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Title: Management Techniques For Induction and Synchronization of Estrus in Prepuberal Gilts in Confinement

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At weights of 81.5-90.5 kg, 187 prepuberal crossbred gilts were subjected to specific environmental stimuli, for up to 17 days, to determine which stimuli or combinations of various ones would initiate onset of estrus in prepuberal gilts. The stimuli used were: movement to new building, mixing or non-mixing of gilts, daily exercise, and various degrees of exposure to a boar. At the end of each trial, all gilts were slaughtered and their ovaries were examined. Presence of corpora lutea was used to verify the occurrence of estrus.

Gilts were raised to test weights away from the sow and boar herd. Moving gilts as a group of familiar penmates to another facility separate from the brood stock herd did not stimulate estrus or follicular growth. Mixing unfamiliar gilts together and moving them to the second facility did induce puberty in gilts that were at least 209 days of age at initiation of the trial.

All remaining gilts in this series of trials were moved from the grower facility to the brood stock facility on the initial day of each trial and were subjected to various degrees of exposure to a boar. Exposure for 17 days to a boar in a contiguous pen initiated estrus in 31% of 16 mixed gilts. Contiguous boar exposure plus 30

minutes of direct contact with another boar stimulated approximately equal percentages of gilts to attain puberty in a group of 23 exercised and a group of 24 non-exercised mixed gilts (70%). Without the 24 hr per day contiguous boar exposure, but with 30 minutes of daily direct boar contact, 78% of 23 exercised mixed gilts attained puberty compared to 46% of 24 non-exercised gilts ($P < .05$). No significant differences were found between 24 mixed and 24 non-mixed gilts (87% vs 79%) when each group was subjected to 24 hr per day direct contact with a different boar during each 24 hr period. A high degree of synchronization of estrus existed among gilts which mated while exposed to the boar: 71% of those gilts mating did so between day-4 and day-10; 90% of those gilts mating did so between day-4 and day-13.

Additional studies indicate exposing gilts at too young an age and to the same boar for extended periods will delay puberty as compared to the previous boar stimulation procedures. Also, moving mixed gilts to new locations separate from the brood stock herd and exercising for 30 minutes daily did not stimulate puberty.

For gilts of the same average initial age (181 days), ovulation and embryo survival rates were compared between stimulated gilts attaining puberty and mating in 17-or-fewer days (average 5 days) and of gilts attaining puberty in 18-or-more days from initial stimulus. Stimuli used were mixing, daily exercise, and five minutes daily boar exposure. The 30 gilts mating within 17 days had fewer corpora lutea (11.7 vs 13.4, $P < .05$) and fewer live embryos (8.8 vs 12.0, $P < .05$) than the nine other gilts at slaughter 30 days postmating. No stastically significant differences existed between embryo survival rates and percentage of gilts conceiving. Sixteen additional gilts, exposed to the same stimuli, experienced 2-4 estrous cycles before an elapse of 30 days occurred without returning to estrus. Fifty percent of these gilts were either infertile or had six or fewer live embryos at 30 days postmating.

Management Techniques For Induction and Synchronization of Estrus in Prepuberal Gilts in Confinement

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I. STATEMENT OF THE PROBLEM

Swine, in comparison to other farm animals, are highly prolific. With adequate management, sows will farrow litters with maximum numbers of pigs at 150-day intervals and will wean more than 90% of the pigs farrowed. Sows adapt well to a wide variety of specific management programs without losing the capability to nurse and wean as many as 14 pigs per litter. The upper limit for number of pigs nursed to weaning is determined by the number of functional teats, inasmuch as each pig nurses one teat and does not share that with other pigs. Pigs in excess of that number can be nursed by use of various other rearing methods.

By increasing litter size and/or frequency, production costs are not seriously increased. That is to say, sow feed costs are not increased during gestation, nor are housing needs greater because of increased prolificacy. Lactation feed intake, creep feed and veterinary costs do increase production costs when sow production is increased. However, the value of the extra pigs weaned should return to the producer more than these added production costs, even in a depressed market. Cost per pig produced can be decreased with increased frequency of farrowing and by increased number of pigs farrowed and weaned per litter. Profits to the producer and meat production for human food could therefore be increased by producing more pigs per sow per year.

Sow costs can also be reduced by decreasing the age at which gilts farrow their first litters. Reducing this time interval by only 42 days will substantially reduce the feed cost of not only the gilt joining the sow herd, but will also reduce the feed cost of non-breeding gilts by eliminating them from the sow herd sooner.

The prevailing practice in the swine industry has been to breed gilts at third estrus. It was popularly accepted that this practice resulted in more ova ovulated at breeding time than if mating occurred at first or second estrus. In turn, an increased number of ova results in more embryos and a larger number of pigs born. The third estrus in gilts usually occurs by or before eight months of age; average gestation length is 114 days. Thus, gilts will usually farrow by 12 months of age if bred at the third estrus. Such timing works very well for a system of farrowing twice a year or of breeding each female to farrow twice a year. A traditional system has been to farrow in the spring and again in the fall to take advantage of the weather favorable to piglet survival. Spring- or fall-born gilts can be bred to farrow their first litter during their respective birth season, and then be rebred, after weaning of the litter, for the next farrowing season six months later.

With confinement housing, however, there is little seasonal advantage to the time of farrowing insofar as weather effects on survival are concerned. Thus it is not necessary to breed gilts to farrow in their twelfth month to take advantage of seasonally mild weather. Spring and fall farrowing can thus be replaced by a year-round farrowing program. However, the practice of farrowing gilts at twelve months of age is still used in confinement production because of the established concept that larger litters will result when compared to farrowing gilts bred at an earlier age. This system is sound practice if the value of the increased number of pigs weaned offsets the additional expense of maintaining a gilt for the 42-or-more-day period between her first estrus and mating at third estrus (or eight months of age).

In many confinement programs, group farrowing is a desireable system. By farrowing a group of sows and gilts within a short time period, for example 72 hours, a herdsman can be scheduled to attend the animals at farrowing. Having a herdsman present at farrowing is desirable for several reasons:

1. To prevent chilling of newborn pigs by drying them and assisting the piglet to find heat.
2. To prevent suffocation of newborn pigs by removing birth material from their mouth and nostrils.
3. To assist weak pigs to nurse.
4. To provide supplemental milk to pigs if their dams do not have adequate milk.
5. To provide assistance and medication to dams having difficulties during or subsequent to farrowing.

In addition, by group farrowing, pigs from large litters (over 12) can be distributed among sows with smaller litters to improve the neonatal environment for all pigs (Page and England, 1975). However, distribution must be made within three days after the foster dam has farrowed as unused udder sections of foster dams will begin to dry up if not used. Also, with group farrowing pigs can be transferred to other sows if their own dam dies or has unsuitable milk production due to MMA or other causes.

Group farrowing also permits moving all the sows out of the farrowing house together. Pigs can subsequently be weaned in a large group, which in turn allows the marketing advantages of selling groups of feeder pigs of uniform size, or of having animals reach market weights in large enough numbers at the same time to favorable influence marketing costs. Replacement gilt selection is made more effective by having a large group of contemporary gilts from which to choose.

Moving the sow herd as a group from the farrowing and nursery facilities also allows opportunity for a complete cleaning and disinfecting of the farrowing facility; this is indeed a recommended disease prevention practice.

Healthy sows usually express estrus within four to seven days after weaning. This provides a reliable means of synchronizing breeding of the sows for a subsequent synchronized farrowing period. Because of the previously mentioned benefits of group farrowing, it would be highly advantageous to also synchronize the breeding of replacement gilts to coincide with the established breeding schedule of the sow herd.

Predicting the time or age of a gilt's first estrus is subject to much error. Age at estrus has been reported to range from 135 to 235 days (Hughes and Cole, 1975). Even when gilts begin to cycle normally (every 18 to 21 days) there is still a low probability of a high proportion of gilts having estrus to coincide with that of the sow herd unless initial estrus is synchronized by some means. Unless gilts are bred in the same time period as the sow herd, two previously mentioned benefits are lost:

1. Having an attendant available at farrowing time, or if one is available, the cost per pig is high because of the reduced number of dams attended per unit of time.
2. Opportunity to transfer pigs to a foster dam is reduced.

A third problem of economic consideration is management of pigs after weaning. (As previously mentioned, weaning dams together synchronizes their next estrus.) Gilts not farrowed in synchrony with the main sow group will have pigs that may be younger and smaller than the average pigs weaned in the group. These smaller pigs will require special attention to prevent death loss or impaired performance following weaning, and at sale time would be an odd lot of pigs that do not fit into a uniform size weight group.

If gilts farrowed earlier than the sow group, they would have to be maintained on the lactation ration for a longer period than normal so as to wean at a time that coincides with the other dams. This would increase feed costs, as lactating sows are fed as much as 4.5 kg more feed per day than gestating sows.

An additional benefit would be to maintain a desired number of pregnant sows to fully utilize the farrowing facilities. After weaning their litters, some sows are usually discarded for various reasons, and others fail to conceive at their first postweaning estrus. A pool of estrus-stimulated gilts could replace these sows to maintain the desired number of pregnant females.

II. PURPOSE OF THE STUDY

The objectives of this study are related to synchronizing the time of breeding of gilts housed in total confinement production systems. This study approached the objectives through the management aspect; that is, how can a manager manipulate the environment to initiate estrus in prepuberal gilts? The study was designed to investigate four aspects:

1. What components of the environment can influence the onset of estrus in prepuberal gilts?
2. How can a manager control these environmental influences?
3. Can a high degree of synchrony of estrus in a group of gilts be obtained by manipulation of the environmental components?
4. Are the average ovulations per gilts high enough to warrant breeding the gilts at first estrus?

The fourth objective was included because of results reported by Brooks and Cole (1973). In a study of two groups of gilts bred at either first or third estrus, no significant difference was found between number of pigs born or number of pigs weaned. The gilts bred at third estrus did farrow slightly more live pigs (8.71 vs 8.33), but because of a higher percentage of death loss prior to weaning, the gilts bred at third estrus weaned the same number of pigs as those bred at first estrus (7.43 vs 7.33).

Libal and Wahlstrom at South Dakota State University (1974) reported similar results for reproductive performance of gilts bred at first estrus. Gilts bred at 6.5 months of age farrowed an average of 8.6 pigs, while gilts bred at 8.5 months of age farrowed an average of 9.1 pigs; the difference was non-significant. Litters, at 21 days of age, were not significantly different, with averages of six and seven pigs respectively. What was significant about the Brooks and Cole study was that the gilts bred at third estrus consumed 174 kg of feed between their first estrus and their mating at third estrus. In 1975, at the initiation of this thesis study, the Oregon State University swine gestation ration cost 18¢/kg. At this price, the cost of the 174 kg of feed consumed by the gilts was $31.32. At the same time, weaner pigs were selling for $20.00 apiece on the existing depressed market.

Thus, the studies by Brooks and Cole (op. cit.) and by Libal and Wahlstrom (op. cit.) indicate that the gilts bred at third estrus do not have an advantage over gilts bred at first estrus in either the number of pigs born or weaned. If this is so, then swine producers are losing money by waiting until the third estrus to breed their gilts. The amount of loss fluctuates with relative prices of various components of production costs, but with equal performance, the added cost of using older gilts will be present.

III. REVIEW OF LITERATURE

A. Using Corpora Lutea For Determining Ovulation Rate

The number of ova shed is usually determined by counting the number of corpora lutea (CL) on the ovaries at slaughter or by laporotomy. Perry and Rowland (1962) reported this to be an accurate estimate for the number of ova shed. Longenecker *et al*. (1968) marked the CL of 30 gilts with India ink three days after the onset of estrus. The gilts were slaughtered at 40 days of pregnancy. Three hundred thirty-nine CL were found of which 331 were marked. The eight unmarked CL represented 2.3% of the total. Thus, Longenecker concluded that counting CL was an accurate method for determining ovulation rate.

However, Reitmeyer and Sorenson (1965) disagree with the above reports. In a study of six bred gilts, 16 unmarked CL were found at 40 days of gestation that were not originally found and marked with India ink at three days postbreeding. These unmarked CL represent an increase of 22.2%. They concluded that in light of this experiment, counting the number of CL to determine embryo survival rate to be inaccurate, and if the number of accessory CL were taken into effect, the survival of embryos increases from about 65% to about 85%.

B. Nutrition -- Flushing

Kirkpatrick *et al*. (1967) increased the energy level of a basal ration (fed at 22% of body weight daily) using glucose or corn oil at 1.72% and 0.69% of body weight. These gilts had a greater ovulation rate than the control gilts fed a basal ration (13.2 vs 11.7 CL, $P<.05$).

Zimmerman et al. (1960) reported that flushing gilts for two weeks prior to breeding significantly increases number of ova shed. Glucose added to the ration at 1.0% of body weight increased ovulation by 2.1 ova in one trial and 0.8 ovum in a second. Adding lard to the ration to increase caloric intake to 150% of the level provided by the glucose ration increased ova shed by 4.1 above the controls, and 2.0 above the glucose ration.

