RESEARCHREPORT
ANIMAL SCIENCE

Title: Effect of Neonatal Litter Size and Early Puberty Stimulation on Sow Longevity and Reproductive Performance - **NPB # 05-082**

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Date Submitted: February 23, 2009

Industry Summary

The current study was designed to examine the effects of neonatal environments and puberty induction strategies for replacement gilts on their longevity and reproductive performance over six parities. The study was conducted within an 80,000-sow commercial production pyramid that used "in-house" gilt multiplication. In this system, replacement gilts remained "on-site" until they were about 190 days of age and then were sent to commercial farms. A total of 3180 gilts were randomly allocated to a factorial arrangement of treatments involving season of birth (spring or fall); neonatal litter size ($\leq$7 litter mates or $\geq$10 litter mates); and puberty stimulation (boar exposure @ 140 days of age; boar exposure @ 140 days of age + PG600®; or boar exposure @ 170 days of age). Between 190 and 210 days of age, gilts were moved to commercial farms. The commercial farms were P.R.R.S. positive, but considered to be P.R.R.S. stable. The average age at which gilts were bred was 232 days and did not differ among treatments. Season of birth did not significantly influence sow longevity or reproductive performance. Similarly, the productivity of gilts exposed to boars at 140 days of age and treated with PG600® was the same as their counterparts receiving only boar exposure during the same time period. Consequently, the only two factors that significantly affected sow longevity and reproductive performance were age at which puberty induction was initiated (140 or 170 days of age) and the size of the lactation litter in which gilts were raised ($\leq$ 7 pigs or $\geq$ 10 pigs). At the end of 6 parities, regardless of age of puberty induction, significantly more sows raised in small litters (35%) were still in production compared with those raised in large litters (17%). Similarly, regardless of the size of the litter in which they nursed, significantly more sows exposed to boars at 140 days of age (33%) remained in the herd compared with their counterparts given boar exposure at 170 days of age (16%). The positive effects of being raised in a small litter and receiving boar exposure at a young age on longevity were additive. As a result, at the end of 6 parities, 45% of sows raised in litters of 7 or fewer pigs and given boar exposure at 140 days of age were scheduled to be rebred after parity 6 compared with only 10% of females raised in litters of 10 or more pigs and given boar exposure at 170 days of age. A similar response was present for farrowing rate. Being raised in a small litter or receiving boar exposure at 140 days of age resulted in a 5% increase in farrowing rate in each of six parities. Consequently, sows from small litters and given boar exposure at 140 days had a mean farrowing rate of 90.8%, while a comparable figure for those from large litters and exposed to boars at 170 days of age was

79.8%. In contrast, only the neonatal environment significantly influenced number of pigs born alive. Sows reared with of 7 or fewer litter mates gave birth to an average of 11.0 pigs over six parities compared with 10.5 pigs for sows raised in litters of 10 or more pigs. Collectively, based on the differences in longevity, farrowing rates and numbers of pigs born alive observed in this study, the total number of pigs produced through 6 parities per gilt bred in each management system was determined and these estimates are as follows:

Large neonatal litter + Boar exposure @ 170 days – 21.9 pigs;
Large neonatal litter + Boar exposure @ 140 days – 29.7 pigs;
Small neonatal litter + Boar exposure @ 170 days – 29.8 pigs; and
Small neonatal litter + Boar exposure @ 140 days – 43.2 pigs.

Given the management structure of many operations in the swine industry, providing good, consistent boar exposure to gilts at 140 days of age might be technically challenging and present problems with maintaining biosecurity. Thus, it may not be practical for many operations to implement this strategy. In contrast, because males born as litter mates to replacement gilts have limited economic value as market animals, strategic cross-fostering for sows nursing potential replacement gilts is a technique that should be easy to implement and improve sow longevity and reproductive performance.

Abstract

The objective of this study was to examine the effects of the neonatal environment and puberty induction strategies for replacement gilts on sow longevity and reproductive performance. The study was conducted within an 80,000-sow commercial production pyramid that uses "in-house" gilt multiplication. In this system, replacement gilts remained "on-site" until they were about 190 days of age; and then were sent to commercial farms. A total of 3180 gilts were randomly allocated to a factorial arrangement of treatments involving season of birth (spring or fall); neonatal litter size ($\leq$7 litter mates or $\geq$10 litter mates); and puberty stimulation (boar exposure @ 140 days of age; boar exposure @ 140 days of age + PG600®; or boar exposure @ 170 days of age). Between 190 and 210 days of age, gilts were sent to commercial farms. The commercial farms were P.R.R.S. positive, but considered to be P.R.R.S. stable. Season of birth did not significantly influence ($p < 0.43$) sow longevity or reproductive performance. Similarly, the productivity of gilts exposed to boars at 140 days of age and treated with PG600® was the same ($p < 0.52$) as their counterparts receiving only boar exposure during the same time period. Consequently, the only two factors that significantly affected sow longevity and reproductive performance were age at which puberty induction was initiated (140 or 170 days of age) and the size of the lactation litter in which gilts were raised ($\leq$ 7 pigs or $\geq$ 10 pigs). At the end of 6 parities, regardless of age at puberty induction, significantly more sows ($p < 0.05$) raised in small litters (35%) were still in production compared with those raised in large litters (17%). Similarly, regardless of the size of the litter in which they were weaned, significantly more sows ($p < 0.05$) exposed to boars at 140 days of age (32%) remained in the herd compared with their counterparts exposed to boars at 170 days of age (16%). The positive effects of being raised in a small litter and receiving boar exposure at a young age on longevity were additive. As a result, at the end of 6 parities, 45% of sows raised in litters of 7 or fewer pigs and given boar exposure at 140 days of age were scheduled to be rebred compared with only 10% of females raised in litters of 10 or more pigs and given boar exposure at 170 days of age ($p < 0.01$). Differences in numbers of sows remaining in production after six parities were a combination of two events. First, being raised in a small litter size or receiving boar exposure at a young age had significant positive effects on whether first parity sows returned to estrus after weaning. Second, farrowing rates in each of the six parities were 5% higher in sows reared with 7 or less litter mates or exposed to boars at 140 days of age. Consequently, approximately one third (15%) of the

