A COMPARISON OF THE OVULATION RATE,

FERTILIZATION RATE AND EMBRYO

SURVIVAL OF HAND-MATED

AND LOT-MATED GILTS

By

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INTRODUCTION

Swine producers are vitally interested in the reproductive performance of their herds. Probably the most important measure of reproductive performance is litter size at weaning, which is a function of: (1) ovulation rate; (2) fertilization rate; (3) embryonic survival; and (4) survival of pigs after farrowing. Any nutritional or environmental change that would increase any one of these would also increase the number of pigs weaned.

Research has shown that the number of ovulations per sow is associated with age, weight and nutritional levels. Most researchers agree that fertilization rate is apparently an "all or none" process in swine, since fertilization rates generally are 95 percent or greater. However, rarely does a sow farrow as many pigs as ova ovulated. Numerous estimates of the percent of ovulated ova unaccounted for by birth of a live pig are found in the literature. These estimates are quite variable but generally run greater than 30 percent. Since fertilization rate is high, it is suggested that embryonic death is probably the major factor in reducing litter size. Some researchers have presented data which indicates post-breeding energy intake affects embryonic death rate. High ambient temperatures have also been shown to increase embryonic death, but not to the same degree in all species. This, and other evidence, suggests that the developing embryo may be vulnerable to all forms of stress.
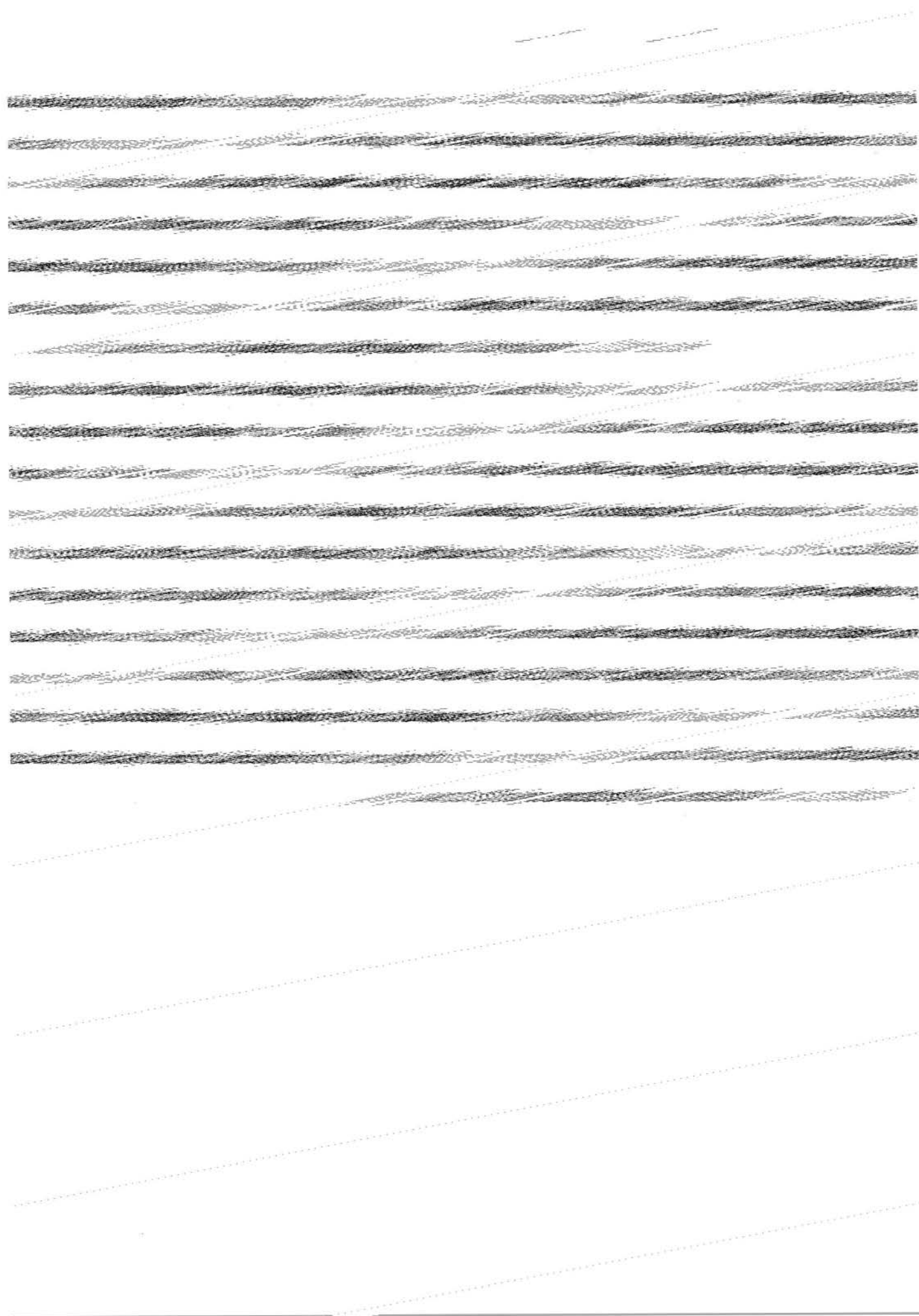
LITERATURE REVIEW

Baker et al. (1958) stated that embryonic survival rate appeared to have greater influence on litter size than did ovulation rate. A 33-40 percent embryonic death loss occurred in 85 percent of 229 sows reported by Becze (1962). He suggested that embryonic mortality was related to nutrition. It was stated by Schultz et al. (1966) that the rate of embryo survival was primarily affected by the level of post-breeding nutrition. When all treatments were pooled, their data indicated that the mean embryonic loss was approximately 18 percent by 25-27 days post-breeding. Perry (1954), Day et al. (1959), and Pomeroy (1960b) have reported embryonic death losses of 33-40 percent by 40 days post-breeding.

Perry (1962) reported that a relationship between the initial size of the litter (ovulation rate) and the proportion of embryos lost in pregnancy appears to be established by the twenty-fifth day post-coitum. He further stated, the relationship is apparently linear within litters in which some loss occurs.

Sorensen and Gossett (1956) compared the efficiency of different slaughter dates for determining embryonic mortality in swine. They found 74 percent of the ova as determined by corpora lutea counts were represented by live embryos at day 25 (post-breeding), compared to 67 percent survival of embryos at day 40. This indicates slaughtering at day 40 gives more accurate data. In a later paper, Gossett and Sorensen (1959b) again preferred slaughtering at 40 days gestation

rather than 25 for greater accuracy, since an additional 5 percent

mortality occurred in the additional 15 days of pregnancy.

<u>Pre-Breeding Nutritional Levels:</u>

Zimmerman <u>et al</u>. (1958) produced a flushing effect in gilts by

feeding glucose at the rate of 1 percent of their individual body weight

in addition to the basal ration. This feeding period extended from day

8 of their estrual cycle to their next estrus resulting in an increase

of 2.1 corpora lutea per gilt. Zimmerman <u>et al</u>. (1960) again illus-

trated there was an increase in ovulation rate caused from flushing.

Flushing intervals of 6, 10 or 14 days produced greater increases in

ovulation rate from one estrual period to the next than occurred as the

normal result of increased age in unflushed gilts (increases of 2.8,

3.2 and 3.9 ova respectively vs. an increase of 1.5 ova for unflushed

gilts).

Haines <u>et al</u>. (1959) obtained comparable results in two separate

trials using a total of 90 gilts. Each trial consisted of two treat-

ments beginning when the gilts were approximately 125 days of age.

Gilts on one treatment were full-fed (prior to mating) and the gilts on

the other treatment were fed at the rate of one-half that of the full-

fed gilts. The full-fed gilts ovulated an average of 2.9 more ova than

did the limited-fed gilts ($P < .01$). Of ova recovered, upon slaughter at

3 days post-breeding, 98 percent and 95 percent showed various stages

of cleavage for limited-fed and full-fed, respectively. Because both

of these are so high, it was assumed that the percentage of fertiliza-

tion was of minor importance in determining litter size at farrowing.

Haines <u>et al</u>. (1955) reported that a high energy intake was desirable

for high ovulation rate, but increased the amount of prenatal death.

Gilts receiving the basal ration supplemented with lard at the rate of 0.70 percent of their body weight for approximately 14 days before estrus, had significantly greater ($P<.05$) ovulation rates and larger mature follicle counts than did non-supplemented control gilts (Rigor, 1961). Rigor et al. (1963) reported supplementing the basal ration with lard for approximately 14 days at the same level as in the previous experiment, resulted in a significant increase of 3.3 ova in the potential ovulation rate ($P<.05$).

McGillivray et al. (1962) imposed three treatments upon sixty gilts, beginning about 10 days prior to the expected date of the estrus at which the gilts were mated. The treatments were: no feed; normal intake (4 pounds per head daily of a 16 percent protein ration); and high energy (4 pounds of the same diet plus 4 pounds of glucose per head daily). Ovulation rates were 11.6, 13.4 and 15.1 for starvation, normal intake, and high energy, respectively.

Additional data were presented by O'Bannon (1964) and O'Bannon et al. (1966) in support of flushing. These data indicate that ovulation rate was significantly affected by dietary energy levels and that a higher energy level increased ovulation rate. Christian and Nofziger (1952), Self et al. (1953), Hafez (1958), Adams (1960) and Schultz et al. (1965) have also shown that a high level of energy, fed for an extended period of time, prior to estrus increased ovulation rate over that of lower energy levels.

Schultz et al. (1966) individually fed 32 crossbred gilts, 6-8 months of age, to study the influence of feed intake on reproductive performance. The treatments were imposed at the end of the estrus just prior to the cycle in which they were mated and were terminated at

slaughter 25-27 days after mating. The high and low energy levels used in this study were 3.63 kg. and 1.81 kg. per head daily. The gilts on the high level prior to mating, ovulated significantly ($P < .05$) more ova per head than did the gilts on the low level prior to mating.

In contrast to the above, Gossett and Sorensen (1956, 1959a) and Goode et al. (1960) reported that gilts on lower energy levels ovulated at a rate quite comparable to high energy levels.

Post-Breeding Nutritional Levels:

Whatever physiological mechanisms are responsible for higher ovulation rates are (directly or indirectly) antagonistic to embryo survival (O'Bannon et al., 1966). In his report, as in other researchers' work, the high energy level increased ovulation. However, if the high energy level was continued after mating, it decreased embryo survival.

