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THE EFFECT OF RATE OF DEVELOPMENTAL GROWTH ON SOW REPRODUCTIVE PERFORMANCE, BODY CONDITION AND PRODUCTIVITY

A Thesis

Presented for the

Master of Science

Degree

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Gregory L. Bilbrey

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DEDICATION

This thesis is dedicated to my parents, Leonard and Betty Bilbrey, in appreciation for their lifelong support, love and encouragement.

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ABSTRACT

Fifty littermate gilt pairs were classified according to their rate of gain during the finishing period. Body weight and backfat thickness at day 110 of gestation and weaning were recorded in addition to the sow productivity traits of total number born, number born alive, pig birth and weaning weights and number of pigs weaned. Females were evaluated for three parities. Gilts exhibiting slower rates of developmental growth (65 kg gain in body weight) produced more pigs born (8.6 vs. 6.4, $p=.05$), more born alive (8.2 vs. 6.0, $p<.05$) and more pigs weaned (7.4 vs. 5.1, $p<.05$) in parity one in addition to more pigs weaned in parity three (8.6 vs. 7.3, $p<.10$) than faster gaining gilts (73 kg gain in body weight). Over three parities, slow gaining gilts produced 26.4, 25.8 and 23.4 pigs born, born alive and weaned, respectively, compared to 25.6, 24.0 and 20.3 pigs, respectively, for fast gaining gilts. Gilt rate of gain did not affect progeny birth or weaning weights ($p>.27$) nor sow 110 day gestation weights or backfat thicknesses ($p>.25$ and $p>.17$, respectively). Fast gaining gilts were heavier at selection (106 kg vs. 96 kg, $p=.0001$) and at first breeding (145 kg vs. 139 kg, $p<.05$) although the only difference observed in sow weaning weight was in parity two where slow growing gilts were heavier (159 kg vs 146 kg, $p<.10$). Slow growing gilts gained 82 kg of body weight (BW) from selection through parity three weaning compared to a 73 kg BW gain for faster growing gilts. Slow growth rate females lost more backfat during their first and third lactations and had negative backfat gains during gestation in parities two and three. Slow growing females had lower culling rates (35%) than faster growing females (39%). Fraternal litter size tended to affect litter sizes produced by the gilts in this experiment though

the effect was observed mostly in the third parity. Parity of the dam in which the gilts were born influenced pig birth weights and number weaned but not until the third parity. Correlations of gain to sow body weights were positive and moderate to high but were low for backfat thickness and productivity traits. These results indicated that fast growing females used for sow herd replacements were not reproductively nor productively superior than their slower growing littermates.

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CHAPTER I

INTRODUCTION

Rate and efficiency of gain have long been associated with profitability in modern swine production enterprises. Since both of these traits are moderately to highly heritable (Krider et al., 1982), swine producers have been advised to select replacement animals with high genetic merit for growth and efficient gain. Ahlschwede and Kuhlers (1985) in the popular layman's guide to swine production, the Pork Industry Handbook, emphasized that pork producers should select the fastest growing and leanest gilts to use for replacements in order to remove slower growing fat gilts and their genetics from the herd. They indicated that replacement gilts are indeed the primary method for improving the genetic base of the herd and suggested that gilts should replace sows at rates of 15% to 20% in each farrowing. Christenson (1986) stated that as much as 30% to 40% of the sow herd may be replaced each year by gilts. Considering these replacement rates, the importance placed on the estimated performance of the gilt and her contribution to the swine enterprise are easily understood.

Since feed costs make up such a large portion (60%-70%) of the expenses encountered in swine production (Isler and Christian, 1978), selection for improved feed efficiency is an obvious method for increasing economic returns. Isler and Christian (1978) stated that faster growing and leaner animals were more efficient in terms of units of feed required per corresponding unit of body weight gain. Krider et al. (1982) supported this statement by concluding that rate and economy of gain were highly

related. Therefore the intense selection pressure on rate of growth has improved feed efficiency.

While efficiency of gain and rate of growth are both extremely important to the swine producer, the performance of the sow must also receive equal, if not greater, attention. Not only is the sow responsible for one-half of the genetic constitution of the herd, she more importantly must be reproductively efficient and prolific. Any swine production enterprise depends on the ability of the sow to cycle and conceive on time and at regular intervals, to produce large litters of healthy pigs and to provide her offspring with enough nutrients and mothering ability for them to survive and be weaned at heavy weights. Reproductive inefficiency results in the culling of sows from the herd, after a substantial amount of time and money has been invested, and a reduction in the number of litters produced per year. Lowering the number of litters produced per sow per year results in increased costs of production by decreasing production system efficiency through poor utilization of facilities and the need to maintain a larger breeding herd. It also results in the need to purchase (or produce) and feed more feedstuffs to the sow without receiving a marketable product in return. Stevermere et al., (1980) indicated that a difference of .6 litters per sow per year (2.0 vs. 1.4) results in an 8% net change in the cost of production of an 18 kg pig. Increasing litter sizes not only produces more pigs to market but also reduces feed and production costs per pig sold by dividing the expenses over a larger number of marketable animals. To more simply emphasize the importance of the sow in relation to growth rate and economy of gain of her progeny, one realizes that growth rate and feed efficiency would be of no importance if there were no pigs present to evaluate these traits.

Heritabilities of growth rate and efficiency of gain have been reported to range from .14 to .58 and .08 to .72, respectively (Krider et al., 1982). With these values, progress through selection has been possible in these traits. Much research over the years has successfully improved growth rate and feed efficiency as evidenced by the lower number of days required to reach market weights. While past research has focused on improving rate of gain, very few studies have examined the effects of these improvements on sow reproductive and productive performance. Ahlschwede and Kuhlers (1985) stated that no documented evidence existed to prove that fast growing females were poorer performers. Kuhlers et al. (1984), however, in a study examining the effects of selection for growth rate on carcass performance, indicated further research involving reproductive efficiencies was needed.

Although some research in this area has been done in the United States (Young et al., 1974; Garnett and Rahnefeld, 1976; Young et al., 1977a,b; Stewart and Drewry, 1983; and Mabry et al., 1985) the research often was limited to the evaluation of either productive or reproductive traits in a single parity and not over multiple parities. Klusacek et al. (1986) examined the effects of growth rate on reproductive performance over three parities but their work was done in Czechoslovakia using Czechoslovakian Improved White gilts and did not represent similar management practices and breed influences common in the United States. Farrowing interval was the main trait examined in their research though they also investigated effects of sow weight on productivity. Gueblez et al., (1987) performed research over four parities but mostly emphasized herd longevity. This work was also done under different conditions normally faced by United States swine producers and the main emphasis of the research was to determine age and fat thickness effects on reproductive performance. Therefore,

the objective of this study was to examine, under general management programs common in the United States, the effects of rate of developmental growth on the reproductive and production performance of female swine over three parities.

CHAPTER II

REVIEW OF LITERATURE

Body condition and sow performance

Practical swine production focuses attention on the condition of females in the herd. Sow body condition, measured by gains and losses of fat thickness and live weight, is generally associated with sow reproductive and productive performance. Contrasting reports regarding the relationship of body condition to sow performance do exist. Esbenshade et al. (1986) found no association of losses in weight, heart girth, backfat thickness and condition score during lactation with rebreeding interval and percent in estrus by 12 days postweaning. They reported, however, highly significant negative correlations between body losses during lactation and the litter performance traits of number born alive, number weaned, adjusted 21 day litter weights and the National Swine Improvement Federation sow productivity index. Those correlations indicated that sows who were more productive lost more weight and sacrificed body condition during lactation. Moderate correlations of number born alive with gestation weight gain (.49) and backfat gain (.-33) in primiparous females were reported. Gilts who farrowed larger litters gained more weight but lost more backfat during their first gestation. The authors concluded that first parity gilts gaining more weight during gestation would be able to perform at higher levels as they matured. Bereskin and Frobish (1981) positively related litter 21 day weight and size with sow gestation weight gain. King et al. (1987) indicated that sows that were heavier in their first

parity returned to postweaning estrus earlier than their counterparts although they lost more weight and backfat during lactation. Heavier sows were generally associated with better condition and more body energy reserves and therefore could withstand production demands better than those who may have began production in poorer condition.Earlier work by King et al. (1982) led to the conclusion that the postweaning return to estrus interval was not related to age, fat thickness or live body weight of females at farrowing but was associated with weight and fat loss during lactation ($r= .23$, $p<.11$ and $r= .23$, $p< .01$, respectively). In the following parity, ovulation rate and litter size were not significantly related to lactation fat and weight losses but more than 37% of parity one sows did not return to estrus within 14 day postweaning. Those were the sows that experienced more severe weight and fat losses while lactating. Average weight loss was 16.9 kg and average fat loss was 4.9 mm across the experiment. Meyen et al. (1985) in a study involving 2560 multiparous crossbreed sows, revealed that sows measured to be lower in last rib fat thickness were longer in their return to estrus following weaning. Sows yielding larger, heavier litters were more apt to be leaner at weaning and rebreeding and were less likely to have gestational backfat gains but did put on more weight during gestation. Davies and Howard (1985) found no significant correlation of backfat thickness with sow productivity traits when 168 crossbred sows were examined. Length of farrowing interval was reported to be longer in second through fifth parity sows who experienced more weight loss from gestation through weaning (Watkins, 1983). In the previously mentioned work of Esbenshade et al. (1986) sow body weight and heart girth continued to increase as parity increased. However, body condition and backfat thickness declined with increasing parities representing the contribution of the sow to her litter(s). The

authors suggested that the mobilization of fat by sows occurred and as the sow's longevity in the herd increased they became leaner. In the 1982 trial conducted by King and associates, the interval between weaning and rebreeding was indicated to be associated with sow condition and subsequent reproductive performance. The sows that lost more weight and fat due to lactation and did not return to estrus by 14 day postweaning produced more pigs born alive in their next parity. This response was also observed by Morrow et al. (1989) who indicated allowing for a longer (12 days or more) interval between weaning and mating can improve litter size. Their study utilized 578 F1 Large White X Landrace primiparous sows to evaluate the effects of different management programs on the improvement of parity two litter size. Sows mated after 17 days postweaning produced larger numbers of pigs born alive and had higher farrowing rates than sows bred on the first estrus after weaning. These reports indicated the increased weaning to service interval may have allowed females to reach improved body condition levels. Reese et al. (1982b) stated that lactation energy intake was correlated inversely to body weight loss of the sow in lactation. In their experiment sows were fed either low (8 Mcal of metabolizable energy (ME)/d) or high (16 Mcal of ME/d) energy diets. Sows receiving low energy diets during lactation returned to estrus by 7, 14, 21 and 70 days postweaning at 44.3, 30.4, 33.2 and 13.9 percent lower rates, respectively, than those fed the high energy rations. A third trial in this experiment included a medium energy level diet of 12 Mcal of ME/d. Weight losses for sows fed the three diets were 25.7 kg, 13.3 kg and 3.3 kg, respectively, with backfat changes reported of -8.4 mm, -4.6 mm, and -1.8 mm, respectively. Percent of sows in estrus at 7, 14, 21 and 70 days again decreased as energy intake decreased (65.2 vs. 91.3 vs. 95.7 at 7 days, 73.9 vs. 95.7 vs. 100.0 at 14 days, 73.9 vs. 95.7 vs.

100.0 at 21 days and 82.6 vs. 95.7 vs. 100.0 at 70 days, respectively). The only productivity trait effect recorded was in the two-ration experiment where average pig weaning weight was lower (.9 kg, $p<.01$) for sows receiving the low energy diet. This relationship of sow body weight loss to energy intake during lactation is supported by the research of Elsley et al. (1968) and O'Grady et al. (1975). In a similar experiment, Reese et al. (1982a) examined first lactation effects on second parity performance and second parity lactation effects on pig performance. Sows which received low energy diets in their first lactation gained more weight and backfat in the subsequent gestation but lost more weight and backfat through the second parity. Their pigs were lighter at birth ($p<.10$), their return to estrus was longer, but farrowing rate was not affected. Low energy intake in the second lactation resulted in lower pig weaning weights but was attributed to lower milk production compared to the high energy fed sows. Lidvall and Griffin (1962), Elsley et al. (1969), Hitchcock et al. (1971) and Varley and Cole (1976) reported changes in weight of the sow were related to lactational feeding levels but conception rate was not affected.

Based on research cited above, sufficient evidence does exist to support the theory that the body condition of the sow influences her reproductive and productive performance. Research by Ferguson et al. (1985) further supports and collaborates this relationship. These researchers utilized Yorkshire and Duroc litter records to examine both genetic and phenotypic associations between sow weight and productivity. Their basic conclusion was that selection for improvement in sow productivity traits resulted in a corresponding increase in body weight of the sow.

Nutritional effects on sow performance have already been discussed to some detail. Sow body condition (i.e. weight and backfat fluctuations) can be largely

associated with the plane of nutrition provided. Reese et al. (1982a) suggested that performance declines due to reduced energy intake in lactation were not permanent and could be corrected by allowing sows the opportunity to improve their condition during the next gestation period. The effects of protein deprivation during lactation have been shown to be rectified in the following gestation as sows restricted in their protein intake during lactation gained more weight in gestation than those receiving lactational diets higher in protein (MacPherson et al.,1969 and O'Grady, 1971). Hitchcock et al. (1971) reported that restricting feed intake of sows during lactation resulted in no significant change in weight between the first and second gestation periods (209 kg vs. 202 kg, respectively). However, sows fed ad libitum in their first lactation were 22 kg heavier ($p<.01$) in the second gestation than in their first. Esbenshade et al. (1986) stated that swine producers operating commercial production systems indicated no measurable effects of small nutritional changes on reproductive performance. Aherne and Kirkwood (1985) concluded that when normal feeding and management practices were employed, nutritional effects on gilt development were small.