45% difference in longevity mentioned previously was due to improved rebreeding performance in first and second parity sows, while the other 30% was the result of a 5% improvement in farrowing rate in each of six parities. In contrast, only the neonatal environment significantly influenced number of pigs born alive. Sows raised in litters of 7 or less pigs gave birth to an average of 11.0 pigs over six parities compared with 10.5 pigs for sows raised in litters of 10 or more pigs ($p < 0.05$). Collectively, based on the differences in longevity, farrowing rates and numbers of pigs born alive observed in this study, the total number of pigs produced through six parities per gilt bred in each management system was determined and these estimates are as follows:

Large neonatal litter + Boar exposure @ 170 days – 21.9 pigs;
Large neonatal litter + Boar exposure @ 140 days – 29.7 pigs;
Small neonatal litter + Boar exposure @ 170 days – 29.8 pigs; and
Small neonatal litter + Boar exposure @ 140 days – 43.2 pigs.

Given the management structure of many operations in the swine industry, providing good, consistent boar exposure to gilts at 140 days of age might be technically challenging and present problems with maintaining biosecurity. Thus, it may not be practical for many operations. In contrast, because males born as litter mates to replacement gilts have limited economic value as market animals, strategic cross-fostering programs for sows nursing potential replacement gilts is a technique that should be easy to implement and improve sow longevity.

Introduction

In 2003, sow replacement rates varied from 31 to 89% with an average of 78% for herds using the PigChamp® recording system in the U.S. and Canada (PigChamp, Inc., 2003). Koketsu and Dial (Therio. 47:1445, 1997) reported that females were most likely to leave the herd during entry-to-first service and weaning-to-service after their first lactation. Collectively, these data indicate that herd productivity is being limited on most farms because females are being replaced before they reach their peak biological period of productivity between parities 3 and 6. Management of replacement gilts has focused primarily on determining the optimum age, weight, and, to some extent, body composition at first mating. Recently, several studies have demonstrated that modern genotypes can vary significantly in these parameters without noticeable effects on their subsequent reproduction (Rozeboom et al., J.Anim. Sci. 74:138, 1996; Patterson et al., J. Anim. Sci. 80:1299, 2002). From a physiological perspective, this may not be too surprising since key developmental periods for a gilt's reproductive system occur during the first 100 days of her life (Pressing et al., J. Anim. Sci. 70:232, 1992). As a result, it is reasonable to speculate that management very early in a replacement gilt's life may have profound effects on her subsequent reproductive performance as an adult.

Objectives

Our overall approach was to manipulate the neonatal environment and puberty stimulation within a commercial production system and monitor sow reproductive performance and longevity. Consequently, our objectives were as follows:

1. To determine the effect of neonatal litter size during lactation on early attainment of puberty gilts; and

2. To determine the effect of early induction of puberty on longevity and reproductive performance through six parities.

Experimental Procedures

The study was conducted within an 80,000-sow commercial production pyramid that uses "in-house" gilt multiplication. In this system, replacement gilts remained "on-site" until they were about 190 days of age; and then were sent to commercial farms. A total of 3180 gilts were randomly allocated to a factorial arrangement of treatments involving season of birth (spring or fall); neonatal litter size (≤7 litter mates or ≥10 litter mates); and puberty stimulation (boar exposure @ 140 days of age; boar exposure @ 140 days of age + PG600®; or boar exposure @ 170 days of age; Figure 1). Between 190 and 210 days of age, gilts were sent to commercial farms. The commercial farms were P.R.R.S. positive, but considered to be P.R.R.S. stable.

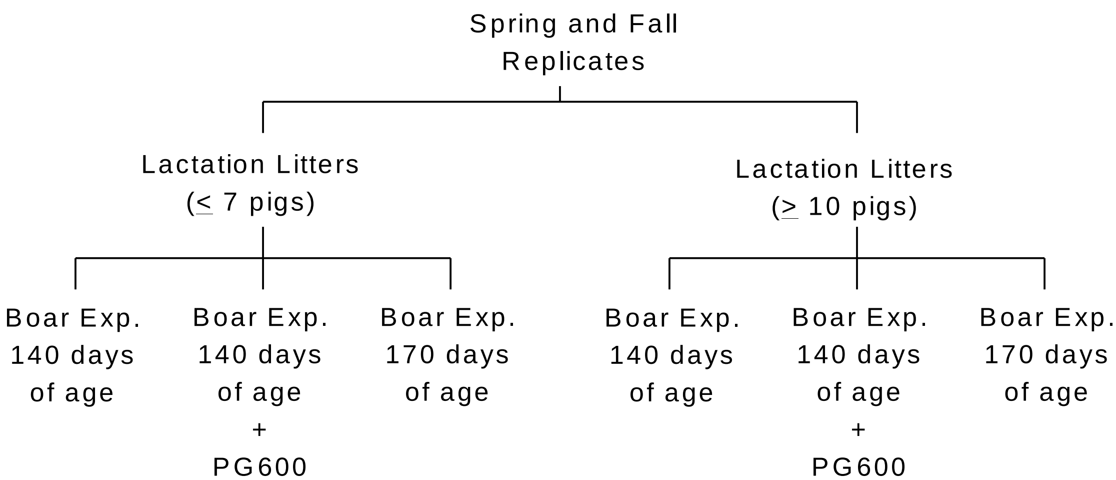

Figure 1. Outline of Experimental Design

The overall goal was to breed 150 gilts in each of 12 treatment combinations (2 seasons x 2 neonatal litter sizes x 3 puberty induction strategies) for a total of 1800 females. Death loss from birth to weaning averaged 17.5% and only 70% of the gilts produced typically were selected to enter production in this herd. As a result, at least 3,116 total gilts at birth were needed to complete the study.