McGillivray et al. (1963) added four pounds of glucose to four pounds of a control ration fed daily to gilts, beginning at day-10 of the estrous cycle and terminated at breeding. The flushed gilts had one more ovum than the controls, with no difference in percent of embryo survival at 25 days postmating.

Bazer et al. (1968b) beginning at 45 kg of body weight fed 190 gilts either 1.81 or 2.72 kg of feed per day for six days each week. Approximately 14 days prior to mating, one-half of each group were flushed by full-feeding until mating and then returned to their previous dietary level. Flushing increased the ovulation rates in the limited-fed gilts ($P<.05$), but all flushed gilts had a higher embryonic death loss ($P<.01$). Flushing increased the ovulation rate in the full-fed gilts in only two of the four trials conducted ($P<.05$). The flushed gilts averaged slightly more embryos in each trial at 40 days than did the non-flushed gilts, but the difference was not significant.

Brooks and Cole (1970a) fed gilts 4 lbs of feed/day until the second estrus, at which time they were serviced by the boar. Immediately following the first service, gilts were given, once, an additional 4 lbs of feed. Following weaning of the litter, these gilts were returned to the 4 lbs/day diet until the first post-weaning estrus. They again received 4 lbs additional feed, once, following mating. The results indicate this short term flushing does not increase the total number of pigs born nor the number of live pigs at either first or second parity.

C. Nutritional Effects On Attainment of Puberty and Ovulation Rate

Clark *et al*. (1972), in work with one-year-old gilts of Yorkshire, Poland China and crosses of these breeds, reported that gilts fed *ad libitum* ovulated two more ova than gilts fed a restricted diet of 1.82 kg/day. Although ovulation rates differed by breed, the two ova advantage was consistent within each breed group for the two ration intake levels.

Beginning at first estrus, Edey *et al*. (1972) fed gilts either a low plane diet (1.4 kg/day) or a high plane diet (*ad libitum*) for one estrous cycle prior to mating. The high plane (HP) gilts ovulated 2.5 more ova than the low plane (LP) gilts (12.6 CL vs 10.1 CL, $P<.01$). The LP gilts lost .24 kg/day while the HP gilts gained .30 kg/day. In a second trial the effects of short term fasting, from day-17 of the first estrous cycle to day-3 of the second cycle, did not affect ovulation rate of either LP or HP fed gilts. The length of the estrous cycle was not affected by the level of nutrition.

Haines *et al*. (1959), using 102 gilts, reported energy intake levels affect age and weight at puberty of Duroc gilts. The gilts fed low energy rations were given one-half the feed of the gilts fed high energy rations, but the daily intake of proteins, minerals, vitamins, and antibiotics were equal for the two groups. Age at puberty was 195 ± 6.5 days for the high energy (HE) gilts and 217 ± 17.1 days for the low energy (LE) gilts ($P<.01$). Weight at puberty for HE gilts was 195 ± 26.7 lbs and was 160 ± 18.8 lbs for LE gilts ($P<.01$). High energy gilts ovulated 2.9 and 3.0 more ova at first and second estrus than did the LE gilts ($P<.01$). Length of estrous cycle and fertilization rate was not affected by ovulation rate.

In a second trial in which 35 gilts were used to determine energy effects on embryonic mortality, the HE gilts shed 1.6 more ova than the LE gilts ($P<.05$). At 25 days postmating, the HE gilts had .2 more embryos than the LE gilts ($P<.05$). Gilts fed either of the two energy levels for a full gestation period had litters of equivalent size (9.0 and 8.7 live pigs). Prenatal mortality was seriously affected by energy intake. At 25 days postmating, the prenatal mortality for HE gilts was 22.1% vs 11.6% for LE gilts. Full gestation prenatal mortality was 31.8% for HE gilts and 20.1% for LE gilts.

Haines concluded that limited energy delayed puberty, depressed ovulation and decreased embryonic mortality. He suggested "full feeding to breeding for high ovulation rates and limited feeding afterward to attain higher embryonic survival rates."

O'Bannum *et al*. (1966) reported results of three trials in which 24 gilts in each trial were fed either a HE diet of ground snap corn (71% TDN), a LE diet of ground snap corn (61% TDN) or a LE diet containing 52% alfalfa (63% TDN). At puberty, the HE gilts were 13 days younger ($P<.01$) and 21 kg heavier than the LE alfalfa gilts. Ovulation rates were, respectively: HE corn diet, 15.0 CL; LE corn diet, 13.8 CL; and LE alfalfa, 12.8 CL ($P<.05$). The low energy diets favored a non-significantly higher percentage of embryo survival (76.9%, 79.9% and 88.9%, respectively). Prebreeding gains between treatments were correlated with number of viable embryos ($r=.30$, $P<.05$), but postbreeding gains for the HE gilts were negatively correlated with the number of viable embryos ($r=-.45$, $P<.05$).

D. Attainment of Puberty

Cunningham et al. (1974) fed 68 gilts (42 days of age) a 10% protein diet in which the protein was derived from high lysine corn (HLC) beginning at weaning. One hundred thirty-seven control gilts were fed a corn/soybean meal ration containing 14% protein. Age at puberty was 158.9 days for the controls and 178.7 days for the HLC gilts ($P<.05$), indicating the importance of total dietary protein and amino acid balance. The faster gaining gilts on both diets reached puberty at an earlier age than the slower gaining gilts. On the control diet, the correlation of daily gain with age at puberty was $r=-.30$ ($P<.05$).

Friend (1973) found that gilts fed a basal corn/soybean meal ration supplemented with .31% L Lysine HCL reached puberty 12-24 days later than control gilts. Faster gaining gilts on both diets reached puberty at an earlier age than slow gaining gilts.

Henson, Eason, and Clawson (1964) fed 168 gilts daily either

3 lbs or 5 lbs of a standard ration. Gilts were maintained either on the same feeding level (3 or 5 lbs) during both rearing and gestation, or were switched to the opposite feeding level at breeding (eight months). Weights at breeding and at farrowing, and average birthweight of pigs, were each significantly influenced by feeding level. However, number of live pigs born and number of pigs weaned were not. All gilts were bred at eight months of age.

Hanson et al. (1953), using 16 litter-mate pairs of gilts, full-fed one group and limited-fed the other group (60% of the full-fed ration) from 120 lbs until breeding (late December through April). After mating, gilts were placed on brome grass pasture and hand fed to prevent fatness, with the limited-fed group receiving less than the full-fed group (actual amounts not stated). The full-fed group averaged about 125 lbs heavier at farrowing (429 lbs vs 304 lbs) and farrowed 8.23 pigs compared to 7.0 pigs for the limited-fed group. By farrowing, the full-fed group averaged 1632 lbs of feed consumed per gilt; the limited-fed group averaged 959 lbs of feed consumed per gilt.

Christian and Nafziger (1952) full-fed (FF) 41 gilts and limited-fed (LF) 50 gilts at 70% of the full-fed ration, beginning at 120 days of age. Age at puberty for both groups was essentially equal (170 days vs 166.6 days), but weight at puberty was heavier for the FF group (166.8 lbs vs 128.0 lbs, $P<.01$). Ovulation rates were also in favor of the FF gilts (15.1 CL vs 13.4 CL, $P<.05$). Fertilization rates were equal for both groups (83.2% vs 85.5%). However, the LF gilts farrowed more live pigs than the FF gilts (7.4 vs 4.7, $P<.01$). Prenatal death loss was 62.9% for the FF gilts and 35.3% for the LF gilts.

Gossett and Sorensen (1959) reported no significant differences in either age at puberty (214 days vs 206.5 days) or weight at puberty (186.1 vs 166.3 lbs) or ovulation rates (12.5 CL vs 11.4 CL) for 52 gilts fed either ad libitum a high energy (HE) ration (93 therms/100 lbs feed) or a low energy (LE) ration (55 therms/100 lbs feed). Weight at puberty was positively correlated with ovulation rate ($r=.36$, $P<.01$), but was negatively correlated with percent live embryos ($r=-.31$, $P<.05$). Gilts fed LE rations had 1.3 more embryos at 40 days postmating than did the HE gilts, and a greater percentage of corpora lutea were represented by embryos for the LE gilts than the HE gilts (74.5% vs 57.7%, $P<.05$).

In later trials studying energy levels, Sorensen, Thomas and Gossett (1961) reported no difference in age at puberty (208 vs 210 days) for gilts fed ad libitum HE rations (93 therms/100 lbs feed) or gilts fed ad libitum LE rations (55 therms/100 lbs feed). The HE gilts ovulated 1.3 more ova than the LE gilts (12.3 vs 11.0, $P<.01$). There was no difference in number of live embryos at 40 days postmating. LE gilts had a 14.9% lower embryonic mortality than the HE gilts (71.8% for HE gilts, 56.9% for LE gilts; $P<.05$). Sorensen concluded that "full-feeding leads to a greater number of ovulations, but also a higher percent of embryo mortality."

Self, Grummer and Casida (1955), using 32 Chester White and 32 Poland China gilts, full-fed (FF) one-half of each group and limited the others to 66.7% of the full-fed group. The rations contained 20% protein to 125 lbs body weight, and 15% protein thereafter. The FF gilts averaged 7.1 lbs feed intake daily and the LF gilts averaged

4.3 lbs daily. In trial I, age at puberty was: FF 223 days, LF 208 days ($P<.01$). In trial II, age at puberty was: FF 222 days, LF 205 days ($P<.01$). Full-fed gilts had a higher ovulation rate (13.9 vs 11.1, $P<.01$) but also had a higher embryonic death rate.

E. Age and Weight at Puberty

Haines (1959) reports a range in age at puberty for Duroc Jersey gilts to be 168-276 days and a weight range of 128-290 lbs (mean= 178 lbs). Robertson _et al_. (1951b) found age of puberty in Chester White and Poland China gilts to range from 167 to 250 days with a mean of 201 days. Weights ranged from 120 to 305 lbs with a mean of 195 lbs. These ages agree very closely with those reported by Reddy, Lasley and Meyer (1958) who reported a range of 169-256 days with a mean of 197.9 days.

Reddy also reported the age at breeding was influenced more by the dam than by the sire of a litter.

Robertson _et al_. (1951b) reported that faster growing gilts tend to reach puberty earlier than slower growing gilts. Correlation between weight at 154 days and age at puberty was $r=-.29$, $P<.01$. Cunningham _et al_. (1974) agree that faster growing gilts reach puberty at a younger age than slow growing gilts, while O'Bannon _et al_. (1966) concluded "that the weight of gilts at the onset of puberty is a more reliable indication of sexual maturity than is age." Cunningham (1974) also reported the correlation of daily gain and age at puberty to be $r=-.30$, $P<.05$ and estimated the heritability of age at puberty to be $h^2=.64$.

Reutzel and Sumption (1968) report correlation coefficients of several traits with age at puberty: weight at puberty, r=.62; weight per day of age, r=-.32; backfat thickness r=.08; (significance levels not given).

Squiers, Dickerson and Meyer (1952) found that crossbred gilts tended to breed at earlier ages than straightbred gilts due to the crossbreed's more rapid growth and earlier sexual maturity.

By using a boar as a stimulus, puberty has been initiated in gilts as young as 135 days of age (Hughes and Cole, 1975). (The influence of the boar on attainment of puberty in gilts is developed in Section I, Boar Effects, on page 24.)

F. Effects of Age and Weight On Ovulation Rate and Litter Size

Stewart (1945) found that age and weight at mating accounted for four percent of the variance in size of first litters and together they provide the most reliable criteria for use in selection for fertility. But Robertson _et al_. (1951b) say neither age nor weight at first or second estrus were closely related to ovulation rate. O'Bannon _et al_. (1966) reported that regardless of diet (high or low energy) breeding age was not significantly correlated with either ovulation rate or number of viable embryos. This conflicts with Reddy, Lasley and Meyer (1955) who found significant correlations of ovulation rate with age at breeding (r=.56) and with weight at breeding (r=.35). Litter size was highly associated with number of ova (r=.380), and older gilts tended to farrow larger litters, irrespective of ovulation rate. This might be due to better uterine environment.

Sherritt (1962) made these four observations:

1. Increased age of a gilt at farrowing resulted in .009 more pigs produced per day of gilt's age.
2. Weight of dam's litter at weaning had a significant negative effect on age of the daughter at farrowing.
3. Age of a gilt had a significant positive effect on the number of pigs farrowed, and a significant negative effect on the total weight of the litter weaned.
4. The weight of the litter weaned by the dam had a negative effect on the age of the daughter at farrowing.

Sherritt stated:

"These results led to the conclusion that selection for number farrowed and weaning weight at the same time was in part ineffective because of the age interrelation of these two factors. These results suggest that correlation for age of gilts at farrowing in selection studies may bias the results and that keeping the age at farrowing of gilts constant tends to cause selection for weaning weight to be ineffective."

