FIRST PARITY PRODUCTIVITY OF SELECTED COMMERCIAL SOWS

by

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ABSTRACT

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This study analysed first parity productivity records over a determined time period of three years from two selected commercial pig production units on the Highveld, and determined whether seasonal differences in productivity occur in relation to seasonal temperature fluctuations, and whether there is a difference in seasonal productivity between farms. The total pool of records used in various models corresponded to first parity breeding records from two farms for 2600 sows born between 1 March 2004 and 28 February 2007. Parameters of performance taken from the records included 1) Date of birth (DoB), 2) Year of Birth (YoB) of gilt, 3) Season of Birth (SB) of gilt, 4) Age at first service (AFS), 5) Season of First Service (SS), 6) Year of First Service (YoS), 7) Number of Services (NoS), 8) Farrowing date (FD), 9) Year of Farrowing (YoF), 10) Season of Farrowing (SF), 11) Total number of piglets born (TB), 12) Number of piglets born alive (BA), 13) Number of stillborn piglets (BD), 14) Number of mummified piglets (GA), 15) Weaning date (WD), 16) Backfat thickness (BF) of the gilts at farrowing (BFF), 17) BF at weaning (BFW) and 18) Weaning to service interval (WSI). The gilts from both farms were of the same synthetic genetic line and originated from one of three Farms of Birth (FoB). Daily maximum and minimum outdoor temperature data for the period between 1 January 2005 and 31 December 2007 were obtained from the South African Weather Service for the areas in which the production farms are situated. There were seasonal differences in productivity between years, within years and between farms but were not necessarily directly linked to the seasonal temperature fluctuations in all cases. The FoB influenced AFS significantly ($P<0.0001$). For farms pooled there was no seasonal difference in AFS between gilts born in summer and gilts born in autumn, winter and spring. However, gilts born in autumn were younger at AFS than gilts born in winter ($P < 0.0001$) and spring ($P=0.0008$), but differences in AFS of gilts born in winter and spring were not significant. There was no difference in TB or BA from sows receiving either one or two services before successful conception. There was no seasonal difference of TB or BA between gilts first served in summer, autumn, winter or spring. There were, however, fewer TB from gilts served during 2006 than from gilts served during either 2005 (P=0.0007) or 2007 (P=0.0002) but differences in TB from gilts served during 2005 and 2007 were NS. There was no difference in BA between years. For farms pooled, there was no seasonal difference in WSI between gilts farrowed in summer, autumn, winter or spring. There was a tendency for the sows to return to service during the summer months more than in any other season. There was a seasonal difference in number of piglets born per litter between farms between years.

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CHAPTER 1

INTRODUCTION AND OBJECTIVE

1.1 Background

Whittemore (2006) stated that the modern pig industry bears little or no resemblence to that of only a few decades ago; either in its structure or in its method of trading, or in its definition of quality in the end-product, or in its breeding, feeding, housing, health and management. Economically it is favourable to select gilts with high ovulation rate (OR), high milk production potential and a tendency toward high feed intake since this will enable production of large litters, weaning of heavy litters and a short recovery, or weaning to oestrus, period for the sow.

The modern pig has been subjected to intense selection pressure for improved lean growth rate (Cosgrove & Foxcroft, 1996). This is not only because consumer preference has shifted away from meat with high fat content toward lean meat as a result of an increased awareness of the risk of health problems linked to a fast-paced lifestyle. Another reason for this selection pressure is that biological response is interpreted in terms of both physical and financial outcomes (Whittemore, 2006). This high growth potential presents a challenge to the pig producer. Piglets with high growth potential have great nutrient requirements for expression of that potential and this puts pressure on the sow to produce enough milk to support the early growth of the litter. Evans and O'Doherty (2001) proposed that to most efficiently meet consumer demands, future selection of pig genotypes should concentrate on daily feed intake, high lean growth rate while also considering the minimum level of fatness required to avoid retardation of attainment of puberty.

The onset of lactation shifts the prioritisation of nutrient utilization of the sow toward the mammary gland delaying further reproduction (Butler, 2005); the frequency of suckling, which determines milk production of the sow, is dependent on the nutrient requirements of the piglets for growth and the level of decrease of backfat (BF) is related to litter size (Maes, Janssens, Delputte, Lammertyn & de Kruif, 2004).