The gilts born in May (Spring replicate) matured and reached puberty during the summer months, where as the gilts born in October (Fall replicated) matured and reached puberty during the winter months. Neonatal litter sizes of ≤7 pigs and ≥10 pigs were created by crossfostering pigs 24 to 48 hours after birth. Crossfostering was done so that lactation litters were balanced with respect to genetics and sex. Gilts were provided with 4 and 10 square feet per pig during the nursery and finishing phases of production, respectively. Finally, within each neonatal litter size treatment, gilts were randomly allocated to receive boar exposure at 140 days of age; boar exposure + PG600® at 140 days of age; or boar exposure at 170 days of age. Boar exposure consisted of introducing a mature boar (average age = 18.2 $\pm$ 0.4 months; average weight = 227 $\pm$ 5 kg) into a pen of gilts for 15 to 20 minutes daily. Boar exposure continued until gilts were moved to commercial units.

Reproductive data collected include age at puberty in response to boar stimulation, farrowing rates, litter characteristics, and rebreeding intervals during parities 1 through 6. Fecal progesterone will be determined in all gilts at the onset of puberty stimulation and 10 days after a detected estrus in order to confirm ovulation via a radioimmunoassay developed and validated in our laboratory (Armstrong et al., 1997; J. Anim. Sci. 75, suppl. 1, 220). Real-time ultrasonography will be used to monitor the ovarian response to puberty stimulation by scanning gilts every 4 days until estrus. This technique has been used successfully by our laboratory to monitor follicular growth in sows on commercial units (Belstra et al., 2004; Anim. Reprod. Sci. 84, 377). Body weights will be collected at 2 days of age; weaning; onset of finishing phase; 140 days of age; 180 days of age; and at breeding, entry into the farrowing barn, and weaning for parities 1 through 6. Backfat depths at the 10^{th} rib and loineye areas with real-time ultrasonography by a certified technician were recorded at 140 days of age; 180 days of age; and at breeding, entry into the farrowing barn, and weaning for parities 1 through 6. Other data obtained at each mating included the number of inseminations; A.I. technician; age of semen; and boar. Weekly high and low temperatures were recorded for each farm during the study.

Analysis of variance procedures for repeated measures in a factorial design were used to analyze farrowing rates, number of pigs born alive, number of pigs weaned, and rebreeding intervals (Koch et al., 1977; Biometrics 33, 133). The statistical model consisted of season, neonatal litter size, puberty stimulation, parity (repeated variable) and appropriate interactions. Survival analyses were used to determine differences in sow longevity from puberty through farrowing of parity 6 (Cox and Oates, 1984; Analyses of Survival Data; Chapman and Hall; London). In the survival analysis, each factorial combination of the main effects will be treated as a unique treatment and the censor variables will consist of the normal length of time in each phase of production: gestation - 115 days; lactation - 21 days; and rebreeding - 7 days.

Body weights, backfat thickness, and loineye areas were used to estimate changes in weight and body composition throughout the study. Our experimental design did not control for these variables a priori. Consequently, it is important to determine if any observed differences among treatments was due to differences in changes in body composition. These data were analyzed with analysis of variance procedures for repeated measures as described previously except the repeated variable was the production phase or age at which the measurement was taken (gestation, lactation, etc.). There were no significant differences in body weights ($p < 0.32$); backfact thickness ($p < 0.21$); or loineye area ($p < 0.17$) during gestation, lactation, or rebreeding among treatments. Nevertheless, these variables were used as covariates in the analyses involving reproductive performance.

Results

Results from this study are presented in Tables 1 through 14. Our hypothesis for the study was based on two basic assumptions. First, gilts that respond to boar exposure at an early age have increased longevity and reproductive performance throughout their lifetime and, second, gilts that are reared in small litters from birth to weaning have accelerated pubertal development and, therefore, should respond to boar exposure at an early age. Consequently, we had two main objectives: 1) to determine the effect of neonatal litter size during lactation on early attainment of puberty; and 2) to determine the effect of early induction of puberty on sow longevity and reproductive performance through 6 parities.

<u>Effect of Small Neonatal Litter Size on Early Attainment of Puberty</u> – Early responders were classified as gilts that exhibit estrus within the first 28 days after boar exposure. There was no effect ($p < 0.51$) of season of birth on the proportion of gilts that exhibited estrus within the first 28 days after boar exposure so means presented in Table 1 were pooled across season of birth. These data indicate that 20% more gilts ($p < 0.05$) allowed to nurse in litters of 7 or less exhibited puberty within the first 28 days after boar exposure compared with their counterparts reared in litters of 10 or greater. A somewhat unexpected, but exciting observation was that the effect of being raised in a small litter had a positive effect on the proportion of early responders in the group of gilts in which boar exposure began at 170 days of age. In our experimental design, the timing of boar exposure was used to assess the rate of sexual maturation. As a result, we expected to see the positive effect of being reared in a small litter at 140 days of age. This is close to the time physiologically when gilts begin to acquire reproductive competence and gilts that matured quickly should respond to the boar and those that haven't should not. However, at 170 days of age, we felt that most of the gilts should have had sufficient time to mature and, in a sense, would simply be "waiting for the appropriate stimulation" to exhibit estrus. In other words, the slow maturing ones would have had time to "catch up", so to speak, with their counterparts that matured rapidly. Therefore, no effect of the neonatal environment was anticipated. Consequently, adjusting the neonatal litter size had positive effects with regards to identifying early responders regardless of age of puberty induction.

Identification of early responders was critical to our experimental design and ultimately understanding sow longevity. Our initial rationale was that any given population of gilts is composed of early and late responders and early responders perform better reproductively than late responders. Consequently, management strategies that stimulate the development of early responders should enhance reproductive performance. One way to think of the data presented in Table 1 is that the combinations of neonatal litter sizes and age of puberty induction created and subsequently identified different proportions of early and late responders. For example, when boar exposure began at 140 days of age, the population of gilts raised in small litters was comprised of 79% early responders and 21% late responders, whereas their counterparts raised in small litters consisted of a mixture of 51% early responders and 49% late responders. Consequently, the population raised in small litters contained 28% more early responders and as a group should be more productive from a reproductive standpoint.