G. Sexual Maturity -- Number of Estrous Periods

Stewart (1945) found litter size of gilts to increase at an increasing rate up to 12 months of age, and then to increase at a decreasing rate to approximately 16 months of age. Gilts farrowing at 320 days of age produced one less pig than gilts farrowing at 12 months of age. Gilts farrowing at 410 days of age farrowed .5 more pigs than gilts of 12 months of age. He also reported heavier gilts farrowed larger litters with the correlation between age and weight at mating to be $r=.60$. Early sexual maturity was apparently associated more closely with growth than with age.

Robertson *et al*. (1951b) found neither age nor weight at first or second estrus to be correlated with ovulation rate, but suggested number of heat periods (sexual maturity) to be more important to ovulation rate than calendar age in outbred gilts. An increase of 1.6 ova in Chester White and 1.2 ova in Poland China gilts between first and second estrus was highly significant ($P<.01$). Litter size also increased with the number of heat periods preceeding that at which the gilts conceived, up to the third heat period, when litter size tended to level off. In a second study (Robertson, 1951a), second-estrus gilts ovulated two more ova than first-estrus gilts (11.8 vs 9.8, $P<.01$).

Warnick *et al*. (1951), at the same station, reported similar results with inbred gilts. They state "reproductive efficiency of gilts as measured by ovulation rate, and fertilization rate increases with advanced sexual age." (Sexual age refers to number of estrous periods.) A significant increase of .08 ovum was found between first and second estrous periods, but the increase found for the third and later heat periods were small and not significant. Gilts conceiving at the third heat period farrowed an average of 1.4 more pigs than those conceiving at second estrus and 2.5 more than those conceiving at first estrus. No significant differences were reported for conception rates at the different heat periods.

Wise and Robertson (1953) found ovulation rate and embryonic mortality to decrease, and fertilization rate of ova to increase, as the number of estrous cycles increased. Twenty-four Duroc gilts were divided into three groups and bred at either first, third or fifth estrus. Number CL, percent fertilization and percent embryonic mortality for first, third, and fifth estrus were: 1st--14.0, 80.4%, 24.3%; 3rd--12.2, 95.0%, 31.6%; 5th--12.5, 96.6%, 6.7%. The decrease in ovulation rate with maturity was thought to be due to limited feeding. Gilts had been full-fed to 175 lbs and limited-fed thereafter (amount not stated). Weight at puberty averaged 190.6 lbs; age averaged 212.5 days.

H. Breeds and Breeding

1. Attainment of Puberty

Warnick *et al*. (1949) reported three lines of inbred gilts reached puberty at these ages: Line 1--226 days, Line 2--228 days, Line 3--236 days. The difference between ages was significant (P not stated), but differences in weights at puberty were not significant for the three lines.

Squiers, Dickerson and Meyer (1952) reported that crossbreds, due to their more rapid growth, reached puberty at 206 days vs 234 days for purebreds and inbred swine. Clark *et al*. (1970) concur; they found crossbred Yorkshire/Poland China gilts to reach puberty significantly earlier than either of the two pure breeds (222 days vs 236 days, $P<.01$). Poland Chinas attained puberty at an earlier age than Yorkshires (226 vs 247, $P<.01$).

2. Effects on Ovulation Rate and Litter Size

Self, Grummer and Casida (1955) reported Chester White gilts at first estrus to ovulate two more ova than Poland China gilts, regardless of feed energy level ($P<.01$). Baker et al. (1958) found Chester White gilts to have 1.4 more CL than Poland China gilts (13.3 vs 11.9, $P<.05$). Kirkpatrick et al. (1967) agree with Self and Baker, as they also found Chester Whites to have a higher ovulation rate than Poland Chinas.

Clark et al. (1972) report that at one year of age, Yorkshires have a greater ovulation rate than Poland Chinas (1.8 more ova), and crossbred gilts of the two breeds have an ovulation rate equal to the Yorkshires.

Johnson and Omtvedt (1973) in a study of Duroc, Hampshire and Yorkshire gilts report no significant differences in ovulation rate or embryo survival between the three breeds. They do report that the purebreds averaged .5 more CL than two-breed cross gilts of the three breeds (13.5 vs 13.0), but that the crossbred gilts produced a greater number of live embryos (10.6 vs 10.0) at 30 days postmating. Two-breed gilts, with three-breed litters, had a significantly greater embryo survival rate than purebred gilts with two-breed cross litters (84.5% vs 78.8%, $P<.05$).

Stewart (1945) found litter size to decrease as inbreeding of the dam increased, but inbreeding of the litter had no effect.

Bereskin et al. (1968) reported inbreeding of the dam to significantly reduce litter size, total litter weight and average weight of pigs born alive.

Baker et al. (1958), using purebred and reciprocal-cross matings of Chester White and Poland China swine, found embryo survival did not vary significantly for breed of sire, breed of dam, kind of mating, or stage of pregnancy.

Wilson et al. (1962) reported that neither the sow's sire (3.5 daughters represented per sire) nor the sow line affected sow productivity.

However, Reddy, Lasley and Meyer (1958) report that the sire exerts a significant source of variation on the ovulation rate of his offspring ($P<.01$) and that crossbred females ovulated 1.59 more ova than purebreds ($P<.05$). They also reported that a boar of normal fertility has no influence on the prenatal death loss or litter size of any litter he sires.

According to Perry (1960), embryonic loss in the first pregnancy is non-randomly distributed and that it was apparently related to the parentage, particularly to the sire, of the pregnant female.

> "It appears that the individual sow is liable to a characteristic incidence of embryonic loss in successive litters, imposed by factors which must be either inherited or else acquired before puberty. Embryonic mortality was not found to be related to the sire with which the female was mated."

Johnson (1976) reported "the boar plays a significant role in determining the number of embryos lost during gestation and pig livability from birth to weaning." For this reason, "within a breed, some boars sire larger litters than other boars and that on the average, there is a difference in litter size for boars of different breeds." Up to 30 days postmating, no significant differences were found in percent fertilization or embryo survival for 237 gilts mated to 45 boars from each of the three breeds studied--Yorkshire, Duroc, and Hampshire. Crossbred litters from Yorkshire and Duroc sires were, on the average, one pig larger at farrowing and weaning than Hampshire-sired crossbred litters. Johnson also reported that purebred gilts weaned .76 more pigs when the litter was crossbred than when the litter was straightbred. Crossbred gilts, when mated to a boar of a third breed, weaned one more pig per litter than purebred gilts producing a two-breed litter. Embryo survival for two-breed and three-breed litters were significantly different (78.8% vs 84.5%, $P < .05$).

Using data from 7,296 litters from herds located at experiment stations and colleges in eight states from the late 1920's through the spring of 1937, Lush and Mollin (1942) ranked eight breeds of swine according to average litter size:

Rank	Breed	Av # Pigs/Litter
1	Yorkshire	10.75
2	Duroc	9.78
3	Danish Landrace	9.74
4	Chester White	9.33
5	Hampshire	8.66
6	Poland China	7.98
7	Berkshire	7.74
8	Tamworth	7.43

In a review of a Purdue University study of 13,000 litters born in the United States, Lessiter (1975) reported a ranking of seven breeds of swine by average number of pigs born per litter:

Rank	Breed	Av # Pigs/Litter
1	Yorkshire	11.13
2	Landrace	10.52
3	Duroc	9.66
4	Chester White	9.53
5	Hampshire	8.78
6	Berkshire	8.07 } Tie
6	Poland China	8.07 }

It is interesting to note that in the 38 years between the two studies, except for the Landrace breed, the average litter size has increased by less than half a pig within each breed, regardless of ranking. (The Duroc breed has actually decreased a slight amount.) And except for the Duroc and the Landrace breeds exchanging positions, the relative ranking of each breed has remained the same.

Boylan, Rempel, and Comstock (1961) estimated heritability for litter size to be $h^2 = .03 \pm .07$ and concluded that with so low a heritability, the response to selection for litter size within a line or breed would be negligible. Cunningham and Zimmerman (1973) disagreed somewhat with Boylan. These two researchers suggest that ovulation rate, measured at a constant estrus, is highly heritable ($h^2 = .52 \pm .05$) and that selection should be effective in increasing ovulation rate. By use of laporotomies of gilts to count the number of CL, within five generations, Cunningham and Zimmerman increased the ovulation rate from 8.0 to 10.1 CL, while in the control line the change was from 8.4 to 9.4. The difference in heritability estimates between the Boylan and Cunningham studies may be because Boylan was using litter size to measure heritability, which is affected drastically by prenatal mortality, whereas Cunningham measured only ovulation rate.

Bradford (1975) selected for litter size in two lines of mice for 14 generations and increased the litter size by one-third above the base population means. The increased litter size seemed to be due more to increased ovulation rate rather than from a change in embryo survival rate. In two other lines of mice, each selected for either ovulation rate or embryo survival, embryo survival rate, measured in late pregnancy, increased from .80 to .90, whereas ovulation rate increased 25% from the base. Litter size increased in the embryo survival line but not in the ovulation line, which Bradford noted was contrary to the results from the lines selected for litter size.

I. Boar Effects

> "Boars do not determine if a sow is in heat by sight or smell, but rather by the sow's behavioral responses to a boar. Most approaches by the boar are mating approaches, and if the sow is in heat the courtship ritual begins. Boars will frequently pursue non-estrus gilts while failing to detect other gilts in the pen that are in heat. The boar normally detects estrus gilts only because of the persistance with which the gilts pursue him. After using boars for some weeks in breeding pens, the normal pattern degenerates to where boars either lose complete interest or try to mount every gilt without the preliminaries. The boars had taken on a passive rather than an active role. The inability of a boar to detect heat does not lend itself to the practice of walking a boar by tethered or stalled sows. If taken to strange areas, boars spend more time investigating their surroundings than they do pursuing the females. It is better to take the gilts to the boar." (Brooks, 1973b)

Brooks and Cole (1970b) found the boar can influence the time of puberal estrus. Introduction of the boar at 165 days or 190 days of age initiated estrous activity. At 165 days of age, considerable synchrony of estrus was obtained when there was a rotation of the boars used, but the effect was much less when only one boar was used. Of 12 gilts introduced to a rotating boar at 165 days of age, 11 gilts expressed puberal estrus within 8 days. Nine of the 11 gilts introduced to a rotating boar at 190 days of age attained puberal estrus within 14 days.

George and England (1974) subjected gilts of three weight groups

(57-61 kg, 70-75 kg, 84-89 kg) to a change in environment and daily exposure to a boar (5 minutes/day). Days to estrus were fewest (20.0, 19.4, 9.8; $P<.05$) in the heaviest and oldest group, while the age at puberty was least in the lightest and youngest group (170, 179, 195).

Hughes and Cole (1975) subjected 53 crossbred gilts to a change of environment at 55 kg live weight and introduced a boar at 64 kg live weight. Gilts were mated twice at second estrus; mean age at first estrus was 178.9 days (range: 135-235 days); mean weight at first estrus was 90.5 kg (range: 70-125 kg). Neither age nor weight at puberty affected ovulation rate at second estrus, nor conception rate nor embryo survival at 20 days postmating. They reported that gilts sired by one boar reached puberty significantly earlier than gilts sired by three other boars in the study.

Zimmerman, Carlson and Lantz (1974) reported that gilts of 125 days and 165 days of age, moved to new locations and exposed to boars 10-15 minutes each day, reached puberty significantly earlier than those who were moved to a new location only. Older gilts tend to reach puberty in fewer days following initiation of treatment than do younger gilts. Bourn et al. (1974), at the same station, found gilts exposed to boars 10-15 minutes each day beginning at 135 days of age attained puberty at an earlier age than gilts exposed to boars beginning at 165 days of age (156 vs 173 days, $P<.01$). The younger gilts also attained puberty at an earlier age than the older gilts when both groups were transported 2.8 km before exposure to the boars (161 vs 167 days, $P<.05$). In each trial, a better synchrony of estrus occurred in the 165-day age group.

Hughes and Cole (1976) controlled the weight gain of 30 gilts so as to reach 73 kg at either 135, 160, or 190 days of age (10 gilts in each group), and these gilts were then exposed to a vasectomized boar once each day for 30 minutes. Mean days to puberal estrus from initial boar exposure were significantly less for the 160 to 190 day age groups (19.0 and 15.2 vs 34.3 days, $P<.05$), but age at estrus was significantly earlier for the 135 and 160 day age groups (169.4 and 178.2 vs 205.3 days, $P<.05$).

Mixing groups of 25 strange gilts (M), transporting in trucks 2.8 km (T), relocation to new pens (R), and exposure to a boar (E) were investigated by Zimmerman, Bourn and Donovan (1976). The combination of M, T, and R more significantly influenced a greater number of the gilts to ovulate within ten days of initiation of treatment than did either M alone or M and T in combination (28% vs 7.2% and 8.3%, $P<.05$). Exposing the gilts to a boar 24 hours per day in addition to the other three stimuli resulted in 87% of the gilts ovulating within ten days vs 28% for only M, T and R ($P<.01$).