First parity litter size has also been related to the previously mentioned reproductive and productivity traits. First parity sows with heavier litters (>55 kg) were indicated to be longer in return to estrus and conceived at lower rates than gilts with medium (42-54 kg) and low (<41 kg) litter weights (Flowers and Stanislaw, 1989). These results indicated that sows nursing heavier litters, especially in their first parity, would make greater demands on their body reserves therefore lowering their body condition.

Maternal effects and sow performance

Maternal effects, including parity, parity born in and fraternal litter size have been reported to effect sow and litter performance.

Parity. Numerous researchers have indicated the effects parity had on reproductive performance and productivity traits. It has already been shown that productive females have lower condition scores and backfat thickness as parity increases (Esbenshade et al., 1986). This research also reported improvements in percent of females in estrus by 12 days postweaning after parity one. The interval from weaning to rebreeding was shorter ($p<.05$) for sows in parities two through four. Other researchers have reported similar results that concluded primiparous sows take longer to return to estrus postweaning than multiparous sows (Fahmy et al., 1979; Stork, 1979; Hurtgen et al., 1980; Britt et al., 1983; and Stevenson et al., 1983. Meyen et al. (1985) indicated sow productivity improved up to the fifth parity but then performance declined. Negative relationships existed between parity and postweaning return to estrus interval. Sows in later parities produced more total pigs but number born alive and litter birth weight declined after the fifth parity. Sows in parities three through six were shown to be superior in terms of productivity traits than sows in other parities or gilts (Yen et al., 1987). Reese et al. (1982b) offered an explanation for the differences between primiparous and second parity sows in postweaning return to estrus. They stated that sows in parity two have different energy requirements for return to estrus than first parity sows. King et al. (1982) suggested that first parity sows are usually still growing and competition for nutrients between growth and reproduction exists. An

advantage (75% vs. 48%) in number of sows in estrus by 7 days postweaning was reported for multiparous sows in comparison to primiparous sows (Szarek et al., 1981; 3119 records included). A significant correlation (r= -.20) between parity level and time period from weaning to farrowing was found by Moody and Spear (1971).

Parity born in and fraternal litter size. While the effects of parity on sow performance are widely documented, the effects of parity an animal is born in have not been reported extensively. This could be due to common knowledge or the knowledge of the effects of parity and particularly the relationship of parity with litter size. The effects of parity on litter size have been discussed. It appears that litter size at birth increases with parity level. Through this relationship, parity born in and postnatal fraternal litter size (size of litter born in) are related. Swine producers have been advised to standardize litter size in order to help alleviate the ill effects of competition between pigs in large litters, particularly in litters containing potential replacement gilts (Isler and Christian, 1978). Other researchers have demonstrated the effects of fraternal litter size on future reproductive and productive performance of females as well as their growth and development. Stewart and Diekman (1989) examined the effects of either six or twelve or more pigs per litter on growth rate, survivability, reproductive performance and productivity. Pigs from smaller litters had greater survival rates to weaning and to market ($p<.01$). Those pigs also reached market weight (105 kg) quicker (5 days, $p<.05$) but did not perform as well reproductively. Gilts from larger litters tended to reach puberty earlier (4 days), conceive better at first breeding and rebreed postweaning at higher rates although the differences between the two litter size groups were not significant. In the first parity, large litter females tended to produce

more live pigs at birth and 21 days but again the differences were nonsignificant. Litter 21 day weight was the same for both groups (40 kg) and second parity traits were also not different between litter size groups. Days to first estrus was not different between small (5 pig) and large (10 pig) fraternity size groups in a study by Kirkpatrick and Rutledge (1988). Ovulation rate for gilts reared in small litters tended to be higher but was not significantly different although number of fetuses at day 30 of gestation was greater (12.03) for small litter gilts than those form larger litters (10.86, $p<.10$). This does not agree with the findings of Stewart and Diekman (1989) and suggests that selecting females from smaller litters (standardized or naturally smaller) may provide replacement gilts who are superior in ovulation rate. Birth weights and weaning weights differed ($p<.10$) with pigs from small fraternities being heavier. Postweaning weights at 12 weeks, 21 weeks, first estrus and slaughter were not affected by size of the litter the gilt was born in. Kirkpatrick et al. (1988) reported similar growth results in mice reared in litters of 5, 10 or 15 pups. Mice from smaller litters were heavier ($p<.01$) at weaning but did not grow as fast following weaning as those from larger litters, indicating faster growing females reached puberty earlier. Mature weight, however, still was greater for mice raised in small fraternities. Days to vaginal opening (puberty measurement) were less for females born in small litters. Litter size was greater for those born in small fraternities until the sixth parity in which litter size became greater in large litter females. van der Steen (1985) found that gilts born in larger litters (12 pigs) produced almost one-half pig less than those reared in lower size litters. In another study, Rutledge (1980) reported 11.3 average pigs born to gilts raised in litters of six and 10.2 pigs born to gilts from larger litters (10). Rutledge stated that approximately a one extra pig improvement in litter size of first

parity sows can be expected by raising herd replacements in smaller litters. His explanation included the theories that weaning weight affects ovulation rate and possibly the ovary of neonatal gilts could be influential on litter size. Weaning weight was greater for gilts from small fraternities and this may be associated with ovarian development. Weight at breeding or farrowing was not influenced by fraternal litter size in Rutledge's experiment. A popular article which is widely cited represents the work of Nelson and Robison (1976). They changed birth litter sizes within 24 hours after farrowing to six pigs (small) and 14 pigs (large) nursed . Reproductive performance, measured by failures to exhibit estrus and to conceive, was not different in estrus failures but more (28% vs. 24%) females from small litters failed to conceive. Size of the litter raised in affected ovulation rate and embryo population on day 25 of gestation. Small litter females averaged 1.01 more ($p<.05$) corpora lutea and 1.18 more ($P<.10$) embryos. Pig weights were significantly different from 14 days to 140 days of age with pigs born from dams of the smaller fraternity size weighing more. Although differences in number born and litter weight were not different between groups, small fraternity sows exhibited trends of producing more total pigs born and heavier litter weights and did yield 1.2 pigs more ($p<.10$) born alive.

The results of Nelson and Robison(1976), although contrasted in the work of other researchers, indicated the possible effects litter size of birth has on subsequent performance. Since litter size has been reported to be associated with parity level of the dam, there exists a natural cause-effect relationship between parity born in and fraternal litter size. This relationship appears to be a possible reason for considering birth parity level when evaluating factors affecting sow performance. Selecting replacement females from early parity sows in order to naturally have smaller litter

sizes, however, is not recommended due to economic and production reasons and the ability to reduce litter sizes by standardization.

It is generally accepted that as sows progress through successive parities their ability to pass disease protection to their offspring increases. This is due to increased opportunities for exposure to disease, allowing the sow to build antibodies against those diseases, and the influence of herd vaccination programs. These antibodies are passed on to the neonatal pigs by consumption of colostrum and milk. Therefore, one effect of birth parity would be level of disease resistance which ultimately affects health, performance, and survivability.

Researchers outside the United States have indicated productivity and reproductive improvements in sows born in later parities (Paska and Durmis, 1986 and Schlegel and Glei, 1986). In the study of Schlegel and Glei (1986) involving 8495 sows and 6432 parity one through four litters, the authors concluded that females born to first litter sows should not be selected for replacements. Paska and Durmis (1986) compared the first four litters of sows that were born in parities one though seven. No evident relationship of birth parity and productivity was found but sows born in the seventh parity produced more pigs overall and remained in the herd longer.

Rate of developmental growth and sow performance

The effects of sow condition on progeny growth rate have been discussed. Sows in more optimum condition prior to farrowing are generally considered able to wean heavier weight pigs and handle the demands of production better. The inverse of this scenario is sows who wean heavier litters are likely to deplete body reserves

and therefore be in poorer condition upon weaning of their litters. Parity and fraternity litter size effects have been reviewed. Pigs born in mid to late parities and reared in smaller litters have been indicated to be better performers. While some of the research previously cited revealed differences in reproductive and productive performance of gilts who weaned at heavier weights, were born in different litter sizes and parities, or approached puberty at quicker rates, the main emphasis of these efforts was not to examine the effects created by different rates of developmental growth. Research involving these effects will be reviewed.

Young et al. (1977a) conducted an experiment to determine the phenotypic and genetic relationships of a gilt's performance before breeding to her reproductive performance. These workers in effect attempted to identify traits which could be measured prior to breeding that would improve ovulation rate and embryo survival and therefore litter size. Average daily gain and age at 100 kg were measured, along with other variables, to classify a gilt's prebreeding performance. Reproductive performance was measured by the variables number of corpora lutea, number of live embryos and embryo survival. Previous work by Young et al. (1974) had reported no strong relationship of a gilt's personal record with her reproductive performance. In the 1977 study, however, average daily gain was moderately positively correlated with number of corpora lutea. From this they concluded that genes causing above average growth rates had the same effect on ovulation rate. The genetic correlation of average daily gain with embryo survival, however, was low. The authors indicated that gilts having superior genetic ability for growth were inferior in their genetic ability for survival of embryos. Phenotypically, breeding age, weight and number of days from 100 kg to breeding were related to number of embryos present. Gilts which grew at faster rates

and thus were younger at 100 kg and heaver at breeding exhibited higher ovulation rates while those with more days to 100 kg, lighter breeding weights, and more days to breeding had more embryos. In another analysis of the same research, the authors, Young et al. (1977b), again stated that gilts with good genetic potential (based on their birth litter average) that perform well prior to breeding were genetically superior for ovulation rate but genetically inferior for embryo survival. Gilts who also had that same good genetic potential but did not perform as well in terms of gain were inferior for ovulation rate but superior in rate of embryo survival. These findings led Young and his associates to suggest that gilts for replacements should be selected for genetic growth superiority but their growth rate should be restricted by limit feeding during the period of weaning to breeding. Stewart and Drewry (1983) also stated that growth rate increases lowered puberty onset age, increased weight at puberty, increased gilt ovulation rate and decreased embryo population and survival. They also reported that restriction of postweaning growth by lowering energy intake resulted in no effect on sow reproduction or productivity. Garnett and Rahnefeld (1976) studied the effects of mass selection for improved rate of gain in Lacombe, Yorkshire and Lacombe X Yorkshire (LY) Crosses. The Lacombes were selected for postweaning average daily gain, the Yorkshires served as controls and LY females were produced by crossing the selected Lacombe boars with control females. Selection in the Lacombe line resulted in a .15 kg/d increase in average daily gain while LY average daily gain improved by .07 kg/d and the Yorkshire control line showed no improvement. LY females produced .51 pigs less per litter ($p<.0001$) than the control line while the Lacombe line was not significantly different but lower (8.88 vs. 9.18 born, respectively) than the Yorkshire females. Number of pigs weaned was lowest for the select Lacombe line (6.92) with

LY weaned litter sizes the next smallest and Yorkshire litter sizes largest (8.10). Birth weights and weaning weights were higher in the Lacombe and LY lines with the Lacombe line being heavier. Reproductive performances were not examined. Watkins (1983) reported that sows who gained weight faster from selection to farrowing and were younger at selection exhibited longer farrowing intervals than those sows that were older at selection and grew at slower rates between time of selection and farrowing. Mabry et al. (1985) reported that gilts which were selected for early puberty gained weight at faster rates, had a more normal estrus cycle, produced more pigs born alive, had higher index scores and more litters per sow. An early composition line (fat) and a late composition line (lean) were also compared. Fatter line sows were higher in average daily gain, backfat at day 230, number with normal estrus cycles, number of pigs born alive and sow productivity index but were not significantly different (2.0 vs. 2.2) in terms of number of litters per sow. Although the sample sizes in this study were small (12 or 13 females per line), the trend of better performance for early puberty and fatter line sows existed as measurements were generally greater for these two lines. Characterization of rapid and slow growing lines of pigs was given by Buchanan et al. (1984). Evaluation of 196 litters revealed that fast growing pigs were heavier at birth (1.49 vs. 1.44 kg), had higher average daily gains to 54.4 kg (.69 vs. .64 kg/d) and to 100 Kg (.84 vs. .76 kg/d), were not different in backfat thickness and were similar in feed efficiency (1.61 vs. 1.63). Woltmann et al. (1987) found backfat differences between growth rate pigs with fast growing lines being higher in backfat thickness. Hetzer and Miller (1972) indicated that selection emphasis on leanness in Duroc pigs, would likely improve growth rate but the opposite effect would occur in Yorkshires. The authors indicated that the backfat thicknesses

of the Yorkshires were at a near optimum levels for growth rate and selection changed this relationship. Nutrition of the dam, not surprisingly, has been shown to also be associated with progeny performance. Hard and Anderson (1982) restricted nutrient intake of dams in the middle or last third of gestation and examined the effects this created on females born to these dams. The effect was mainly observed in growth of gilts in early stages of life while at 150 days of age body weights were similar indicating compensatory growth of those pigs born to nutrient deprived dams. Reproductive performance was not affected but first estrus occurred earlier in the progeny of sows restricted in gestational nutrient intake.