Prenatal death rates of 62.9 percent for high energy fed gilts vs. 35.3 percent for low energy fed gilts were estimated by Christian and Nofziger (1952). When the high plane of nutrition was continued after mating, the high energy gilts farrowed only 4.7 live pigs per litter compared to 7.4 live pigs per litter for low energy fed gilts ($P < .01$).

Ray and McCarty (1965) imposed four treatments upon 81 gilts after mating: Group 0 - mated and returned to original lot; Group 1 - mated and removed from feed for 24 hours; Group 2 - mated and removed from feed for 48 hours; and Group 3 - mated and removed from feed for 72 hours. When the gilts were slaughtered at 25-33 days post-breeding, group 0 had the lowest number of normal embryos per gilt and the lowest percent embryo survival. Group 2 had the most favorable results, yielding the highest number of normal embryos per gilt and highest percent embryo survival. However, when an additional 41 gilts were placed on

only groups 0 and 2, these results were not repeated.

Self et al. (1953) presented data indicating that regardless of prepuberal feed level, gilts full-fed from puberty to slaughter tended to have approximately 25 percent fewer embryos than corresponding limited-fed gilts. This is in agreement with Haines et al. (1955), Adams (1960), and Schultz et al. (1965).

A decrease in embryonic survival at 25 days gestation caused by a high plane of nutrition during post-breeding was noted by Goode et al. (1960), Goode (1962) and Goode et al. (1965). Goode et al. (1960) estimated this increase in embryonic death to be about 1.4 embryos per gilt.

Age and Weight:

Warnick et al. (1951) observed that ovulation rates tend to increase rapidly with successive heat periods, at least through the third period. Gilts conceiving at the third, and later head periods farrowed an average of 1.4 pigs per litter more than those conceiving at second heat, and 2.5 pigs more than those conceiving at first heat. An increase in ovulation with successive heat periods was also observed by Robertson et al. (1951a, 1951b), Self et al. (1953), Haines et al. (1955), and Goode et al. (1960).

Squiers et al. (1952) reported that number of ova shed was significantly correlated $(P < .05)$ with the age at which estrus was observed $(r = 0.31)$. An increase of 10 days age was associated with a linear increase of 0.35 of an ovum shed. Age was also significantly correlated $(P < .05)$ with litter size at 25 days $(r = 0.33)$. An increase of 10 days age at breeding was associated with an increase of 0.5 embryo present. The correlation between age at breeding and total ovum mortality was not

significant (r = -.11).

Reddy et al. (1958a) reported a correlation of 0.564 between ovulation rate and age of breeding. They also stated that age of gilt provides a better estimate of the reproductive functional stage than does live body weight. Rathnasabapathy et al. (1956) reported the following correlations at 55 days gestation: between litter size and age in days (r = 0.105); ovulation rate and age in days (r = 0.317); and mortality rate and age in days (r = 0.322). Each 10 days increase in age at breeding resulted in 0.48 more ovum shed. The highest correlation involving ovulation rate, however, was with 154 day weight (r = 0.342). Lerner et al. (1957) reported a significant (P$<$.01) correlation of 0.38 between age at breeding and number of corpora lutea.

Newman (1963) reported the regression of corpora lutea count on age at breeding in days of Lacombe gilts was .065 $\pm$ .025 corpus luteum per day. In contrast to this, Goode et al. (1965) found the number of eggs shed by Duroc gilts increased by 0.14 for each 10 days increase in age. Age at breeding was reported by Omtvedt et al. (1965) to be significantly (P$<$.01) and positively correlated with litter size (r = 0.12). However, this correlation was not significant when breeding weight was held constant. This indicates that the association of age at breeding with litter size was due primarily to the increased weight of gilts at breeding. Each 10 days increase in age at breeding resulted in an increase of 0.16 $\pm$ 0.03 pig farrowed per litter. Breeding weight was positively correlated to litter size (r = 0.19) and the regression of number of pigs farrowed per litter on breeding weight of dam was 0.02 $\pm$ 0.01.

O'Bannon (1964) correlated numerous factors with ovulation rate

and number of viable embryos obtained using 72 crossbred gilts. Ovulation rate was significantly (P<.01) correlated with: breeding weight (r = 0.421); and backfat thickness (r = 0.350). Significant correlations (P<.05) with number of viable embryos were: breeding weight (r = 0.253); post-breeding daily gains (r = 0.305); and backfat thickness (r = 0.258). In contrast to this latter correlation, Reddy et al. (1958b) reported a significant (P<.05) negative correlation (r = -.31) between probed backfat and pigs farrowed.

Within ration, O'Bannon et al. (1966) reported correlations between corpora lutea number and age and weight at time of breeding. When all animals and energy levels were pooled, age at time of breeding was positively correlated (r = 0.20) with corpora lutea number. Correlation between weight at time of breeding and the number of corpora lutea (r = 0.42) was highly significant (P<.01). Also reported was the correlation of 0.25 between body weight at time of breeding and number of viable embryos (P<.05).

Ellinger (1921) studied the records of 134 Danish sows where each had farrowed 10 litters. There was a quadratic line covering the litter means and increase in litter size occurred up to the sixth litter. Olbrycht (1943) reported that reproductive performance is lower in the first litter and increases with age of the sow, reaching its highest point in different breeds at a different age or litter order. The lower reproductive performance of young sows is due to the formation of a smaller number of ova. Stewart (1945) stressed that litter size increases with age of dam, but the rate of increase is quadratic, becoming less as age increases. According to this data, the effect of age on litter size is much more severe in the months before 12 than in those

after that age, and there is no further effect after 15 months of age. Pomeroy (1960a) and Bruflot (1962) stated those gilts that farrowed first at 14=15 months of age had a higher average litter size than those that farrowed first at the age of 12 months or less.

By simple regression, Sherritt (1962) found that each one=day increase in age of gilt at farrowing caused an increase of 0.009 pig farrowed. Squiers et al. (1950) concluded that both ovulation rate and embryo mortality were related to age in gilts.

Rathnasabapathy et al. (1959) studied 95 Landrace-Poland gilts and found weaning weight, 154=day weight and breeding age were positively associated with ovulation rate and mortality rate. Zimmerman et al. (1957) reported that such individual characteristics as pre=flush and post=flush weight, backfat thickness, as well as average daily gain and feed consumption during the flushing period were not significantly associated with an increase in ovulation rate of the 48 gilts studied.

Results presented by Bowman et al. (1961) indicate that weight of gilt at breeding exerts a greater influence on litter size than does age. Eckstein and McKeown (1955) found litter size of guinea pigs was positively correlated with maternal weight at conception and this association was independent of maternal age.

Temperature:

Heitman and Hughes (1949) stated that as air temperature increased, body temperature and respiration rate increased, but pulse rate decreased. Heitman et al. (1951) reported that exposure of sows approximately 85 days pregnant to high ambient temperatures will result in death of the sow before it will cause death and abortion of the litter.

Whatley et al. (1957) reported that sows and gilts sprinkled during

pregnancy (June-August) farrowed 10.06 live pigs per litter compared to 7.71 for the non-sprinkled. This difference was significant. The sprinkled sows also farrowed more total pigs but this was non-signifi-cant. During this period of 92 days, the average temperature was 96.3° F.

Warnick et al. (1961) subjected 32 Duroc-Landrace gilts to either an outside control or environmental chamber. The environmental chamber treatments were either 90° F. or 60° F. with one-half of each group reversed at 3 days post-breeding. Although the gilts exposed to 90° F. temperatures tended to have fewer embryos at 25 days post-breeding, the difference was nonsignificant. Their data indicated, however, that a high temperature of 90° F. may be more harmful to embryonic survival after 3 days post-breeding than a high temperature previous to 3 days post-breeding. In a continuation of this experiment, Warnick et al. (1965) reported that cooling sows during high ambient temperatures, especially soon after breeding, may increase embryo survival and sub-sequent litter size.

Ahlschivede and Robison (1966) collected data at two locations over a 5-year period representing 937 litters from Duroc, Yorkshire and crossbred females bred to Duroc and Yorkshire boars. Within the limitations of the study, they reported there was little association between climatic conditions at time of breeding and size of the subse-quent litters.

Ogle (1934) subjected white mice to a warm humid environment and showed lowered fertility in three ways: (1) low percentage of matings that resulted in pregnancy; (2) small litter size; and (3) low viability of offspring. Shah (1956) using the technique of reciprocal ova trans-

plantation in rabbits, concluded that the heat was acting adversely on the maternal tissue rather than directly on the embryo itself.

Fernandez-Cano (1958a) reported that either an increase or decrease in ambient temperature caused an increase in embryonic degeneration, mainly before implantation, in intact rats. However, a hypoxia condition induced embryonic degeneration mainly after implantation. Fernandez-Cano (1958b) found in adrenalectomized rats that an increase or decrease of body temperature or hypoxia did not increase significantly the embryonic mortality. It was observed by Austin (1956) that a hyperthermia condition induced before and during the time of ovulation in rats reduced the mean number of eggs ovulated from 10.5 to 7.5. It also decreased the rate of fertilization from 97 to 66 percent. Hyperthermia after ovulation, but before and during the time of spermatozoon entry, also led to a greater proportion of eggs containing two or more spermatozoa. Evidently the process involved in the 'zona reaction' is reduced in efficiency by hyperthermia whether applied before or after ovulation.

Macfarlane et al. (1957) used the Wistar strain of rats to show that resorptions took place mainly between the eighth and sixteenth day of gestation when exposed to temperatures of $35 \pm 0.4^{\circ}$ C. This resorption rate was significantly reduced in rats given 2-10 weeks acclimatization before mating. Aldred et al. (1961) subjected virgin female mice to 104° F. for 1, 3 or 5 hours on the day following mating or for 5 hours on day 1 and day 2 following mating. At autopsy on day 17 of pregnancy, there was a consistent increase in embryo loss as thermal stress was prolonged (control - 14.0 percent; 1 hour - 14.5 percent; 3 hours - 16.8 percent; 5 hours - 19.3 percent; 5 hours - day 1 and 2 -

32.5 percent). Embryo mortality following high temperatures was greater on day 1 (19.3 percent) than on day 2 (9.8 percent).