Stress can influence reproduction and is defined as any environmental alteration severe enough to cause a change in behaviour or physiology of the animal in response to it (Bearden, Fuquay & Willard, 2004). Stress can also be defined as a biological response elicited when an individual perceives a threat to its homeostasis and response to such stressors requires a progression of events, starting from sensory perception signalling the presence of such a threat to activation of the neurophysiologic mechanisms to resist and prevent major damage (von Borell, Dobson & Prunier, 2007). Some stressors can exert a positive influence on reproduction, such as with mixing stress inducing synchronised puberty in gilts (Arey & Edwards, 1998). The stress discussed here will encompass heat stress, nutritional stress and social stress in relation to their eliciting a physiological response and thereby depressing reproduction, with a possibility of this manifesting as seasonal infertility.

Sow productivity is measured by number of pigs born alive (BA), number of pigs weaned per sow per year, litter weight at weaning and weaning to service interval (WSI). Other factors that must be taken into account when evaluating sow breeding records are season, parity, length of lactation, genotype, boar age and genotype, breeding protocol used, that is AI versus natural mating or a combination of the two, and the use of skip-a-heat breeding of gilts, housing type, grouping and feeding strategies.

1.2 Objective

The objective of this study was to analyse first parity productivity records over a determined time period of three years from two selected commercial pig production units on the Highveld, one situated in the Cullinan area of Gauteng Province and the other situated near Bela Bela in Limpopo Province, and to determine whether seasonal differences in productivity occur in relation to seasonal temperature fluctuations, and whether there is a difference in seasonal productivity between farms.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

The primary purpose of a sow herd is the production of suckling pigs in an economical way (Kemm, 1993). The use of AI has allowed the focus of the breeding herd to be directed toward the female breeding stock and has reduced the overall cost of maintenance requirements of the breeding herd. This is true as long as the sow herd delivers enough saleable product to cover the costs of breeding and feeding during gestation and lactation.

One must bear in mind that many of the factors playing a decisive role in sow productivity are affected by management aspects such as housing, environment, diseases and behaviour more than quality and quantity of feed supplied alone (Kemm, 1993). According to Bearden *et al.* (2004), management of the breeding herd to maintain optimum production includes feeding a diet sufficient to meet the requirements of the animal as established by the National Research Council (NRC), managing the health of the animal as well as applying good oestrus detection techniques to ensure correct time of breeding. An insemination protocol that consistently introduces a sufficient number of viable spermatozoa into the uterus of each sow in oestrus, within 24 hours prior to ovulation, should optimise the reproductive performance of those sows (Belstra, Flowers & See, 2004).

Pork production starts with selection of parent lines that will produce offspring with desirable feed conversion rates and carcass traits. Nelson, Mabry, Benyshek and Marks (1990) showed that selection for low backfat thickness in cycling females decreased fat and increased the amount of lean deposited by the offspring of the selected sows. Selection pressure on carcass traits has produced a modern pig that is more sensitive to nutritional mismanagement than genotypes used previously because of the inherent lower appetite and low energy reserves at the beginning of the productive life (Kummer, Bernardi, Wentz & Bortolozzo, 2006).

2.2 Stress susceptibility

A single point mutation in the skeletal muscle ryanodine receptor (RYR1) was found to be correlated with malignant hyperthermia (MH) (Fujii, Otsu, Zorzato, De Leon, Khanna, Weiler, O`Brien, & MacLennan, 1991) which induces an acceleration of the postmortem fall in muscle pH. This feature results in an increased incidence of pale, soft, exudative (PSE) meat in animals carrying the mutant allele. PSE pork is associated with an animal highly susceptible to stress. The affected pigs are likely to die during periods of natural stress as would occur during fighting, mating and transport (Heinze &

Snyman, 1993). There are several quantitative trait loci (QTL) located near the genomic region of RYR1, which are involved in protein and lipid deposition. As a consequence, pigs carrying the RYR1 allele associated with MH showed extreme lean carcasses (Roehe, Plastow & Knap, 2003). The implications of such stress susceptibility on reproduction are of importance. Porcine stress syndrome (PSS) positive, also known as halothane positive (HP, nn) and PSS negative carrier (Nn) sires have been used to produce leaner market pigs (Stalder, Christian, Rothschild & Lin, 1997). Although most of the commercial pig herds are free of the mutant allele, PSE carcasses are on occasion still found in some batches. The reasons for this are varied and numerous and will not be discussed here.