European researchers have extended these research efforts through later parities. Klusacek et al. (1986) found that farrowing interval was shorter in gilts that gained at slow rates from birth to 100 kg of body weight. Gilts that gained .48 to .50 kg/d farrowed at 171 days of age in parity one, within 162 days in parity two and by 158 days in parity three. The longest farrowing intervals recorded were for the gilt group exhibiting the highest average daily gain, .63 kg/d to .65 kg/d. Farrowing intervals were 171 day, 168 day and 160 day for parities one through three, respectively. The slow gaining group recording the lowest farrowing intervals was actually the second lowest gaining gilt group in the study. Gueblez et al. (1987) in France have examined the effects of age and backfat thickness at 100 kg body weight on performance and herd longevity through four parities. Gilts that were determined to be the poorest performers at 100 kg were equal to or greater than 170 days of age and possessed 20 mm or more backfat. Good performing females were less than 140 days of age at 100 kg body weight and contained under 14 mm of backfat. Percent of poor performers remaining in the herd through four parities was 45%. Those from the good performing

group reached parity four at a rate of 28%. While these trials do provide information, studies designed to examine growth rate effects on later parities need to be performed in the United States in order to better represent conditions similar to those faced by American swine producers.

The previously mentioned research of Young et al. (1977a,b) has similarities with the research of this thesis. Although Young and co-workers included the effects of fraternal litter size and gain, they did not have the opportunity to further study the productivity traits of birth weight, weaning weight, number born alive or number of pigs weaned since the gilts in their study were slaughtered prior to parturition. This also prevented them from evaluating reproductive performance and determining if any effects were present in later parities.

CHAPTER III

MATERIALS AND METHODS

Data for this study were collected from April 25, 1988 to October 13, 1989 in a complete confinement swine unit at Ames Plantation, Grand Junction, Tennessee.

Experimental animals

The 100 experimental animals utilized in this study were crossbred gilts containing the influence of Duroc, Hampshire, Landrace or Yorkshire breeds. Dams of the gilts were either three or four-way crosses of the breeds mentioned above. The dams were mated to purebred sires of one of the four breeds. One-half Hampshire dams were most common followed by one-half Landrace and one-half Duroc females, respectively. Gilts were also mated to purebred boars but may have been bred by sires of different breeds when double matings occurred. Due to the large number of possible crossings and the extent of crossbreeding in the herd, the breed component of the experimental gilts was not considered to be a main factor for analysis in this study.

Gilts selected for use in the experiment were chosen on their rate of growth during the finishing period. A minimum selection weight of approximately 91 kg was first set but animals weighing as low as 82.6 kg at selection were also included. A subjective evaluation of each gilt was performed to determine if the females chosen were capable of being productive sows. Structural soundness, body length and depth, vulva size and underline quality were evaluated. Normally the fastest and slowest

gaining gilts from each litter were selected. If they did not, however, meet or pass the subjective evaluation the second fastest or slowest growing gilt from that litter was chosen. This resulted in the inclusion of some gilts weighing below the weight standard of 91 kg. Littermate pairs were chosen to attempt to minimize genetic variation between the growth rate groups. All gilts were removed from the experiment following completion of their third parity. Gilts were bred to farrow at approximately one year of age.

Production system

The swine production system was a total confinement, all-in all-out system with a breeding and gestation barn, an environmentally controlled farrowing house, a controlled environment nursery and two finishing barns. Facilities were located adjacent to each other and progression through successive production phases sequentially moved animals from one unit to the next. After weaning, sows were returned to the breeding and gestation barn while their litters were relocated to the nursery unit. Pigs moved then from the nursery to the finishing barns and upon completion of the finishing phase were taken to market or, in the case of experimental gilts, were moved to the breeding and gestation barn.

Three herds produced seven farrowings per year at 52 day intervals. Pigs were weaned at approximately 40 days of age.

Herds. Two sow herds in system three were developed and used to investigate the objectives of this study. Herd one was the first replication while herd two functioned

as replicate two. Both growth rate groups were included in each herd. Differences between the two herds included normal variation between animals and time of progression through the production system. Herd two followed herd one through the same facilities but approximately 50 days later. Management procedures were the same for both herds and were standard swine production management practices.

A total of 100 gilts were selected for development of the two herds. Twenty-five fast growing gilts and 25 slow growing gilts were used to initiate each experimental herd. These numbers of gilts were chosen to attempt to provide 24 to 26 litters at the first farrowing for both herds.

A third herd existed as a control herd without restrictions to parity or longevity and functioned mainly to fill facilities and maximize production system efficiency. Data from this herd were not included in the analysis of the experiment.

Animal management. Pig processing practices included weighing, clipping of needle teeth, ear notching pigs with their pig number and injecting .5 cc of long lasting oxytetracycline (200 mg) subcutaneously within the first 24 hours after birth. On day three, male pigs were castrated and all pigs were tail docked, given iron dextran injections and ear notched with their litter number. Between the third and fourth weeks of life, pigs were vaccinated for erysipelas and atrophic rhinitis. Pigs were creep fed the nursery ration (Table 1) beginning at about three weeks of age. Litters were standardized when extreme large and small birth litter sizes occurred. Following weaning pigs were weighed, given an oral dose of spectinomycin and allocated to their respective nursery pens. Pigs were penned based on body weight at weaning and litter of origin. Uniform pen weights were attempted to allow equal performance

TABLE 1. Ration composition

Feedstuff	Nursery	Grower	Finisher	Sow Gestation	Sow Lactation
	----------% in Diet----------				
Yellow Corn	60.00	73.00	77.00	75.00	60.00
SBM (44%)	25.00	23.00	20.50	11.25	20.00
Tankage (50%)	--	--	--	8.75	--
Alfalfa Meal	--	--	--	--	5.00
Wheat Bran	--	--	--	--	10.00
Dried Whey	10.00	--	--	--	--
Swine Premix	5.00[1]	3.75[1]	2.50[2]	5.00[1]	5.00[1]
Synthetic Lysine	.15	--	--	--	--
Aureomycin	--	.15	--	--	--
Crude Protein	17.35 (+ added lysine)	16.41	15.64	15.78	16.31

[1]Sow vitamin premix (Table 2)

[2]Swine 50 vitamin premix.

TABLE 2. Contents of Sow Vitamin Premix

Nutrient	Amount
Vitamin A	80,000 UPS Units
Vitamin D-3	20,000 IC Units
Vitamin E	100 Int. Units
Riboflavin	80 Mgs
d-Pantothenic Acid	200 Mgs.
Niacin	400 Mgs.
Choline Chloride	4,000 Mgs
Vitamin K	20 Mgs.
Vitamin B-12	300 Mcg.
Lysine (added)	0.25%
Methionine (added)	0.25%
Calcium (Ca), Maximum	18.0%
Calcium (Ca), Minimum	15.0%
Phosphorus (P), Minimum	7.5%
Salt (NaCl), Maximum	8.4%
Salt (NaCl), Minimum	7.0%
Zinc (Zn)	0.24%
Iron (Fe)	0.24%
Manganese (Mn)	0.16%
Copper (CO)	0.024%
Cobalt (Co)	0.004%
Iodine (I)	0.0014%
Selenium (Se)	0.0002%

Ingredients

Vitamin A supplement, D-Activated Animal Sterol (source of Vitamin D-3), Vitamin E supplement, Riboflavin supplement, Calcium Pantothenate, niacin, Vitamin B-12 supplement, BHT (a preservative), Zinc Oxide, Ferrous Sulfate, Manganous oxide, Copper Oxide, Cobalt Carbonate, Ethlyenediamine Dihydriodide, Menadionine Sodium Bilsulfite Complex (source of Vitamin K), Sodium Selenite, Sodium Bentonite, Dicalcium Phosphate, Defluorinated Phosphate, Salt, Distillers Dry Solubles, Yeast Culture, Dehydrated Alfalfa Meal, Dried Whey, Potassium Magnesium Sulfate, Calcium Carbonate, L-Lysine, DL Methionine, Fish meal.

opportunities. Littermates were included in pens but may have been distributed over many pens. All pigs in the nursery were allowed free access to the nursery ration (Table 1) and fresh water. The nursery was emptied after about six weeks and when pig weights approached 32 kg.

Pen allotment in the finishing facility was done similar to methods used in the nursery. All pigs were again provided feed (Table 1) and water ad libitum. No data were collected on gilts during the finishing period but body weights and backfat measurements were recorded for each gilt when the finishing phase ended. The subjective evaluation procedure previously mentioned was performed at this time. Body weight gain during the finishing period and the evaluation results were used to classify gilts as either fast or slow growing and select them for development of the two experimental herds.

After gilts were allocated into growth rate groups and removed from the finishing facility they were placed in pens adjacent to boars in the breeding and gestation barn. Gilts were fed 2.7 kg/d of the breeding and gestation ration (Table 1) and offered free choice water. All gilts were penned adjacent to boars to assist estrus onset. Gilts were mated at 12 and 24 hours of their second or third estrus and were then placed in gestation crates in the same building until about four days prior to farrowing. Gilts in gestation were offered 1.8 kg of the breeding and gestation ration (Table 1) and watered periodically. Pregnancy determinations (ultrasound) were done on day 45 of gestation with open gilts going back to pens adjacent to boars and being removed from inclusion in the experiment. Prior to breeding gilts were vaccinated for prevention of parvovirus and leptospirosis and for atrophic rhinitis prior to farrowing. An autogenous vaccine, made by incorporating manure from the nursery into the

gestation ration , was also given prior to farrowing. External and internal parasites were controlled by the use of ivermectin.

At day 110 of gestation females were moved into the farrowing barn. The lactation ration (Table 1) was fed at the rate of 2.3 kg/d for the sow plus an additional .45 kg/d per each pig nursed. Sows were fed three times per day and rates were adjusted depending on condition of the sow. Water was provided free choice through nipple waterers. After measuring sow weaning weights and backfat thicknesses, sows were moved back to the breeding and gestation barn. The breeding and gestation ration (Table 1) was offered at the rate of 2.7 kg/day through breeding. Sows were bred on their first postweaning estrus. The management practices previously mentioned for gilts were also used through subsequent parities with the only difference being the increased amount of feed provided to sows to offset lactation weight losses or gains.

Facilities. The breeding and gestation barn was a partially slatted building with concrete floors and slats. Doors and curtains on both sides were used to provide temperature control and ventilation. An overhead poly tube assisted with air flow and pit fans removed manure gasses. Gilts and sows were housed either in individual crates or free-stall pens. Housing in crates or pens was done randomly among all females in all parities. Boars were penned near the front of the barn next to a larger pen used for breeding. Females in free stall pens were watered via nipple waterers and fed on concrete while a concrete trough served as both feeder and waterer for females in gestation crates.

A 24 crate farrowing house with in-crate feeders and nipple waterers was used to accommodate females during the farrowing-lactation period. Temperature was

controlled by regulation of wall fans which also provided ventilation. An overhead air duct with outlets directed toward the sow was used to help cool sows. Pigs were warmed by hanging heat lamps over one side of the crate. Farrowing crate floors were concrete with various materials (expanded metal, coated metal, etc) in place over the manure pits. Pit fans directed manure gases outside the building. The walls of the crates were collapsible and were removed, cleaned, and sanitized between farrowing groups. The farrowing room was also cleaned and sanitized between each farrowing.

The nursery was new and was used for the first time during this experiment. Twelve 2.4 meter by 2.4 meter pens were equipped with adjustable height nipple waterers and a rectangular fence line feeder. The flooring was tri-bar or Behlen stainless steel slats which completely covered the flush alley underneath. Room temperature was held at approximately 27 degrees Celsius by a wood furnace and ceiling fan system in the winter and the ceiling fan system with wall air inlets in the summer. Cleaning and sanitation of the nursery was done between groups.

Both finishing buildings were partially slatted with 2.4 meters of slats covering the manure collection pits. Pens were 2.4 meters wide by 6.1 meters long. The two buildings were modified open fronted with curtains. Nipple type waterers and fence-line feeders were used in one building with some round floor feeders being used in the other facility. Sprinkler systems were used to cool animals during warmer temperature periods.

Data collection and Statistical Analysis. The gain in body weight during the finishing period was calculated by subtracting the weight at which pigs left the nursery from their weights at the end of the finishing phase. This was used to classify gilts as

either fast or slow in their rate of developmental growth. Growth rate was considered to be the primary main effect variable in the analysis of this study. Data collected that were considered as covariate variables included parity number the gilt was born in, fraternal litter size (size of litter gilt was born in) and body weight and backfat thickness at selection. Parity born in and fraternal litter size were utilized as covariates in order to remove their effect on performance and productivity and to determine if they were significant sources of variation in the traits evaluated in this experiment. Body weight and backfat thickness at selection were included as covariates in order to remove the effects of body weight of a gilt when she becomes part of the breeding herd and to allow a stronger focus on the effects created by differences in growth rate. These four variables were the ones that were measured prior to measurement of the dependent variables. Therefore, by using these variables to remove or adjust for their effects, all gilts were equal except for their growth rate when dependent variables were measured.

Dependent variables chosen to measure sow performance and productivity, as well as the effects of growth rate on those variables, included sow body condition measurements and productivity traits. Body weight and backfat thickness at both the 110th day of gestation and weaning for three parities were used to represent sow body condition. Sow productivity traits measured over three parities included total number of pigs born, number born alive, average pig birth weight, number of pigs weaned and average pig weaning weight. Differences among these variables were tested by analysis of variance in a completely randomized design using the General Linear Models (GLM) procedure of the Statistical Analysis Systems (SAS, 1985). The statistical model used was:

y= growth rate replication growth rate X replication parity born in

fraternal litter size selection weight selection backfat

All variables were tested by the residual error term. Pearson correlation coefficients were calculated by the CORR procedure of SAS (1985) to examine relationships and trends between the main effects, covariates and dependent variables. The GLM procedure of SAS (1985) also produced least square means and their standard errors for all dependent variables.