Kinsey _et al_. (1976), by exposing gilts to auditory stimulation (A) of a recorded boar chant 10-15 minutes each day, alone or in concert with fenceline contact with a barrow (B), reduced age of puberal estrus over controls (C) of 52 crossbred, confinement-raised gilts (A=183.3, A + B =183.6 vs C=190.1 days, $P<.01$). In a second trial, of 139 pasture-reared gilts stratified by litters across trials, the auditory stimulation alone produced a similar age at puberty as did boar exposure (BE) and barrow exposure (B), (A=182.1, BE=178.9 and B=180.8 days). Exposing gilts to olfactory stimulation (O) of boar urine alone or with auditory stimulation significantly delayed puberty as compared to use of the other three stimuli (O=198.1, O+A=196.4 vs others, $P<.01$). In each of the trials gilts were exposed to the stimuli initially at 165 days of age for 10-15 minutes each day.

Zimmerman, Carlson and Nippert (1969) found that exposing gilts to a boar at too young an age can delay the age at puberty beyond that of gilts of older ages when first exposed to boars. Age at puberty for gilts first exposed at 103 days, or 126 days, of age and for gilts not exposed to a boar were: 160.5, 148.1 and 182.6 days, respectively. In a second trial the ages of attainment of puberty for the group were: 180.3, 165.0 and 195.8 days.

The mechanism by which the male triggers the onset of puberal estrus in the female is not fully known. Chesworth and Tait (1974) report a large and sudden increase in luteinizing hormone levels in blood serum of ewes within ten hours following introduction of a ram. Introduction of a male rat to young female rats at an early age will influence the opening of the vagina, an indication of puberty (Rutledge, Kalscheur and Chapman, 1974). In a bull, the sight of a cow will produce a release of luteinizing hormones via the neuroendocrine reflex (Katongole, Naftolin and Short, 1971).

J. Season of the Year

Gossett and Sorensen (1959) reported fall-farrowed gilts reached puberty 9.9 days (N.S.) earlier than spring-farrowed gilts and that fall-farrowed gilts weighed 160.3 lbs at puberty vs 184.1 lbs for spring-farrowed gilts. Spring-farrowed gilts, however, experienced a

19% greater ovulation (13.0 vs 10.9 CL, $P<.05$) and 28% more live embryos at 40 days postmating than fall-farrowed gilts. Sorensen, Thomas and Gossett (1961) reported spring-farrowed gilts to be two days older (N.S.) than fall-farrowed gilts and that spring-farrowed gilts were 12 lbs heavier at puberty ($P<.01$). The fall-farrowed gilts had significantly higher ovulation rates (12.3 vs 11.0, $P<.01$) and more embryos (8.2 vs 6.8, $P<.01$) at 40 days postmating. There was, however, no difference in embryo mortality rates for fall- and spring-farrowed gilts. The study by Wiggins, Casida and Grummer (1950b) reported spring-farrowed gilts to reach puberty later than fall-farrowed gilts.

Robertson et al. (1951b) reported gilts born later in the spring farrowing season tend to reach puberty at a younger age than those born earlier; whereas Wise and Robertson (1953) found the time of birth in the farrowing season to be unassociated with age at puberty.

K. Environmental Temperature

Teague, Roller and Grifo (1968) found that as the environmental dry bulb temperature increased, the number of CL decreased in second-estrus gilts. Temperature levels were 26.7, 30.0 and 33.3° C. Percentage of gilts pregnant decreased with each increase in temperature, but differences in embryo number at 25 days postmating were not significantly associated with temperature level.

Edwards et al. (1968) reported no significant differences in ovulation or conception rates for gilts exposed to 38.9° C temperatures 17 hours per day for five days (32.2° C for the remaining five hours) prior to expected estrus when compared to gilts maintained at 23.4°C. Gilts exposed to the 38.9° C temperature for one complete estrous cycle prior to breeding showed a slightly lower, but non-significant difference in number of live embryos at 30 days postmating. Five of the gilts exposed to elevated temperatures died from heat prostration. The number of live embryos at 30 days postmating was lower ($P<.05$) in gilts exposed to high temperatures for 1-15 days postmating, but was equal to controls when gilts were exposed to heat 15-30 days postmating.

Warnick et al. (1965) reported that gilts maintained at 60° F averaged 1.9 more embryos at 25 days postmating than gilts maintained at 90° F. The number of CL was the same for both groups.

L. Uterine Development

In an attempt to increase uterine development, McMenamin and Icing (1973) hormonally induced a second ovulation in eight gilts (age: 140-150 days) three to six weeks after inducing their first ovulation. Their results stated: "Based on histological studies and ratio of endometrium to total uterine area, there is no gradual maturation or morphological alteration of the uterus during successive early estrous cycles."

Perry and Rowlands (1962) found the uterus to be elongated throughout the first 18 days of pregnancy and the elongation was most rapid between the second and sixth day when a 50% increase in length occurred. Uterine length was not found to be related to the number of CL, nor the number of surviving embryos. Average uterine length, at the 3rd day and the 13th-18th day of pregnancy was 190 cm and 360 cm respectively. It was not known what caused the uterus to elongate.

Reddy, Lasley and Meyer (1958), however, found litter size to be correlated with linear capacity of the uterus (r=.16).

M. Maternal Limit

Bazer *et al*. (1968a) found that when embryos were transferred from sows to 53 crossbred gilts, "uterine capacity" limited the number of live embryos at 91 days gestation to a maximum average of 9.9 for both transfer-embryo-receiving gilts and control gilts. Embryo-receiving-gilts with a total of 16 embryos (ovulated and transferred) averaged 8.8 embryos at 91 days gestation whereas gilts with 28 embryos (ovulated and transferred) averaged 9.9. These averages were not different from the non-operated and sham-operated control gilts (9.9 and 8.2 embryos).

Bazer *et al*. (1968b) also reported embryos from flushed or non-flushed gilts to be equally viable and that the reduced embryonic survival in gilts with high levels of energy intake prior to mating was due to some uterine factor. Survival rates of transferred and non-transferred embryos were equal in this study (44% vs 46%). They concluded that the uterus can effectively limit litter size and that this limit, called "uterine capacity, is not greater than that now reflected in the normal litter size of gilts."

Rampacek and Ulberg (1973) found no significant differences among three genetic groups of embryo-receiving-gilts (eight from each breed). Breed, average CL, average number of embryos transferred, and average number of embryos at 25 days gestation were:

Duroc:	14.8, 13.1, 16.8
Yorkshire:	12.9, 13.3, 18.1
Crossbreds:	13.9, 15.6, 20.8

No significant difference was found in progestin levels among the three groups.

N. Uterine Abnormalities

Wiggins, Casida and Grummer (1950a) examined the genital tracts of 2,967 open gilts. A total of 5.1% of the post-puberal open gilts had genital abnormalities including tubal abnormalities, cystic follicles and missing parts. They estimated that these abnormalities could cause 20% of the breeding failures in gilts that fail to conceive.

Squiers, Dickerson and Meyer (1952) found 7% of 359 gilts to have abnormalities of the reproductive tract.

Warnick, Grummer and Casida (1949), using 63 repeat-breeding females (2-4 estrous cycles without pregnancy), found 50% of the gilts and 15.8% of the sows to have genital abnormalities preventing fertilization. Embryonic death loss was responsible for 23.9% of the repeat matings in the gilts, and 67.4% in the sows. Wilson, Nalbandov and Krider (1949), using 79 hard-to-settle females, reported that about 50% had anatomical or endocrine aberrations of the reproductive system causing their sterility.

Perry and Pomeroy (1956) examined the reproductive tracts of 863 female pigs, mostly sows, discarded from commercial herds in East Anglia, England. The reproductive organs of more than half the discarded sows were found to be normal. The percentage of females with some degree of cystic abnormality was twice as high in the spring as in the fall. This variation was not thought to be from sampling error. There was no seasonal variation in number of CL or embryos.

O. Embryo Mortality

Nutritional effects on embryo survival were reviewed in the nutrition section.

Reddy, Lasley and Meyer (1958) stated, "Litter size is largely determined in order by prenatal death loss, number of ova shed, and linear capacity of the uterus." Baker *et al*. (1958) stated, "Embryo survival rate appeared to have greater influence than ovulation rate in determining litter size." Squiers, Dickerson and Meyer (1952) found that for gilts bred once in early estrus, only 65% of the ova shed are embryos at 25 days gestation. Sows also experienced a 35% death loss by the 25th day. However, the gilts experienced an additional 11% embryo loss prior to farrowing for an embryo mortality rate of 46%. There was a slight tendency for the proportion of ova lost to increase with the number of ova shed.

Perry and Rowlands (1962) found 95.5% of all ova recovered by the tenth day of the estrous cycle to be fertilized. Embryo death loss was 28.4% by the 18th day and 34.8% by the 40th day.

P. Effect of Mating By the Boar

Reddy, Lasley and Meyer (1958) found a second boar service 20 hours after the onset of estrus reduced (non-significantly) the prenatal death loss as reflected by ovulation rate and litter size;

whereas Squiers, Dickerson and Meyer found a second boar service to increase conception rate among gilts from 66% to 89%, with a small but uncertain increase in litter size.

In a study of hand-mated vs lot-mated gilts, Rich, Turman and Hillier (1968) reported no difference in ovulation rate between the two groups. The hand-mated gilts were handled as quietly as possible and mated once each day when showing estrus. Lot-mated gilts had the boar changed every few hours and no limit was placed on the number of services nor was any attempt made to control the harrassment of gilts by the boar. Hand-mated gilts had a larger number of embryos ($P<.10$), fewer dead embryos ($P>.10$), and a greater percent embryo survival ($P<.05$) at 30-35 days postmating.

Q. Hormonal Control of Estrus

No attempt will be made to review the extensive research that has been conducted in the use of hormones for the control of estrus in farm animals. It will suffice to say that injections of Pregnant Mare Serum (PMS) in doses of 250 to 2000 IU followed 48 hours later by 500 IU of Human Chorimic Gonadotrophin (HCG) did induce ovulation in crossbred gilts of 100 to 180 days of age. Ovulation rates were increased linearly ($P<.01$, $b=.22$) with the dose of PMS (Baker and Coggins, 1966).

Dziuk and Baker (1962) induced ovulation in gilts by oral administration of 500 mg of 6-a-methyl-17-a-hydroxyprogesterone acetate per female for eight to ten days. Ovulation occurred between the 10th and 18th day from the initial dosage. In other gilts, 250 to 2000 IU of HCG, given at either 5, 6, 7 or 8 days after the above treatment, caused ovulation in 94% of the gilts within 40 hours of the injection.

Ulberg, Grummer and Casida (1951) reported that injections of more than 25 mg per day of progesterone were capable of inhibiting heat and ovulation when injections were started on the 15th day of the estrous cycle. Cystic follicles were common for the treated gilts.

R. The Pituitary Gland and Gonadotrophic Hormone

Clark et al. (1972), in his nutritional study of ovulation rates of Yorkshire, Poland China and crossbreds as affected by nutrition level and parity, reported that the higher ovulating Yorkshire and crossbreds had heavier anterior pituitary glands than did Poland Chinas (398 gm vs 330 gm, $P<.01$). The level of nutrition affects the size of the anterior pituitary gland as well as follicle weight. The increase in ovulation rate due to parity was accompanied by an increase in anterior pituitary gland weight.

Robinson and Nalbandov (1951) found a high association between gonadotrophic potency and the number and size of follicles ($r=.69$, $P<.01$). A change in the weight of the pituitary gland was found dur- the estrous cycle, with no association between the gland's weight and the rate of hormone secretion. Genetically different strains of swine were found to produce significantly different amounts of gonadotrophic hormone (results not published).

S. Productivity of Early-Mated Gilts

Reproductive response of early-mated females, as reported by various researchers, has not been consistent. As previously mentioned, Brooks and Cole, and Libal and Wahlstrom, reported no significant differences in number of piglets born or weaned when gilts mated at first estrus are compared to gilts mated at third estrus.

England (1973) reported that of 16 gilts mated at first estrus, 14 were pregnant at 30 days postmating. Mean number of CL was 12.4. Mean number of embryos at 30 days postmating was 9.3, or 75% of the ova shed.

George and England (1974), using gilts of three weight groups (57-61 kg, 70-75 kg, and 84-89 kg) and bred at first estrus, found the lighter (and also younger) gilts to have significantly fewer embryos than the larger and older gilts at 25 days postmating. Embryo averages for the three groups were 7.9, 8.7 and 9.2 ($P<.05$). However, there was no difference in number of corpora lutea among the three groups (12.7, 12.0, and 12.1).

In rats (Rutledge, Kalscheur and Chapman, 1974), early-mated females, i.e. joined with males at three weeks of age, had one less pup than conventionally-mated females joined with males at nine weeks or age (8.2 vs 9.2, $P<.05$).