Alliston and Ulberg (1961) concluded that the critical period for the detrimental effects of temperature on fertility in sheep is while the ova are still in the oviduct. A decrease in fertilization rate accompanying an increase in temperature was reported by Alliston et al. (1961). Also, a loss of potential young occurs as a result of a cessation of development during cleavage. This is in agreement with experiments reported by Dutt et al. (1956, 1959) and Dutt (1960, 1963) showing that the zygote is most sensitive to the harmful effect of high ambient temperature during the initial stage of cleavage and while still in the oviduct of the ewe. In independent trials, Yeates (1953), Ulberg (1958) and Vincent and Ulberg (1965) presented additional information supporting the concept that short time exposure to temperature stress at time of breeding is harmful to subsequent embryo survival.

Dutt and Simpson (1957) concluded that a higher percentage of fertilized ova were recovered from ewes mated to rams kept at 45-48° F. during the summer months, as compared with rams kept under prevailing summer temperatures. It was reported by Whiteman and Brown (1959) that cooled rams produced more lambs primarily because they made more matings. Salisbury and Flerchinger (1963) reported a drop in conception rate of 10 percent occurred during the hot months of July-September in dairy cattle. Evidence was presented by Warnick et al. (1965) which indicated that high temperature did not reduce fertility of the boar.

In a review on environment and reproduction in farm animals, Hafez (1965) stated that thermal stress causes morphological abnormalities of ova. He further stated that overheating results in physiological stress

which conceivably could affect reproduction by creating an unfavorable endocrine balance.

In working with cattle, Paufler (1963) reported a significant correlation (r = 0.87) between fertility and relative humidity during the grazing season in South Hanover when the summer was very hot and humidity very low. Stott and Williams (1962) presented evidence which indicates that a low rate of fertilization and a high rate of embryonic mortality are the major factors causing the low seasonal breeding efficiency associated with high ambient temperature.

Mating Behavior:

Turkheimer et al. (1957) studied the effect of collection interval on semen characteristics in 6 Yorkshire boars 10 months of age. Half of the group was collected daily and the other half at 3-day intervals for 3 weeks, the groups were then rested for 5 weeks and reversed for an additional 3 weeks. Volume and concentration were lower in the group collected daily. Hale and Almquist (1960) concluded it is the number of sperm removed, rather than the number of ejaculates, that is critical.

Gerrits et al. (1962) assigned 4 adult boars (1-2 years of age) to a sequence of collection intervals of once every 4 days, every other day and daily for a period of 20 days. Volume and concentration decreased as collection interval decreased. When boars were collected daily, a decrease in percent of motility and an increase in percent of abnormal spermatozoa was observed. There was significant difference in the percent of abnormals between boars, but not between treatments. In this study, the boars collected at 48-hour intervals resulted in greater total spermatozoa production.

A series of observations on the mating habits of swine were

reported by the Nebraska station. Multiple matings were reported to have occurred quite frequently as a result of the boars being allowed free access to the group of females. Twenty-one of 26 gilts observed were mated 2 or more times with the average mating frequency of 3.54 (Sumption and Adams, 1961). Great variation was noticed in female behavior. For example, 1 gilt mated with 7 of 9 boars in a 2-day period for a total of 12 times, and another gilt mated 10 times with 8 different boars (Sumption et al., 1959). On the other extreme, some gilts yielded to one mating only after persistent pursuit (Sumption, 1961).

Borton and Nellor (1964) found no significant differences in litter size due to number of services at time of breeding. An additional 1.5 pigs per litter when gilts were mated twice at intervals of 16-20 hours was reported by Reddy et al. (1958a), but no additional benefit was realized from a third service. Squiers et al. (1952) stated that a higher percent of females became pregnant when mated twice (24 hours apart) than when mated only once, although no advantage in litter size was observed. In contrast, Rathnasabapathy et al. (1956) presented data indicating "two-service gilts" (24 hours apart) had a smaller litter size than "single service" even though they had a larger ovulation rate.

Ova Recovery:

Corner (1921) and Anderson (1927) estimated the time ova spent in the oviduct of the sow to be approximately 3 days. Pomeroy (1955) reported that earlier workers had overestimated the time and actually it was between 24 and 48 hours. Ovulation time has been estimated to occur 32-39 hours after the onset of estrus and the duration of ovulation was 1-3 hours (Pitkjanen, 1958; 1962). Results presented by Vincent et al. (1964) agreed with the above time of ovulation.

Oxenreider and Day (1965) studied transport and cleavage of ova in 55 gilts. Estrus was checked at 6-hour intervals with mature boars, with onset of estrus estimated to be midway between last refusal and first acceptance of the boar. The animals were slaughtered at 6-hour intervals between 24 and 108 hours after onset of estrus (except those between 66 and 78 hours that were slaughtered on 3-hour intervals). It was found that all ovulation had occurred between 30-42 hours after onset of estrus and that ova had remained in the oviduct until 66-90 hours after onset of estrus.

Fertilization rates of 95 percent or greater have been reported by Squiers et al. (1950), Haines et al. (1959), Perry and Rowlands (1962) and Burfening and Ulberg (1966). Squiers et al. (1952) stated that fertilization appears to be an "all or none" process. Warnick et al. (1951) reported an overall fertilization rate of 82 percent, but found that only 3.2 percent of the animals had no fertilized eggs, and 49.2 percent had all eggs fertilized when bred in the first 24 hours of heat.

Cleavage has been the standard criteria used in determining fertilization rate. Dziuk (1960) described ova fragments in 8-16 equal sizes resemble a normally-cleaving, fertilized ova and is a potential source of error. This fragmentation was also reported by Hancock (1961), who suggested that changes resembling those that occur in fertilized ova are more common in the pig than in other species. Hancock (1961) further suggested that where cleavage is to be used as evidence of fertilization, the most suitable time for recovery of ova is about 72 hours after the onset of heat for sows mated on the first or second day of heat.

Hancock (1961) and Hancock and Hovell (1962) estimated that

cleavage began about 20 hours after fertilization in the pig. Rate of cleavage was estimated to be about one division per day by Heuser and Streeter (1929).

Forced Stress:

Nofziger and Ensminger (1960) subjected 40 Palouse gilts (about 30 days pregnant) to 4 environmental conditions. These included transportation stress (hauled by truck 160 miles), a change in surroundings (placed in pen with strange sows), a combination of the previous two, and a control group. No significant difference was observed in potential litter size when gilts were slaughtered 10 days post-treatment. However, all three of the stressed groups had a lower mean litter size than controls. Nofziger (1961) reported on a similar experiment utilizing 80 Palouse gilts but no significant differences were reported.

One hundred forty-four fine wool ewes were randomly assigned to one of four experimental treatments: forced exercise, shade plus a water sprinkler, air conditioned room or outside ambient temperature (Spies et al., 1965). Those ewes cooled at approximately 65° F. had the highest percent fertilized ova. Larger lambing rates were observed among ewes cooled until day 25 of pregnancy compared with non-cooled ewes. Ewes exercised daily for 30 minutes or 1 hour from 7 or 10 days prior to breeding to day 3 post-breeding had lower ($P < .05$) fertilization rates than nonexercised ewes. Rectal temperatures were significantly increased by exercise and it took 3-5 hours for body temperature to subside after 30 minutes exercise.

In the content of this literature review, it has been shown that approximately 30 percent of the fertilized ova are not represented at 30-40 days post-breeding by a viable embryo. Some of the factors

contributing to the loss of potential fetuses are level of nutrition, temperature and physiological stress.

MATERIALS AND METHODS

This study was composed of eight trials conducted at the Oklahoma
State University swine farm, Stillwater, Oklahoma, between August 1964
and November 1966. Following is a description of the general character-
istics common in all trials. The specific characteristics within each
group will be described later under their respective trials.

A total of 148 purebred Yorkshire gilts, ranging in age from 7 to
14 months were involved in this study. All of the gilts were from the
Oklahoma State University swine herd, and, prior to placement on the
experiment, were managed in a practical and conventional manner. An
effort was made to balance weight, age and litter mates when allotting
gilts to treatment. The boars used were also from the purebred York-
shire herd at Oklahoma State University and were mature boars of proven
fertility.

Treatment groups were maintained in pens 48 x 200 feet with a
20 x 10 x 8 feet quonset hut for shelter. The shelters ran north and
south, had an earth floor, were open on the south, and could be either
opened or closed on the north. Automatic waterers were available and
located in the same position in each lot. With the exception of Trial
8, the two treatment groups in each trial were separated by one pen of
similar size to eliminate any possible effect the presence of a boar in
the adjacent lot could have upon the reproductive performance of the
hand-mated group.

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Feeding facilities and rations were the same for all trials. In Trials 2 through 4 and 6 through 8, inclusive, the gilts were flushed by increasing daily feed levels for 2 weeks prior to expected date of breeding and then decreasing to preflush levels after breeding. In Trials 1 and 5, flushing was not carried out. A standard 14 percent protein ration was fed in all trials. Composition of the ration is shown in Table 1. The gilts were fed in individual stalls and given approximately one hour to clean up their feed. They were then returned to the pen with other gilts on the same treatment. All gilts were weighed at 2-week intervals and just prior to slaughter.

TABLE I

COMPOSITION OF THE RATION FED DURING THIS SERIES OF TRIALS

Component (% protein)	lb./ton
Milo (8%)	1592.4
Soybean Oil Meal (50%)	208.6
Tankage (60%)	50.0
Alfalfa Meal (17%)	100.0
Dicalcium Phosphate	25.0
Calcium Carbonate	10.0
Trace Mineral Salt	10.0
Vitamin B_{12}	2.4
Fortafeed 2-4-9-90	1.2
Zinc Sulfate	.4

After breeding, the gilts were slaughtered at a local packing house and the reproductive tracts were recovered. Slaughter was limited to 2 or 3 days per week; therefore, gilts utilized to study embryonic survival were slaughtered in the range of 30-35 days post-breeding. The following observations were made 2-6 hours after recovery of the repro-

ductive tract: (1) number of corpora lutea on each ovary; (2) number of
viable embryos present in each uterine horn; and (3) number of dead
embryos present in each uterine horn. An incision was made the full
length of the uterine horn, all embryos were removed and carefully
examined. Any grossly abnormal, severely hemorrhagic or decomposed
embryo was classified as dead.