Longevity of females in the herd was examined by measuring the number of gilts who remained in the herd through three parities. Differences between growth rate groups were not statistically analyzed but a comparison was made based on actual records. No reasons for removal from the herd were recorded which restricted the evaluation of reproductive performance. While larger numbers of a growth rate group in a particular parity did indicate more of that group had cycled, conceived and farrowed it did not identify those females of the opposing group as being culled for reproductive reasons.

Sow 110 day gestation weights were taken as they entered the farrowing house while 110 day backfat measurements were done in the gestation barn about two days before. Sow weaning weights and backfat thicknesses both were measured on weaning day. Pig weaning weights were actually recorded about one or two days prior to weaning to allow time to determine nursery pen allotments. Each variable was measured on the same date for both growth rate classification groups within herds one and two. The one exception to this was average pig birth weight which was measured on slightly different dates due to the variability in sow farrowing times.

A comprehensive covariate analysis using factors of previous lactations and other

related variables as covariates was done to gain more information from this study by revealing the factors that affected a particular trait. The main effect variable and covariates previously mentioned were included in this model along with several different covariates. Variables were tested by the model error mean square. This analysis was not done to satisfy the objectives of the study but to gain supporting information.

CHAPTER IV

RESULTS

Sow productivity

Least squares means and their standard errors for sow productivity traits are presented in Table 3. Sows which exhibited slower rates of developmental growth produced 2.2 more pigs at birth ($p=.05$), 2.2 more pigs born alive ($p<.05$) and 2.3 more pigs at weaning ($p<.05$) in their first parity compared to females who grew at faster developmental rates. Litter sizes in the second parity were not different ($p>.28$) although fast growing sows tended to farrow more pigs (9.7 vs. 8.3, $p>.28$) and have more pigs born alive (9.2 vs. 8.2, $p>.38$) but weaned only .5 pigs more (7.9 v.s 7.4, $p>.66$) than sows who grew at slower rates. In the third parity, slower growing sows weaned more pigs (8.6 vs. 7.3, $p<.10$) though litter size at birth or number of pigs born alive were not different ($p>.99$ and $p>.56$, respectively). Over three parities, slower growth rate sows farrowed more pigs (26.4 vs. 25.6), had more pigs born alive (25.8 vs. 24.0) and weaned more pigs (23.4 vs. 20.3) though these differences were not tested statistically. Average pig birth and weaning weights were not different between the two groups ($p>.27$ and $p>.40$, respectively).

Sow Condition

Sow 110 day gestation and weaning weight and backfat thickness least squares

TABLE 3. Productivity traits of females classified as fast or slow growing during the finishing period[a]

Variable	Parity	Classification				PR>F
		Fast	(n)[b]	Slow	(n)[b]	
Total number pigs born	1	6.4±.65	(28)	8.6±.74	(21)	.05
	2	9.7±.78	(19)	8.3±.83	(16)	.28
	3	9.5±.79	(17)	9.5±.93	(13)	.99
Number pigs born alive	1	6.0±.50	(28)	8.2±.68	(21)	.04
	2	9.2±.74	(19)	8.2±.79	(16)	.38
	3	8.8±,65	(17)	9.4±.77	(13)	.56
Average pig birth weight, kg	1	1.6±.06	(28)	1.5±.97	(20)	.27
	2	1.6±.07	(19)	1.6±.07	(16)	.73
	3	1.7±.07	(17)	1.6±.08	(13)	.61
Number pigs weaned	1	5.1±.56	(28)	7.4±.65	(20)	.02
	2	7.9±.67	(10)	7.4±.71	(16)	.66
	3	7.3±.41	(16)	8.6±.47	(13)	.06
Average pig weaning weight, kg	1	10.0±.48	(28)	9.9±.56	(20)	.90
	2	8.7±.48	(19)	9.2±.35	(16)	.40
	3	10.1±.53	(16)	9.8±.58	(13)	.71

[a]Data are least squares means + or - standard errors.

[b]n = number of litters sampled.

means and their standard errors are reported in Table 4. Sow weights at 110 days of gestation were not different (p>.98) in parities one and two but slower growth rate sows tended to be heavier in their third gestation period (196 kg vs. 185 kg, p>.25). Backfat thickness at day 110 of gestation was not significantly different between the two groups though faster growth rate sows tended to have more backfat in all gestation periods.

Weaning weights of the sows in parities one and three were virtually identical (143 kg vs. 142 kg and 179 kg vs. 178 kg, respectively) but slower growth rate sows were 13 kg heavier (159 kg vs 146 kg, p<.10) at weaning in the second parity. Faster growth rate sows had more backfat at weaning in the first parity (23.6 mm vs. 19.7 mm, p=.05) although slower growth rate sows had more at the second parity weaning (18.6 mm vs 14.3 mm, p<.05). Faster growth rate sows tended to be higher in backfat thickness at weaning in parity three (14.1 mm vs. 11.9 mm, p>.28). Weight fluctuations during gestation and lactation revealed few trends between the growth rate groups though slower growth rate sows were more uniform in their weight losses during lactation. Slower growth rate sows also lost backfat during both gestation periods following their first parity in comparison to backfat losses during parity two gestation for faster rate of growth sows. Backfat losses in lactation were greater for slow growth rate sows except in parity two when faster growth rate sows lost 7.3 mm of backfat while lactating compared to no backfat loss in the slower rate of growth group. Net weight change from selection to the third parity weaning was +73 kg for faster growth rate females and +82 kg for slower rate of growth females. Net changes in backfat were not different (-4.7 mm vs. -4.6 mm).

TABLE 4. Body condition measurements through three parities for females classified as fast or slow growing.[a]

Variable	Parity	Classification				PR>F
		Fast	(n)	Slow	(n)	
Body weight at 110 d gestation, kg	1	171±3.5	(28)	171±3.9	(21)	.99
	2	175±5.1	(19)	175±5.4	(16)	.98
	3	185±5.1	(17)	196±6.1	(13)	.25
Backfat at 110 d gestation, mm	1	24.5±1.33	(27)	21.4±1.49	(20)	.17
	2	21.6±1.84	(19)	18.6±1.96	(16)	.31
	3	16.6±1.88	(16)	15.7±2.09	(13)	.77
Sow weaning weight, kg	1	143±3.4	(28)	142±3.9	(20)	.89
	2	146±4.5	(19)	159±4.8	(16)	.09
	3	179±6.0	(16)	178±6.6	(13)	.96
Sow backfat at weaning, mm	1	23.6±1.12	(28)	19.7±1.29	(20)	.05
	2	14.3±1.10	(19)	18.6±1.17	(16)	.02
	3	14.1±1.22	(16)	11.9±1.36	(13)	.28

[a]Data are least squares means + or - standard errors.

Sow reproductive performance

Sow longevity in the herd is reported in Table 5. Eleven faster gaining sows were removed from the experiment between the first and third parities while seven slow growth rate sows failed to complete three parities. Culling rates for the two groups were 39% and 35% for fast and slow growth rate sows, respectively.

Covariate effects

Covariates measured prior to the gilt's first gestation period are presented in Table 6. The gilts were born in similar dam parity levels (3.6 vs. 3.3) and their fraternal litter size was also similar (10.2 pig vs. 10.1 pigs). Parity levels ranged from one to seven for faster growth rate gilts and one to six for slower growth rate females. Fraternal litter sizes ranged from four to 13 pigs for the fast growth rate group compared to a range of four to 14 pigs farrowed in the litters the slower growth rate group were born in.

Faster growth rate gilts gained 73 kg from the time they entered the finishing facility until selection compared to a body weight gain of 65 kg for the slower growth rate group ($p=.0001$). Faster growing females were also heavier at first breeding (145 kg vs. 139 kg, $p<.05$) though backfat thickness at the first breeding was not different (20.9 mm vs. 19.1 mm, $p>.24$). Selection backfat thickness favored the fast growth rate group by 2.3 mm (18.8 mm vs. 16.5 mm, $p=12$).

Effects of these covariates on the traits measured in individual parities are reported in Tables 7, 8 and 9. Parity of the dam the gilt was born in did not

TABLE 5. Sow longevity for both fast and slow growth rate groups through three parities

	Growth rate group	
Variable	Fast	Slow
Number present in parity one	28	20
Number present in parity two	19	16
Number present in parity three	16	13
% culled from herd	39%	35%

TABLE 6. Characteristics of littermate pair gilts classified by rate of growth during the finishing period.[a]

Variable	Classification		PR>F
	Fast	Slow	
Body weight gain, kg[b]	73±.98	65±1.00	.0001
Body weight at selection, kg	106±1.2	96±1.7	.0001
Backfat at selection, mm	18.8±.86	16.5±1.12	.12
Parity born in	3.3±.38	3.6±.36	.58
Number born alive in gilt's birth litter	10.1±.34	10.2±.51	.68
Body weight at first breeding, kg	145±2.1	139±2.2	.04
Backfat at first breeding, mm	20.9±1.12	19.1±1.23	.24

[a]Data are means of 28 (fast) and 21 (slow) gilts except for body weight and backfat at first breeding for fast growing gilts where n = 27.

[b]Body weight gain represents gain from time of entering finishing facility till selection. Body weights at entering were 33 kg (fast) and 31 kg (slow) which were not significantly (P<.18) different.

TABLE 7. Analysis of pre-gestation covariate effects on first parity dependent variables.

Dependent Variable	Model EMS[#]	COVARIATE MEAN SQUARES			
		Parity Born In	Fraternal Litter Size	Selection Weight	Selection Backfat
110 d gestation weight	234.30	45.69	21.450	918.60[c]	90.11
110 d gestation backfat	32.97	9.91	7.320	49.41	409.14[b]
Total number pigs born	8.18	16.38	11.940	48.31[c]	1.62
Number pigs born alive	6.95	9.93	16.640	43.87[c]	1.74
Average pig birth weight	.07	.09	.003	.08	.01
Number pigs weaned	6.15	7.87	31.950[c]	39.71[c]	.44
Average pig weaning weight	4.54	2.43	3.910	.34	.18
Sow weaning weight	222.56	.33	122.240	1223.05[c]	93.67
Sow backfat at weaning	24.41	5.06	.001	67.52[d]	163.96[b]

[a]p = <.0001
[b]p = <.01
[c]p = <.05
[d]p = <.10
[#]Error mean square

TABLE 8. Analysis of pre-gestation covariate effects on second parity dependent variables

Dependent Variable	Model EMS[#]	Covariate Mean Squares			
		Parity Born in	Fraternal Litter Size	Selection Weight	Selection Backfat
110 d gestation weight	331.27	233.36	260.640	1222.230[d]	146.45
110 d gestation backfat	43.67	38.94	2.580	9.410	30.64
Total number pigs born	7.83	1.12	3.300	.230	.08
Number born alive	7.03	1.16	3.250	.004	.12
Average pig birth weight	.06	.04	.001	.000	.01
Number pigs weaned	5.71	3.08	.140	.080	.53
Average pig weaning weight	1.41	2.39	1.430	.070	.06
Sow weaning weight	263.66	45.22	439.220	5306.360[a]	880.30[d]
Sow backfat at weaning	15.59	3.34	22.380	127.050[b]	77.96[c]

[a]p = <.0001
[b]p = <.01
[c]p = <.05
[d]p = <.10
[#]Error mean square

TABLE 9. Analysis of pre-gestation covariate effects on third parity dependent variables.

Dependent Variable	Model EMS#	COVARIATE MEAN SQUARES			
		Parity Born in	Fraternal Litter size	Selection Weight	Selection Backfat
110 d gestation weight	324.00	250.73	644.88	2652.390[b]	42.280
110 d gestation backfat	38.65	32.83	59.84	.290	46.330
Total number pigs born	7.58	11.25	27.53[d]	9.710	.310
Number born alive	5.14	11.07	29.54[c]	5.670	.650
Average pig birth weight	.06	.27[c]	.22[d]	.001	.000
Number pigs weaned	1.87	18.45[b]	8.18[c]	18.97[b]	6.520[d]
Average pig weaning weight	3.05	1.32	1.01	1.130	.610
Sow weaning weight	389.63	33.78	1733.88[c]	2624.400[c]	90.190
Sow backfat at weaning	16.43	17.02	25.82	3.240	29.770

[a]p = <.0001
[b]p = <.01
[c]p = <.05
[d]p = <.10
#Error mean square

significantly affect any trait measured in parity one or two. Dam parity did, however, influence average birth weight ($p=.05$) and number of pigs weaned ($p<.01$) in the third parity. A similar response was observed for fraternal litter size. This covariate also had a larger effect in the third parity. Litter size in parity three was affected by the size of the litter the gilts were born in as were pig birth weight and sow weaning weight. The only other observed influence of fraternal litter size occurred in the first parity litter size at weaning. Body weight at selection affected 110 day gestation and weaning weights and sow backfat at weaning in the first two parities. Selection weight also influenced litter size in parity one and number of pigs weaned in the third parity. Backfat thickness at selection was a factor determining backfat thickness at weaning in the first two parities and at 110 days of gestation in the first parity. The backfat thickness of the sows when they were selected also influenced the number of pigs they weaned in the third and final parity.