Previous studies reported that HP sows produced litters with poorer birth and 21-day-weaning weights despite having BA and number of piglets weaned per litter similar to that of halothane negative (HN) females (Stalder *et al*., 1997). It was also reported that the litter weight and survival rate of piglets within the first three days postpartum tended to favour HN carrier females (Nn) over HN normal (NN) females, but that by 21 days NN females weaned more piglets per litter at heavier litter weight than Nn females (Stalder *et al*., 1997). As the differences in maternal performance between NN and Nn Landrace females reported by Stalder *et al.* (1997) were not significantly different, commercial producers are advised to use factors other than maternal performance when considering the use of animals with the PSS gene in the breeding herd. Adverse effects of stress have been identified at all levels in the hypothalamo-pituitary-ovarian axis, resulting in inhibition of gonadotrophin releasing hormone (GnRH) secretion by the hypothalamus as well as suppressed pituitary responsiveness to GnRH and as a result reduced luteinizing hormone (LH) release (Arey & Edwards, 1998).

2.3 Importance of LH in sow reproduction

In gilts, LH is the hormone important for determining age of puberty through controlling ovarian development (Evans & O'Doherty, 2001). Ovulation in the sow occurs in midoestrus following a pre-ovulatory LH surge by 40 to 45 hours and oestrus lasts 48 to72 hours (Bearden *et al*., 2004). This pulsatile LH secretion is inhibited by feed restriction or suckling stimulus (Butler, 2005). Neuropeptide Y (NPY) together with other neuropeptides from intra- and extra-hypothalamic origin, allows the animal to integrate information of internal (age, metabolic and health status) and external (ambient temperature, light, nutrient supply, social environment) origin to regulate the secrection of LH by acting on GnRH neurons (Prunier & Quesnel, 2000).

In the female pig, LH is an essential component of maintenance of the corpora lutea (CL) and consequently early pregnancy, therefore any factor affecting LH secretion will influence embryonic survival and maintenance of early pregnancy (Peltoniemi, Tast & Love, 2000). The implantation phase is known to be a particularly stress-sensitive stage in pig reproduction and hormonal perturbation can increase embryo mortality and so reduce conception rate and litter size (Arey & Edwards, 1998). Maintenance of pregnancy is important because return to oestrus results in an increase in non-productive days of the sow, which is costly in terms of feed and cost of repeated artificial insemination (AI) without a saleable product to cover the expenses. Problems with repeat breeding may result in a need for a large pool of replacement gilts to be maintained, which is costly.

2.4 The physiological satiety mechanism

Satiety signals primarily regulate how much energy is consumed during a specific meal, whereas adiposity signals are more directly related to how much fat the body carries and maintains (Woods, 2005). Specific areas of the hypothalamus namely the arcuate nucleus (ARC), the ventromedial hypothalamus and the lateral hypothalamus, regulate feeding and satiety (Hossner, 2005).

The adiposity signals, insulin and leptin, provide a background tone in the hypothalamus because both hormones are transported through the blood-brain barrier to gain access to the neurons in the hypothalamus and so determine the sensitivity of an animal to the satiety signals which influence how much feed is consumed at any one time (Woods, 2005).

Trials done using rats have demonstrated the possible physiological mechanism of satiety to be such that hypothalamic signals that are responsive to changes in energy homeostasis regulate the effect of peripheral satiating hormones (satiety signals) like cholecystokinin (CCK) through interconnected pathways (Osto, Wielinga, Alder, Walser & Lutz, 2007). Inputs into the central nervous system (CNS) may be neural, nutrient-mediated or hormonal and the regulation of appetite and thus energy homeostasis can be acute or chronic (Hossner, 2005). NPY is a key regulator for increased intake and its effects are known to be inhibited by leptin (Roehe *et al.*, 2003).