Kotarbinska and Kielanowski (1973) of Poland reported meat production, color and texture to be very good from 16 Large White gilts mated at approximately six months of age and 90 kg of weight and slaughtered following weaning of litters at six weeks. The number of weaned pigs averaged 8.8 and the dams averaged 152 kg of weight. An additional nine gilts were mated at the same age and weight and were kept for a second litter. The second litter averaged 11.1 pigs farrowed and 10.8 pigs weaned. They concluded:

> "1. Early-mated pigs can be kept for further production.
> 2. Meat production from females which have produced one litter can be recommended whenever a rapid increase in the number of baby pigs is desired and the price of pigs marketed at heavy weights is acceptable."

Feed efficiency for the farrowing gilts was 3.67 kg/kg of live weight. In addition, three gilts, with small litters, were slaughtered and the piglets transferred to other gilt dams, which added to the economy of feed utilization.

Hughes and Cole (1976), at second estrus, mated gilts whose growth was controlled so as to reach puberty at 135, 160 or 190 days of age. Mean age at puberty was 169.4, 178.2, and 205.3 days ($P<.05$) respectively. No significant difference existed between litter size, number born alive or average birth weight. Mean litter size was 9.83, 9.29 and 9.38 respectively. Mean number of live births was 9.50, 8.71 and 7.25 respectively.

Libal and Wahlstrom (1976) found the total reproductive performance of early-mated gilts to be inferior compared to conventionally-mated gilts. Fifty-six crossbred gilts were divided into two groups and hand-mated to boars during a 28-day mating period. Group A was bred at an average age of 202 days and group B at an average age of 246 days. In group A, 64% of the 26 gilts farrowed and in group B, 86% farrowed. The number of pigs born alive and weaned favored the B group, but was not statistically significant. After weaning, all the group A gilts exhibited estrus within 10 days and 79% of the group B gilts did within 21 days. Of the gilts bred, 11 gilts in group A and 17 in group B farrowed second litters. These numbers represent 39% and 68% respectively of the initial 28 gilts assigned to each group.

Warnick *et al.* (1951) reported conception rates of inbred gilts at the first three heat periods not to be statistically different (1st heat: 58.9%, 2nd heat: 80.0%, 3rd heat: 55.0%).

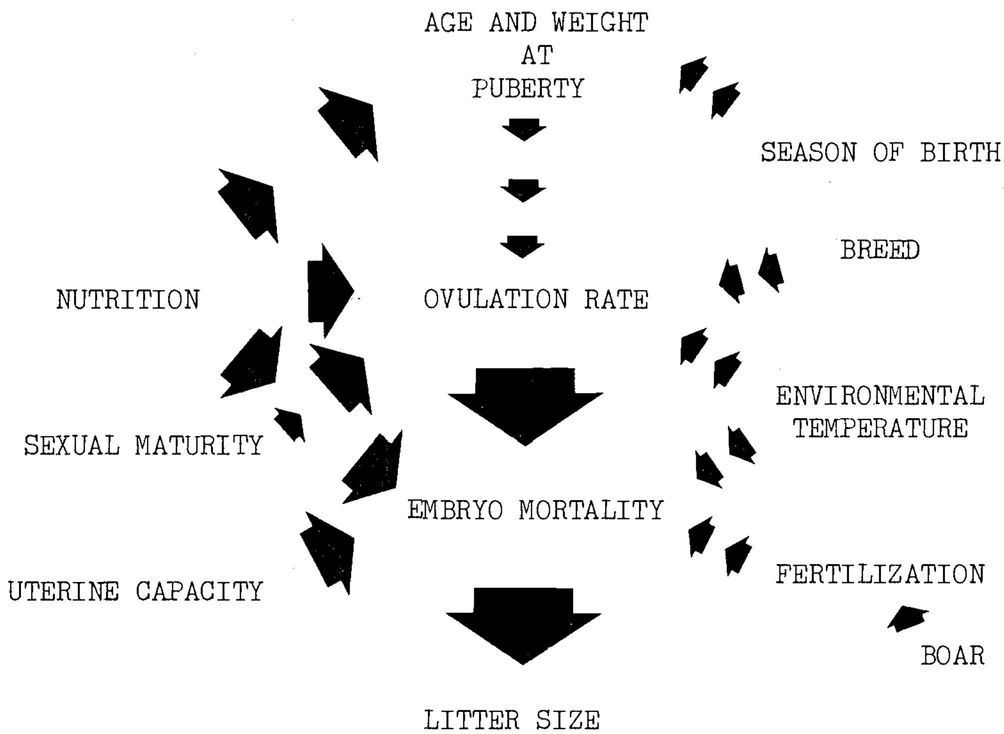
In a comparison between early-mated and conventionally-mated gilts, Brooks and Cole (1973b) reported conception rates of 81.8% for gilts mated at first estrus and 94.4% for gilts mated at third estrus. There was no significant difference in the number of pigs born or weaned between the two groups.

Pay and Davies (1973) report conception rates of 72.5% for gilts mated at first estrus, and 91.3% for gilts mated at third estrus ($P<.05$), in gilts fed 1.4 kg of feed daily from 55 kg live weight through farrowing. Litter size was 7.9 and 9.27 pigs respectively ($P<.01$). Gilts mated at first estrus consumed 106 kg less feed from 55 kg of weight to farrowing than did the older gilts. These researchers reported "no practical problems" with mating the small, first-estrus gilts, but that the poor conception rate may have been from using "young, immature boars." They also stated:

> "No obstetrical problems were encountered during farrowing of small gilts. Skeletal frame was of normal size but muscle and fat was less well developed. Managerially, the greatest problem to be overcome in the one-litter system is the lack of predictability of estrus in gilts compared to weaned sows. Certainly more work is required on the best method of achieving a synchronized early puberty."

Pomeroy (1960) conducted a survey in East Anglia, England, as to why swinemen dispose of breeding females. The survey was conducted from February 1951-April 1952, and the lifetime performance of the sows was obtained. The lifetime production records of 36 sows that farrowed their first litters at less than 12 months of age compares very favorably with the lifetime production records of 138 sows which farrowed their first litter at 12-13 months of age. Average results for each group, with the younger group given first, were: litters/sow, 3.19, 3.20; total pigs born/sow, 31.6, 33.2; % pre-weaning deaths, 23.8, 28.8; # pigs weaned/sow-lifetime, 24.0, 23.9. Reasons for disposing of sows were: failure to breed, 27.8%, 26.1%; piglet mortality, 8.3%, 17.4%; low fertility, 16.7%, 8.7%; other reasons, 47.2%, 47.8%. It is interesting to note that even though the older gilts farrowed slightly more pigs, the higher piglet mortality resulted in an equal number of pigs weaned per sow-lifetime for both groups. This observation is in agreement with data by England and Day (1970) which indicates the 56-day survival rate of litters with 3-12 pigs to be fairly constant (84.1% $\pm$ 3%). Therefore, with a constant death percentage in a litter, increasing the litter size by one live pig at birth results in a weaned pig advantage of less than one additional pig.

SCHEMATIC SUMMARY OF FACTORS AFFECTING SWINE PRODUCTIVITY



Note: Heaviness of line indicates degree of influence according to author's subjective opinion.

IV. METHODS

A. Gilt Allotment

Crossbred gilts of Yorkshire and Composite (a purebred-like population developed from *inter se* breeding of crosses of the Oregon State University purebred Yorkshire X Berkshire herds) were allotted at weights of 81.5 to 90.5 kg (180-200 lbs). No consideration was given to the age of the gilts, and because these genetic groups farrowed relatively similarly-sized litters, no consideration was given to the percentage of genetic background in each group of gilts.

In a preliminary study, 30 gilts of 81.6-113.4 kg (180-250 lbs) were slaughtered and their ovaries examined. Only those gilts that weighed a minimum of 104.3 kg were found to have ovulated. Therefore, it was considered that few, if any of the gilts in the population would have naturally attained puberty at the weight of 81.5-90.5 kg.

At the initiation of each trial, gilts were weighed and moved from their home pens to the test pens. During their growing phase and throughout the testing period, gilts were fed *ad libitum* a 14% barley-soybean meal ration.

For the most part, trials were conducted with eight animals in each pen-replicate group.

B. Environmental Influences

Gilts were exposed to one or a combination of the following stimuli:

1. Change of Housing

All gilts experienced a change in housing. Gilts were raised to test weights in buildings away from the sow and boar herds. On the initial day of testing, gilts were weighed and moved to one of two barns. The nutrition barn, used only for pre-market animals, was used to test gilts away from the sow and boar herds. Thus movement of gilts to this barn tested only the effects of change in housing on the mixed and non-mixed gilt groups. Pen size in the nutrition barn was 1.2 by 3.6 meters.

The brood stock barn was the other facility used a gilt test housing. Gilts were in pens adjacent to gestating sows and within 18 meters of the boar pens. Pen size in this facility varied by treatment.

2. Non-mixed vs Mixed Gilts

Non-mixed gilts had been raised together as a group for a minimum of six weeks prior to testing. It was assumed that the social order had been well established before the gilts were placed on test. Mixed gilts were taken, at random, from various pens and placed together on the initial day of the trials. The maximum number of gilts familiar with one another was limited to one-half the number in a test pen in an attempt to equalize exposure to fighting and other interactions subsequent to mixing.

3. Boar Exposure

Four variations of boar exposure were practiced with the gilts housed in the sow barns:

(a.) Contiguous contact 24 hours per day with a boar in an adjacent pen, allowing no periods of direct contact with a boar. A different boar was used in the adjacent pen each 24 hours. One replicate of 16 gilts was used. Pen size was 6.0 by 3.5 meters.

(b.) No contiguous contact with a boar, but 30 minutes of daily direct contact with a boar. The same boar was not used on any two successive days. Two pen groups were tested simultaneously. One group was exercised by going 30 meters daily to the breeding pens for 30 minutes of direct contact with a boar, while the second group of gilts had a boar brought daily to their pen for 30 minutes of direct contact. Pen size was 3.5 by 4.0 meters.

(c.) Continuous contact to a contiguous boar in an adjacent pen, with 30 minutes per day direct contact with a different boar. The boars used for direct contact were rotated daily while those boars in the contiguous pen were rotated every 2-3 days. Two pen groups were tested simultaneously, one on either side of the contiguous boar. Pen groups were either exercised or non-exercised as described in (b.) above. Pen size was 3.5 by 4.0 meters.

(d.) Continuous direct contact provided by having a boar in the test pen with the gilts 24 hours per day. Boars were rotated each 24-hour period. Pen size was 6.0 by 3.5 meters.

Table 1 lists the stimuli involved in each trial of this experiment.

TABLE 1. STIMULI INVOLVED IN EACH TRIAL

Trial	Stimulus
I	All gilts subjected to a change in housing A. Non-mixed gilts B. Mixed gilts
II	Gilts subjected to a change in housing All gilts mixed Contiguous boar 24 hours/day
III	All gilts subject to a change in housing All gilts mixed No contiguous boar A. Gilts taken 30 m daily to boar for 30 min. contact B. Boar brought to gilts daily for 30 min. contact
IV	Groups A & B same as III except 24 hrs/day contiguous boar
V	Change of housing Gilts with boar 24 hrs/day; Boar changed daily A. Non-mixed gilts B. Mixed gilts

Gilts were separated from the contiguous boar by a metal gate, two meters long, constructed of vertical steel pipes. The spacing between the vertical pipes allowed the gilts and boar to have nose to nose contact and exposed the gilts to the sight, sounds and smell of the boar.

Boars, when used for direct contact, were introduced on the second day of a trial. This one day of delay allowed the gilts time to begin to establish their social order without interference by the boar, and prevented injury to the boar from fighting during the initial

24 hours. Boars in contiguous pens were present beginning with the first day. (See Section C, Use of the Boar, below.)

Because of the limited size of the breeding pens (2.7m x 2.7m) gilts taken to the boars were divided into groups of four and each group was placed with the boar for 30 minutes.

All gilts were slaughtered on the morning of the final test day and their reproductive tracts recovered for examination. On the afternoon prior to slaughter (18-21 hours), gilts were weighed and tatooed on each shoulder with a slap marker to identify the carcass.

C. Use of the Boar

Several boars were used during these trials. Younger boars, one to two years of age, were preferred as they were not so large that the gilts would not be able to bear their weight during mounting. The younger boars tended to be more sexually aggressive than the older boars, especially if gilts were not expressing estrus. The young boars would display interest in the gilts for most of the 30-minute exposure periods. Older boars would tend to make a quick check of the gilts and, if none were in estrus, would either stand at the breeding pen door waiting to leave, would attempt to lie down, or if in the gilt pens, feast at the self-feeders. (Boars were maintained on 2.25 kg of feed per day.) As the young boars became older and more experienced, they, too, tended to develop the habits of their seniors. For maximum effect, it was desirable to require the boars to be active with the gilts during the entire 30-minute contact periods. To counteract the above-mentioned tendencies, a slap with a soft whip or other noninjurious material by the researcher would arouse the boars to mingle with the gilts. When boars were with the gilts 24 hours per day, no direction was given to the boar's behavior.