Comprehensive covariate analysis results are reported in Appendix Tables A1 through A4.

Correlations

Correlations among selection criterion and pre-gestation covariates are presented in Table 10. Gilt body weight gain and backfat thickness at selection were negatively related to the parity of the dam in which they were born and their fraternal litter size. Body weight gain was highly correlated ($r=.84$, p,.0001) with selection weight while gain was lowly correlated ($r=.29$, $p<.05$) with selection backfat thickness. Weight and backfat at selection were moderately correlated ($r=.40$, $p<.01$).

TABLE 10. Correlations among gilt selection criterion and related covariates.

Variable	Parity Gilt Born In	Gilt's Birth Litter Size (live)	Gilt Weight at Selection	Gilt Backfat at Selection	Body weight Gain during Finishing Period
Parity gilt born in		-.18	.12	-.06	-.05
Gilt's birth litter size (live)			-.12	-.19	-.09
Gilt weight at selection				.40[b]	.84[a]
Gilt backfat at selection					.29[c]
Body weight gain during finishing period					

[a] p = .0001
[b] p = ≤ .01
[c] p = ≤ .05
[d] p = ≤ .10

Correlations of selection criterion and pre-gestation covariates with sow body condition are reported in Table 11. Selection weight was moderately correlated (r=.38 to r=.52) with sow body weight at day 110 of gestation and sow weaning weights in all three parities. Body weight gain during the finishing period was similarly related to sow gestation and weaning weights though coefficients were wider in range (r=.25 to r=.55). All correlations were significant.

Correlations among sow body condition measurements are recorded in Table 12. Most weights and backfat thicknesses were significantly correlated with previous weight and backfat measurements and ranged form r=.29 to r=.89.

Correlations of selection criterion and pre-gestation covariates with sow productivity traits are presented in Table 13. Gain was negatively related to pig weaning weights, total number of pigs born and number born alive in parity three. Gain was also negatively related to pig birth weight in parities one and two although the coefficients were low (r=-.15 and r=-.10, respectively). Selection weight was positively related to litter size in the first two parities but negatively related to total number born and number born alive in parity three. The negative relationship did not exist, however, with number of pigs weaned. Fraternal litter size was negatively related to number of pigs weaned in parity three as was parity of the dam in which the gilts were born. Dam parity was negatively related to litter size in parities one and three though fraternal litter size was positively related to parity on

litter size. Both covariates were significantly correlated to pig birth weight in parity three (r=.32 and r=.33, respectively, p<.10).

Correlations of sow condition with productivity traits are reported in Table 14. Sow weaning weights and backfats were generally non-associated with or negatively

TABLE 11. Correlations of gilt selection criterion and related covariates with body condition measurements through three parities.

	Parity	Parity Gilt Born In	Gilt's Birth Litter Size(live)	Gilt Weight at Selection	Gilt Backfat at Selection	Body weight Gain during Finishing Period
Sow 110 d weight	1	.10	.08	.38[b]	.21	.25[d]
	2	.21	.07	.44[b]	.07	.43[b]
	3	.01	.18	.42[c]	.12	.46[b]
Sow 110 d backfat	1	-.02	.03	.10	.45[b]	.08
	2	.11	.02	.13	.16	.09
	3	.12	.03	.22	.21	.17
Sow weaning weight	1	.10	-.01	.42[b]	.09	.49[b]
	2	.16	.21	.52[b]	.00	.55[b]
	3	.19	.28	.43[c]	.04	.50[b]
Sow weaning backfat	1	-.03	.15	.06	.28[d]	.13
	2	.04	.02	.49[b]	.51[b]	.34[c]
	3	.15	.16	.04	.15	.09

[a] $p = .0001$
[b] $p = \leq .01$
[c] $p = \leq .05$
[d] $p = \leq .10$

TABLE 12. Correlations among sow body condition measurements through three parities.

Variable	Parity	Sow 110 d Weight			Sow 110 d Backfat			Sow Weaning Weight			Sow Weaning Backfat		
		PARITY											
		1	2	3	1	2	3	1	2	3	1	2	3
Sow 110 d weight	1		.29[d]	.32[d]	.48[b]	.33[d]	.36[c]	.49[b]	.48[b]	.47[b]	.44[b]	.41[b]	.44[c]
	2			.77[a]	.36[c]	.59[b]	.66[a]	.79[a]	.69[a]	.72[a]	.39[c]	.34[c]	.53[b]
	3				.34[d]	.48[b]	.61[b].	.75[a]	.88[a]	.81[a]	.36[c]	.30[d]	.55[b]
Sow 110 d backfat	1					.79[a]	.72[a]	.33[c]	.25	.38[c]	.71[a]	.40[c]	.67[a]
	2						.81[a]	.51[b]	.33[c]	.47[b]	.70[a]	.38[c]	.77[a]
	3							.38[c]	.46[b]	.54[b]	.48[b]	.43[c]	.70[a]
Sow weaning weight	1								.83[a]	.89[a]	.58[a]	.31[d]	.58[b]
	2									.87[a]	.32[d]	.39[c]	.48[b]
	3										.56[b]	.23	.65[a]
Sow weaning backfat	1											.23	.87[a]
	2												.22
	3												

[a]p = .0001
[b]p = ≤ .01
[c]p = ≤ .05
[d]p = ≤ .10

TABLE 13. Correlations of gilt selection criterion and related covariates with sow productivity traits over three parities.

Variable	Parity	Parity Gilt Born In	Gilt's Birth Litter Size (live)	Gilt Weight at Selection	Gilt Backfat at Selection	Body weight Gain during Finishing Period
Total number born	1	-.15	.19	.17	.01	.11
	2	-.01	.11	.13	.05	.10
	3	-.27	-.29	-.30[d]	-.07	-.25
Number born alive	1	-.12	.22	.17	-.01	.08
	2	-.01	.09	.15	.07	.13
	3	-.28	-.37[c]	-.29	-.06	-.21
Average pig birthweight	1	.14	-.01	-.02	.01	-.15
	2	.18	-.08	-.04	-.11	-.10
	3	.32[d]	.33[d]	.10	-.09	.05
Average pig weaning weight	1	.07	.01	-.03	-.01	-.18
	2	.20	.08	-.12	-.15	-.28[b]
	3	.07	.02	.06	.28	-.05
Number weaned	1	-.12	.31[c]	.16	.00	.03
	2	.14	-.10	.17	.12	.08
	3	-.24	-.32[d]	.31[d]	.04	.36[c]

[a]p = .0001
[b]p = ≤ .01
[c]p = ≤ .05
[d]p = ≤ .10

TABLE 14. Correlations of sow body condition measurements with sow productivity traits over three parities.

		Sow 110 D weight			Sow 110 D backfat			Sow weaning weight			Sow weaning backfat		
		PARITY											
Variable	Parity	1	2	3	1	2	3	1	2	3	1	2	3
Total number born	1	.24[d]	.04	.19	.15	.10	.20	.07	.32[d]	.05	.04	.40c	.00
	2	-.19	.32[d]	.01	-.06	.02	-.07	.16	-.10	.12	.08	.03	.06
	3	-.46[b]	-.02	-.10	-.10	-.13	-.16	-.18	-.21	-.39[c]	-.30	-.17	-.25
Number born alive	1	.21	.02	.10	.11	.07	.18	-.01	.26	-.06	.02	.40[c]	-.40
	2	-.24	.35[c]	.03	-.04	.05	-.03	.19	-.07	.14	.08	.07	.06
	3	-.49[b]	.00	-.11	-.08	-.14	-.04	-.22	-.22	-.38[c]	-.40[c]	-.10	-.27
Average pig birth weight	1	.28[c]	-.32[d]	-.41[c]	.21	-.02	-.15	-.19	-.29[d]	-.36[d]	.08	-.10	-.16
	2	.34[c]	-.13	-.04	.19	.18	.26	-.16	.04	-.15	-.05	.03	.05
	3	.34[d]	.03	-.01	.03	.11	.14	.02	.06	.18	.21	.04	.20
Average pig weaning weight	1	-.07	-.24	-.21	-.14	-.26	-.10	-.37[b]	-.23	-.27	-.40[b]	-.06	-.41[c]
	2	.12	.16	.13	.24	.21	.38[c]	-.08	.13	-.02	.03	.02	.08
	3	-.25	.02	.01	.19	.12	.11	-.12	-.15	-.12	.20	.08	.10
Number weaned	1	.17	.00	.05	.05	-.04	.23	-.11	.20	-.11	.00	.40[c]	-.03
	2	-.23	.19	-.11	-.18	-.10	-.17	.10	-.16	.01	.00	.06	-.04
	3	-.26	.14	.26	-.24	-.19	-.02	.15	.21	.00	-.41[c]	.24	-.34d

[a]p = .0001
[b]p = ≤ .01
[c]p = ≤ .05
[d]p = ≤ .10

related to total number of pigs born and number born alive after sows farrowed their first litters. A similar relationship tended to exist between sow weaning backfat and number of pigs weaned though the correlations varied a great deal both in their sign and magnitude. Sow 110 day gestation backfat tended to be negatively related to total number of pigs born and number born alive although the correlations were not significant. Sow body weight at day 110 of gestation was positively related to total number born in the corresponding parity except in the third parity when the correlation was negative though small and nonsignificant. Average pig weaning and birth weights were mostly negatively related to all sow condition measurements. Weight of the gilts prior to their first farrowing was positively and significantly correlated with pig birth weights in all three parities.

Correlations among litter traits are presented in Table 15. Total number of pigs born, number born alive and number of pigs weaned were positively correlated in all parities. Birth weights and weaning weights were generally negative in their association to litter size. Weaning weights and birth weights were positively related though their relationship appeared to decrease with increasing parity levels.

Finally, some correlations observed were illogical. Careful examination of the relationships should be done prior to basing inferences on the relationships reported.

TABLE 15. Correlations among sow productivity traits through three parities.

		Total Number Born			Number Born Alive			Average Pig Birthweight			Avg. Pig Weaning Weight			Number Weaned	
		PARITY													
Variable	Parity	1	2	3	1	2	3	1	2	3	1	2	3	1	2
Total number born	1		-.18	.19	.96[a]	-.15	.18	-.32[c]	-.03	-.12	-.16	.14	-.18	.82[a]	-.17
	2			.24	-.10	.96[a]	.13	-.13	-.63[a]	-.14	.02	-.30[a]	.17	.00	.78
	3				.27	.22	.93[a]	-.22	-.21	-.74[a]	.03	.07	.04	.17	.11
Number born alive	1					-.07	.24	-.25[d]	-.01	-.13	-.17	.13	-.11	.92[a]	-.11
	2						.15	-.14	-.61[a]	.08	-.02	-.38[c]	.12	.01	.88
	3							-.27	-.15	-.75[a]	.03	.12	.02	.15	.07
Avg. pig birthweight	1								.48[b]	.37[c]	.44[b]	.15	.08	-.17	-.10
	2									.37[c]	.10	.27	-.05	-.08	-.56
	3										-.07	-.11	.04	-.04	.08
Avg. Pig weaning weight	1											.29[d]	.29	-.18	.02
	2												.34[d]	.15	-.47
	3													-.03	.14
Number weaned	1														-.04
	2														

[a] p = .0001
[b] p = ≤ .01
[c] p = ≤ .05
[d] p = ≤ .10

CHAPTER V

DISCUSSION

Productivity

The productivity advantages observed for slow growth rate gilts in this study are partially supported by Stewart and Drewry (1983) and Young et al. (1977a,b). Stewart and Drewry (1983) reported that restricting the postweaning (70-170 days of age) growth rate of gilts resulted in no adverse effects on their reproductive and production performance which coincides with the findings of the present study. Drewry (1981) reported this same response though growth rate was restricted by as much as 22%. Stewart and Drewry (1983) indicated that faster gaining gilts, however, tended to ovulate at higher rates although the embryo survival rate in those gilts was lower. This effect was also found by Young et al. (1977a,b) who reported higher ovulation rates and lower embryo survival rates in faster gaining female swine. Young and coworkers stated that the mechanism creating this relationship was genetical and that the genes which resulted in higher growth rates were also responsible for the increased ovulation rate and decreased embryo survival. Therefore there appears to be a negative genetic relationship between growth rate and embryo survival. This relationship is supported by the work of other researchers (Squiers et al., 1952; Rathnasabapathy et al., 1956; Reddy et al., 1958; Young and Omtvedt, 1973; Young et al., 1978; and Krider et al., 1982) who found positive relationships between growth rate and ovulation rate but lower and nonsignificant relationships between rate of growth and litter size.