All of the gilts in Trial 5 and one-half of the gilts in Trial 8
were utilized to study fertilization rate in lot-mated and hand-mated
gilts. Gilts were slaughtered 2 days after the first day of heat, if in
heat only 1 day, or 3 days after the first day of heat if in heat 2 or
more days. The following method for recovering and examining fertilized
ova was carried out within 2-6 hours after recovery of the reproductive
tract. The broad ligament was trimmed away from the oviduct to facili-
tate flushing. The oviduct was separated from the uterus one-half inch
posterior to the utero-tubal junction and flushed with 10 cc of 0.9 per-
cent saline solution. The flushings were collected in test tubes and
allowed to settle for approximately one hour. The supernatant fluid was
carefully decanted to avoid disturbing the bottom 0.5 cc in the tube.
This fraction was poured into a watch glass and examined under a micro-
projector for the presence of ova. As ova were located, they were
removed by means of an eye dropper and transferred to a separate watch
glass for more detailed study of cleavage under high power magnification.
Any normal appearing ovum that had undergone at least one cellular
division was classified as fertilized. The supernatant was saved for
additional observations if necessary to attempt to recover the number of
ova indicated by the number of corpora lutea.

Two types of mating systems were imposed in this study: lot-mating

and hand mating. In the lot-mated groups, one boar was allowed to run with a group of gilts and mate at will. The boars were rotated two or three times a day to insure that a fresh boar ran with the gilts at all times. No limit was placed on the number of services per gilt nor was there any control of the stress placed upon the gilt by the mating behavior of the boar. The lot was checked frequently to obtain breeding dates.

In the hand-mated groups, the herdsman checked the gilts for evidence of estrus. A gilt was determined to be in estrus by visual observation of the external genitalia and her response to pressure applied on the back. In all cases, when a gilt was in standing estrus she would stop and assume a receptive stance when pressure was applied on the back. When a gilt was observed to be in estrus, she was removed from the pen, placed in an adjacent breeding crate and a boar allowed to mate with the gilt. Each hand-mated gilt was allowed one mating for each day of standing heat in an attempt to hold any stress associated with mating to a minimum.

Trial 1:

Twenty Yorkshire gilts were allotted equally to either the lot-mated group or the hand-mated group on August 10, 1964. The average ages and weights of the two groups were: lot-mated, 252 days and 286 pounds; and hand-mated, 249 days and 287 pounds. Gilts on both treatments were fed at the rate of 4.0 pounds per head daily from August 10 to August 25. On August 25, this was increased to 4.5 pounds for the duration of the trial or until slaughter. Fresh boars were rotated in the lot-mated group at 8:00 a.m. and 5:00 p.m. daily.

Trial 2:

Eighteen Yorkshire gilts were allotted equally November 3, 1964 to either the lot-mated or hand-mated group. The average ages and weights at onset of the trial were: lot-mated, 269 days and 285 pounds; and hand-mated, 274 days and 294 pounds. These gilts were started on 5 pounds per head daily and increased to 7 pounds per head daily for 14 days prior to breeding. As each individual gilt was bred, the energy level was decreased to 5 pounds per head daily. In the lot-mated group, fresh boars were rotated daily at 8:00 a.m., 1:00 p.m. and 5:00 p.m.

Trial 3:

Twenty Yorkshire gilts were allotted equally to either a lot-mated or hand-mated group on February 4, 1965. The average ages and weights at the beginning of the trial were: lot-mated, 350 days and 372 pounds; and hand-mated, 350 days and 378 pounds. Gilts in Trial 3 were started on 5.5 pounds per head daily, which was then increased to 8 pounds per head daily for approximately 14 days. As each individual gilt was bred, her daily energy intake was decreased to 5.5 pounds. Fresh boars were rotated in the lot-mated group at 8:00 a.m., 1:00 p.m. and 5:00 p.m. daily. In this trial, an additional stress was imposed upon the lot-mated gilts. Beginning the day following the last day of heat, each gilt was placed in the boar lot for 5 minutes on each of 5 consecutive days. The boars were allowed to run the gilt at will.

Trial 4:

Eighteen Yorkshire gilts were allotted equally to either a lot-mated or hand-mated group on March 25, 1965. The average ages and weights of the two groups were: lot-mated, 236 days and 290 pounds; and hand-mated, 235 days and 282 pounds. All gilts were fed 5.5 pounds per

head daily until April 20, 1965. Energy level was then increased to 7
pounds per head daily until bred. After breeding, the energy level was
decreased to 5 pounds per head daily. Fresh boars were rotated in the
lot-mated group at 8:00 a.m., 1:00 p.m. and 5:00 p.m. daily. The lot-
mated gilts were again exposed to added stress as in Trial 3.

Trial 5:

Fourteen Yorkshire gilts were allotted equally to one of two treat-
ments on June 8, 1965. The average ages and weights for the two groups
were: lot-mated, 194 days and 267 pounds; and hand-mated, 196 days and
254 pounds. These gilts were maintained on 5 pounds of feed per head
daily. Boars were rotated daily at 8:00 a.m., 1:00 p.m. and 5:00 p.m.
in the lot-mated group. All gilts on this trial were slaughtered at 2
or 3 days post-breeding to obtain an estimate of fertilization rate.

Trial 6:

Twenty Yorkshire gilts with an average age and weight of 229 days
and 244 pounds were placed on test September 24, 1965. All gilts in
this trial were treated the same. They were flushed with 6 pounds of
feed per head daily, hand-mated and reduced to 5 pounds per head daily
after breeding. These gilts are included in the correlation and
regression study only.

Trial 7:

Fourteen Yorkshire gilts were allotted equally to two treatments
on December 23, 1965. Treatments imposed in this trial were different
levels of energy intake after mating. Both groups were hand-mated after
flushing for approximately 14 days with 7 pounds feed per head daily.

In Treatment 1, the gilts were reduced in feed intake to 3 pounds
per head daily for 10 days after breeding, and then increased to 5

pounds per head daily until slaughter. Treatment 2 consisted of
decreasing the energy level to 5 pounds per head daily after breeding
where it remained until slaughter. The average ages and weights for the
two treatments were: Treatment 1, 205 days and 230 pounds; and Treat-
ment 2, 210 days and 230 pounds.

Trial 8:

Twenty-four Yorkshire gilts were equally allotted to two treatments
on August 12, 1966. The average ages and weights for the two groups
were: lot-mated, 249 days and 259 pounds; and hand-mated, 251 days and
259 pounds. Both groups were fed the same throughout the trial. They
were flushed for approximately 14 days with 7 pounds per head daily. At
the time of breeding, the feed level was reduced to 5 pounds per head
daily where it remained until slaughter. Boars were rotated in the lot-
mated group at 6:00 a.m., 12:00 noon and 5:00 p.m. One-half of the
gilts were slaughtered at 30-37 days post-breeding. The order of breed-
ing determined which gilts would go in which slaughter group.

Within each treatment group, the first, fourth, fifth, eighth,
ninth and twelfth gilts to breed were slaughtered 2-3 days post-breeding
to estimate the rate of fertilization. The second, third, sixth,
seventh, tenth and eleventh gilts to breed were slaughtered 30-37 days
post-breeding for an estimate of embryo survival. If for any reason a
gilt failed to settle and returned to estrus, she was rebred and
slaughtered 2-3 days post-breeding. This was done because it was desir-
able to complete the trial as quickly as possible to reduce the possible
effect of season.

RESULTS AND DISCUSSION

This study was conducted to measure the effect of hand-mating and lot-mating on the reproductive performance of gilts. Differences in numbers of embryos and percent embryo survival at 30-35 days post-breeding were tested by covariance analysis with ovulation rate held constant. Differences in number of corpora lutea between the two mating systems were tested by the "t" test.

In this study, 137 of 148 gilts started on experiment gave data which could be statistically interpreted. Eleven gilts were eliminated for various reasons. One gilt from the lot-mated group of Trial 3 aborted April 12, 1965, but there was no evidence that this abortion was the result of the treatment. The data on two gilts, one from each group, were removed from Trial 5 prior to analysis because it appeared that they would have returned to estrus the next cycle. The lot-mated gilt had zero percent fertilization of those ova recovered and the hand-mated gilt had only 16.7 percent fertilization (1 of 7 ova recovered had undergone cleavage). Polge et al. (1966) presented evidence which suggested that more than 4 embryos were required in the pig to establish and maintain pregnancy. In Trial 8, 6 gilts failed to contribute applicable data. Included in this group was 1 lot-mated gilt that had failed to ovulate by the time of slaughter 2 days post-breeding. One gilt from the lot-mated group was pregnant to an unobserved mating at an unknown date prior to going on trial. Two gilts, one from each group,

were observed in estrus 31 days post-breeding, were bred and the rate of fertilization was excellent in both gilts, however, the data from these two gilts were not used because there had been a considerable time lapse and also a drastic change in weather conditions. One other hand-mated gilt was removed because she did not exhibit estrus and upon slaughter was found to have large cystic ovaries.

Ovulation Rate:

The ovulation rates observed are presented in Table II and shown graphically in Figure 1. There were no significant differences in ovulation rate, as measured by number of corpora lutea. The means for all trials were 16.02 for 51 lot-mated gilts and 15.77 for 52 hand-mated gilts. The lot-mated gilts had the larger ovulation rate in four trials compared to two trials in which the hand-mated gilts had a greater rate of ovulation. The data indicated that method of mating had very little, if any, effect upon ovulation rate. It would appear that the most apparent advantages of lot-mating were to reduce labor requirements and to reduce human error in detecting estrus.

The observed differences in mean ovulation rates between trials appear to be largely due to the differences in age and weight at the beginning of each trial (Table III). It was interesting to note that as age or weight increased, ovulation rates tended to increase. There was also evidence that other factors, in addition to weight and age, were important in governing the number of ovulation sites per estrus.

Although flushing and non-flushing were not compared in the same trial, some indication of the effect of flushing could be obtained when Trials 1 and 2 were compared. The increased number of ovulation sites in the flushed gilts of Trial 2, as compared to the non-flushed gilts of

TABLE II

MEAN OVULATION RATE AND MEAN DATE OF CONCEPTION FOR
LOT-MATED AND HAND-MATED GILTS

	Lot-Mated				Hand-Mated		
Trial	No. Gilts	No. C.L.	Mean Conception Date		No. Gilts	No. C.L.	Mean Conception Date
1	9	15.44	Sep. 12		10	14.40	Oct. 5
2	9	17.44	Dec. 24		9	17.67	Dec. 18
3	9	19.00	Mar. 1		10	18.40	Mar. 3
4	9	16.11	May 17		9	15.33	May 11
5	5	14.60	Jul. 20		6	14.50	Jul. 15
8[a]	10	13.50	Sep. 8		8	13.63	Sep. 10
All	51	16.02			52	15.77	

a = Includes both slaughter groups (2 day and 30 day gilts).