The boars were rotated daily so that at least one day elapsed before an individual boar was reintroduced to a group of gilts. An individual boar was often used three days in succession by rotating him among different groups of gilts before he was returned to the boar quarters for rest. Boars showing evidence of frequent breeding activity were used no more than two days in succession before resting. Rotating the boars in this manner maintained active and aggressive boars with the gilts at all times. Sexually aggressive boars were used more often than boars that tended to show little interest in the gilts other than when the gilts were in estrus.

During the warmer months, boars were placed with the gilts either in the morning or late afternoon to avoid breeding excitement and activity during the heat of the day. During the warm weather, both the gilts and the boars were less sexually agressive than in cooler weather.

All boars were experienced breeders and were easily trained to enter and leave the breeding pens and/or gilt pens. Boars were usually ready to leave the gilts after the 30-minute exposure time, especially when no gilts were in estrus. Boars were often reluctant to leave a test pen in which there was a gilt in which the boar was especially interested, but had not yet mated.

Copulation was encouraged and assistance was given to the boar when necessary for the boar to accomplish intromission. It was almost impossible for mating to occur if the penis was extended without having made entry. Detailed records of the frequency of assistance were not kept, but an estimated 50% of the matings required assistance by the researcher. Anal copulation was common, especially with long-bodied Yorkshire boars, or among relatively inexperienced young boars.

D. Records Maintained

Gilts were weighed at the beginning and end of the trials. Daily observations of the vulva were recorded using a score of 0-3. Zero indicated a vulva of small size and light color normally associated with diestrus. A score of three indicated maximum enlargement and darkening of color. Mating behavior was recorded when a gilt was bred or when a gilt stood for the boar but the boar was unable to penetrate.

Presence of corpora lutea at slaughter was used as the criterion bo verify occurrence of estrus. The number of follicles 5 mm or greater in size were recorded for gilts which had not ovulated.

Ovaries were also examined for the presence of corpora albicans to indicate occurrence of estrus prior to the gilt being placed on test. No occurrence of corpora albicans was found.

E. Additional Experiments

1. One replicate group of eight mixed gilts were moved to the nutrition barn and exercised daily for 30 minutes. Gilts were exercised alternately by walking five minutes and resting five minutes for the 30-minute period. During this 17-day trial, gilts were away from

influences of the sow and boar herd.

2. Five sister gilts were raised with their intact brother boar until 174 days of age, at which time this boar was removed and a strange boar was introduced. This new boar remained with the gilts for 26 days, at which time the gilts were slaughtered.

3. Fifty-nine gilts were used in hormonal experiments. Injections of a relatively new hormonal product were given in various dosage levels to 47 of the gilts, weighing 84.0-88.4 kg (185-195 lbs). Twelve gilts received a placebo injection. All gilts were exposed to five minutes daily contact with a boar until mating occurred. In this trial, there was no statistically significant difference between gilts receiving the hormone treatments and those receiving the placebo injections with regard to occurrence of puberty or rate of ovulation.

For this particular trial, the 84.0-88.4 kg gilts were divided into two groups:

(a.) gilts that bred in 17 or fewer days from initial exposure to the boar.

(b.) gilts which mated in 18 or more days from initial boar exposure. (Maximum days to mating was 56.)

The question asked in this last trial was, "Among gilts of this weight, is there a difference in ovulation rate and embryo survival between gilts which attain puberty by responding in fewer days to puberty-initiating stimuli and those gilts that take longer to attain puberty in response to the stimuli?" The stimuli were: mixing of gilts, daily exercise and five minutes daily exposure to a boar.

F. Statistical Methods

Differences between means of treatments were compared using analysis of variance (Snedecor and Cochran, 1967). Correlation coefficients between variables were determined using regression analysis, and significance of vulva characteristics were determined with a chi-square analysis.

V. RESULTS AND DISCUSSION

A. General Results

Table 2 summarizes the results of these trials. Mean initial ages and weights of gilts were similar among all groups, although the initial ages ranged from 156 to 244 days. Except in Trial IB, the mean number of corpora lutea (CL) for each group was very similar. Overall mean number of CL for ovulating gilts was 11.8, with a range of 7 to 16. The percentage of gilts ovulating varied between trial groups.

In Trial I, gilts were moved to the nutrition barn away from the influences of the sow and boar herd. A greater percentage of group B (mixed gilts) attained puberty than did the non-mixed gilts of group A (26% vs 0%, $P < .05$), indicating that the interaction and stress from establishing the social order may influence the onset of puberal estrus. The mean number of CL was 9.6, the lowest of any group in the experiment. However, of the five gilts that ovulated in group B, the youngest gilt to ovulate was 209 days of age at the initiation of the trials. Mean initial age of the five ovulating gilts was 213 days as compared to the mean initial age of 171 days for the non-ovulating gilts. These results indicate that with only the stimuli of moving and mixing, age may be a more deciding influence for inducing puberal estrus than is weight.

In the various trials of this study, many gilts older than 210 days did not attain puberty regardless of the stimuli used. Also, 24 young gilts (152-174 days of age) were in the various trials; 17

TABLE 2. WEIGHT, AGE, OVULATION AND FOLLICLE DEVELOPMENT OF STIMULATED GILTS

Trial	I		II	III		IV		V	
	A	B		A	B	A	B	A	B
Stimuli**	1	2	1,2,3	2,4	2,5	2,3,4	2,3,5	1,6	2,6
Number of gilts	10*	19	16	23	24	23	24	24	24
Mean initial weight (kg)	88.9	88.0	88.0	85.3	84.8	86.8	87.5	88.4	88.9
Mean initial age (days)	176	183	202	184	185	191	184	200	187
Range in age (days)	165-185	156-216	181-229	152-212	130-244	158-219	161-204	156-233	176-213
Number ovulating	0	5	5	18	11	11	16	19	21
Percent ovulating (%)	0	26	31	78	46	48	67	79	88
Mean number of CL	0	9.6	12.8	12.2	11.0	11.8	12.7	11.4	11.8
Range of CL	-	7-11	9-16	10-15	8-16	8-15	10-15	8-14	9-14
Mean age of ovulating gilts	-	213	198	183	187	191	182	200	188
Age range of ovulating gilts	-	209-216	181-215	159-210	166-208	158-219	161-203	156-233	176-213
Mean weight, ovulating gilts	-	88.9	87.1	84.8	84.8	87.8	86.6	88.9	88.9
Number of gilts with follicles, 5mm+	1	1	4	2	3	8	2	4	0
Mean days to estrus/Bred gilts	-	-	-	9.5	7.8	7.3	10.4	8.1	7.0
Mean initial age, non-ovulating gilts	176	171	204	187	183	190	188	201	190

*Four additional gilts were involved with Trial IA but are not included with these data as the gilts were outside the weight limits on the initial day of the trials. The puberal response of these gilts was identical to the data presented under IA.

**Number designates stimuli used: 1--Non-mixed, 2--Mixed, 3--Contiguous boar 24 hr/day 4--Taken to boar 30 min/day, 5--Boar brought to gilts 30 min/day, 6--Boar with gilts 24 hr/day of these attained puberty. Therefore, age per se, would not be a limiting factor in attaining estrus. To illustrate this point, Table 3 lists, by 14-day age groups, the response of the 140 gilts in Trials III, IV and V in which large numbers of gilts attained puberty.

Trial II involved one replicate group of 16 gilts housed in the sow herd facility and penned adjacent to an intact boar. No direct contact was allowed with a boar. Five (31%) of the 16 gilts attained estrus. These gilts averaged 12.8 CL, the highest for any group.

Trial III involved three replicates each in group A and group B. All gilts were mixed; no contiguous boars were used for this trial. Group A was exercised; that is, taken daily to a boar for 30 minutes of direct contact, whereas a boar was brought daily to the non-exercised gilts of group B. Group A had a greater number of gilts attaining puberty than did group B (78% vs 46%, $P<.05$).

For Trial IV, groups A and B were handled the same as in Trial III, with the addition of a contiguous boar 24 hours per day. In this trial, group B had a greater number of gilts attaining puberty (48% vs 67%), but the difference was not statistically significant.

In Trial V, gilts were penned with a boar 24 hours per day, the boar being changed daily. Group A consisted of non-mixed gilts; group B consisted of mixed gilts. No differences were found between the two groups in percentages of gilts attaining puberty.

These results imply that exercise and boar exposure are two major stimuli which can influence the attainment of puberal estrus in gilts. Each of these stimuli are discussed in the following two sections.

TABLE 3. PUBERAL RESPONSE OF GILTS BY 14-DAY AGE GROUPS
TRIALS III, IV & V

Age	Non-ovulating Gilts Number	%	Ovulating Gilts Number	%	Total
<161	1	25.0	3	75.0	100%
161-174	6	30.0	14	70.0	100%
175-188	11(3)	23.4	36	76.6	100%
189-202	17(12)	41.5	24	58.5	100%
203-216	8(4)	38.1	13	61.9	100%
>217	2	28.6	5	71.4	100%

Note: Numbers in parentheses denote gilts of this age with follicles 5 mm or greater.

B. Boar Exposure

Presence of the boar had a stimulatory effect on the attainment of puberty. In all trials where the gilts were subjected to some degree of direct boar exposure (Trials III, IV and V), a greater percentage of gilts attained puberty compared to the non-exposed, non-mixed gilts of Trial IA ($P<.05$). Compared to the non-exposed, mixed gilts of Trial IB, the percentage of exposed gilts ovulating was greater only in Trials IIIA and V A & B ($P<.05$).

Table 4 combines the percent of gilts ovulating, in groups A and B, within a trial to give the total means for gilts ovulating. Compared to Trial I, the percentage of gilts ovulating was greater in Trials III and V ($P<.01$) and in Trial IV ($P<.05$). Trial II was not included in the comparison as only one replication of 16 gilts was conducted compared to the three replications conducted in the other trials.

TABLE 4. PERCENTAGE OF GILTS OVULATING BY TRIAL

Trial	I	III	IV	V
Means	17.2%	62.3%*	57.4%**	83.6%*

*P<.01, **P<.05; as compared to Trial I.

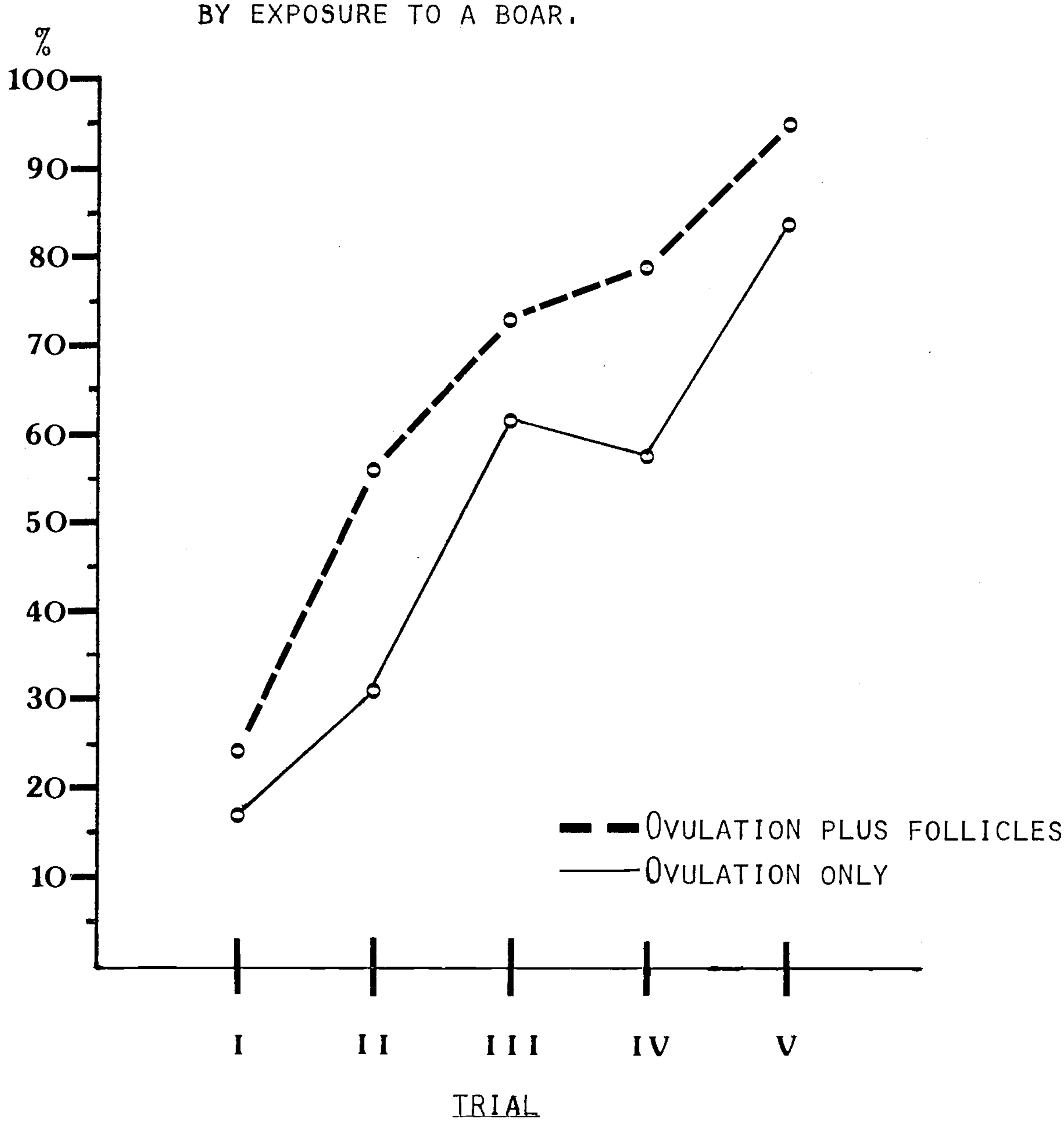
Table 4 indicates a general increase in percentage of gilts ovulating as the amount of exposure to the boars increases. The slight drop in Trial IV may be because one replication of eight gilts was on test for only 14 days. Of these gilts, five, at slaughter, had follicles of 5 mm or greater in size. As can be seen in Table 2, the total number of gilts (8) with large follicles in Trial IV A was double that of any other trial. Gilts with follicles of 5 mm and greater in size are in the late stage of proestrus and are rapidly approaching the estrous period during which ovulation occurs. Thus it could be concluded that several more gilts in Trial IV A would have ovulated if they had been on test for the full 17 days. Therefore, Table 5 shows, by Trial, the percentage of gilts ovulating plus the percentage of gilts in each trial with follicles of 5 mm or greater in size.