Rathnasabapathy et al. (1956) reported positive significant correlations (r=.33 and r=.34, respectively) of weaning weight and weight at 154 days of age with ovulation rate but no correlation with litter size. These correlations were somewhat higher, however, than the .10 correlation of growth rate with ovulation rate found by Squiers et al. (1952) and .20 by Young et al. (1978). Stewart and Drewry (1983) indicated that Gossett and Sorenson (1959), Haines et al. (1959), Sorenson et al. (1961), Frobish et al. (1966), Mayrose et al. (1966), O'Bannon et al. (1966) and Frobish (1970) also found that providing higher levels of nutrient intake resulted in faster growth rates and increased ovulation rates though embryo survival rates and litter sizes were not improved. Krider et al. (1982) indicated that superovulation of females caused an increase in litter size at day 25 to 30 of gestation but resulted in very small improvements in litter size at birth. Rutledge et al. (1980) offered an explanation for these superior ovulation rates based on the findings of Black and Erickson (1968), Fulka et al. (1972) and Gondos (1978). Rutledge et al. stated that oogenesis in swine begins prior to day 40 of fetal life and lasts until 35 days after birth which results in the development of oocytes occurring totally during the fetal or early neonatal time period. The oocytes, after development, form the primordial follicle which consists of the majority of follicles present in the mature ovary. This group of follicles then is associated with the number of ova to be released in the mature animal thereby affecting ovulation rate. Rutledge indicated that environmental conditions in the early life of the neonatal pig can affect their growth rate and lower the degeneration of these oocytes resulting in a larger group of follicles accumulating and being present for use later in life. Therefore positive conditions for increased growth would also provide positive conditions for greater oocyte survival resulting in faster growing pigs containing more potentially

active follicles. One should also consider the theory that faster growing females may reach puberty earlier and, if females are bred to farrow at a fixed age, may pass through more estrous cycles, thereby increasing their ovulation rate. These collective results support the theory that faster growing female swine tend to be either genetically or physiologically superior for ovulation rate.

Since litter size is a function of both ovulation rate and embryo survival, the reported advantage in ovulation rate exhibited by fast growth rate gilts must be accompanied by an increased rate of embryo mortality or else litter sizes of faster growing females would be larger. Reddy et al. (1958) indicated that rate of gain from 154 days of age to breeding was negatively correlated (r=-.21) with embryo mortality but weight at 154 days and breeding were positively related to embryo death rate (r=.16 and r=.11, respectively). Rathnasabapathy et al. (1956) found correlations of .32 and .35 of embryo mortality with breeding age and body weight gain from 90.7 kg to day 55 of gestation, respectively. Squiers et al. (1952) reported contrasting results in correlations of breeding age and weight with embryo mortality with coefficients of -.11 and -.05, respectively. The work of Reddy et al. suggested that gain to 154 days of age was inversely related to embryo survival, assuming those heavier at 154 days of age gained at faster rates, and Rathnasabapathy et al. indicated that gain from 90.7 kg body weight to day 55 of gestation was negatively related to embryo survival. Those results are in agreement with Young et al. (1978) who reported that growth rate to weaning and average daily gain to 100 kg of body weight were positively correlated (r=.91 and r=.27, respectively) with embryo death rate. Although ovulation rates and embryo survival were not measured in the present study, the results found by the above mentioned authors could be associated with the litter size responses observed in the

current experiment.

Young et al. (1977a,) stated that gilts who reached 100 kg of body weight later and were lighter at breeding than their faster growing counterparts were superior in embryo population. This response was also observed in the current experiment as slow growth rate gilts reached 100 kg of body weight later than the fast gaining gilts, were lighter at breeding (145 kg vs. 139 kg, $p<.05$), and tended to produce more pigs throughout the study which indicated higher embryo survival and therefore population. Greater embryo survival in the present study is further indicated by the lower difference between total number of pigs born and number of pigs born alive observed in the slow growth rate gilts. Fast gaining gilts had a difference of -.4, -.5 and -.7 pigs between total number born and number born alive in parities one, two and three, respectively, compared to differences of -.4, -.1 and -.1 through the three parities, respectively, for slower growth rate gilts. In the experiment conducted by Young et al. (1977a), gilts were slaughtered at 30 days of gestation to determine number of corpora lutea and embryos present. Therefore, they could not examine performance in later parities nor at or after farrowing in the first parity although most embryonic mortalities would have occurred prior to the time gilts were slaughtered (Nalbandov, 1976).

The mechanism causing embryo survival or mortality is not well understood. Nalbandov (1976) indicated that the number of embryos surviving is much less than the number of ova fertilized. This is expected when evaluating litter size and factors affecting it. Nalbandov stated that 30-50% of the mortality happens in the first third of gestation but more so prior to attachment in the uterus. He also mentioned that embryo mortality is more common in females with higher ovulation rates. Nalbandov directed attention to the commonly known reasons for embryo mortality such as disease

or sickness, low vigor sperm and feeding regime but also mentioned sperm and egg quality and age, unfavorable uterine environments and possible overcrowding effects in the uterus. Such effects as sickness, disease, feeding regime, and sperm quality would have been common to all gilts in the current experiment but perhaps crowding in the uterus occurred in faster growing gilts that would have potentially ovulated at higher rates. Nalbandov reported conflicting ideas regarding the crowding effect, stating that 90% of the females who lost ova or embryos did not lose embryos due to the number of eggs ovulated. In the highest ovulation rate group, embryo mortality was 33% compared to 35% in the medium ovulation rate group and 31% in those that ovulated at the lowest rates. Nalbandov also reported positive correlations between embryo mortality and fertilized ova.

In the present study, there appeared to be a trend in pig survival rates to weaning favoring the slow growth rate sows. Stewart and Drewry (1983) reported no difference in survival rate to weaning between multiparous sows fed high or low energy diets during development as a gilt (day 70 to 170 postweaning). Overall least squares means for both diet groups were not reported. Young et al. (1978) reported a phenotypic correlation of -.57 between average daily gain and number of pigs weaned though the correlation between number weaned and number born alive was high (.83, $p<.01$). No survival rates were reported. Stewart and Drewry (1983) indicated that survival rates decreased with increases in parity. This does not agree with the weaning percentages for slow growing sows in the present study though fast growing sows decreased in weaning percentage between parities two and three. Reasons for the differences in pig survival rates observed in this study are somewhat unclear. A potential explanation is that sows which grew at slower developmental rates were more

efficient in their conversion of body energy reserves to the production of larger litter sizes at weaning. These sows lost only slightly more backfat while weaning larger litters. They lost .8 mm more backfat in parity one though they weaned an extra 2.3 pigs. In parity three they lost 1.5 mm more backfat than fast growth rate sows and weaned 1.3 pigs more though litter sizes at birth were equal. Faster growth rate sows farrowed 1.4 pigs more in parity two, had 1.0 pigs more born alive and lost 7.3 mm more backfat while weaning only one-half pig more. Slower growth rate sows lost no backfat in parity two and the litter size advantages that tended to occur for faster growth rate sows in this parity were all nonsignificant. Whether or not there exists some biological mechanism creating this response is unknown. More research is needed to determine if this effect does in fact occur or if the response was isolated to this study. If this superiority in the potential to save more pigs from farrowing to weaning is in fact associated with slower rates of developmental growth it could be the major response found in this study.

There was no difference observed in progeny birth weights between the two growth rate groups in the current study. This finding is in disagreement with results found by Garnett and Rahnefeld (1976) who reported pig birth weights were higher in lines selected for superior growth rates. Stewart and Drewry (1983), however, found no differences in birth weights between sows developed on low or high energy diets. Pig weight at birth has generally been related to survivability with heavier birth weight pigs being more likely to survive to weaning. This advantage is commonly given to pigs weighing 1.4 kg or more at birth. Birth weights reported in the present study were above this level in all parities in both rate of growth groups indicating exceptional performance of sows who grew at fast or slow rates of developmental gain. There did

tend to be a nonsignificant advantage for faster growth rate sows in two of the parities studied. In parities one and three, pigs born to fast rate of growth sows were .1 kg heavier but it must be noted that in parity one these sows farrowed a significantly lower number of pigs (6.4 vs. 8.6, p=.05). In parity three, however, total pigs farrowed were equal between the growth rate groups (p>.99). Faster growth rate sows still produced a .1 kg birth weight advantage although the effect on survivability was not as important since all pig birth weights were above the 1.4 kg level. Garnett and Rahnefeld (1976) also indicated pig weaning weights were heavier in sow lines selected for growth rate. This relates birth weight to weaning weight which is in agreement with Young et al. (1978) who stated that pigs who were heavier at earlier ages would also be heavier later in life. Rathnasabapathy et al. (1956) also related weaning weight to growth rate. It appears, therefore, that progeny born to advanced growth rate animals would also have the same growth rate advantage and would be heavier at birth and at weaning. Weaning weights in the present experiment, however, were not different between growth rate female groups indicating that pigs farrowed by the faster growth rate sows were not superior in growth rate compared to pigs born to sows who grew at slower developmental rates. This effect was of some concern prior to the analysis of this study since rate of gain in progeny (especially market animals) is economically important and it was hypothesized that progeny of slower gaining animals might also exhibit slower growth rates. The use of littermate gilt pairs, however, should have removed some potential for this response since both groups had similar genetic backgrounds.

Condition

Normal responses associated with increasing parity levels were observed. Sows in both growth rate groups increased in body weight from the first to third parities with increased amounts of gain occurring in each parity. The backfat response was inverse since sow backfat thickness declined from parity one through parity three. This indicated that as sows progressed through each parity they became heavier but leaner. These findings agree with those of Elsley et al. (1968), O'Grady et al. (1975), Whittenmore et al. (1980) and Esbenshade et al. (1986). Esbenshade et al. (1986) reported larger backfat losses during lactation which also occurred in the present study. These results reflect the effect the litter has on the sow. The differences observed in litter sizes between the two groups restricts the formation of conclusions regarding developmental growth rate effects on sow body condition since it is impossible to remove the influence of the litter on sow condition. Patterns in either weight or backfat fluctuations can, however, be observed. The first response to note is the compensatory gain exhibited by slow growth rate gilts between breeding and the 110th day of gestation in parity one. Since the two groups were different in body weight at breeding (145 kg fast vs. 139 kg slow, $p<.05$) but equal prior to farrowing their first litter, the slow growth rate gilts must have experienced compensatory gain which is supported by the higher gestational backfat gain observed in faster growth rate sows. Since fat is deposited at greater rates as maturity approaches, it is expected those gilts who grew at faster rates were closer to physiological maturity and therefore tended to deposit greater amounts of fat (3.6 mm vs. 2.3 mm). Gilts who grew at slower rates, however, had more weight gain in first parity gestation (32 kg vs. 26 kg). Gilts who

grew at faster rates appeared to be more severely affected by lactation than slower growth rate gilts although they were generally higher in backfat through all three parities. These gilts actually weighed less at weaning in parity one than when they were bred. Realizing that slow growth rate gilts lost as much weight in their first lactation and had a lower breeding weight to decline to, they weaned 2.3 more pigs (7.4 vs. 5.1, p=.05) than their faster growing counterparts. Even though litters born to gilts are expected to be smaller in comparison to older sows, a 5.1 pig litter size at weaning would normally not be associated with the weight loss observed especially when pig weaning weights were not different (p>.90).

Lodge (1969) reported that weight losses were greater in the first lactation and then declined as parity increased. This response was observed in the present study for the slow rate of growth group but not for the faster growth group. Their weight losses in the second parity were equal to and slightly greater than those in the first parity. The faster growth rate group weighed slightly more (1 kg) at weaning in parity two than they did at first breeding whereas the slower growth rate group had gained 20 kg and weaned a combined 1.8 pigs more. Granted, the fast growth rate sows had a larger litter size in their second parity than in their first (7.9 weaned vs. 5.1 weaned) but they had only a nonsignificant one-half pig more at weaning than the slower growth rate sows. Slower growth rate females did lose more backfat in their first and third lactations (-1.7 mm vs. -.9 mm and -3.8 mm vs.-2.5 mm, respectively) but they weaned more pigs in these parities (7.4 vs. 5.1, p<.05 and 8.6 vs. 7.3, p<.10, respectively). A strange response was observed for the fast growth rate group in their second parity lactation. These sows lost 7.3 mm of backfat between day 110 gestation and weaning though they weaned a nonsignificant one-half more pig than the slower

growth rate sows and had weaned 2.3 pigs less in the previous parity. The causative mechanism associated with this response is unknown. It would seem natural to relate the large backfat loss to larger rates of production. The second parity number of pigs born alive was the highest observed for these sows but in parity three they had just .6 pigs less born alive and lost only 2.5 mm of backfat. They lost just .9 mm of backfat in the previous lactation and weaned only 5.1 pigs. From breeding to day 110 of gestation, fast growth rate sows had a net backfat gain of +.7 mm while slow growth rate sows had a -.5 mm net change. Therefore, it does not appear that low body condition nor extreme demands placed on body energy reserves would have created this response. Perhaps the answer lies in energy metabolism with faster growth rate females being biologically different in their control of metabolism and energy expenditure.

Esbenshade et al. (1986) reported negative correlations (r=-.41) between number of pigs born alive and sow productivity index (National Swine Improvement Federation, Robison, 1981) with backfat gain during gestation. This relationship, however, was found from data that included only first litter gilts but the results of the present study may apply this relationship to later parities. Slow growth rate females were more productive and lost backfat in both the second and third parity gestations while fast rate of growth females had a positive backfat gain during gestation in the third parity. Esbenshade et al. suggested that gestational gains in backfat were inversely related to backfat in lactation. Though isolated cases in this experiment were similar, the results do not support that relationship since the opposite response was common.

Esbenshade et al. (1986) also indicated that gestational weight gains were associated with improved sow productivity. Bereskin and Frobish (1981) found that

sows who gained more weight in gestation produced superior litters both in size and weight. A relationship of those results to those found in the present study could not be confirmed since both growth rate groups gained similar amounts of weight during gestation although gilts which grew at slower rates gained 6 kg more in body weight in their first gestation period.