For the treatments in which boar exposure began at 170 days of age, there were high proportions of gilts that exhibited estrus within 28 days of the initiation of boar exposure. This was expected. It is important to examine the differences between these treatments and their counterparts in which boar exposure began at 140 days. One important component of our study was that boar exposure at 170 days of age would actually be too late to accurately identify early responders. At 170 days of age, we felt that most of the gilts would have had sufficient time to mature and, in a sense, would simply be "waiting for the appropriate stimulation" to exhibit estrus. In other words, the slow maturing ones would have had time to "catch up", so to speak, with their counterparts that matured rapidly. This appears to be what happened. For the gilts raised in small litters, we anticipate about 18% of the gilts that exhibited estrus within 28 days of boar exposure at 170 days of age were actually late responders that had sufficient time to mature prior to puberty stimulation (94% - 76% = 18%). A similar estimate for gilts raised in large litters is 22% (75% - 53% = 22%). Thus, even though treatments that were given boar exposure at 170 days of age had a higher proportion of gilts exhibiting estrus during the subsequent 28 day period compared with gilts given boar exposure at 140 days of age, we anticipate that longevity and reproductive performance should be increased in gilts given boar exposure at 140 days of age.

A secondary objective was to determine whether inclusion of PG600® could be used to synchronize estrus of early responders. It has been well documented that the synchrony of estrus improves as gilts age. In other words, a higher percentage of gilts will show estrus in a shorter period of time in a group of gilts given boar exposure at 170 days of age compared with a contemporary group exposed to boars at 150 days of age. Because boar exposure requires a significant amount of labor and in most operations gilts that are 140 days of age are still housed in finishing barns, any technology that facilitates the response of gilts to boar exposure would be beneficial. In theory, PG600® synchronizes the response of gilts that are capable of responding to boar exposure. This was the rationale for inclusion of the puberty simulation treatments with PG600®. Use of PG600® appears to be of limited usefulness for this purpose. There were really no discernable differences in the timing or number of gilts that responded to boar exposure with and without PG600® at 140 days of age ($p < 0.27$). What is interesting is that there were a considerable number of gilts whose external genitalia became red and swollen and behaviorally were definitely interested in the boars, but would never stand. All of these gilts were detected in estrus subsequently and bred between 190 and 210 days of age, so it appears that there was not a negative effect of PG600®. The reproductive performance of these gilts was similar ($p < 0.41$) to their counterparts that did exhibit a standing reflex (data not shown). Consequently, it might be possible to use PG600® as a screening tool for early responders, if the criterion used to classify an early response focuses on physiological responses such as swelling of the external genitalia rather than the standing reflex.

<u>Effect of Neonatal Environment on Sow Longevity</u> – Tables 2 through 15 contain data with regards to the effect of neonatal litter size and boar induction strategies on sow longevity and reproductive performance. These can be grouped in the following manner: Tables 2 through 5 contain sow longevity data. Table 6 contains farrowing rate data. Tables 7 through 12 contain litter size data and Tables 13 and 14 contain estimates of piglets produced per gilt bred for each treatment combination.

As was the case with puberty induction, there were no effects of season and no season by neonatal environment interaction on any of the longevity or reproductive variables ($p < 0.74$). A good example of this is shown for the disposition of females over six parities (Tables 2 and 3). Consequently, means presented for all subsequent dependent variables were averaged across season (Tables 4 through 12).

Collectively, data presented in Table 5 indicate that both puberty induction strategy ($p < 0.01$) and neonatal environment ($p < 0.01$) influenced the proportion of sow still in production after six parities. The relative advantages of being raised in a small litter and being exposed to boars at 140 days of age were 18% and 17%, respectively. Moreover, these effects were additive. Consequently, 45% of gilts raised in small litters and given boar exposure at 140 days of age were still in production after six parities compared with only 10% of their counterparts raised in large litters and given boar exposure at 170 days of age. This difference in longevity can be attributed to two main areas (Table 4). First, during the first two parities, 15% more sows that were from small litters and given boar exposure early compared with sows from large litters and exposed to boars at 170 days of age. Second, sows raised in small litters had an average of 5% higher farrowing rates than sows from large litters. This translates into a 30% advantage in longevity over 6 parities (6 parities x 5% per parity). Thus, about one-third of the advantage in longevity was due to improved rebreeding performance during the first two parities, while the remaining two thirds appeared to be the result of increased farrowing rates in each of six parities.

In contrast, only the neonatal environment affected numbers of pigs born alive ($p < 0.05$). Litter size increased ($p < 0.05$) in all treatment combinations between the first and third parities and then remained relatively constant ($p < 0.43$) between parities 4 through 6 (Table 7)). Sows that were weaned from litters of 7 or less piglets averaged 0.5 pigs more per parity compared with their counterparts that came from litters with 10 or more piglets (Table 8).

Tables 9 through 12 contain numbers of pigs born alive over six parities from sows classified as early and late responders based on when they exhibited estrus in response to boar exposure during sexual maturation. As mentioned previously, early responders were classified as those that showed an estrous response within 28 days, while late responders were classified as those that exhibited estrus after this time interval. A significant two-way interaction was present for estrous response to boar exposure and neonatal environment ($p < 0.01$). Consequently, differences in number of pigs born alive were determined early and late responders within each neonatal environment. The interaction was due to the magnitude of the response between early and late responders. For sows from small litters, early responders farrowed 1.2 more ($p < 0.05$) piglets over six parities compared with late responders. Early responders raised in large litters showed a tendency to farrow more pigs ($p < 0.08$) than their counterparts that were classified as late responders. However, the difference between the two groups was only 0.6 piglets.