TABLE 5. OVULATION AND FOLLICLE RESPONSE OF GILTS

	Trial				
	I	II	III	IV	V
% gilts ovulating	17.2	31.0	62.3	57.4	83.6
% gilts with follicles 5 mm+	6.9	25.0	10.6	21.3	12.5
Total %	24.1	56.0	72.9	78.7	95.1

Table 5 indicates a linear increase in percent of gilts responding to an increased period of contact with the boar. Figure 1 portrays this linear relationship. No significant differences in ovulation response exists between Trials III, IV and V.

FIGURE 1. OVULATION AND FOLLICLE DEVELOPMENT AS INFLUENCED BY EXPOSURE TO A BOAR.



The influence of direct contact and daily rotation of the boars was not dependent on mixing or non-mixing of gilts. The boar effect was maximum when the boar was in the pen continuously with the gilts (Trial V-A & B). This procedure is in fact the simplest to accomplish, as rotating the boar is much easier and simpler than moving gilts and boars to and from the breeding pens. Daily breeding activity is easily noted following introduction of the new boar as the boar is sexually aggressive in seeking estrous females. Periodic observations would thereafter be advisable to note gilts not mating during the initial time of daily introduction of the boar. Using the procedure, an estrous gilt would normally be bred by two boars. In many commercial swine operations, two-boar breeding is used as insurance against small litters due to possible infertility of one of the boars.

This procedure could be modified for purebred operations when the sire of a gilt's initial litter is to be identified. Either a vasectomized boar could be used for continous direct contact to initiate estrus, and then mating could be accomplished by the desired intact boar, or 24-hour per day contiguous boar exposure could be provided with limited daily contact with a boar to provide mating.

Two cautions for using the boar are provided by Additional Experiment 2. Five gilts were raised with their brother boar until 174 days of age and 81.5 kg minimum weight. A different boar replaced the brother boar from day-175-200. None of the gilts attained estrus. One gilt weighing 114.5 kg (252 lbs) at slaughter had follicles 5 mm+ in size. These results are in agreement with Zimmerman et al. (1969) and indicate that introduction of a boar at too young an age retards puberty. They are also in agreement with the results of Brooks and Cole (1970) which indicate that using only a single boar (no rotation of boars) decreases the stimulatory effect of the boar.

C. Exercise

In Trials III and IV the results of exercising plus boar exposure are confusing. In Trial III, the exercised gilts (Group A) exhibited a greater ovulation response than the non-exercised gilts (Group B) (78% vs 46%, $P<.05$). However, in Trial IV, where the gilts experienced continuous 24-hour per day contiguous boar exposure, the non-exercised gilts of group B showed a greater degree of ovulation than the non-exercised gilts of group A (67% vs 48%). If, however, we consider the shortened (14 days) replication in IV A, then the percentage of gilts ovulating would certainly have been increased. (In the two other replicates of IV A, 73% of the gilts ovulated, as compared to the 67% ovulation rate of IV B.) The percentage of gilts ovulating in IV A would therefore certainly be closer, if not equivalent to, the percentage in III A and IV B, and the difference, as earlier stated, between IV A and B would probably not exist.

Without exercise, the presence of the contiguous boar increased the ovulating response in IV B compared to II B (67% vs 46%), but the difference was not statistically significant.

In Additional Experiment 1, exercising eight mixed gilts for 30 minutes daily for 14 days (five minutes walking alternating with five minutes of rest) without the presence of a boar, did not produce puberty in any of the gilts. Mean age on test for these gilts was 171 days. Two gilts of this group did have follicles of 5 mm+ in size at slaughter.

From the three Trials, III, IV and Additional Experiment 1, it would appear that these two stimuli, i.e. change in housing and 30 minutes of forced exercise, do not influence the occurrence of puberal estrus. Limited exercise combined with 30 minutes of direct daily contact with a boar will influence a significantly larger number of gilts to attain puberal estrus than non-exercised gilts exposed to a boar for 30 minutes daily. Exercising does not influence the occurrence of estrus when the gilts have a contiguous boar present 24 hours per day and are directly exposed to another boar for 30 minutes each day.

It should be noted that exercising, by taking the gilts to the boar, was not the only stimulus involved in this procedure. The gilts were normally excited somewhat by the activity involved in moving to and from the breeding pens although the gilts quickly learned to leave and return to their pens with a minimum of activity. There may also have been some additional stimuli for the gilts resulting from being in a different or strange environment for 30 minutes each day.

D. Overall Puberal Response

Analyzing the puberal response of all the gilts by age produced the following relationships:

1. Age at puberal estrus and number of CL had a negative correlation ($r=-.34$, $P<.05$).
2. Age and number of follicles 5 mm+ were positively correlated ($r=.30$, P .05).
3. A negative correlation existed between age in days at estrus

and days to reach estrus from initial test day ($r=-.34$, $P<.05$).

4. Days to estrus from initial test day did not affect the number of CL.

5. Age of the gilts at initiation of testing (on-test age) did not influence attainment of puberty. When gilts were divided into 14-day age groups, a surprisingly equal percentage of gilts from each group ovulated (See Table 3).

The weight range of the gilts was limited to 9.0 kg (81.5-90.5 kg; 180-200 lbs live weight) and thus weight did not exhibit as great an influence as did age. The following relationships for this weight range were found:

1. No significant correlation between weight and days to estrus (from initial day of trial).
2. No significant correlation between weight and number of CL.
3. No significant correlation between weight and number of follicles 5 mm+.
4. There was a trend for more of the heavier gilts than of the lighter gilts to ovulate.

E. Mating Response

Of the 142 gilts exposed daily to the boar and observed for mating behavior, 96 ovulated. Fifty-four (56.3%) of these 96 gilts were observed to stand/mate with the boar; 42 experienced a non-observed estrus. Undoubtedly, the number of non-observed estruses should be lower for two reasons:

1. Most of the gilts were exposed to boars for only 30 minutes each day. Several of the ovulating gilts may have had short heat periods ($<$24 hrs) and may not have been in active estrus at the time of exposure. In the trials where a boar was with the gilts 24 hours per day, their behavior was observed and recorded for only 45 minutes following introduction of a replacement boar each day. On several days, when no mating behavior was observed during the observation time, the swine herdsman reported mating to have occurred other than during the observation period.
2. On several occasions, it was not possible for this researcher to be present with the gilts during the boar exposure period. As various people conducted the experiment during these times, no accurate record was maintained of mating behavior.

Four gilts experienced a false heat (mating without ovulating). These false heats appeared to be at random. Thus, false heat was not characterized by age or weight groups.

F. Changes in Vulva Characteristics

Daily observations were made of the vulva of 171 gilts (Trials I, III, IV and V). A score of 0-3 was used to indicate change in color and size. Table 6 indicates the accuracy of using these vulva characterizations for determining the occurrence of estrus in puberal gilts. In Table 6, the vulva score indicates the most pronounced stage observed.

TABLE 6. ACCURACY OF VULVA SCORE AS AN INDICATOR OF ESTRUS IN PREPUBERAL GILTS

Vulva Score	Non-ovulating Gilts Number	%	Puberal Gilts Number	%
0	48	68.6%	6	*5.9%
1	10	*14.3%	15	14.9%
2	11	*15.7%	38	37.6%
3	1	* 1.4%	42	41.6%
Total	70	100.0%	101	100.0%

*Inaccuracy of vulva characteristics for determining occurrence or non-occurrence of estrus.

Thirteen non-ovulating gilts with vulva scores of 1-3 actually had follicles of 5 mm or greater in size, which is 18.6% of the 70 non-ovulating gilts, and constitutes over one-half of the total inaccuracy (31.4%) of the vulva score for non-ovulating gilts. These 13 gilts were considered to be in the late proestrous stage of the estrous cycle when follicle growth is most rapid. Ovulation in swine usually occurs in the latter half of the 36 hour estrous period and the vulva usually enlarges in preparation for estrus. Therefore, it is felt that these 13 gilts were slaughtered within approximately 48 hours of the time of ovulation and the vulva was preparing for the approaching estrus. Hence, the inaccuracy of using vulva characteristics for non-ovulating gilts would actually be less than 31%. Nevertheless, using a chi-square analysis, the vulva score was highly accurate in determining the occurrence or non-occurrence of estrus ($P<.01$). A complete summary of vulva response by ovulating and non-ovulating gilts is given by Table 7. The general change in vulva condition of these puberal gilts was very similar to the vulva changes of

TABLE 7. VULVA CHARACTERISTICS OF PUBERAL AND NON-PUBERAL GILTS OF 81.5-90.5 KG (VULVA SCORE 0-3**)

Trial	I		II*	III		IV		V	
	A	B		A	B	A	B	A	B
Number of gilts	10	19	16	23	24	23	24	24	24
Mean vulva score (vulva ≥1)	2.0	2.0	-	2.1	2.2	1.7	2.4	2.0	2.6
Mean days of highest score	2.0	2.5	-	1.7	1.7	2.3	2.1	2.1	3.0
# gilts vulva ≥1, not ovulating	3	2	-	1	3	8	1	4	0
# gilts vulva ≥2, not ovulating	3	2	-	0	2	2	0	3	0
# gilts vulva >0, follicles 5mm+	0	0	-	1	2	6	1	3	0
# gilts vulva=0, follicles 5mm+	1	1	-	2	1	1	1	1	0
Number of gilts ovulating	0	5	-	18	11	11	16	19	21
Mean vulva score	-	1.6	-	1.9	1.8	2.1	2.4	2.1	2.6
# gilts 0 vulva score ovulating	0	0	-	2	2	1	1	0	0

Note: *Vulva of gilts not monitored for Trial II.