Reproductive performance

Since reasons for culling were many and variable during the experiment, reproductive performance could only be measured by longevity within the herd and number of females remaining in each parity. Equal numbers (50) of fast and slow growth rate gilts were selected for use in this study. Of those selected, 28 fast growth rate and 20 slow growth rate gilts farrowed in the first parity. This does not indicate that a reproductive superiority (or inferiority) should be associated with either growth rate group. Gilts were mated on their second or third estrus. Those that came in estrus and were bred at the same time were included in an experimental herd. Those that came in estrus at different times were not used in this experiment. These animals may have bred and farrowed consistently at regular intervals but were excluded from the experiment simply because they did not first cycle together with those used in the study. Since there were more of the fast growth rate gilts present in parity one there may have been more of these reach puberty at earlier ages which has been shown to occur in females who exhibit faster rates of growth and thereby reach sexual maturity earlier. These females tend to reach the weight and fat thresholds for puberty at earlier ages (Kirkwood and Aherne 1985). If this response did in fact occur, the difference

in group population created by the effect was minimal. Group sizes could also have been affected by health problems resulting from farrowing difficulties or injury.

Of those females who were present in the first parity, nine fast growing females and four slow growing females did not return in parity two. In parity three, the number of females not returning was two in the fast growth rate group compared to three from the slow growth rate group. These samples sizes were small as were the differences observed between the two groups. Caution should be used when making inferences concerning reproductive performance based on these data. The trend, however, did favor the slow growth rate group since fewer of these females left the experiment between the first farrowing and weaning in parity three. Gueblez et al. (1987) indicated a similar response in the 5000 gilts they examined over four parities. Gilts which took 170 days or more to reach 100 kg reached parity four at a rate of 45% compared to 28% for gilts that grew to 100 kg in 140 days or less. Klusacek et al. (1986) reported that gilts with lower average daily gains from birth to 100 kg of body weight also had lower conception rates. Klusacek et al. (1986) found that gilts with lower average daily gains had lower farrowing intervals than those who had higher average daily gains from birth to 100 kg. Watkins (1983) reported that females who were younger at selection had longer farrowing intervals.

Sow condition would seem to play a larger role in determining longevity and reproductive performance. Sow condition responses in different growth rate groups has been discussed and can therefore be related with longevity and reproductive performance. Flowers and Stanislaw (1989) indicated that sows weaning heavier litters in their first parity lowered their body energy reserves and were longer in their postweaning return to estrus and had lower conception rates. Slow growth rate sows

in the present study weaned heavier litters in parity one but had lower culling rates between parity one and two which disagrees with the findings of Flowers and Stanislaw (1989). King (1987) reported that sows who were heavier but lost more weight and backfat during their first lactation returned to estrus following weaning later than those who had less severe fluctuations in body condition. There was no difference in body weight four days prior to the first farrowing between the growth rate groups in the current experiment but slower growth rate sows lost more backfat during their first lactation. Weight losses, however, were similar. King et al. (1982) suggested that return to estrus was more affected by weight and backfat losses in lactation rather than age, fat thickness or weight at farrowing. Meyen et al. (1985) also found that sows who were lower in backfat were longer in their return to estrus postweaning while Watkins (1983) reported similar results between lactational weight losses and farrowing interval. Contrasting results were reported by Esbenshade et al. (1986). Those researchers indicated that weight and backfat fluctuations were not associated with rebreeding interval and return to estrus.

It would be expected to find decreased reproductive performance in cases of extreme declines in body condition. Sows who had severely lowered their energy reserves would be more apt to direct nutrients toward improving their condition, resulting in a decrease in reproductive performance. Whether this occurs in situations of normal and nonexcessive deprivations in body condition is unclear. In the present study, both groups of sows lost weight and backfat during lactation and gestation. These changes were not associated with culling rates since periods of greatest weight and backfat losses were not related to higher culling levels.

Correlations

Correlations among pre-gestation traits, between pre-gestation traits and sow condition and among sow body condition are presented in Tables 10, 11, and 12, respectively. Correlations between gain, selection weight, selection backfat and other body measurements were significant and positive indicating that animals who grew faster were heavier and had more backfat. Selection weight and gain were significantly correlated with sow 110 day gestation and weaning weights. These relationships are supported by Young et al. (1978) and Ferguson et al. (1985) who reported large positive correlations between sow weights at different ages and reflects, as Ferguson et al. stated, the "part-whole" relationship between body measurements. Backfat of sows at weaning was correlated with selection weight and gain only in parity two which indicated the response of the sows to their first litter and that as weight and gain at selection were higher, backfat was also higher. King (1987) indicated that heavier females at farrowing could withstand the effects of lactation easier since they had larger body reserves to draw from. Weaning backfat was associated with selection backfat which again is the part-whole relationship indicated by Ferguson et al.(1985). It was not, however, related to backfat of the sow in the previous weaning but was related to day 110 of gestation backfat which represents weight fluctuations between lactation and gestation.

Correlations of pre-gestation body measurements with productivity traits (Table 13) were rarely significant although high coefficients and trends were observed. In parity three, total number of pigs born was correlated with selection weight ($r=-.30$, $p<.10$) and negatively related to body weight gain ($r=-.25$, nonsignificant (NS)). Also,

number born alive was negatively related to selection weight (r=-.29,NS) though the relationship was positive for number weaned (r=.31, p<.10). Reasons for these associations and their inconsistencies are not evident. Body weight gain was also negatively related to total number born in parity three (r=-.25, NS) though positively correlated with number weaned (r=.36, p<.05). Gain during the finishing period was negatively related to average pig weaning weight in all three parities which disagrees with the results reported by Garnett and Rahnefeld (1976) who stated that progeny of fast growing females also grew faster and were heavier at weaning. Bereskin and Frobish (1981) reported the same response in 21 day litter weight. Gain was also negatively related to birth weight in parities one and two (r=-.15,NS and r=-.10,NS).

Correlations of sow condition with productivity traits are reported in Table 14. Gestation weight gain in parity one was significantly and positively correlated with average pig birth weight in all three parities which agrees with Bereskin and Frobish (1981) who stated that sows who gained more weight in gestation farrowed heavier litters. The relationship reversed in parity two and three, however, as sows who gained more weight in gestation produced lighter birth weight pigs. Esbenshade et al. (1986) reported that gestational backfat gains were negatively related with productivity. This is reflected in the present study by the negative correlations of 110 day gestation backfat in parities two and three with total number born, number born alive and number weaned. All sow weight and backfat measurements were negatively related to total number of pigs born and number of pigs born alive in parity three although all were not in parity one and two. It was expected that this response would be commonly observed. This does reflect the contribution the sow makes to her litter as well as the effect the litter has upon sow body condition. Effects of pig weaning

weights on sow condition were further demonstrated by the negative correlations of pig weaning weight in parity one with all sow weight and backfat measurements in that parity.

Presented in Table 15 are the correlations among productivity traits. These relationships are to some degree part-whole as is evidenced by the correlations observed. Total number born was associated with number born alive, pig birth weight and number weaned. In parity three, there appeared to be another factor influencing number of pigs weaned since this was the only litter size variable not significantly related to total number born. Significant correlations were found within corresponding parities. Total number born and number born alive were negatively related to average pig birth weight which simply illustrates the effect observed in large litter sizes. The negative relationship observed between number of pigs weaned and pig birth weight also existed between number of pigs weaned and pig weaning weight. As litter sizes at weaning were larger birth and weaning weight were smaller.

Correlations of parity of the dam in which the gilt was born and gilt fraternal litter size with sow condition are reported in Table 11. No relationships were observed between parity of the gilt's dam and sow weight or backfat. Nor was there any association of fraternal litter size with body condition. Parity the gilt was born in and her fraternal litter size were related, however, with productivity traits. These correlations are presented in Table 13. Parity of the dam in which the gilt was born was negatively correlated with total number of pigs born, number born alive and number weaned. These two live litter size traits, however, were naturally both related to total number of pigs born. A generally accepted relationship associated with parity level is that litter sizes tend to increase as parity level increases. These larger litter

sizes create more competition for nutrients between the littermates thereby lowering their level of performance. In this way, parity a gilt was born in and her fraternity litter size are related. In the present study, the same relationship was generally observed between fraternal litter size of the gilt and her production. Average pig birth weight increased significantly as parity increased and can be related to larger litter sizes at birth. These results are supported by Rutledge (1980) and Nelson and Robison (1976).

Covariate effects

Sow body condition in all three parities was influenced by gilt condition at selection as well as level of production. The analysis of the covariates measured prior to the first gestation period (Tables 7, 8 and 9) revealed that body weight and backfat thickness at selection affected the weight and condition of the sows in all three parities. This finding reflects the part-whole relationship previously discussed. Analysis of comprehensive covariate effects across three parities (Tables A2 through A4) indicated that previous parity litter size and sow condition also influenced the body condition of the sow in a particular parity. These results suggest that the level of production exhibited by a sow greatly affects her body condition and that the condition of the sow is related to her subsequent productivity. These relationships are commonly found in swine production and generally accepted as factual occurrences.

A more interesting result observed from the covariate analysis involved the influences of the parity of the dam in which the gilts were born and the litter size they were born in. These variables did not tend to affect any traits until the third parity.

Third parity litter size and average pig birth weight were influenced by both dam parity and fraternal litter size while weaning weight of the sow was affected by fraternal litter size only. Reasons for these relationships or, more importantly, why they were evident in only the third parity, are not clear. Perhaps the explanation involves the relationship of parity with litter size. Litter size has been shown to increase with parity level increases which has already been discussed. Fraternal litter size has been negatively related to the performance of pigs born in the larger litters due to the effects of increased competition among littermates (Yen et al., 1987; Meyen et al., 1985; van der Steen, 1985). Considering these relationships, gilts born in later parities would tend to be born in larger litters and therefore would possibly produce smaller litter sizes. van der Steen (1985) indicated that pigs born in larger litters produced .5 pigs less per litter. Nelson and Robison (1976) reported a difference of 1.18 pigs born alive in favor of females born in smaller litters. The significant effect on pig birth weight could then be related to the litter size response with birth weight of pigs being inversely related to litter size. Using the above relationships as an explanation for the effects of dam parity and fraternal litter size observed in the present study is somewhat restricted since the gilts were born in similar litter sizes and parities. The relationships also do not offer any explanation of why the effects were observed mainly in the third parity. Fraternal litter size did have a significant effect on the number of pigs weaned, however, in the first parity although the effect on total number of pigs born and number of pigs born alive was not significant ($p=.23$ and $p=.13$, respectively). No other effects were observed. The reason for these effects being isolated to the third parity, therefore, remains uncertain.

Conclusion

Swine producers are generally advised to select replacement females who exhibit faster rates of developmental growth. This practice is suggested in order to improve production efficiency by improving feed efficiency in both the gilts selected and their progeny. The results of the present study indicate that gilts who grow at slower rates during development may be superior in sow productivity traits, more efficient in converting their body energy reserves to marketable progeny, remain productive equally as long as their faster growing counterparts and produce progeny who perform just as well to weaning. These conclusions are based on a relatively low number of females examined and therefore need to be evaluated in research involving larger numbers of animals. The results do, however, indicate that current methods for selecting replacement gilts may need to be re-evaluated.

CHAPTER VI

SUMMARY

Data from 100 crossbred Duroc, Hampshire, Landrace, and Yorkshire gilts at the University of Tennessee Ames Plantation Agricultural Experiment Station were analyzed to determine the effects of rate of finishing period gain on subsequent sow body condition, reproductive performance, and productivity over three parities. Measurements of sow body condition were weights and backfat thicknesses taken at day 110 of gestation and when sows weaned their litters. Productivity of the sows was evaluated by the traits total number of pigs born, number born alive, pig birth and weaning weights and number of pigs weaned. Sow presence in the herd through three parities was the only indicator of reproductive performance although females may have also been culled due to injury or health problems. Differences in condition and productivity traits between the two growth rate groups were determined by analysis of variance through the Statistical Analysis System (SAS). Parity of the dam in which the gilts were born and their fraternal litter size were also evaluated to determine and remove their effects on sow performance.

Fast growing gilts gained 73 kg body weight (BW) during the finishing period compared to 65 kg BW for the slower growing littermate gilts ($p<.0001$). Gilts which gained faster were heavier at selection (106 kg BW vs. 96 kg BW, $P=.0001$) and tended to have more backfat (18.8 mm vs. 16.5 mm, $p=12$). They were also heavier at first breeding (145 kg BW vs. 139 kg BW, $p<.05$) though not different in first breeding backfat thickness ($p>.20$). Of the 100 gilts selected, 28 fast and 20 slow

growth rate gilts farrowed in the first parity, 19 fast and 16 slow gaining gilts were in the study in parity two, and 17 fast and 13 slow growing gilts were present in parity three.

Sow 110d gestation weights were virtually identical in the first two parities though the slower growth rate group tended to be heavier in the third parity (196 kg vs 185 kg,$p>.25$). Sow weaning weights were similar in the first and third parities but the slow growth rate group was 13 kg heavier at weaning of their second litter (159 kg vs 146 kg,$p<.10$). The faster growth rate group tended to have more backfat throughout all three parities except for in parity two when slower growing females had more backfat at weaning (18.6 mm vs 14.3 mm,$p<.05$). Backfat thickness declined equally in both growth rate groups during the experiment while body weight increased. Slower growth rate sows lost backfat in both gestation periods following their first litter while the faster growth rate group lost more backfat during lactation.

Pig birth and weaning weights were not affected by dam rate of gain ($p>.27$) but slower gaining gilts produced more pigs born (26.4 vs. 25.6), more born alive (25.8 vs. 24.0), and more pigs weaned (23.4 vs. 20.3) over three parities than faster gaining gilts. Slow gaining sows yielded 2.2 more pigs born ($p=.05$), 2.2 more born alive ($p<.05$) and 2.3 more weaned ($p<.05$) in parity one and also more pigs weaned (8.6 vs. 7.3, $p<.10$) in parity three. No other differences in litter sizes within a particular parity were significant.