TABLE III

MEAN AGE AND WEIGHT AT THE BEGINNING OF THE TRIAL
FOR LOT-MATED AND HAND-MATED GILTS

	Lot-Mated				Hand-Mated		
Trial	No. Gilts	Age, Days	Weight, lbs.		No. Gilts	Age, Days	Weight, lbs.
1	10	252	286		10	249	287
2	9	269	285		9	274	294
3	10	350	372		10	350	378
4	9	236	290		9	235	282
5	7	194	267		7	196	254
8	12	249	259		12	251	259

Trial 1, was greater than would be expected if the only difference between the two groups of gilts were the few additional days of age and pounds of weight. The effects of flushing were also noted by Zimmerman et al. (1958), Haines et al. (1959), Zimmerman et al. (1960), and Rigor et al. (1963). It was also interesting to note that the younger, non-flushed gilts in Trial 5 had a larger mean ovulation rate than the flushed gilts in Trial 8; even though they weighed practically the same. This evidence suggested that some genetic or management factor, or factors, associated with the difference in "doing ability", as measured by difference in weight per day-of-age, was responsible for the increase in ovulation rate of Trial 5 over Trial 8. In agreement with this, Bowman et al. (1961) indicated that weight of gilt at time of breeding exerts a greater influence on litter size than does age. Also, this was in partial agreement with Omtvedt et al. (1965); they reported that the association of age at breeding with litter size was due primarily to the increased weight of gilts at breeding.
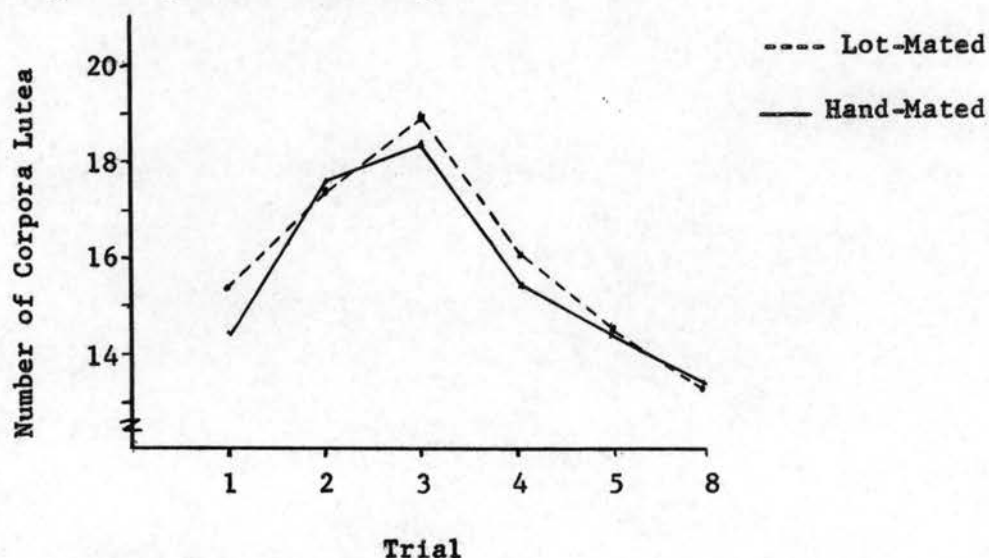

Figure 1. Mean Number of Corpora Lutea
Per Gilt in Each Trial for
Lot-Mated and Hand-Mated
Gilts

Shelton (1960) with Angora does; Schinckel (1954) and Watson and Radford (1960) with ewes; Whitten (1956a, 1956b, 1959) and Parkes and Bruce (1960) with mice; reported that the estrus cycle of certain mammals was modified by an exteroceptive stimulus functioning through one of the chemical senses. Therefore, it was postulated that the constant presence and teasing of the boar might stimulate additional ovulation sites or cause earlier breeding than observed in hand-mated gilts, which were not in physical contact with a boar except for the period required for copulation. However, the data presented in Table II does not indicate that the constant presence of the boar caused either an increased ovulation rate or an earlier conception in the lot-mated gilts. There was no consistent advantage in average date of conception in favor of either method of mating. Only in Trial 1 was there a marked difference in the mean date of conception. Since this was the first trial conducted, this difference might not be real; but rather could be caused by undetected estrus periods in the hand-mated gilts due to lack of experience by the herdsman. This suggestion was substantiated by the evidence in succeeding trials. Also, there was no indication that conception rate was impaired by the hand-mating technique. Throughout the course of this experiment, 3 gilts from each group, lot-mated and hand-mated, failed to conceive from first service.

Embryo Survival:

The mean number of viable embryos, percent embryo survival and their standard errors, by trials, are presented in Table IV. Also, these means are presented graphically in Figures 2 and 3. Analysis of covariance was run on number of viable embryos and percent embryo survival at 30-35 days post-breeding with number of corpora lutea held

TABLE IV

MEANS AND STANDARD ERRORS FOR NUMBER OF CORPORA LUTEA, NUMBER OF EMBRYOS AND
PERCENT EMBRYONIC SURVIVAL PER GILT 30-35 DAYS POST-BREEDING
OF LOT-MATED AND HAND-MATED GILTS

Trial	Lot-Mated				Hand-Mated			
	No. Gilts	No. C. L.	No. Embryos	% Embryo Survival	No. Gilts	No. C. L.	No. Embryos	% Embryo Survival
1	9	15.44+.858	10.55+1.005	68.13+6.209	10	14.40+.814	11.50+ .954	81.73+5.891
2	9	17.44+.737	12.11+1.018	70.44+5.926	9	17.67+.737	14.44+1.018	82.09+5.926
3	9	19.00+.743	12.78+ .784$_a$	67.57+2.913$_b$	10	18.40+.705	15.40+ .743$_a$	83.45+2.763$_b$
4	9	16.11+.711	12.56+1.058	79.51+6.778	9	15.33+.711	11.92+1.058	77.04+6.778
8$_e$	5	13.00+.860	10.80+1.073	83.72+3.861	2	14.00+.962	10.00+1.697	70.75+6.105
All	41	16.51+.221	11.85+ .381$_d$	71.79+2.477$_c$	40	16.33+.224	13.15+ .386$_d$	80.55+2.508$_c$

a, b Values with the same subscript are significantly different ($P < .005$).

c   Values with the same subscript are significantly different ($P < .05$).

d   Values with the same subscript are approaching significance ($P < .10$).

e   The ovulation rates reported in this table for Trial 8 include only those gilts slaughtered
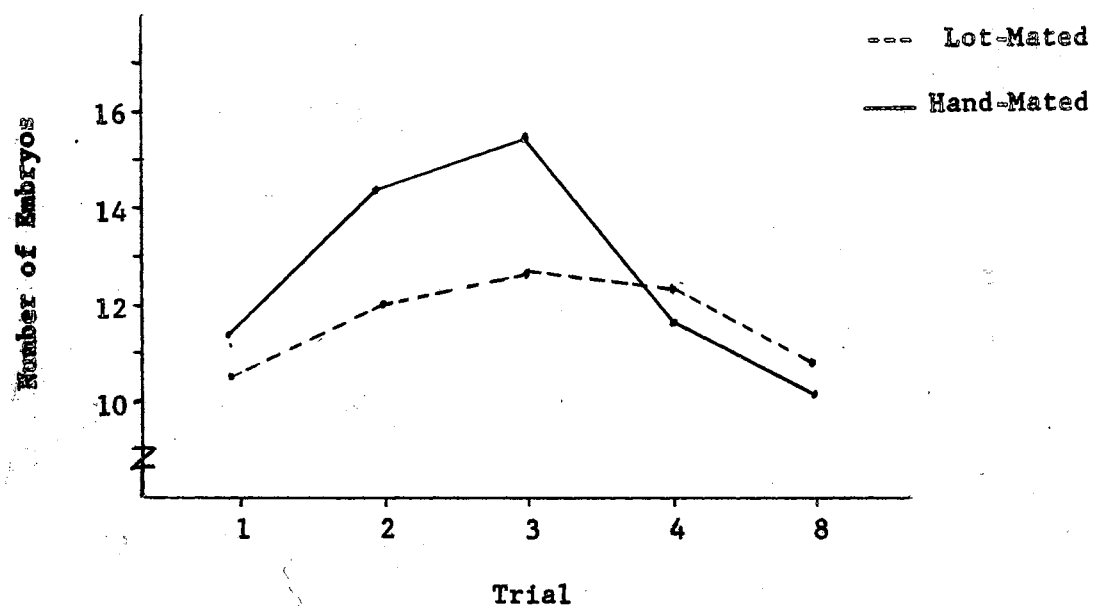at 30-35 days post-breeding.