Tables 13 and 14 contain estimates of the reproductive efficiency for each gilt development strategy. Data presented in both tables are based on the number of gilts within each treatment group that were bred and entered production and consider both the total number of litters farrowed within each system and the number of pigs born in each litter. In essence, these are estimates of the average number of piglets produced for each bred gilt over her normal productive lifespan, 6 parities. While these data were not analyzed statistically, differences among the different gilt development strategies are striking. In this production system, reducing the number of littermates in which future replacement gilts were raised in conjunction with providing early boar exposure basically doubled the lifetime productivity of each bred female. The estimate for this approach was 43.2 pigs produced per bred gilt, whereas the estimate for raising gilts in litters of 10 or more pigs and providing boar exposure at 170 days of age was 21.9 pigs produced per bred gilt (Table 13). Finally, regardless of the puberty induction strategy or their neonatal environment, gilts that show estrus within the first 28 days of boar exposure had a distinct advantage in terms of lifetime productivity (Table 14). Their superiority varied from 26 pigs when gilts were raised in small litters and given boar exposure at 140 days of age to 12 pigs when they were raised in large litters and given boar exposure at 170 days of age.

Discussion

Results from this study clearly show effects of gilt development strategies on sow longevity and lifetime productivity through 6 parities. Reducing the competition to which future replacement gilts are exposed during lactation by reducing size of the litter in which they nurse increased longevity and lifetime reproductive performance. Although the exact mechanism by which this occurred is not known, it is tempting to speculate that reduction of the social and, perhaps, nutritional stresses of being raised in a large litter are involved. Since key developmental periods occur during the first 100 days after birth in gilts, decreasing any factors that could potentially retard the reproductive development of females should improve their performance as adults. It is conceivable that this is what occurred by limiting the number of piglets nursing in the present study.

The positive effect of early induction of puberty observed in the present study most likely is related to an increased ability to identify early responders. Gilts that responded within 28 days to boar exposure remained in the herd longer and produced more piglets compared with those that did not. This was true regardless of the age at puberty induction. However, the difference in performance between early and late responders identified by boar exposure at 140 days of age was twice as great as that between their counterparts identified at 170 days of age. Boar exposure at 140 days of age provided a more critical assessment of an early response compared with boar exposure at 170 days of age. The additional 30 days of maturation in the latter provided additional opportunities for gilts to mature to the point that they could exhibit estrus. Consequently, the population of early responders at 170 days of age included some animals that would have been classified as late responders at 140 days of age. Based on differences between the proportion of early and late responders at 140 and 170 days of age, there should be about 20% of the gilts classified as early responders at 170 days of age that would have been considered late responders if boar exposure had begun at 140 days of age.

Given the management structure of many operations in the swine industry, providing good, consistent boar exposure to gilts at 140 days of age might be technically challenging and present problems with maintaining biosecurity. Thus, it may not be practical for many operations to implement this strategy. Administration of PG600® at young age in combination with the visual assessment of changes in the vulva may prove to be a reasonable alternative. However, additional research is needed to verify this approach. However, for production systems that move future replacement gilts to sow farms at young ages (after the nursery phase), this certainly is a practice that could be incorporated very easily. In contrast, because males born as litter mates to replacement gilts have limited economic value as market animals, strategic cross-fostering for sows nursing potential replacement gilts is a technique that should be easy to implement and improve sow longevity and reproductive performance. Finally, regardless of the gilt management system that is used, culling gilts that do not exhibit estrus within 28 days of boar exposure should help eliminate a population of subfertile animals that are present in most herds.

Table 1. Effect of Neonatal Litter Size and Puberty Induction Strategies on the Proportion of Gilts in Estrus within 28 days after Boar Exposure.

	Neonatal Environment		
Puberty Stimulation	**Small Litters ($\leq$ 7 pigs)**	**Large Litters ($\geq$ 10 pigs)**	*Main Effect of Puberty Stimulation*
Boar Exposure @ 140 days	238 / 300 (79%)	155 / 315 (49%)	*383 / 615[a] (62%)*
Boar Exposure @ 140 days + PG600®	218 / 299 (73%)	174 / 306 (57%)	*392 / 605[a] (65%)*
Boar Exposure @ 170 days	282 / 300 (94%)	226 / 300 (75%)	*508 / 600[b] (85%)*
Main Effect of Neonatal Environment	*738 / 899* (82%)*	*555 / 921 (60%)*	----------

*significantly different from Gilts raised in Large Litters ($p < 0.05$)
[a,b] means with different superscripts within the same column differ ($p < 0.05$)

Table 2. Effect of Neonatal Environment and Puberty Induction Strategies on Percentage of Females Still in Production through Six Parities for the Spring Replicate.

Production Status	Boar Exposure @ 140 days		Boar Exposure @ 140 days + PG600®		Boar Exposure @ 170 days of age	
	Small Litter	Large Litter	Small Litter	Large Litter	Small Litter	Large Litter
Number Moved into Breeding	150 gilts	155 gilts	148 gilts	149 gilts	145 gilts	150 gilts
Bred and Entered Sow Herd	95% (143)	90% (139)	97% (144)	94% (140)	95% (138)	93% (139)
Farrowed – Parity 1	84% (126)	74% (115)	82% (122)	77% (115)	76% (110)	69% (103)
Rebred after First Lactation	80% (120)	65% (100)	78% (115)	66% (98)	63% (92)	59% (89)
Farrowed – Parity 2	72% (108)	55% (85)	69% (102)	54% (80)	52% (75)	46% (69)
Rebred after Second Lactation	67% (100)	49% (76)	62% (92)	47% (70)	4% (70)	37% (55)
Farrowed – Parity 3	59% (88)	41% (64)	54% (80)	38% (57)	40% (58)	29% (44)
Rebred after Third Lactation	57% (85)	38% (59)	52% (77)	35% (52)	38% (55)	24% (36)
Farrowed – Parity 4	56% (84)	35% (54)	53% (79)	32% (48)	36% (52)	21% (31)
Rebred after Fourth Lactation	55% (82)	32% (50)	50% (74)	28% (42)	31% (45)	17% (26)
Farrowed – Parity 5	52% (78)	31% (46)	49% (72)	25% (37)	28% (40)	15% (22)
Rebred after Fifth Lactation	49% (74)	26% (40)	45% (67)	21% (31)	23% (33)	11% (17)
Farrowed – Parity 6	47% (70)	24% (37)	44% (65)	16% (24)	19% (28)	9% (14)

Table 3. Effect of Neonatal Environment and Puberty Induction Strategies on Percentage of Females Still in Production through Six Parities for the Fall Replicate.