Parity born in was a significant source of variation in pig birth weight and number weaned in the third parity but was not significant in parities one and two. Fraternal litter size had an influence on the number of pigs weaned in parities one ($p<.05$) and three ($p=.05$) and also on total number born ($p<.10$) and born alive ($p<.05$)

in parity three. Average pig birth weights in parity three were influenced by fraternal litter size ($p<.10$) as was weight of the sow at weaning ($p=.05$).

Gain was highly positively correlated with selection weight and all other sow weight measurements but was correlated only with selection backfat and sow backfat at weaning of her second litter. There was also a significant correlation of gain with number of pigs weaned in parity three ($r=.36$, $p=.05$) though slow growing gilts weaned more pigs ($p<.10$) in parity three.

The results of this experiment indicated that selection of faster gaining females for sow herd replacements produced no advantages in sow condition, reproductive performance and productivity traits through the first three parities.

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APPENDICES

APPENDIX A

TABLE A1. Definition of acronyms

Acronym	Trait
DPAR	Parity of the dam in which the gilt was born
FLITSIZE	Fraternal litter size
Selwt	Gilt body weight at selection
Selbf	Gilt backfat thickness at selection
110dwt1,2,3	Gilt body weight at d 110 of gestation in parity 1,2,3
110dbf1,2,3	Gilt backfat thickness at d 110 of gestation in parity 1,2,3
TNB1,2,3	Total number of pigs farrowed in parity 1,2,3
NBA1,2,3	Number of pigs born alive in parity 1,2,3
APBWT1,2,3	Average pig birthweight in parity 1,2,3
NOWN1,2,3	Number of pigs weaned in parity 1,2,3
APWWT1,2,3	Average pig weaning weight in parity 1,2,3
SWWT1,2,3	Sow body weight at weaning in parity 1,2,3
SWBF1,2,3	Sow backfat thickness at weaning in parity 1,2,3

TABLE A2. F values indicating comprehensive covariate effects in the first parity.

		Dependent variables							
Covariate	(df)	110DWT1 (47)	110DBF1 (47)	TNB1 (48)	NBA1 (48)	APBWT1 (47)	NOWN1 (47)	APWWT1 (47)	SWWT1 (47)
DPAR		.08	.13	2.00	.19	.56	.98	.17	.10
FLITSIZE		.03	.12	1.46	1.49	.01	3.19[d]	1.80	.03
Selwt		6.45[c]	4.55[c]	5.91[c]	.36	.12	1.57	.06	20.61[a]
Selbf		.69	12.41[a]	.20	.06	.04	.19	.04	6.63[c]
110dwt1			9.26[b]						
110dbf1		9.26[b]							
TNB1					350.14[a]	3.41[d]	13.44	.11	.15
NBA1							68.70[a]	.24	.03
APBWT1							.03		2.08
NOWN1								.90	2.78[d]
APWW1									.16
SWWT1									
SWBT1									21.13[a]

[a]p = .0001
[b]p = <.01
[c]p = <.05
[d]p = <.10
[e]see Table A1. for definition of acronyms.

TABLE A3. F values indicating comprehensive covariate effects in the second parity.

		Dependent Variables							
Covariate	(df)	110DWT2 (34)	110DBF2 (34)	TNB2 (34)	NBA2 (34)	APBWT2 (34)	NOWN2 (34)	APWWT2 (34)	SWWT2 (34)
DPAR		.39	.41	.09	.01	.01	2.11	.69	.04
Flitsize		.22	.33	.10	.53	.06	3.15[d]	.05	.61
Selwt		.26	.14	.15	.01	.17	.15	.37	.24
Selbf		.08	.12	.00	.19	.30	.00	1.02	.19
110dwt1									
110dbf1									
TNB1		.66	.00	2.08	.24	1.00	2.38	.91	1.72
NBA1		.10	2.55	.41	1.18	.87	3.17[d]	.24	4.66[c]
APBWT1		.07	1.88	.35	.45	3.50[d]			.01
NOWN1		1.99	7.52[b]	.15	1.39	.24	1.50	.00	7.71[c]
APWWT1		.05	.17	.84	.28	.35	.04	2.69	.59
SWWT1		17.27[b]	.14	.02	.22	.01	.22	2.66	5.73[c]
SWBF1		.92	13.16[b]	.19	.34	.84	.16	1.17	2.84
110DWT2			3.81[d]	.66	.01	.88	.02	4.5[c]	3.11[d]
110DBF2		3.81[d]		.70	.54	.52	.05	.20	.23
TNB2					131.54[a]	14.18[b]	8.50[b]	.14	6.90[c]
NBA2							40.41[a]	.06	4.75[c]
APBWT2							.07		.55
NOWN2								.80	4.66[c]
APWWT2									.01
SWWT2								.00	
SWBF2								.01	.62

[a]p = .0001 [c]p = <.05 [e]see Table A1 for definition of acronyms.
[b]p = <.01 [d]p = <.10

TABLE A4. F values indicating comprehensive covariate effects in the third parity.

		Dependent variables							
Covariate	(df)	110DWT3 (28)	110DBF3 (28)	TNB3 (28)	NBA3 (28)	APBWT3 (28)	NOWN3 (27)	APWWT3 (27)	SWWT3 (27)
DPAR		.71	.68	.50	5.91[c]	.02	.02	.60	.29
FLITSIZE		.25	.00	4.13[d]	3.98[d]	.05	.13	.11	.06
Selwt		.58	.04	5.14[d]	1.08	.02	.40	.16	.15
Selbf		.42	.42	2.49	.32	.00	.60	.14	.50
WT110D1									
BF110D1									
TNB1		.28	.00	.50	2.54	.68			
NBA1		.92	.02	.47	1.83	.35			
APBWT1		.73	.08	1.20	.08	.02			
NOWN1		.89	.02				.13	.01	.06
APWWT1		.49	.04				.40	3.92	11.13[c]
SWWT1		.04	.32	.11	3.47	.93	.00	1.10	2.35
SWBF1		.19	1.47	2.08	1.90	.12	.02	1.87	5.60[d]
WT110D2				.50	1.24	2.16	1.04	.62	2.06
BF110D2				.29	3.88[d]	.22	.11	2.67	10.31[c]
TNB2		.53	.07	1.84	3.75[d]	.91			
NBA2		.37	.08	.01	1.44	2.47			

TABLE A4. (Continued)

Covariate	(df)	Dependent Variables 110DWT3 (28)	110DBF3 (28)	TNB3 (28)	NBA3 (28)	APBWT3 (28)	NOWN3 (27)	APWWT3 (27)	SWWT3 (27)
APBWT2		.57	.07	.37	.31	2.37			
NOWN2		.16	.18				.16	.15	.00
APWWT2		.76	.00				.36	.58	2.51
SWWT2		3.12	.02	.10	.28	.02	.04	2.98	9.93[c]
SWBF2		.46	.67	.39	1.75	.03	.53	.81	.98
WT110D3			1.66	2.40	1.44	.11	.61	.35	.27
BF110D3		1.66		.10	13.96[b]	.00	.41	.05	.01
TNB3					53.54[b]	2.43	2.40	1.21	1.78
NBA3							2.33	.66	1.00
APBWT3							.26		
NOWN2								.38	
APWWT3									5.19
SWWT3								5.19	
SWBF3								.58	.38

[a]p = .0001
[b]p = <.01
[c]p = <.05
[d]p = <.10
[e]see Table A1 for definition of acronyms.

APPENDIX B

TABLE B1. Sow productivity over three parities for females in replicate groups.[a]

Variable	Parity	Replicate 1	Replicate 2	PR>F
Total number pigs born	1	7.4±.61	7.6±.64	.87
	2	9.2±.71	8.9±.75	.80
	3	9.7±.81	9.3±.74	.68
Number pigs born alive	1	7.1±.56	7.2±.59	.93
	2	9.0±.67	8.4±.71	.58
	3	9.7±.67	8.4±.61	.16
Average pig birth weight, kg	1	1.5±.06	1.6±.06	.35
	2	1.6±.06	1.5±.07	.71
	3	1.6±.07	1.6±.07	.94
Number pigs weaned	1	6.4±.53	6.1±.56	.67
	2	7.9±.60	7.4±.64	.65
	3	8.4±.40	7.5±.35	.12
Average pig weaning weight, kg	1	10.8±.45	9.2±.48	.03
	2	9.2±.30	8.7±.32	.32
	3	9.9±.51	9.9±.50	.99

[a]Data are least squares means + or - standard errors.

TABLE B2. Sow productivity traits over three parities for classification replicate groups[a]

Variable	Parity	Classification x Replicate Group: Fast Rep 1	Fast Rep 2	Slow Rep 1	Slow Rep 2
Total number pigs born	1	6.7±.71	6.2±1.03	8.2±1.03	9.0±.91
	2	10.3±.84	9.2±1.24	8.09±1.23	8.6±.96
	3	10.2±.91	8.8±1.23	9.3±1.42	9.8±1.04
Number pigs born alive	1	6.3±.66	5.8±.95	7.9±.96	8.5±.94
	2	10.0±.80	8.4±1.18	7.9±1.17	8.4±.91
	3	10.1±.75	7.4±1.01	9.4±1.17	9.4±.86
Average pig birth weight, kg	1	1.5±.07	1.6±.10	1.5±.10	1.5±.09
	2	1.6±.07	1.5±.11	1.6±.11	1.6±.08
	3	1.6±.08	1.7±.11	1.6±.13	1.5±.09
Number pigs weaned	1	5.4±.61	4.8±.89	7.4±.91	7.3±.81
	2	8.4±.72	7.4±1.07	7.3±1.06	7.3±.82
	3	7.6±.45	7.0±.67	9.3±.71	8.0±.51
Average pig weaning weight, kg	1	10.8±.53	9.2±.77	10.7±.78	9.2±.69
	2	9.0±.36	8.5±.53	9.4±.53	9.0±.41
	3	10.2±.58	10.0±.85	9.7±.90	9.8±.66

[a]Data are least squares means + or - standard errors.+

TABLE B3. Body condition measurements through three parities for replicate groups.[a]

Variable	Parity	Gilt group 1	(n)	Gilt group 2	(n)	PR>F
Body weight at 110 d gestation, kg	1	165±3.2	(27)	177±3.4	(22)	.01
	2	178±4.6	(19)	172±4.9	(16)	.43
	3	189±5.3	(15)	191±4.9	(15)	.77
Backfat at 110 d gestation, mm	1	21.4±1.23	(26)	24.5±1.28	(22)	.09
	2	19.2±1.67	(19)	21.1±1.76	(16)	.46
	3	17.8±1.82	(15)	14.6±1.75	(14)	.21
Sow weaning weight, kg	1	136±3.2	(27)	149±3.4	(21)	.01
	2	149±4.1	(19)	156±4.3	(16)	.27
	3	171±5.8	(15)	186±5.7	(14)	.09
Sow backfat at weaning, mm	1	17.4±1.05	(27)	25.8±1.12	(21)	.0001
	2	17.4±1.00	(19)	15.6±1.05	(16)	.23
	3	10.9±1.19	(15)	15.0±1.16	(14)	.02

[a]Data are least squares means + or - standard errors.

TABLE B4. Body condition measurements through three parities for classification by replicate groups.[a]

Variable	Parity	Classification x Replicate Group			
		Fast Rep 1	Fast Rep 2	Slow Rep 1	Slow Rep 2
Body weight at 110 d gestation, kg	1	167±3.8	175±5.5	162±5.6	179±4.9
	2	182±5.5	169±8.1	174±8.1	176±6.2
	3	184±5.9	186±8.0	197±9.3	197±6.8
Backfat at 110 d gestation, mm	1	24.8±1.49	24.2±2.08	17.9±2.09	24.8±1.85
	2	22.6±1.99	20.7±2.95	15.8±2.93	21.4±2.27
	3	20.0±2.04	13.3±2.96	15.6±3.21	15.8±2.35
Sow weaning weight, kg	1	138±3.7	148±5.4	134±5.5	150±4.9
	2	142±4.9	150±7.2	156±7.2	162±5.6
	3	184±6.5	184±9.6	168±10.2	189±7.4
Sow backfat at weaning, mm	1	19.8±1.22	27.4±1.78	15.1±1.82	24.2±1.61
	2	15.2±1.19	13.4±1.76	19.5±1.75	17.7±1.35
	3	13.3±1.34	14.9±1.97	8.6±2.09	15.1±1.52

[a]Data are least squares means + or - standard errors.

VITA

Gregory L. Bilbrey was born in Jamestown, Tennessee. He graduated from the Alvin C. York Agricultural Institute in June of 1979 and enrolled in the College of Agriculture at Tennessee Technological University in the Fall of that year.

After graduating from Tennessee Tech he was employed by Tennessee Farmers Cooperative (T.F.C.). During his four years with T.F.C., he served as a management trainee, assistant store manager, branch store manager and outside salesman. In August of 1988 he was awarded a Graduate Teaching Assistantship in the Department of Animal Science at the University of Tennessee, Knoxville. While serving in that capacity he assisted in the teaching of livestock management, nutrition, ration formulation and breeding and genetics courses.

In April of 1990 he received the 1990 Exemplary Graduate Student Award from the Department of Animal Science and the Animal Science Graduate Student Association. He served as president of that organization during the 1989-1990 school year.

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