Figure 2. Mean Number of Live Embryos Per Gilt
in Each Trial for Lot=Mated and
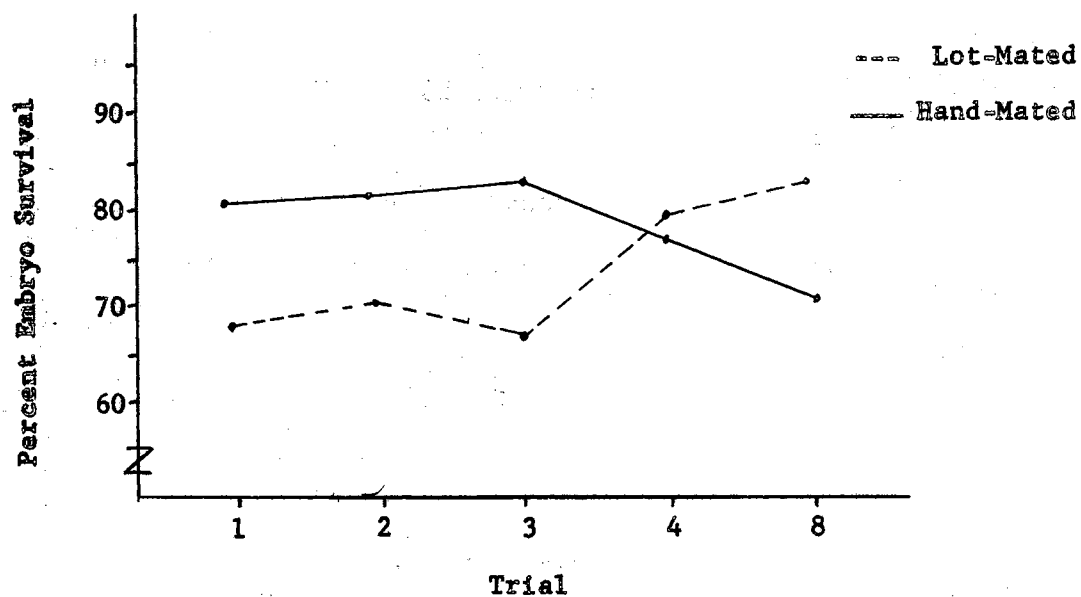Hand=Mated Gilts at 30=35 Days
Post=Breeding

Figure 3. Mean Percent Embryo Survival Per Gilt
in Each Trial for Lot=Mated and
Hand=Mated Gilts at 30=35 Days
Post=Breeding

constant. The mean percent embryo survival was determined by the total number viable embryos at 30-35 days post-breeding divided by total number corpora lutea.

Within Trials 1 and 2 the ovulation rates of the two methods of mating were very similar; but in both trials the hand-mated gilts had a larger number of viable embryos, which resulted in an increase of approximately 12 percent in embryo survival. The means were: for lot-mated gilts, 10.55 and 12.11 embryos with 68.13 and 70.44 percent survival for Trials 1 and 2, respectively; for hand-mated gilts, 11.50 and 14.44 embryos with 81.73 and 82.09 percent survival for Trials 1 and 2, respectively. Although these differences were non-significant, it suggested that some factor associated with the presence of a boar with the gilts at all times, was responsible for an increase in embryonic death. One very logical assumption was that this factor was the stress created by the mating behavior of the boar.

To test this more critically, in Trials 3 and 4 the lot-mated gilts were exposed to an added stress. Assuming the day of breeding as day 0, additional stress was placed on each lot-mated gilt by placing her in a pen with several fresh boars for 5 minutes each day for 5 consecutive days, beginning on day 1. Within Trial 3, the differences in number of embryos and embryo survival in favor of the hand-mated gilts were both highly significant ($P < .005$). The means were 12.78 embryos and 67.57 percent survival compared to 15.40 embryos and 83.45 percent embryo survival for lot-mated and hand-mated gilts, respectively. This evidence was in agreement with the results obtained from previous trials, and was further evidence that the mating behavior of the boar was placing a deterimental stress upon the lot-mated gilts.

However, in Trial 4, these results were reversed, although the differences were not significant. The lot-mated gilts had a mean of 12.56 embryos and 79.51 percent survival vs. 11.92 embryos and 77.04 percent embryo survival for hand-mated gilts. The reason for this reversal in reproductive performance was not evident; but was partially due to the performance of one gilt in the hand-mated group of Trial 4. This gilt had only 3 embryos (a survival rate of 20%) and no other gilt of either group had less than 9 embryos (a survival rate of 69%). Also, this same gilt had a considerably lower percent survival than any other gilt (20% survival compared to the next lower survival rate of 52%). Assuming her performance was the result of a chance occurrence and had a disproportional effect upon the mean of a small sample (9 head), removing this one gilt increased reproductive performance to 13.00 embryos and 84.55 percent survival for hand-mated gilts compared to 12.56 embryos and 79.51 percent survival for lot-mated gilts. Although, the difference between these values would not be of the same magnitude as previous trials, the advantage would be in the same direction. One can only speculate as to the reason for the smaller difference observed in Trial 4 as compared to previous trials. One possible reason is related to the season of the year in which the trial was conducted. The gilts in Trial 4 were bred and slaughtered during the months of May and June.

One-half of the gilts in each mating group of Trial 8 were slaughtered 30-35 days post-breeding for a measure of embryonic survival. Unfortunately, only 2 gilts from the hand-mated group contributed applicable data; for this reason they are included for information only and no importance is attached to them. The lot-mated gilts had a larger

number of embryos and percent embryo survival than hand-mated gilts
(10.80 embryos and 83.72% survival compared to 10.00 embryos and 70.75%
survival for lot-mated and hand-mated gilts, respectively). These
results were opposite of those reported for Trials 1, 2, and 3. They
would have also been in contrast to Trial 4, if an adjustment was made
for the one extremely low performing gilt in that trial. Therefore, it
was believed that the information obtained from this segment of Trial 8
was not a precise estimate of the response caused by lot-mating and
hand-mating Yorkshire gilts.

One of the reasons for finding significance only in Trial 3 was
probably related to the nature of the variation within groups. Although
Trial 3 had the largest means in quantity, it also had the smallest
amount of within variation, approximately one-half that of any other
trial as judged by the size of the standard errors. This small varia-
tion within groups of Trial 3 allowed a smaller error term for testing
significance. There was no apparent reason why this sample of gilts
should have had a smaller within group variation because they were
chosen by the same method and from the same base population as were the
gilts in other trials. They were also housed, fed and managed under the
same conditions; therefore, environment should not have been a major
factor. There is always the possibility that the results obtained in
Trial 3 were due to chance; however, it is also possible that the true
difference between the two systems of mating was so small that it
required a uniform responding group of gilts, such as those in Trial 3,
to show this difference statistically when a small sample was used.

When methods of mating were pooled across trials, the hand-mated
gilts exhibited a slight advantage in number of viable embryos ($P < .10$)

and percent embryo survival (P< .05) of 13.15 embryos and 80.55 percent survival vs. 11.85 embryos and 71.79 percent survival for lot-mated gilts. This was equivalent to a mean difference of 1.3 additional live embryos and 8.76 percent increase in embryo survival per hand-mated gilt at 30-35 days post-breeding. This significant advantage disagrees with the suggestion that the significance reported in Trial 3 was due to chance alone. These results are in agreement with those reported by Nofziger and Ensminger (1960) in which they exposed bred gilts (30 days pregnant) to a stress by hauling them 160 miles by truck, placing in a pen with strange sows or a combination of the two. They reported a non-significant reduction in the mean potential litter size in the stressed groups 10 days post-treatment.

Fertilization Rate:

One reason for the differences observed in embryo survival could be a difference in fertilization rate. In an attempt to determine whether there was a difference in fertilization rate and, if so, its magnitude, two trials (Trials 5 and 8) were conducted. All of the gilts from Trial 5 and one-half of the gilts from Trial 8 were slaughtered either 2 or 3 days post-breeding, the ova were recovered and examined for fertilization. Rate of fertilization was determined by the percent of those ova recovered that had undergone cleavage. The results are shown in Table V.

There were no significant differences in percent of ova fertilized between the two mating systems in either Trial 5 or 8. As was the case in previous trials, the variation within groups was greater than the variation between groups. However, there was a trend existing in the means which agreed with other trials. The lot-mated gilts had a

TABLE V

MEANS AND STANDARD ERRORS FOR NUMBER OF CORPORA LUTEA AND PERCENT
FERTILIZED OVA RECOVERED 2-3 DAYS POST-BREEDING
FROM LOT-MATED AND HAND-MATED GILTS

Trial	Lot-Mated				Hand-Mated			
	No. Gilts	No. C. L.	% Ova Recovered	% Fertilized of those Recovered	No. Gilts	No. C. L.	% Ova Recovered	% Fertilized of those Recovered
5	5	14.60± .826	65.8	88.64±6.093	6	14.50± .754	74.7	90.38±5.563
8	5	14.00±1.216	84.3	94.06±2.393	6	13.50±1.110	81.5	96.97±2.185
Both	10	14.30± .760	74.8	89.72±3.071	12	14.00± .694	78.0	92.37±2.803

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slightly larger rate of ovulation than the hand-mated gilts (Figure 4).
In contrast to this, a greater percent of the ova recovered from hand-
mated gilts had undergone cleavage upon examination (Figure 5). These
results were obtained in both trials and were almost the same magnitude.

This evidence suggested that the greater percent survival at 30-35
days post-breeding among hand-mated gilts was partially due to more ova
fertilized at mating. The advantage however, was not large enough to
account for the total difference in number of live embryos at 30-35 days
post-breeding between the two mating systems.

It should also be pointed out that, although there were differences,
the fertilization rates obtained in both treatment groups of this study
were quite respectable. The pooled means of 89.72 percent and 92.37
percent for the lot-mated and hand-mated gilts, respectively, were in
close agreement with the results published by Squiers et al. (1950);
Warnick et al. (1951); Christian and Nofziger (1952); Haines et al.
(1959); and Burfening and Ulberg (1966).

These data do, however, support the hypothesis of a greater physio-
logical stress being placed upon the lot-mated gilts. While a compar-
able stress has not been reported by others, the results would agree
with researchers that have indicated a thermal stress imposed upon the
ewe during the estrus period resulted in a decrease in rate of fertili-
zation (Alliston et al., 1961; Dutt et al., 1956; Dutt et al., 1959;
Dutt, 1960, 1963; Hafez, 1965; and Ulberg, 1958).