Production Status	Boar Exposure @ 140 days		Boar Exposure @ 140 days + PG600®		Boar Exposure @ 170 days of age	
	Small Litter	Large Litter	Small Litter	Large Litter	Small Litter	Large Litter
Number Moved into Breeding	150 gilts	160 gilts	151 gilts	157 gilts	155 gilts	150 gilts
Bred and Entered Sow Herd	97% (145)	92% (147)	93% (140)	92% (144)	98% (152)	93% (139)
Farrowed – Parity 1	82% (123)	74% (118)	80% (121)	73% (115)	81% (125)	71% (106)
Rebred after First Lactation	79% (118)	62% (99)	77% (116)	60% (94)	72% (112)	58% (87)
Farrowed – Parity 2	70% (105)	51% (82)	66% (99)	47% (74)	59% (91)	47% (70)
Rebred after Second Lactation	65% (98)	46% (74)	62% (93)	44% (69)	50% (77)	41% (61)
Farrowed – Parity 3	61% (92)	43% (69)	58% (88)	39% (61)	45% (70)	36% (54)
Rebred after Third Lactation	59% (89)	39% (63)	55% (83)	36% (57)	43% (67)	33% (49)
Farrowed – Parity 4	56% (84)	36% (57)	51% (77)	32% (50)	38% (59)	26% (40)
Rebred after Fourth Lactation	55% (82)	33% (53)	51% (77)	29% (46)	34% (52)	23% (34)
Farrowed – Parity 5	48% (72)	28% (44)	45% (68)	25% (40)	29% (45)	19% (28)
Rebred after Fifth Lactation	47% (70)	24% (38)	41% (62)	21% (33)	25% (38)	14% (21)
Farrowed – Parity 6	43% (65)	21% (33)	37% (56)	18% (28)	23% (36)	11% (16)

Table 4. Effect of Neonatal Environment and Puberty Induction Strategies on Percentage of Females Still in Production through Six Parities.

Production Status	Boar Exposure @ 140 days		Boar Exposure @ 140 days + PG600®		Boar Exposure @ 170 days of age	
	Small Litter	Large Litter	Small Litter	Large Litter	Small Litter	Large Litter
Number Moved into Breeding	300 gilts	315 gilts	299 gilts	306 gilts	300 gilts	300 gilts
Bred and Entered Sow Herd	96%[a] (288)	91%[a] (286)	95%[a] (284)	93%[a] (284)	97%[a] (290)	93%[a] (278)
Farrowed – Parity 1	83%[a] (249)	74%[a,b] (233)	81%[a,b] (243)	75%[a,b] (230)	78%[a,b] (235)	70%[b] (209)
Rebred after First Lactation	79%[a] (238)	63%[b,c] (199)	77%[a] (231)	63%[b,c] (192)	74%[a,b] (222)	59%[c] (176)
Farrowed – Parity 2	71%[a] (213)	53%[c] (167)	67%[a,b] (201)	50%[c] (154)	55%[b,c] (166)	46%[c] (139)
Rebred after Second Lactation	66%[a] (198)	48%[c] (150)	62%[a,b] (185)	45%[c] (139)	49%[b,c] (147)	37%[c] (111)
Farrowed – Parity 3	60%[a] (180)	42%[c] (133)	56%[a,b] (168)	39%[c] (118)	46%[b,c] (138)	33%[c] (98)
Rebred after Third Lactation	58%[a] (174)	39%[c] (122)	54%[a,b] (160)	36%[c] (109)	41%[b,c] (122)	28%[c] (85)
Farrowed – Parity 4	56%[a] (168)	35%[b] (111)	52%[a] (156)	32%[b] (98)	37%[b] (111)	24%[b] (71)
Rebred after Fourth Lactation	55%[a] (164)	34%[b] (106)	51%[a] (151)	29%[b,c] (88)	32%[b,c] (97)	20%[c] (60)
Farrowed – Parity 5	50%[a] (150)	29%[b] (90)	47%[a] (140)	25%[b] (77)	28%[b] (85)	17%[b] (50)
Rebred after Fifth Lactation	48%[a] (144)	25%[b] (78)	43%[a] (129)	21%[b] (64)	24%[b] (71)	13%[b] (38)
Farrowed – Parity 6	45%[a] (135)	22%[b] (70)	40%[a] (121)	20%[b] (60)	21%[b] (64)	10%[b] (30)

[a,b,c] Means within the same row with different superscripts differ ($p < 0.01$)

Table 5. Effect of Neonatal Litter Size and Puberty Induction Strategies on Proportion of Sows Remaining in Herd after Six Parities.

Puberty Stimulation	**Neonatal Environment** Small Litters ($\leq$ 7 pigs)	**Neonatal Environment** Large Litters ($\geq$ 10 pigs)	*Main Effect of Puberty Stimulation*
Boar Exposure @ 140 days	45.0% (135 / 300)	22.2% (70 / 315)	*33.3%*[a] *(205 / 615)*
Boar Exposure @ 140 days + PG600®	40.4% (121 / 299)	19.6% (60 / 306)	*29.9%*[a] *(181 / 605)*
Boar Exposure @ 170 days	21.3% (64 / 300)	10.0% (30 / 300)	*15.6%*[b] *(94 / 600)*
Main Effect of Neonatal Environment	*35.6%* (320 / 899)*	*17.3% (160 / 921)*	----------

*significantly different from Gilts raised in Large Litters ($p < 0.01$)
[a,b] means with different superscripts within the same column differ ($p < 0.01$)

Table 6. Effect of Neonatal Litter Size and Puberty Induction Strategies on Farrowing Rate over Six Parities.

