASURED AS PERCENTAGE OCCURRENCE OF PUBERTY BY LITTERMATE AND NON-LITTERMATE PAIRS OF GILTS, TO OPPORTUNITY TO ATTAIN PUBERTY DURING A 42-DAY TEST PERIOD IN CONFINEMENT

Group	Number of gilts	Total % reaching puberty	% both reaching puberty	% only one reaching puberty	% neither reaching puberty	% both responding puberty
A. Littermates						
1. Reared together-exposed together	28	54	43	21	36	79
2. Reared together-exposed separately	24	57	42	50	8	50
3. Reared separately-exposed together	22	73	64	9	27	91
4. Reared separately-exposed separately	24	79	67	25	8	75
AVERAGE LITTERMATE EFFECT		66[a,e]	54[a,e]	26[a,e,f]	20[a,e,f]	74[a,e]
B. Non-littermates						
1. Reared together-exposed together	20	55	30	50	20	50
2. Reared together-exposed separately	24	58	33	50	17	50
3. Reared separately-exposed together	22	73	55	36	9	64
4. Reared separately-exposed separately	22	55	18	73	9	27
AVERAGE NON-LITTERMATE EFFECT		60[a,e]	34[a,e,f]	52[a,e]	14[a,e,f]	48[a,e]

[1]From beginning of the experiment.

[a]Between average littermate and non-littermate, means having different superscripts are significant ($P < .05$).

[e,f]Within average littermate and non-littermate, means having different superscripts are significant ($P < .05$).

ANALYSIS OF VARIANCE TABLE FOR OBTAINING ESTIMATES OF PERCENTAGE OCCURRENCE OF PUBERTY BASED ON HERITABILITY ESTIMATE OF PATERNAL, MATERNAL AND FULL-SIB ESTIMATES

Source of variation	D.F.	SS	MS	EMS
Between sires	S-1	SS_S	MS_S	$\sigma_W^2 + K_1\sigma_D^2 + K_3\sigma_S^2$
Between dams, within sires	S(d-1)	SS_D	MS_D	$\sigma_W^2 + K_1\sigma_D^2$
Between progeny within dams	Sd(K-1)	SS_W	MS_W	σ_W^2

K_1 = Number of sires/line = 3.1.

K_2 = Number of dams/sire = 2.7.

K_3 = Number of dams/line = 17.1.

ANALYSIS OF VARIANCE TABLE FOR OBTAINING ESTIMATES OF DAYS TO PUBERTY BASED ON HERITABILITY ESTIMATES OF PATERNAL, MATERNAL AND FULL-SIB ESTIMATES OF HERITABILITY

Source of variation	D.F.	SS	MS	EMS
Between sires	S-1	SS_S	MS_S	$\sigma_W^2 + K_2\sigma_D^2 + K_3\sigma_3^2$
Between dams, within sires	S(d-1)	SS_D	MS_D	$\sigma_W^2 + K_1\sigma_D^2$
Between progeny within dams	Sd(K-1)	SS_W	MS_W	σ_W^2

K_1 = Number of sires/line = 2.4

K_2 = Number of dams/sire = 2.2

K_3 = Number of dams/line = 10.8

PERCENTAGE HEREDITY FROM EACH SIRE LINE GROUP IN SUCCESSIVE GENERATION OF PROGENY IN A THREE-SIRE-LINE ROTATIONAL PUREBRED BREEDING PROGRAM[1]

		% Heredity from each source			
Generation	Group	Original dams	Sire Group I	Sire Group II	Sire Group III
1	I	50.00	50.00		
2	II	25.00	25.00	50.00	
3	III	12.50	12.50	25.00	50.00
4	I	6.50	56.25	12.50	25.00
5	II	≃3.00	≃28.00	56.25	12.50
6	III	≃1.50	≃14.00	≃28.00	56.25

[1]Subsequent to establishment of the three sire groups, the mating pattern for herd use has been: Daughters of Sire Group 1 are mated to males of Sire Group II; daughters of Sire Group II are mated to males of Sire Group III; daughters of Sire Group III are mated to males of Sire Group I; the cycle is then repeated. Thus, at any time, the herd will be composed of offspring of all three sire-line-groups.

NUMBER OF GILTS PER YEAR AND PER SIRE EXPOSED FOR OCCURRENCE OF PUBERTY

Year	Sire	Number gilt exposed	Number cycled
1	I	4	4
	II	10	7
	III	12	10
	IV	36	29
	V	17	9
	VI	14	5
	VII	16	9
	VIII	20	15
	IX	8	4
	X	12	8
	XI	23	11
2	I	3	0
	II	31	18
	III	4	1
	IV	3	0
	V	17	3
	VI	16	6
	VII	5	2
	VIII	23	5
	IX	18	12
	X	49	16
	XI	14	2
	XII	25	16
	XIII	27	11
	XIX	26	8

NUMBER OF GILTS EXPOSED FOR OCCURRENCE OF PUBERTY EACH YEAR BY MONTHS

	Number exposed for estrus	
Year 1	186	
April		32
May		23
June		41
July		50
August		18
September		32
October		20
Year 2	251	
March		24
April		20
May		25
June		25
July		60
August		49
September		24
October		13
November		11

AVERAGE UTERINE TRACT WEIGHT AT SLAUGHTER FOR GILTS THAT DID NOT ATTAIN PUBERTY DURING A 42-DAY TEST PERIOD

Parameters	Sample size[1]	Sample size[2]	% estrus[3]	Uterine weight (g)
Silent estrus	39	25	31	96
Non-pubertal	88	74	--	337

[1]Total number slaughter that was not observed in estrus.

[2]Uterine weight obtained for only 99 gilts.

[3]Based upon total number slaughter.