Post-Breeding Nutrition:

Trial 7 was a study of the effect of two different post-breeding
nutritional levels upon embryo survival. Both groups of gilts were
hand-mated and had been fed the same level prior to breeding (7 lbs.
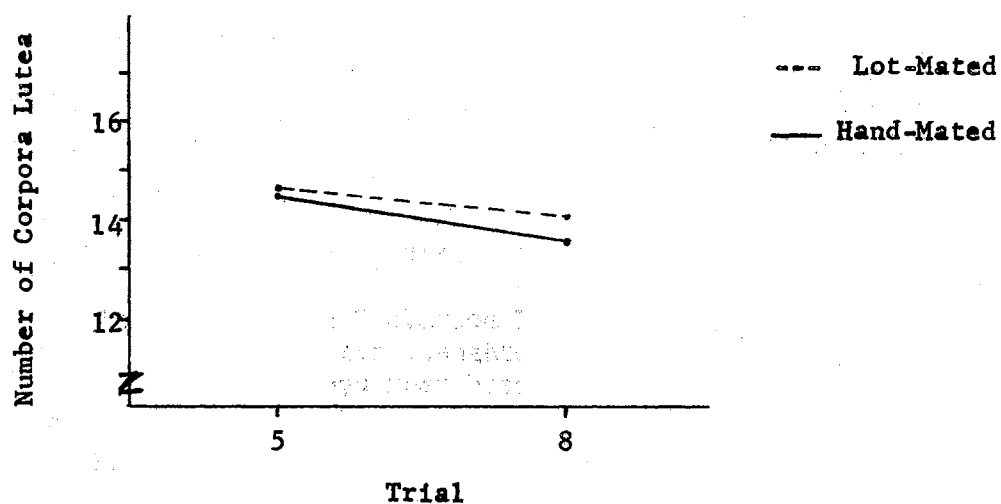
Figure 4.   Mean Ovulation Rate of Those
            Gilts Slaughtered 2 or 3
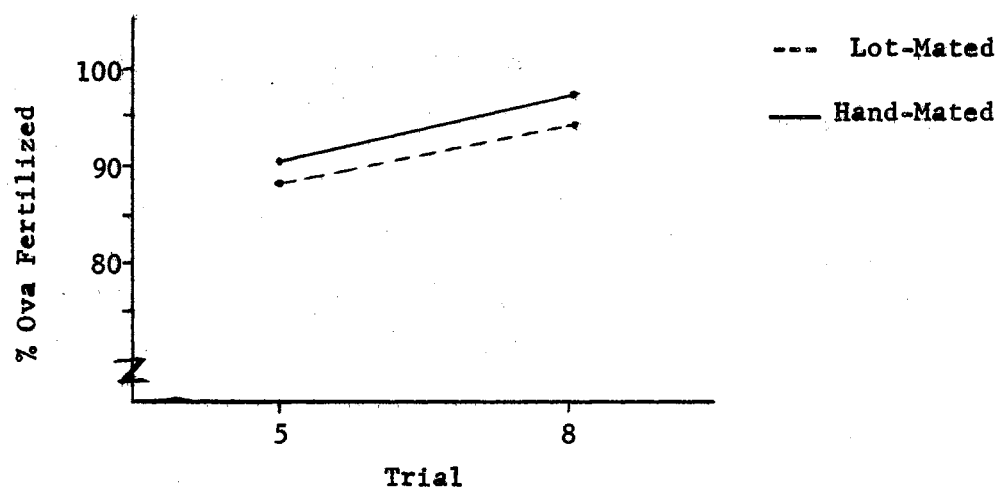   Days Post-Breeding

Figure 5.   Mean Percent Ova Fertilized
            of Those Ova Recovered

daily). On the day after breeding, gilts on Treatment 1 were decreased in feed intake to 3 pounds daily for 10 days, then increased to 5 pounds until slaughter at 30-35 days post-breeding. For gilts on Treatment 2, the daily feed intake was decreased to 5 pounds the day after breeding and held at this level until slaughter. The results for Trial 7 are shown in Table VI.

TABLE VI

MEANS AND STANDARD ERRORS FOR NUMBER OF CORPORA LUTEA, NUMBER
OF EMBRYOS AND PERCENT EMBRYO SURVIVAL OBTAINED IN TRIAL 7
FROM HAND-MATED GILTS REDUCED TO 3 OR 5 POUNDS FEED
FOR TEN DAYS, BEGINNING THE DAY AFTER BREEDING

Treatment	No. Gilts	No. C. L.	No. Embryos	% Embryo Survival
3 lb. Per Day	7	13.43+.907	10.14+.625	76.89+4.392
5 lb. Per Day	7	13.71+.907	11.00+.625	80.60+4.392

Ovulation rates in the two groups of gilts, as indicated by number of corpora lutea, were similar which would be expected since they were treated the same prior to breeding. The slight advantage in ovulation rate in favor of the gilts decreased to 5 pounds feed on day 1 after breeding (13.71 vs. 13.43) was non-significant. The gilts reduced to 5 pounds tended to have a larger number of viable embryos and greater percent survival than did the gilts reduced to 3 pounds, but the differences were non-significant. These results were not very meaningful because feed levels of 3 and 5 pounds daily were probably not different enough to cause a measurable difference in response.

Relationships Between Breeding Age, Weight and Reproductive Performance:

Gilts were pooled across trials and a simple correlation and

regression analysis was conducted. Only those gilts that contributed meaningful data were considered in the analysis. Shown in Table VII are the number of observations, mean and standard deviation of each variable correlated. Those simple correlations obtained are presented in Table VIII.

The correlation between age at breeding and ovulation rate (r = 0.51) was highly significant (P<.01). This correlation was slightly higher than those for the same variables and reported by: Lerner et al. (1957), 0.38; O'Bannon et al. (1966), 0.20; Rathnasabapathy et al. (1956), 0.317; and Squiers et al. (1952), 0.31. It was less, however, than the correlation of 0.564 reported by Reddy et al. (1958a).

A moderately high correlation was expected because the population that was sampled is known to be a high ovulating breed (Yorkshire), and the age range (218-418 days) includes the period when the greatest ovulatory response to increasing age has been reported. Illustration of this phenomena was demonstrated in Table IX by pooling the gilts from all trials and dividing them into four age groups of approximately equal numbers. There was an obvious, consistent and progressive increase in number of ovulations from the youngest to the oldest age groups. This evidence supported the results reported by Robertson et al. (1951b) and Warnick et al. (1951), that ovulation rates tend to increase rapidly with successive heat periods after puberty, at least through the third estrus. Also, Stewart (1945) reported a rapid increase in ovulation rate with age, but with a tendency to level off at around 15 months.

Weight at time of breeding was significantly correlated (P<.01) with ovulation rate (r = 0.53). This correlation agreed with that

TABLE VII

NUMBER OF OBSERVATIONS, MEANS AND STANDARD
DEVIATIONS OF CORRELATED VARIABLES

Variable	No. Gilts	Mean	S.D.
Number Corpora Lutea	139	15.74	2.741
Number Embryos	115	12.12	3.047
Percent Embryo Survival	115	76.27	16.679
Age at Breeding, Days	133	290.43	46.227
Weight at Breeding, lbs.	133	298.41	41.401

TABLE VIII

SIMPLE CORRELATION COEFFICIENTS BETWEEN SOME REPRODUCTIVE
PERFORMANCE CHARACTERISTICS, AGE AT BREEDING
AND WEIGHT AT BREEDING

Variable	Age at Breeding	Wt. at Breeding	No. Embryos	% Embryo Survival
Ovulation Rate	.51**	.53**	.49**	-.24*
Age at Breeding		.73**	.37**	-.01
Weight at Breeding			.42**	.06

* Level of Significance (P <.05)
** Level of Significance (P <.01)

TABLE IX

MEAN NUMBER CORPORA LUTEA, MEAN NUMBER OF LIVE
EMBRYOS AND MEAN PERCENT SURVIVAL PER GILT
ACCORDING TO AGE AT BREEDING

Age at Breeding	No. C. L.	No. Embryos	% Embryo Survival
Oldest ¼	17.78	13.43	74.6
Second ¼	15.79	13.32	80.9
Third ¼	14.97	10.85	72.5
Youngest ¼	14.15	10.93	76.8

TABLE X

MEAN NUMBER CORPORA LUTEA, MEAN NUMBER OF LIVE EMBRYOS
AND MEAN PERCENT SURVIVAL PER GILT ACCORDING
TO WEIGHT AT TIME OF BREEDING

Weight at Breeding	No. C. L.	No. Embryos	% Embryo Survival
Heaviest ¼	17.12	13.82	81.5
Second ¼	16.42	12.44	73.0
Third ¼	15.45	11.85	73.6
Lightest ¼	13.58	10.48	76.9

reported on two-way crossbred gilts (r = 0.42) by O'Bannon et al. (1966)
(P<.01). Likewise, a positive correlation between weight at breeding
and size of litter born to guinea pigs was reported by Eckstein and
McKeown (1955). The relationship between weight at breeding and ovula-
tion rate was illustrated in Table X by showing a marked increase in
ovulation rate as weight increased.

Other variables for which significant (P<.01) correlations were
obtained were: ovulation rate and number of embryos (r = 0.49); age at
breeding and number of embryos (r = 0.37); and weight at breeding and
number of embryo (r = 0.42). The effect that weight and age at breeding
had upon the number of embryos was probably due to the relationship
these variables have with the rate of ovulation. This was substantiated
by the evidence presented in Tables IX and X. Number of embryos
increased with both age and weight but percent embryo survival did not.
This implied that the larger number of embryos were due to the larger
ovulation rate.

The correlation between ovulation rate and percent embryo survival
was -.24 (P<.05) as was expected; however, it was lower than the
correlation of -.38 (P<.01) reported by Gossett and Sorensen (1959).
This difference could have been partially caused by the breeds used.
This study was conducted using Yorkshire, a breed known for large
litters; while the Texas data included the Duroc, Hampshire and Poland
China breeds which are known for medium to small litters. Other
researchers have also presented evidence which indicated a negative
correlation between ovulation rate and embryo survival. In swine, Perry
(1956, 1962) reported prenatal mortality was heaviest in very large
litters and this relationship was established by the twenty-fifth day

post-breeding. McLaren and Michie (1956) observed when the number of implantations began to exceed the normal quota in mice, the proportion of dead resorbing embryos began to rise.

Percent embryo survival was non-significantly correlated with age at breeding (r = -.01) and weight at breeding (r = 0.06) indicating that neither age nor weight at breeding account for a major portion of the variation in percent embryo survival. This was evident from examination of Tables IX and X since there was no trend or pattern apparent in the percent embryo survival with varying ages or weights at time of breeding.

A prediction equation used to estimate the rate of ovulation per estrus was developed by regressing number of corpora lutea on age at time of breeding and number of corpora lutea on weight at time of breeding. It was postulated that the slope of the regression lines would be curvilinear; therefore, the model used was $\hat{Y} = \beta_0 + \beta_1 X_1 + \beta_2 X_1^2$. The regression coefficients were obtained by the abbreviated Doolittle procedure and analysis of variance was used to test significance of the linear and curvilinear responses. The results of these analysis for the dependent variables are shown in Tables XI and XII.