Leptin expression up-regulation by insulin was demonstrated in experiments on rodents; and experiments using tissue culture have shown this up-regulation to occur in pigs in a similar way as in rodents (Barb, Hausman & Houseknecht, 2001). Insulin and leptin are both anorectic hormones, decreasing feed intake by increasing the hindbrain response to the satiating signal CCK; and leptin also seems to enhance satiation response to CCK by acting directly on the same vagal afferent neurons (Osto *et al.*, 2007).

Down-regulation of porcine leptin mRNA in subcutaneous adipose tissue, induced by fasting, was shown to be associated with an increase in nonesterified fatty acid (NEFA) concentrations and decreased plasma insulin concentrations (Barb *et al.*, 2001). Insulin, like leptin, exerts a catabolic action by stimulating the hypothalamic melanocortin system along with amylin (Osto *et al.*, 2007).

Amylin is co-secreted with insulin by the pancreas and is mediated by the same signalling pathway as leptin suggesting that it, together with insulin, may functionally interact in regulating feed intake (Osto *et al.*, 2007).

2.5 Adipose tissue

Most of the body fat (adipose lipid) reserves develop postnatally and the content of fat reserves of most farm animals at birth is about one to four percent fat, which can increase to 40% of body weight at maturity (Hossner, 2005).

Adipose tissue has the function of an energy reservoir and is involved in storage and release of energy by sequestering and mobilizing triacylglycerols (Hossner, 2005). Fully differentiated adipocytes, once filled with lipid droplets, are capable of expressing enzymes that catalyze lipogenesis, namely fatty acid synthase, pyruvate carboxylase and acetyl-CoA carboxylase (Hossner, 2005). Mobilisation of fat stores occurs when dietary energy intake is reduced or when the animal is subjected to stress (Hossner, 2005).

Changes in nutritional status are characterised by alterations in serum levels of hormones and growth factors such as insulin, glucocorticoids, growth hormone (GH) and insulin-like growth factor I (IGF-I) that regulate adipocyte development (Barb *et al.*, 2001). The primary hormonal inducers of lipolysis in mammals are the catecholamines, epinephrine and norepinephrine (Hossner, 2005).

Adipose tissue is no longer viewed exclusively as an energy reservoir but is now recognised to be an endocrine organ (Ahima & Flier, 2000), which produces the prostaglandins prostacyclin and $PGF_{2\alpha}$ (Hossner, 2005). The endocrine role of adipose tissue is best characterised by leptin (Ahima & Flier, 2000). Adipose tissue in the adult animal is highly vascularised (Hossner, 2005) and leptin provides the link between adipose tissue stores and the brain centres which regulate food intake and energy homeostasis and so plays a role in the regulation of whole-body energy homeostasis as well as reproduction (Vernon & Houseknecht, 2000). Leptin levels are proportional to body fat, so it was hypothesised that leptin may act as the signal to the reproductive system indicating if sufficient body fat exists to support successful conception and pregnancy (Hossner, 2005).

2.5.1 Leptin

Leptin is a protein hormone synthesised and secreted by adipose tissue (Spicer, 2001) and was first identified as the gene product found to be deficient in the obese (*ob/ob*) mouse (Barb & Kraeling, 2004).

Leptin modulates fat reserves and reproductive function through one of two mechanisms; one where the fall in leptin levels associated with insufficient body reserves inhibits reproduction or the other, where the level of leptin above some threshold value impairs ovarian steroidogenesis thereby inhibiting reproduction (Cardinali, Dal Bosco, Bonanno, Di Grigoli, Rebollar, Lorenzo & Castellini, 2008). Its weight reducing effect was demonstrated by the normalisation of the obese, diabetic state in *ob/ob* mice (Zieba, Amstalden & Williams, 2005). It is recognised as an adiposity signal which provides an ongoing message to the brain proportional to total body fat (Woods, 2005).

Leptin receptors have been found in the gonads (ovary and testes), anterior pituitary and hypothalamus indicating that reproductive functions can in this way be regulated by leptin (Spicer, 2001). Receptors localised in the brain and pituitary of the pig suggest that leptin has a profound influence on regulation of the neuroendocrine axis and appetite regulation (Barb *et al.*, 2001), as well as directly affecting LH secretion from the pituitary gland independent of CNS input (Barb, Hausman & Czaja, 2005). Receptors have also been found in the porcine CL (Spicer, 2001).