**Score of 0 = no vulva development; Score of 3 = maximum estrous enlargement.

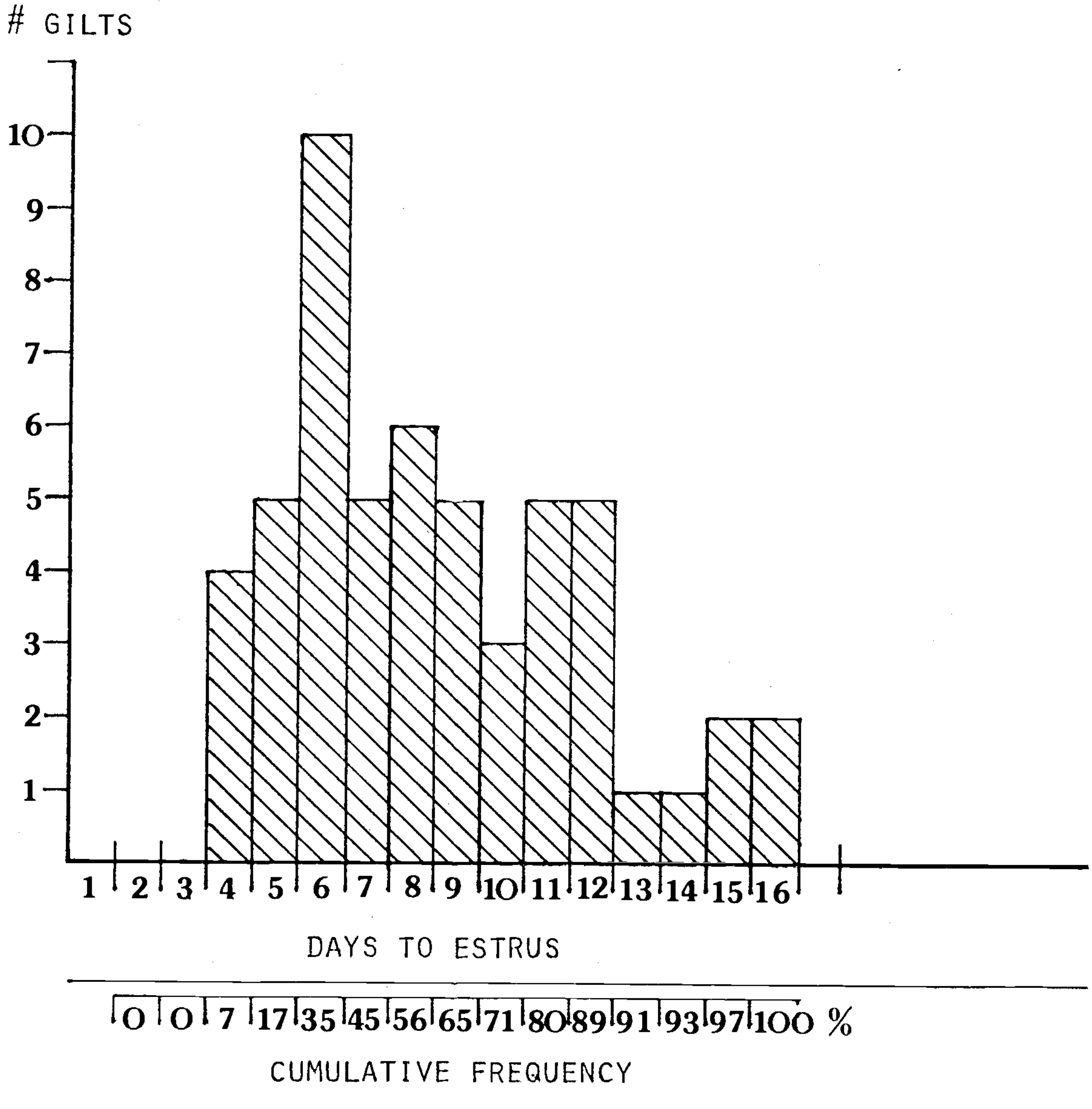
the sow as described by Lasley (1962).

G. Synchronization of Estrus

Fifty-four of the 142 gilts exposed to the boars stood/mated. The initial day the gilts stood/mated was assumed to be the day of occurrence of estrus. (False heats not included) No gilts mated before day-4 of the trials. Synchronization of estrus was very good, in that 71% of the gilts that mated did so in the seven days between day-4 and day-10, and 91% of the gilts that mated did so during the 10-day period from day-4 to day-13. Mean days to estrus was 8.4 Figure 2 illustrates the standing/mating response of the 54 gilts. These results are in agreement with George and England (1974) who reported puberal estrous activity within 10 days by 68% of 59 gilts weighing 84.1-88.6 kg and taken to the boar daily for five minutes of exposure.

As explained in the section "Statement of the Problem," synchronized mating of replacement gilts and sows is beneficial for the purposes of maintaining pregnant sow numbers, providing an attendant to assist at farrowing, and for transferring of orphan or excessive pigs to foster sows. By these means, many newborn pigs could be saved at birth that would otherwise die from suffocation, exposure, or hunger; labor expense, per pig, would be reduced by having a shorter farrowing period for which an attendant is required to be present. Also, foster sows for orphan and excessive pigs are more readily available when a large number of sows farrow in a short time interval.

FIGURE 2. DAILY INCIDENCE OF GILTS STANDING/MATING WITH A BOAR.



To synchronize the replacement gilts' estrus with that of the sow herd, a pool of replacement gilts could be stimulated by the methods advanced by this research, beginning one or two days prior to weaning litters from a group of sows. As healthy sows usually begin to express estrus and mate within 4-7 days after weaning, a large number of stimulated replacement gilts could be expected to mate during this same period.

H. Additional Experiment #3: Gilts Used in Hormonal Studies

In this experiment, 59 gilts, beginning at weights of 84.0-88.4 kg, were initially injected with various dosages of a hormonal product which ultimately proved to have no significant influence on inducing puberty. The gilts were exposed five minutes daily to the boars unmating, and then were slaughtered at 30 days postmating, at which time their reproductive tracts were removed for recording CL and embryos. Gilts returning to heat prior to 30 days postmating were rebred and held for an additional 30 days. All gilts were exposed daily to a boar until slaughter as a means of detecting a return to estrus.

For the purposes of the current report, the gilts having one estrus and not returning to heat 30 days postmating were divided into two groups--those that mated in less than 17 days and those that mated in 18 or more days from the initial exposure to a boar. Mating and reproductive performance of the gilts is presented in Table 8.

TABLE 8. MATING AND REPRODUCTIVE PERFORMANCE OF GILTS MATED AT DIFFERENT PERIODS FOLLOWING INITIAL STIMULATION BY A BOAR

	Number of Days to Mating	
	≤17 Days	18+ Days
Number of Gilts	30	9
Mean Initial Age, in Days	180.8	181.7
Number of False Heats	2	2
Number of Gilts with Cystic Follicles	2	0
Number of Gilts Ovulating	26	7
Mean Age at Estrus	185.4	212.6
Mean Number of CL	11.7	13.4*
Number of Gilts With Embryos	25	7
Age at Conception, in Days	188.5	218.0
Mean Number of Embryos	8.8	12.0*
Embryo Survival Rate	75.1%	89.1%
Conception Rate	83.2%	77.8%

*P<.05

From this small sample, two factors favor the 18+ day group of gilts: more CL (11.7 vs 13.4, P<.05) and more embryos at 30 days postmating (8.8 vs 12.0, P<.05). There was no statistically significant difference in percent conception or embryo survival rate between the two groups. The 18+ day group of gilts were, on the average, 27 days older at first estrus. The greater ovulation rate and subsequent larger number of live embryos indicates that their additional age may permit some endocrine development to occur which favors the older group in growth and maturation of Graafian follicles. Although no statistical difference existed between embryo survival rates, a trend existed for the older gilts to maintain more of their embryos (89.1% vs 75.1%). Perhaps their additional age also allowed some physiological development of the uterus to aid in maintaining live embryos to 30 days postmating.

Of the 20 remaining gilts in this study, four were not observed to have had an estrous cycle by day-70 of treatment. Two of these four gilts actually experienced a silent estrus (12.0 CL, average); a third had cystic follicles; and the remaining gilt never attained puberty. Eleven gilts experienced two estrous cycles; four experienced three estrous cycles; and one experienced four estrous cycles. The gilt experiencing four estrous cycles had cystic follicles at slaughter, and, as only seven days elapsed between the third and fourth matings, the last mating could have been a false heat. The response of these gilts is indicated in Table 9.

TABLE 9. NUMBER OF CORPORA LUTEA AND LIVE EMBRYOS AT FIRST FERTILE ESTRUS FOLLOWING A STIMULATED BUT NON-FERTILE PUBERAL ESTRUS

	Number of Estrous Cycles		
	2	3	4
Number of gilts	11	4	1
Av Number of CL	12.4	7.2	0
Range	7-15	13-14	0
Number gilts with embryos	9	3	0
Av number live embryos*	8.0	11	0
Range	4-14	8-13	0
Length of Estrous Cycles (days)			
2nd	13-33	8-14	21
3rd	-	21-25	20
4th	-	-	7

* at 30 days postmating

Of the 16 gilts with two or more estrous cycles, eight (50%) had seven or more live embryos at 30 days postmating; four (25%) had six or less live embryos; and four (25%) were infertile. These results indicate that a large percentage of gilts experiencing a nonfertile puberal estrus may have reproductive abnormalities which cause infertility or small litters. In contrast, of the 39 gilts that experienced only their puberal estrus and were mated, seven (18%) were infertile; four (10%) had six or less live embryos and the remaining 28 (72%) had seven or more live embryos at 30 days postmating.

VI. SUMMARY AND CONCLUSION

One hundred eighty-seven prepuberal, crossbred gilts of 81.5-90.5 kg were moved from a growing building to test areas, either as penmate groups or mixed together as strangers on the initial day of each trial. Several of the groups were exposed to a boar in various combinations of time and degree of exposure.

Several findings emerged from this study:

1. Moving penmate gilts to a new building was not a sufficient stimulus to cause the occurrence of puberty.

2. Mixing unfamiliar gilts combined with movement to a different building had a slight stimulatory effect on the occurrence of puberty (only for gilts over 210 days of age).

3. Exposing gilts daily to a boar, along with movement to strange buildings, for either mixed or non-mixed gilts, influenced a greater percentage of gilts to attain puberty than occurred among gilts not exposed to a boar ($P<.05$).

4. As the degree of daily exposure to a boar increased, the percentage of gilts attaining puberty also increased.

5. Providing daily exercise by taking the gilts approximately 30 meters to a boar increased the percentage ovulating ($P<.05$) for gilts which had only 30 minutes of daily contact with a boar.

6. By using a boar to induce estrus, a considerable degree of synchrony of puberal mating was obtained. Seventy percent of those gilts mating did so within a 7-day period, and 90% did so within a 10-day period.

Two conclusions can be drawn from these findings:

1. Boar presence significantly influences the attainment of puberty in the prepuberal gilt.

2. In studies where gilts have been subjected to factors for inducing estrus, such as hormonal injections or nutritional experiments and a boar has been used to ascertain the occurrence or estrus, the boar may well have a greater influence on the occurrence of puberty than the factor being investigated.

Age, as a factor affecting puberty, presented some surprising results. For example, on-test age had no effect on the attainment of puberty, but of those gilts ovulating, the younger gilts attained puberty in fewer days from the initial day of testing than did the older gilts ($P<.05$). However, the older non-ovulating gilts with large follicles had more large follicles than the younger, non-ovulating gilts with large follicles ($P<.05$). Age at estrus and number of CL for ovulating gilts were negatively correlated ($r=-.34$, $P<.05$). Days from initiation of test to estrus did not affect the number of CL. If the trials had been continued for several more days, then possibly the negative correlation between age and number of CL would not exist because the older gilts possessed a greater number of follicles 5 mm+ in size than did the younger gilts.

Within the narrow weight range (81.5-90.5 kg) of these experiments, weight had no effect on number of follicles, days to estrus, or number of CL. A trend did exist for the number of gilts attaining puberty to increase as their on-test weight increased.

False heat was not characterized by any age or weight group.

The change in size and color of the vulva of puberal gilts was highly indicative of the occurrence of estrus ($P<.01$). Ninety-four percent of the ovulating gilts exhibited vulva changes that were subjectively scored 1, 2, or 3 on at least one day during the trial, whereas 68.6% of the non-ovulating gilts were given a vulva score of zero throughout the entirety of the trial. Of the remaining 31.4% of the non-ovulating gilts (21 gilts), which constituted an error by having received a vulva score greater than zero and not ovulating, 18.6% (13 gilts) was contributed by gilts which had follicles greater than 5 mm in size, indicating ovulation probably would have occurred within 48 hours. These 13 gilts were rapidly approaching puberty and the vulva score reflecting vulva development was indicative of the approaching estrous period.

In the hormone study, gilts of 84.0-88.4 kg were taken to boars for five minutes daily exposure until mating and were mated once each day if in estrus. Thirty gilts bred in 17 or fewer days from initial boar exposure, and nine gilts required more than 17 days to mate from the initial day of exposure to the boar. Mean initial age on test for both groups was 181 days. The nine gilts that mated after the 17th day averaged 27 days older at first estrus (212.6 vs 185.4). Range in days to estrus was 19-56. Seven of these nine gilts ovulated and had 1.7 more CL (13.4 vs 11.7, $P<.05$) than did the 29 ovulating gilts (of the 30) that bred in 17 days or fewer.

These differences suggest that the additional 27 days between these two groups permitted some endocrine and/or other physiological development to occur which favored the older group in number of CL and number of live embryos at 30 days postmating. No differences in percentage of conception or embryo survival existed between the two groups.

The live embryo advantage in the older gilts fosters the idea that management practices which induce estrus in healthy, fast-growing gilts at an earlier than usual age would allow the gilts to undergo one or two more estrous cycles before mating, and may increase the number of ovulations and surviving embryos of the gilts above the current levels of gilts bred at equivalent ages but not experiencing an equal number of estrous periods. Accordingly, if inducement of estrus is allowed, a gilt could possibly experience her third estrus several weeks earlier than the standard eight months of age. In large herds, the savings in feed from younger mating age and from earlier culling of non-breeding gilts could be substantial and would more than offset any cost incurred by inducing early estrus.

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