Curvilinear responses were non-significant in both regression equations within the limits of this sample of gilts. The expectation that the older and heavier gilts would cause a curvilinear response to develop did not materialize in this study. Linear responses were highly significant ($P < .0005$) as was expected because the majority of the gilts were of the age and weight range that should yield linear response. The beta values and their standard errors are listed in Table XIII. These beta values indicate the amount of change in Y (dependent variable) per

TABLE XI

ANALYSIS OF VARIANCE FOR SLOPE OF THE LINE WITH
OVULATION RATE REGRESSED ON AGE AT BREEDING

Source	df	M.S.
Age	1	256.482****
Age X Age	1	1.634
Error	130	5.661

**** Level of Significance (P<.0005)

TABLE XII

ANALYSIS OF VARIANCE FOR SLOPE OF THE LINE WITH
OVULATION RATE REGRESSED ON
WEIGHT AT BREEDING

Source	df	M.S.
Weight	1	275.120****
Weight X Weight	1	.828
Error	130	5.524

**** Level of Significance (P<.0005)

unit change in X (independent variable).

TABLE XIII

REGRESSION COEFFICIENTS AND STANDARD ERRORS FOR NUMBER CORPORA
LUTEA REGRESSED ON THE TWO INDEPENDENT VARIABLES,
AGE AT BREEDING AND WEIGHT AT BREEDING

Independent Variable	Linear (X)	Curvilinear (X^2)
Age at Breeding	.002402+.001165	.000046+.000376
Weight at Breeding	.057169+.001123	-.000037+.000359

A comparison of the error mean squares in Tables XI and XII can be
used as an indicator of accuracy of the regression coefficient as a pre-
dictor. If the regression line was to go through every observation, the
error mean square would be zero. Since the regression line is a least
square estimate with minimum variance, and the error mean squares
obtained from the two regression analyses were very similar, there is no
reason to suggest that one regression was a more accurate predictor than
the other. The prediction equations obtained from this study and their
standard error of estimates are plotted in Figures 6 and 7.

The linear regression coefficient obtained in this study from
regressing number corpora lutea on age at breeding was lower than those
reported by Newman (1963) and Rathnasabapathy et al. (1956). Their
regressions were run on crossbred gilts that had recently reached
puberty. This type of population should respond with a rapid increase
in ovulation rate per unit change in age, and in addition, there should
be a heterosis effect from crossbreeding. In contrast, the majority of
the gilts in this study had exhibited at least one estrus prior to the
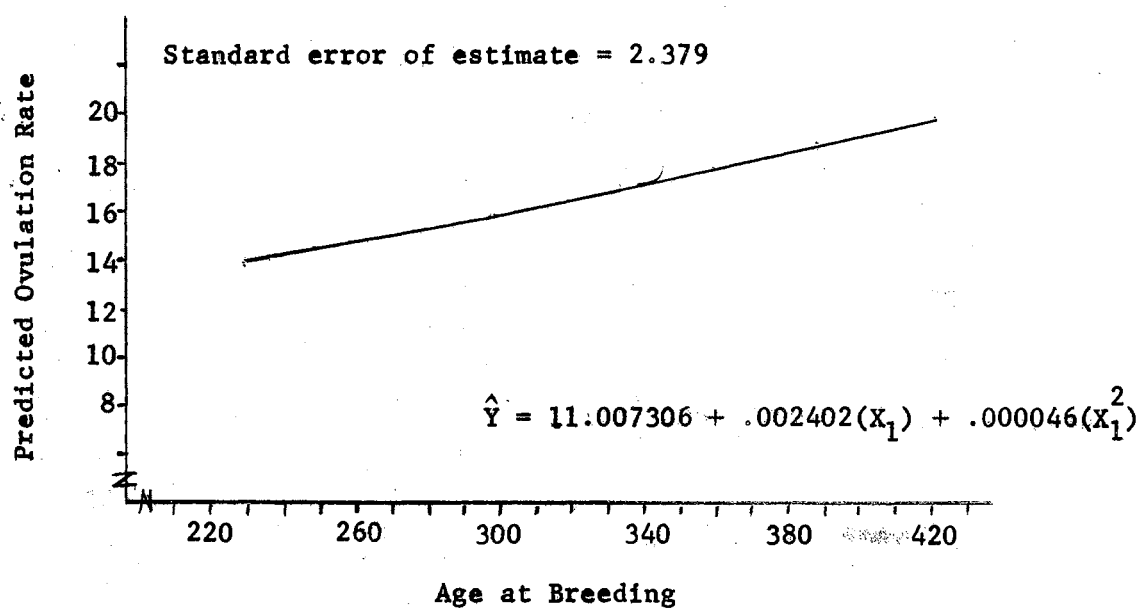start of the experiment. Therefore, the data in this study was probably

Standard error of estimate = 2.379

$$\hat{Y} = 11.007306 + .002402(X_1) + .000046(X_1^2)$$

Predicted Ovulation Rate

Age at Breeding

Figure 6. Regression of Number of Corpora Lutea on Age
in Days at Time of Breeding

Standard error of estimate = 2.350

$$\hat{Y} = 1.982082 + .057169(X_1) - .000037(X_1^2)$$

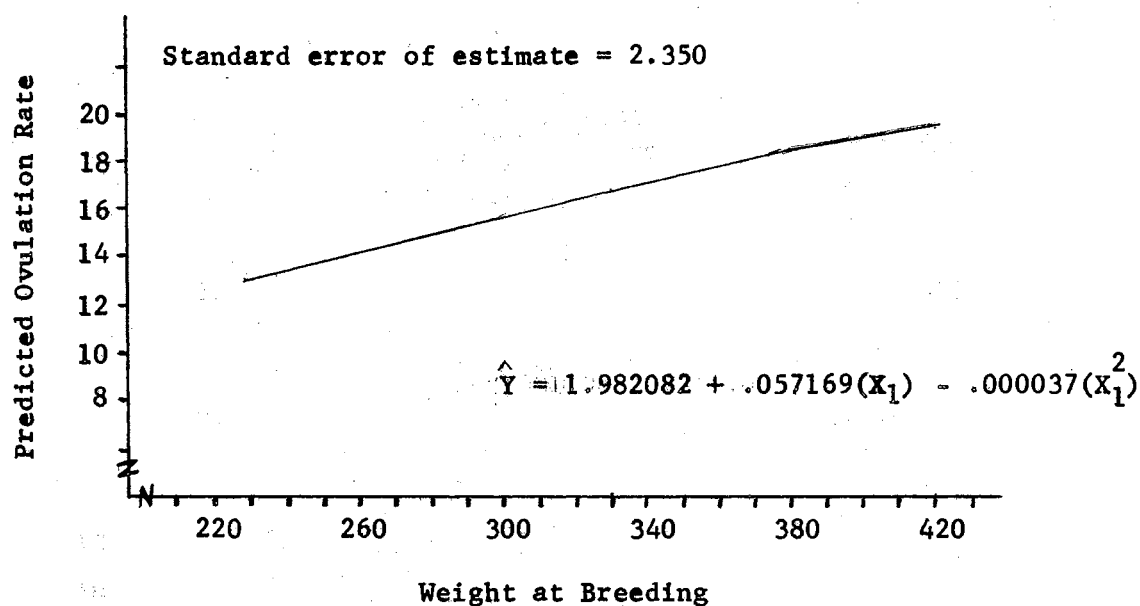Predicted Ovulation Rate

Weight at Breeding

Figure 7. Regression of Number of Corpora Lutea on
Weight in Pounds at Time of Breeding

SUMMARY

The major objective of this study was to measure the effect of hand-mating and lot-mating on reproductive performance. The data included 137 Yorkshire gilts. There were no significant differences between the two methods of mating in ovulation rate, as measured by number of corpora lutea. When all trials were pooled, the mean ovulation rates were 16.02 for 51 lot-mated gilts and 15.77 for 52 hand-mated gilts. The lot-mated gilts averaged slightly more corpora lutea in 4 out of 6 trials, but an overall analysis of the data indicated that method of mating had little, if any, effect upon ovulation rate.

When methods of mating were pooled across trials, the hand-mated gilts exhibited a slight advantage $(P < .10)$ in number of viable embryos and a greater advantage $(P < .05)$ in embryo survival (13.15 embryos and 80.55 percent survival compared with 11.85 embryos and 71.79 percent survival). This was equivalent to a mean difference of 1.3 additional live embryos and 8.76 percent embryo survival per hand-mated gilt at 30-35 days post-breeding than observed in lot-mated gilts. Prior to pooling, significant differences in number of embryos or percent embryo survival were reported only in Trial 3. Within Trial 3, the hand-mated gilts had a highly significant $(P < .005)$ greater number of viable embryos and percent embryo survival than did the lot-mated gilts.

There were no significant differences in percent ova fertilized between the two mating systems in either of the two trials in which data were collected. The pooled means of 89.72 percent and 92.37 percent

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fertilized ova for lot-mated and hand-mated gilts respectively, suggested that the greater percent survival at 30-35 days post-breeding of hand-mated gilts was partially due to more ova fertilized at mating. However, this advantage was not large enough to account for the total difference in number of live embryos at 30-35 days post-breeding between the two mating systems. Therefore, this data could be interpreted as implying that the mating behavior of the boar could be a source of detrimental stress upon the potential litter size in Yorkshire gilts. A capable and reliable herdsman, however, would be a definite requirement before hand-mating or artificial insemination could be successfully substituted for lot-mating. Additional research upon the effects of these methods of mating is necessary before insinuating a change in present breeding practices.

In Trial 7, the effect of two different post-breeding nutritional levels upon embryo survival was studied. There were no significant differences in number of viable embryos or percent embryo survival between hand-mated gilts fed either 3 or 5 pounds per head daily of a 14 percent protein ration. It was suggested that 3 and 5 pounds per head daily, were not enough different to cause a measurable difference in response to the 10 day treatment period.

The following variables were significantly correlated with ovulation rate: at $P < .01$; age at breeding ($r = 0.51$), weight at breeding ($r = 0.53$), and number of embryo ($r = 0.49$); at $P < .05$; percent embryo survival ($r = -.24$). Age at breeding and weight at breeding had little, if any, effect upon percent embryo survival as indicated by the correlations of $-.01$ for age at breeding and 0.06 for weight at breeding respectively. Within the age and weight ranges of this sample of

Yorkshire gilts, ovulation rate increased as age or weight increased at a highly significant (P<.0005) linear response. Curvilinear responses to the same two variables were non-significant.

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