

Number of ovulations in culled Landrace × Yorkshire gilts in the tropics associated with age, body weight and growth rate

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(Received 9 October 2013/Accepted 30 March 2015/Published online in J-STAGE 11 May 2015)

ABSTRACT. The objective of the present study was to determine the number of ovulations in culled Landrace × Yorkshire (LY) crossbred gilts in the tropics associated with age, body weight and growth rate. The genital organs from 316 gilts were examined for gross abnormalities, and those with normal cyclic ovaries ($n=155$, 307 ± 4.1 days of age, 148 ± 1.6 kg body weight) were included in the analyses. Number of ovulations was defined by a count of the corpora lutea (CL) from both ovaries. On average, the number of ovulations in LY gilts was 15.9 ± 0.3 (range 4 to 27). The number of ovulations correlated with the body weight ($r=0.31$, $P<0.001$) and growth rate ($r=0.20$, $P=0.015$) of the gilts, but not with their age ($P>0.05$). Gilts with a body weight of 141 to 150 kg (17.0 CL, $n=31$) ovulated more than those with a body weight ≤ 130 kg (14.1 CL, $P=0.014$, $n=23$). In conclusion, both the body weight and growth rate of the gilts were significantly correlated with the number of ovulations. The maximum number of ovulations was found in gilts at a body weight of above 141 kg.

KEY WORDS: corpora lutea, ovary, puberty, reproduction, swine

doi: 10.1292/jvms.13-0496; *J. Vet. Med. Sci.* 77(9): 1095–1100, 2015

Age at first mating in gilts influences their subsequent reproductive performance as sows and their longevity [4, 6, 8, 17]. Under field conditions, the reported age at first mating in gilts varies considerably within the range of 150 to 348 days [16], while the mean age at first mating in gilts varies among populations within the range of 198 [5] to 268 days [15]. Based on economic evaluation, Schukken *et al.* [11] found that gilts in North America should be mated before 220 days of age. In Japan, Koketsu *et al.* [4] found that gilts mated later than 230 days of age display inferior subsequent reproductive performances and longevity. Gilts mated at an older age have a shorter herd life and a higher risk of being culled due to infertility problems [25]. In addition, Tummaruk *et al.* [21] found that gilts exhibiting first standing estrus between 180 to 200 days of age have a litter size in the first 3 parities that is larger than that of gilts expressing first estrus between 201 to 220 days. These findings indicate the importance of gilt management as well as the first mating decision to their subsequent reproductive performance as sows. In practice, 40 to 50% of sows in herds are culled annually and replaced by gilts; therefore, the reproductive performance of gilts largely influences the overall reproductive performance of a swine herd. Unfortunately, a number of replacement gilts in Thai swine breeding herds are culled before their first litter has been accomplished; the major

reason for this culling is reproductive failure [10].

On average, Landrace × Yorkshire (LY) crossbred gilts in Thailand attain puberty at 196 days and 106 kg (body weight) [21]. In practice, replacement gilts are usually mated at a second or later observed estrus, at about 210 to 270 days of age. The delay in age at first mating in gilts increases the number of nonproductive days (NPDs) from entry to conception and influences their subsequent reproductive performance [21]. Our previous study found that reproductive problems contribute to 47% of the reasons for the removal of gilts from swine breeding herds [18]. Common reproductive problems include anestrus, repeated breeding, not being pregnant, abnormal vaginal discharge, abortion and birth problems at first farrowing [15].