Puberty Stimulation	**Neonatal Environment** Small Litters ($\leq$ 7 pigs)	**Neonatal Environment** Large Litters ($\geq$ 10 pigs)	*Main Effect of Puberty Stimulation*
Boar Exposure @ 140 days	90.8% (1095 / 1206)	85.4% (804 / 941)	*88.5%*[a] *(1899 / 2147)*
Boar Exposure @ 140 days + PG600®	90.3% (1029 / 1140)	84.1% (737 / 876)	*87.6%*[b] *(1766 / 2016)*
Boar Exposure @ 170 days	84.2% (799 / 949)	79.8% (597 / 748)	*82.3%*[b] *(1396 / 1697)*
Main Effect of Neonatal Environment	*88.7%* (2923 / 3295)*	*83.3% (2138 / 2565)*	----------

*significantly different from Gilts raised in Large Litters ($p < .05$)
[a,b] means with different superscripts within the same column differ ($p < 0.05$)

Table 7. Effect of Neonatal Environment and Puberty Induction Strategies on Numbers of Pigs Born Alive in Parities 1 through 6.

Production Status	Boar Exposure @ 140 days		Boar Exposure @ 140 days + PG600®		Boar Exposure @ 170 days of age	
	Small Litter	Large Litter	Small Litter	Large Litter	Small Litter	Large Litter
Parity 1	10.2 ± 0.2 (249)	9.8 ± 0.2 (233)	10.1 ± 0.2 (243)	9.8 ± 0.2 (230)	10.0 ± 0.2 (235)	9.6 ± 0.2 (209)
Parity 2	10.8 ± 0.2 (213)	10.4 ± 0.2 (167)	10.7 ± 0.2 (201)	10.1 ± 0.2 (154)	10.4 ± 0.2 (166)	10.1 ± 0.2 (139)
Parity 3	11.5 ± 0.2 (180)	11.0 ± 0.2 (133)	11.3 ± 0.2 (168)	10.8 ± 0.2 (118)	11.0 ± 0.3 (138)	10.6 ± 0.2 (98)
Parity 4	11.8 ± 0.3 (168)	11.0 ± 0.2 (111)	11.2 ± 0.2 (156)	10.8 ± 0.2 (98)	11.3 ± 0.3 (111)	10.9 ± 0.3 (71)
Parity 5	12.1 ± 0.3 (150)	11.5 ± 0.3 (90)	11.9 ± 0.2 (140)	11.3 ± 0.3 (77)	11.5 ± 0.3 (85)	11.0 ± 0.4 (50)
Parity 6	11.7 ± 0.3 (135)	11.4 ± 0.4 (70)	11.8 ± 0.3 (121)	11.5 ± 0.4 (60)	11.6 ± 0.4 (64)	11.3 ± 0.5 (30)

Table 8. Effect of Neonatal Litter Size and Puberty Induction Strategies on Average Number of Pigs Born Alive through Six Parities.

Puberty Stimulation	Neonatal Environment: Small Litters (≤ 7 pigs)	Neonatal Environment: Large Litters (≥ 10 pigs)	*Main Effect of Puberty Stimulation*
Boar Exposure @ 140 days	11.2 ± 0.1 (1095)	10.6 ± 0.2 (804)	*10.9 ± 0.1[a] (1899)*
Boar Exposure @ 140 days + PG600®	11.0 ± 0.1 (1029)	10.5 ± 0.2 (737)	*10.8 ± 0.1[a,b] (1766)*
Boar Exposure @ 170 days	10.7 ± 0.2 (799)	10.2 ± 0.2 (446)	*10.5 + 0.2[b] (1245)*
Main Effect of Neonatal Environment	*11.0 ± 0.1* (2923)*	*10.5 ± 0.2 (1987)*	----------

[a,b] means with different superscripts within the same column differ ($p < 0.10$)
*significantly different from Gilts raised in Large Litters ($p < 0.05$)

Table 9. Effect of Neonatal Environment and Occurrence of Estrus in Gilts Exposed to Boars at 140 Days of Age on Number of Pigs Born Alive.

Production Status	Small Litters (≤ 7 pigs)		Large Litters (≥ 10 pigs)	
	Early Responders	**Late Responders**	**Early Responders**	**Late Responders**
Parity 1	10.4 ± 0.2 (197)	9.7 ± 0.3 (52)	10.1 ± 0.2 (114)	9.5 ± 0.2 (119)
Parity 2	10.9 ± 0.2 (181)	10.0 ± 0.4 (32)	10.6 ± 0.2 (92)	10.2 ± 0.3 (75)
Parity 3	11.6 ± 0.2 (162)	10.4 ± 0.5 (18)	11.3 ± 0.2 (79)	10.6 ± 0.2 (54)
Parity 4	12.0 ± 0.3 (152)	9.3 ± 0.9 (16)	11.5 ± 0.3 (63)	10.3 ± 0.3 (48)
Parity 5	12.2 ± 0.3 (140)	10.7 + 1.1 (10)	11.8 ± 0.4 (52)	11.1 ± 0.4 (38)
Parity 6	11.7 ± 0.3 (131)	11.8 ± 1.0 (4)	11.6 ± 0.5 (46)	11.0 ± 0.6 (24)
Mean	11.4 ± 0.3 (963)	10.0 ± 0.6 (132)	11.0 ± 0.3 (446)	10.2 ± 0.4 (358)

Table 10. Effect of Neonatal Environment and Occurrence of Estrus in Gilts treated with PG600® and Exposed to Boars at 140 Days of Age on Number of Pigs Born Alive.