NPY has been proposed as the primary mediator of leptin action in the hypothalamus to regulate LH and GH secretion (Barb & Kraeling, 2004). Reduction in feed intake and energy expenditure regulation is mediated by leptin through inhibition of NPY neurons in the ARC of the hypothalamus (Osto *et al.*, 2007).

Although many candidate genes associated with growth and obesity in pigs have been identified, those contributing most to increasing the knowledge of control of feed intake and regulation of energy balance are the candidate genes for leptin on porcine chromosome (SSC) 18 at location q31-q21; genes for the leptin receptor, mapped to SSC 6q3.3-q3.5 and genes for NPY mapped to SSC 18q24 (Roehe *et al.*, 2003). There is emerging evidence that leptin may affect the hypothalamo-pituitary-gonadal axis (Spicer, 2001). Much of the literature available on the subject of physiological mechanisms of leptin reports data collected from experiments using sheep and rodents. Experiments generating results directly applicable to pigs used porcine cell cultures and to date no studies of leptin function in pigs have been done *in vivo*. It has been shown that results inferred from rodent data can be extrapolated so that the underlying principles can be applied in making assumptions about physiological mechanisms in the pig.

There are commercial multi-species leptin radioimmunoassay (RIA) kits available where the antibody used was raised against human leptin and the specificity for porcine leptin is over 60%. The feasibility of testing leptin concentrations in blood samples of a pig in production, however, is questionable because of the challenges encountered. The collection and laboratory analysis of blood samples is costly and labour intensive.

2.5.2 Reproductive efficiency and body condition

The link between body condition and reproductive performance has long been recognised although only recently, with the discovery of adipose tissue as an endocrine organ and the isolation of leptin as an adiposity indicator, have the underlying mechanisms of this link started to become clearer**.**

Neither BF of the gilt at entry into the gilt pool nor BF gained within the gilt pool was found to be correlated with age at first service (AFS) (Tummaruk, Tantasuparuk, Techakumphu & Kunavongkrit, 2009). The body condition of the gilt and sow, however, determines the ability to conceive and to support susequent lactation, so evaluation of body condition of breeding females is of considerable importance, especially in the modern breeding herd, because of economic pressure to achieve optimal production targets (Maes *et al*., 2004).

Understanding the link between adiposity and ovualtion rate has the potential to fine-tune the overall management of the female animals, allowing for adequate supply of milk during lactation and weaning of heavy litters. It could also aid in creating better feeding plans; using feed that is formulated to meet the energy and protein requirements of the primiparous and multiparous sow at each stage of production, with satiety levels in mind, to prevent underfeeding, feed wastage and potential problems with maintanence of pregnancy, farrowing and lactation within the most sensitive groups.

Further understanding the satiety mechanism and its link to adiposity will become increasingly important as lines are developed for rapid growth and low satiety levels to sustain this rapid growth, increasing the risk of inducing nutritional stress on the gestating and lactating females of such lines.

It is important to ensure gilts reach an optimum weight and body condition at first breeding to prevent reproductive failure at first breeding. Management of the gilt during gestation and lactation to prevent excess BF loss is important as this is the group most sensitive to reproductive failure after parity. Reproduction in gilts is mostly compromised due to conflicting nutrient partitioning, namely the gilt is required to grow while simultaneously supporting a pregnancy and subsequent lactation (Whittemore, 1996). Lower production levels, as influenced by a greater sensitivity to lactation weight loss, implies a need for a higher level of management of primiparous sows, in order to achieve higher production levels (Thaker & Bilkei, 2005). As many as one third of the all removals observed in a study by Lucia, Dial and Marsh (2000) was culling due to reproductive failure at lower parities and it was stated that decreasing the number of females removed from the herd for reproductive failure has the potential to increase lifetime reproductive efficiency.