In practice, the management of replacement gilts needs special emphasis. The selection criteria for replacement gilts include age, body weight, backfat thickness, number of estrus cycles and number of teats. Replacement gilts must have at least six pairs of teats, and it is recommended that they be mated at 240 days of age when their body weight is 130 kg, their backfat thickness is 17 mm, and they are at their second or later observed estrus [19]. These parameters are carefully determined in some herds in order to ensure a high prolificacy at first farrowing [19, 21]. However, no comprehensive data on the relationship between these parameters and number of ovulations in replacement gilts raised in tropical climates have been published. In general, litter size at birth in gilts and sows depends on number of ovulations, fertilization and embryonic/fetal loss [22]. The number of ovulations is the primary factor influencing the litter size at birth of gilts. For a better understanding of the factors influencing litter size at birth in gilts under field conditions, information concerning the number of ovulations in replacement gilts needs to be explored. The number of

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ovulations in replacement gilts can be possibly determined by performing expensive serial slaughter experiments. Nevertheless, it can also be studied by carefully determining the number of corpora lutea (CLs) in slaughtered gilts together with evaluation of their historical data, reasons for culling and gross morphological examinations.

Due to heat stress, pigs reared in tropical climates have a relatively poor feed intake. Furthermore, in tropical climates, the appetite of pigs is generally too low to meet their nutrient requirements. The feed intake of growing pigs is closely related with their growth rate. Therefore, the growth rate of replacement gilts may be associated with their fertility and fecundity. The objective of the present study was to determine the number of ovulations of culled LY crossbred gilts and its association with age, body weight and growth rate.

MATERIALS AND METHODS

Animal and tissue samples: In total, genital organs from 316 LY crossbred gilts were collected from 6 commercial swine herds in Thailand between May 2005 and September 2008. The organs were examined for gross abnormalities by a pathologist, and those with normal cyclic ovaries were included in the analyses ($n=155$). The ovarian appearance and definition of normal cyclic ovaries were determined according to our previous study [15] (see below). The genital organs of the gilts were collected, placed on ice and transported to the laboratory within 24 hr of slaughter. Historical data including the herd of origin, gilt's identity, breed, birth date, date that the gilt entered the herd, first observed estrus date, culling date, body weight at culling and culling reasons were collected. Age at first observed estrus, age at culling, number of NPDs and growth rate of the gilts were calculated: growth rate (g/day) from birth to culling = $((\text{body weight [kg] at culling} - 1.5)/\text{age at culling}) \times 1,000$ [19]. The number of NPDs of the culled gilts was defined as the number of days from entry into the herd to culling. In general, the criteria required for movement of the gilts from the gilt pool to the breeding house included age (≥ 224 days), body weight (≥ 130 kg) and completion of a herd monitoring program. The reasons for culling of replacement gilts were classified into 6 groups, i.e., anestrus, abnormal vaginal discharge, repeated service, abortion, not being pregnant and miscellaneous causes. "Anestrus" included gilts that were culled because no behavioral estrus could be observed. "Abnormal vaginal discharge" included gilts that were culled because purulent vaginal discharge was observed. "Repeated service" included gilts that were culled because they returned to estrus after insemination had been repeated for ≥ 2 consecutive estrous cycles. "Abortion" included gilts that were culled due to abortion. "Not being pregnant" included gilts that were culled because of failure to detect pregnancy and gilts that were found to be nonpregnant when they were sent to the farrowing barn (not-in-pig). "Miscellaneous" included gilts that were culled due to nonreproductive causes, i.e., inverted nipple, leg problems and poor conformation.

Historical data, herd location, climatic data and general management: The herds were located between latitude 13°