Production Status	Small Litters ($\leq$ 7 pigs)		Large Litters ($\geq$ 10 pigs)	
	Early Responders	**Late Responders**	**Early Responders**	**Late Responders**
Parity 1	10.3 ± 0.2 (177)	9.6 ± 0.3 (66)	10.0 ± 0.3 (131)	9.6 ± 0.2 (99)
Parity 2	10.9 ± 0.2 (161)	10.0 ± 0.4 (40)	10.2 ± 0.3 (92)	9.9 ± 0.3 (62)
Parity 3	11.4 ± 0.2 (143)	10.7 ± 0.5 (25)	11.1 ± 0.3 (69)	10.3 ± 0.3 (49)
Parity 4	11.5 ± 0.2 (138)	10.0 ± 0.8 (16)	11.2 ± 0.4 (59)	10.2 ± 0.5 (39)
Parity 5	12.0 ± 0.3 (124)	11.1 ± 1.1 (16)	11.5 ± 0.5 (48)	11.0 ± 0.6 (29)
Parity 6	11.9 ± 0.3 (113)	10.4 ± 1.3 (8)	11.7 ± 0.7 (42)	11.0 ± 0.9 (18)
Mean	11.2 ± 0.2 (856)	10.1 ± 0.4 (171)	10.7 ± 0.3 (441)	10.1 ± 0.3 (296)

Table 11. Effect of Neonatal Environment and Occurrence of Estrus in Gilts Exposed to Boars at 170 Days of Age on Number of Pigs Born Alive.

Production Status	**Small Litters (≤ 7 pigs)**		**Large Litters (≥ 10 pigs)**	
	Early Responders	**Late Responders**	**Early Responders**	**Late Responders**
Parity 1	10.1 ± 0.2 (221)	9.1 ± 0.5 (14)	9.7 ± 0.2 (156)	9.3 ± 0.2 (53)
Parity 2	10.4 ± 0.2 (161)	8.9 ± 0.9 (5)	10.2 ± 0.3 (117)	9.5 ± 0.4 (22)
Parity 3	11.0 ± 0.3 (138)	-----	10.7 ± 0.3 (88)	10.2 ± 0.4 (10)
Parity 4	11.3 ± 0.3 (111)	-----	10.9 ± 0.4 (63)	10.7 ± 0.8 (8)
Parity 5	11.5 ± 0.3 (85)	-----	11.0 ± 0.6 (46)	11.0 ± 0.8 (4)
Parity 6	11.6 ± 0.4 (64)	-----	11.3 ± 0.7 (29)	11.0 (1)
Mean	10.8 ± 0.3 (780)	9.0 ± 0.7 (19)	10.4 ± 0.3 (499)	9.6 ± 0.6 (98)

Table 12. Effect of Occurrence of Estrus in Response to Puberty Induction and Neonatal Litter Size on Number of Pigs Born Alive.

Puberty Stimulation	**Small Litters (≤ 7 pigs)**		**Large Litters (≥ 10 pigs)**	
	Early Responders	**Late Responders**	**Early Responders**	**Late Responders**
Boar Exposure @ 140 days	11.4 ± 0.2 (963)	10.0 ± 0.3 (132)	11.0 ± 0.3 (446)	10.2 ± 0.2 (358)
Boar Exposure @ 140 days + PG600®	11.2 ± 0.2 (856)	10.1 ± 0.3 (171)	10.7 ± 0.2 (441)	10.1 ± 0.3 (296)
Boar Exposure @ 170 days	10.8 ± 0.3 (780)	9.0 ± 0.7 (19)	10.4 ± 0.2 (499)	9.6 ± 0.6 (98)
Main Effect of Neonatal Environment[1]	*11.2 ± 0.1* (2,599)*	*10.0 ± 0.3 (322)*	*10.7 ± 0.2*[†] *(1,386)*	*10.1 ± 0.3 (752)*

[1]neonatal environment x estrous response interaction ($p < 0.01$)
*significantly different from Late Responders raised in Small Litters ($p < 0.05$)
†significantly different from Late Responders raised in Large Litters ($p < 0.08$)

Table 13. Estimated Effects of Different Gilt Development Strategies on Total Number of Pigs Produced per Bred Gilt over Six Parities.

Strategy	Number of Litters Farrowed / Gilt	Average Number Born Alive / Litter	Total Pigs / Bred Gilt
Boar exposure @ 140 days of age + Small neonatal litter size	3.86	11.2	43.2
Boar exposure @ 140 days of age + Large neonatal litter size	2.81	10.6	29.8
Boar exposure @ 140 days of age + PG600 + Small neonatal liter size	3.62	11.0	39.8
Boar exposure @ 140 days of age + PG600 + Small neonatal litter size	2.60	10.5	27.3
Boar exposure @ 170 days of age + Small neonatal litter size	2.78	10.7	29.7
Boar exposure @ 170 days of age + Large neonatal litter size	2.15	10.2	21.9

Table 14. Estimated Effects of Different Gilt Development Strategies on Total Number of Pigs Produced per Bred Gilt over Six Parities for Early and Late Responders.

Strategy	Number of Litters Farrowed / Gilt	Average Number Born Alive / Litter	Total Pigs / Bred Gilt
Boar exposure @ 140 days of age + Small neonatal litter size + Early responders	4.22	11.4	48.1
Boar exposure @ 140 days of age + Small neonatal litter size + Late responders	2.20	10.0	22.0
Boar exposure @ 140 days of age + Large neonatal litter size + Early responders	3.19	11.0	35.1
Boar exposure @ 140 days of age + Large neonatal litter size + Late responders	2.45	10.2	25.0
Boar exposure @ 170 days of age + Small neonatal litter size + Early responders	2.85	10.8	30.8
Boar exposure @ 170 days of age + Small neonatal litter size + Late responders	1.11	9.0	10.0
Boar exposure @ 170 days of age + Large neonatal litter size + Early responders	2.41	10.4	25.1
Boar exposure @ 170 days of age + Large neonatal litter size + Early responders	1.38	9.6	13.2