and 17°N and between longitude 100° and 104°E . The average outdoor minimum and maximum daily temperatures and humidity in the area of study in the hot (15 February to 14 June), rainy (15 June to 14 October) and cool (15 October to 14 February) seasons were 24.6°C , 34.9°C and 71.7% ; 24.8°C , 33.0°C and 78.1% ; and 21.4°C , 32.1°C and 68.1% , respectively. All were breeding herds with the number of sows in production being between 900 and 4,000 sows/herd. The gilts entered the gilt pool at a body weight of 80 to 100 kg. All the gilts were housed in an open housing system. The gilts were kept in a pen with a group size of 6 to 15 gilts/pen and a density of 1.5 to 2.0 m^2/gilt . Estrous detection was performed daily by a back pressure test together with the observation of reddening and swelling of the vulva with fence-line boar contact. The boar exposure was initiated within 1 to 2 weeks of the gilts entering the gilt pools. Gilts expressing a standing response in front of the boar were defined as being in standing estrus. In general, it was recommended that replacements gilts be bred at about 32 weeks of age onwards when their body weights were at least 130 kg and they were at their second or later observed estrus. The mating technique for all herds was conventional artificial insemination (AI). Herd health was monitored by the herd veterinarian. In general, the veterinarian recommended vaccinating the gilts against foot-and-mouth disease, classical swine fever, Aujeszky's disease and porcine parvovirus at between 22 and 30 weeks of age. Replacement gilts generally entered the herd (gilt pool) every 1 to 2 weeks. About one week after gilts entered the herd, the weaned sows in the herd selected for culling were taken to acclimatize them for about 4 to 6 weeks with a ratio of one sow per six to ten gilts. In general, the sows for acclimatization were rotated on a weekly basis. Feed was provided twice a day (about 3 kg/day/head), and water was provided *ad libitum*. The feed was corn-soybean-fish based and contained 16 to 18% crude protein, 3,000 to 3,400 kcal/kg metabolizable energy and 0.85 to 1.0% lysine. Estrus detection was carried out by the observation of vulva symptoms and a back pressure test in the presence of a mature boar once or twice a day.

Postmortem examination: The genital tract including ovaries was dissected and examined macroscopically. The stages of the reproductive cycle were defined according to the appearance of the ovaries and their structure, i.e., corpora lutea (CLs) and follicles [15]. Gilts with ovaries having only small follicles (≤ 5 mm) were defined as prepubertal. Gilts with ovaries having CLs (luteal phase) and/or follicles of 7 to 12 mm in diameter accompanied by old CLs (follicular phase) were defined as pubertal. Therefore, gilts were defined as cyclic, if the ovaries had a corpus hemorrhagicum (CH), CLs or preovulatory follicle 7 to 12 mm in diameter. The number of CLs was counted. Number of ovulations was defined as the total number of CLs from both ovaries. The ovaries were weighed using an electronic balance (max=210 g, d=0.01 g; BJ 210C, Precisa Gravimetrics AG, Dietikon, Switzerland). Cystic ovaries were characterized by the presence of single (one cyst/gilt) or multiple cysts (\geq two cysts/gilt), although they were accompanied by any other normal structure [15]. Cystic ovaries and other ovarian

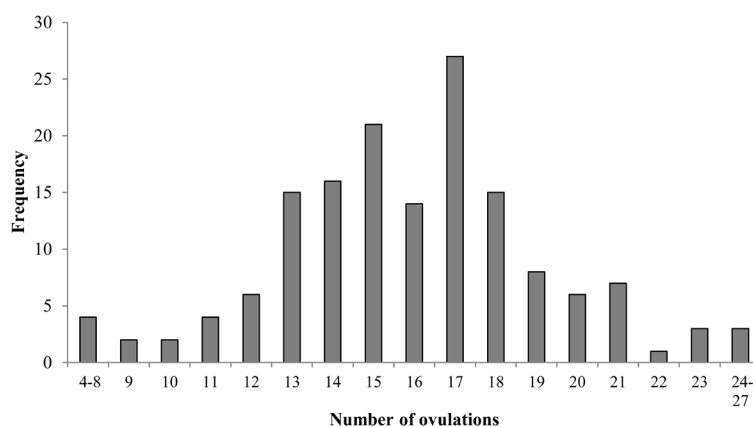


Fig. 1. Frequency distribution of the number of ovulations in Landrace × Yorkshire pubertal gilts

Table 1. Descriptive statistics for reproductive data of 155 Landrace × Yorkshire crossbred gilts in Thailand with normal cyclic ovaries

Parameters	Means ± SEM	Range
Age at culling (days)	307.2 ± 4.1	209–489
Body weight at culling (kg)	148.2 ± 1.6	97.5–203.0
Average daily gain (g/day)	486.1 ± 6.2	297–689
Interval from entry to culling (days)	79.9 ± 4.7	18–250
Age at first observed oestrus (days)	234.8 ± 3.1	170–374
Age at first mating (days)	265.7 ± 3.3	204–374

Table 2. Pearson's correlation between number of ovulations, and body weight, age and growth rate of the gilts

Variables	Number of gilts	Correlation coefficient	Significance
Body weight	150	r=0.314	P<0.001
Age	150	r=0.027	Ns
Growth rate	148	r=0.200	P=0.015

Ns, not significant ($P>0.05$).

abnormalities ($n=49$) were excluded from the analyses.

Statistical analyses: The statistical analyses were carried out using the Statistical Analysis System software (SAS version 9.0, SAS Institute, Cary, NC, U.S.A.). All continuous data for reproductive parameters and gross morphology are presented as the mean ± SEM, and proportional data are presented as a percentage. Pearson's correlation and multiple regression analyses were used to analyze the association among the number of ovulations, body weight, age and growth rate of the gilts. The multiple regression model included the effects of body weight, age at culling and growth rate. In addition, multiple ANOVA models were also conducted. The pubertal gilts with normal cyclic ovaries were classified according to their body weight at culling (≤ 130 , 131 to 140, 141 to 150, 151 to 160 and ≥ 161 kg), age at culling 8 (209 to 269 days), 9 (270 to 299 days), 10 (300 to 330 days) and 11 (≥ 331 days) months] and growth rate from birth to culling (<400 , 400 to 499, 500 to 599 and ≥ 600 g/day). The effect of body weight, age at culling and growth rate on the number of ovulations and weight and length of the uteri was analyzed with the general linear model procedure of SAS. The statistical model included the effects of body weight, age at culling and growth rate classes. Least-square means were obtained from each class of variables and were compared by a least significant difference test with Tukey-Kramer adjustment for multiple comparisons. $P<0.05$ was considered statistically significant.

RESULTS

Of the 316 gilts, 49 gilts with ovarian abnormalities [multiple cysts 23 gilts (7.4%), single cyst 17 gilts (5.5%), unilateral ovotestis 2 gilts (0.6%) and miscellaneous abnormalities 7 gilts (2.3%)] were excluded from the analyses. Of the 267 gilts with normal ovaries, five gilts were excluded due to pregnancy. Therefore, 262 gilts with normal ovaries were included. Of these gilts, 86 gilts were prepubertal, and 176 gilts were pubertal. Of the 176 pubertal gilts, 155 gilts had dominant CLs, and 21 gilts did not have dominant CLs. Gilts with a CH or preovulatory follicle were defined as cyclic ($n=21$); but excluded from the analysis. Therefore, only 155 gilts with dominant CLs were included in the analyses. However, due to some missing historical data for the gilts, i.e., 2, 5, 5 and 7 gilts with missing data concerning reason for culling, body weight, age and growth rate, respectively, the final statistical models for analyses of the influences of reason for culling, body weight, age and growth rate on the number of ovulations in gilts included 153, 150, 150 and 148 gilts, respectively.

The frequency distribution of the number of ovulations is presented in Fig. 1. On average, the number of ovulations was 15.9 ± 0.3 , and the diameter of the CL was 9.3 ± 0.2 mm. The weight of the cyclic ovary was 6.8 ± 2.5 g (range 1.9 to 15.0 g). Descriptive statistics for the reproductive data of these gilts ($n=155$) are presented in Table 1. On average, the gilts showed first observed estrus at 234.8 ± 3.1 days of age, and they were culled at 307.2 ± 4.1 days of age, at which

Table 3. Number of ovulations (least-square means \pm SEM) in Landrace \times Yorkshire gilts in relation to their body weight at culling

Body weight (kg)	Number of gilts	Number of ovulations
≤ 130	23	14.1 \pm 1.1
131 to 140	24	15.4 \pm 0.9
141 to 150	31	17.0 \pm 0.7
151 to 160	36	16.6 \pm 0.7
≥ 161	36	16.7 \pm 0.7
<i>P</i> -value	150	<0.001

Table 5. Number of ovulations (least-square means \pm SEM) in Landrace \times Yorkshire pubertal gilts in relation to their growth rate

Growth rate (g/day)	Number of gilts	Number of ovulations
<400	24	15.7 \pm 1.0
400 to 499	54	15.1 \pm 0.5
500 to 599	62	16.0 \pm 0.6
≥ 600	8	17.1 \pm 1.7
<i>P</i> -value	148	0.622

point their body weight was 148 \pm 1.6 kg. The interval from entry to culling (i.e., number of NPDs) in these gilts was 79.9 \pm 4.7 days (Table 1).

The correlations among the number of ovulations and body weight, age and growth rate of gilts are presented in Table 2. As can be seen from the table, the number of ovulations correlated with body weight ($r=0.314$, $P<0.001$) and growth rate ($r=0.200$, $P=0.015$), but not with age ($P>0.05$) of the gilts. Multiple regression analyses indicated that for every 10 kg increase in the body weight of the gilts, the number of ovulations tended to increase (+1.1 CL, $P=0.182$). The number of ovulations in relation to the body weight of the gilts is presented in Table 3. The relationships between the number of ovulations and the age at culling and the growth rate are presented in Tables 4 and 5, respectively.

Of all the gilts with ovaries containing dominant CLs ($n=155$), 32.7%, 23.5%, 13.7%, 12.4%, 9.2% and 8.5% were culled due to anestrus, abnormal vaginal discharge, repeated service, abortion, not being pregnant and miscellaneous causes, respectively. The number of ovulations classified by the reasons for culling is presented in Table 6. As can be seen from the table, the number of ovulations did not differ significantly among the gilts culled due to the different culling reasons. In addition, of these gilts ($n=155$), 67.7% exhibited standing estrus at least once before culling, while 32.3% had never exhibited standing estrus before culling. The numbers of ovulations in the gilts that had exhibited standing estrus before culling and those that had never exhibited standing estrus before culling were 15.8 \pm 0.3 and 16.1 \pm 0.5, respectively ($P=0.609$).

DISCUSSION

It is known that gilts raised in tropical climates have a poorer litter size at birth than the same breeds in temperate

Table 4. Number of ovulations (least-square means \pm SEM) in Landrace \times Yorkshire gilts in relation to their age at culling

Age of gilts (month)	Number of gilts	Number of ovulations
8	31	14.6 \pm 0.8
9	46	16.7 \pm 0.6
10	36	16.4 \pm 0.7
11	37	16.1 \pm 1.0
<i>P</i> -value	150	0.144

Table 6. Number of ovulations (least-square means \pm SEM) in Landrace \times Yorkshire pubertal gilts in relation to reason for culling

Reasons for culling	Number of gilts	Number of ovulations
Anestrus	50	15.8 \pm 0.5
Abnormal vaginal discharge	36	15.8 \pm 0.6
Repeated service	21	16.9 \pm 0.8
Abortion	19	16.9 \pm 0.8
Not being pregnant	14	15.9 \pm 0.9
Miscellaneous	13	13.8 \pm 1.0
<i>P</i> -value	153	0.160

areas [20]. Number of ovulations is a primary factor influencing litter size at birth in gilts [22]. In practice, mating decisions for the replacement gilt are made based on the gilt's age and body weight. In general, farmers breed their replacement gilts at about 224 days of age onwards when the body weight of the gilts is at least 130 kg. Therefore, to obtain a high prolificacy in gilts, number of ovulations in relation to age, body weight and growth rate should be carefully determined. In the present study, the mean number of ovulations in LY crossbred gilts was 15.9. This is within the normal range that has been reported earlier in the literature (13.5 to 18.1) [7, 22–24] and is higher than that reported in Thailand for purebred Landrace (13.8) and Yorkshire (15.3) gilts, as determined by laparoscopic examination [13]. An increase in the number of ovulations in gilts leads to an increase in the number of viable embryos [22]. Our previous study found that LY gilts in Thailand attained puberty at 196 days of age [21], which is about 2 to 4 weeks older than those in Europe and North America [2, 8]. Mating decisions for gilts should therefore be made with caution, because mating gilts at a suboptimal time may result in inferior reproductive performance and longevity [4, 11, 17]. Under field conditions, the record of first standing estrus in replacement gilts is often missed and is sometimes not recorded. This causes difficulties for the mating decision. Therefore, the body weight of the gilt is one of the most practical indicators for selecting the optimal time of first insemination. The present study indicates that the highest number of ovulations of LY gilts in Thailand is obtained at a body weight of at least 141 kg.

In the present study, over one-fourth of the gilts (i.e., 27%, 86/316 gilts) were prepubertal at the time of culling. This is economically important for swine producers. The mean number of NPDs from entry to culling in these gilts is

79.9 days. These data indicate that puberty acceleration and/or induction needs to be intensively revised. Effective estrus acceleration/induction in replacement gilts would benefit swine producers in the introduction of replacement gilts into breeding herds at the optimal period and help reduce the costs associated with the size of the gilt pool, number of NPDs, feed cost and manpower. In general, puberty induction in gilts should be initiated by effective boar contact with careful estrus detection. Gilts should have a direct contact with boars at 165 days of age onwards until they have reached puberty (i.e., exhibit first standing estrus). In addition, other management procedures, e.g., increasing the frequency of boar exposure, relocation, mixing and transportation stress, have also been recommended [1, 9, 23]. Furthermore, estrus and ovulation induction in gilts may also be carried out by the administration of PG600® (400 IU eCG and 200 IU hCG) intramuscularly or subcutaneously at 165 to 180 days old [3, 7]. In the present study, the number of estrus cycles was not known. However, most of the gilts that had a body weight of more than 131 kg might have had at least one estrus cycle [21].

A number of studies have shown that lifetime growth rate influences the reproductive performance of gilts. Tarrés *et al.* [14] demonstrated that culling of Duroc sows due to fertility problems increased when the growth rate from birth to 167 days of age was below 585 g/day. Age at first farrowing also increased in gilts with a low growth rate compared with those with a high growth rate [12]. Our previous study demonstrated that replacement LY gilts with a growth rate >560 g/day attained puberty earlier than those with a growth rate <530 g/day [19]. These findings indicate the importance of lifetime growth rate for the reproductive performance of gilts; hence, in the present study, number of ovulations was compared between gilts with different growth rates, and it was found that replacement gilts should be selected from those with an optimal growth rate.

A limitation of the present study is that the number of ovulations was obtained from replacement gilts from commercial swine herds with different genetic backgrounds, nutrition and management. Moreover, most of the gilts had been culled due to reproductive failures. Nevertheless, only normal genital organs based on postmortem examination were selected. Moreover, it was found that the reasons for culling were not influenced by the number of ovulations in gilts (Table 6). Therefore, the number of ovulations of the gilts in the present study was based on data from a selected group of LY crossbred gilts culled from commercial swine herds in Thailand. Clinical implementation of these data should be made with special concern being paid to genetic background, nutrition and management. In the present study, some gilts did not exhibit standing estrus (silent heat), but ovulated normally (i.e., 15.8). This indicates that the ability of the gilts to exhibit standing estrus symptoms or the ability of farm workers to detect standing estrus in gilts is poor. Therefore, routine management of estrus detection needs to be improved. Furthermore, the data in this study can be used as a benchmark for number of ovulations associated with body weight, age and growth rate of culled LY crossbred

gilts raised in tropical climates.

In conclusion, the body weight and growth rate of the gilts significantly correlated with their number of ovulations. For every 10 kg increase in body weight, an increase of 1.1 CLs was observed. Based on data from selected groups of LY crossbred gilts, the maximum number of ovulations was found at a body weight above 141 kg.

ACKNOWLEDGMENT. Financial support for the present study was provided by a grant for International Research Integration: Chula Research Scholar, Ratchadaphiseksomphot Endowment Fund.

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