Reducing lactation condition loss is important in decreasing the replacement rate of the sow herd because failure to return to oestrus, especially in primiparous sows, is the main reason for culling sows from the breeding herd (Stalder, Saxton, Conatser & Serenius, 2005) and negative energy balance inhibits ovulation in high producing sows (Butler, 2005). It was found by Schenkel, Bernardi, Bortolozzo and Wentz (2010) that by achieving adequate body condition at parturition and adequate feed intake during lactation sows will have adequate body reserves at weaning and minimised body condition losses during lactation.

The body condition scoring (BCS) method used on sows combines visual appraisal with estimation of BF depth and there is an optimum BCS for different stages of the production cycle (Cardinali *et al.*, 2008). This optimum will differ depending on the genotype used for production. Although a visual scoring system is a subjective evaluation (Whittemore & Schofield, 2000) this is a helpful tool to manage body condition during lactation through adjustment of energy intake to prevent excessive lactation condition loss. P2 BF thickness, measured 6.5 cm from the midline at the last rib, is an objective measure of body condition that is associated with reproductive efficiency and can be manipulated through nutrition (Maes *et al.*, 2004).

2.6 Importance of nutrition management during the sow cycle

The control of feed intake, the subsequent utilization of nutrients and the ultimate production of a desireable meat product are linked (Hossner, 2005). Feed efficiency has been focused on mainly in the context of growing pig production because feed costs make up the greatest operating expense and market value of the product is determined by carcass composition. This feed efficiency and efficient growth start with selection of the correct male and female lines to acquire an animal with the genetic potential to produce the desired carcass composition economically. In the context of productivity of primiparous and multiparous sows, correct nutritional management is important in promoting the production of piglets of a good weaning weight and for shortening the WSI for the production of more litters per year at minimal feed costs.

Increased lean growth and decreased body fat content is the result of the improved genotype of modern sows and this decrease in body fat has contributed toward gilts being less able to deal with the simultaneous demands of growth, maintaining preganancy and the subsequent lactation (Evans & O'Doherty, 2001). Nutrition during gestation and lactation is thought to have an effect on the WSI (Butler, 2005) through its influence on adiposity. Increased energy requirements of lactation in mammals are mostly met by increased feed intake but when this becomes inadequate to meet the energy demands, adipose tissue lipid deposited during early pregnancy is used to supplement this deficit (Vernon & Houseknecht, 2000).

In every animal production system, reproductive processes are ultimately determined by nutrient availability to adequately meet the requirements of the animal for all reproductive processes from gametogenesis through lactation (Cosgrove & Foxcroft, 1996). It has also been shown that body condition, live weight and fatness seem to influence reproductive performance of primiparous and multiparous sows (Everts & Dekker, 1995). Adequate energy stores are required for efficient reproduction, to support growth and development of the embryo and foetus, parturition and lactation (Hossner, 2005).

High voluntary feed intake during lactation is important for sustaining milk production and provides the basis for rapid return to oestrus after weaning (Butler, 2005). Feed intake during gestation influences feed intake during lactation through body fatness at parturition (Whittemore, 1996). The capacity of the gastro-intestinal tract is often a major limiting factor for lactational feed intake and is usually compensated for by feeding high caloric feedstuffs (van den Brand, Schouten & Kemp, 2004). The BF thickness of the primiparous or multiparous sow at weaning influences the future reproductive efficiency of that sow (Maes *et al.*, 2004).

2.6.1 Nutrition and gestation

Feed deprivation in early gestation is associated with changes in reproductive and metabolic hormones that might lead to changes in the oviductal environment, resulting in the presence of fewer viable spermatozoa in the reservoir and a lower cleavage rate of the embryos (Mburu, Einarsson, Kindahl, Madej & Rodriguez-Martinez, 1998).

The restricted level of feeding during gestation ensures that the gilt or sow will retain appetite in order for feed intake to be able to satisfy nutrient requirements during lactation. Gilts and sows fed to appetite during gestation consume more energy than is required for the maintenance and development of the foetuses and the foetal membranes, resulting in excessive weight gain from fat and protein deposition during this period (NRC, 1998). Females fed *ad libitum* during gestation have lower feed intakes during lactation, leading to greater weight losses during this period than those limit-fed during gestation and fed *ad libitum* during lactation (Cole, 1982). In late gestation the aim of nutrition is to allow for adequate increase in birth weight of the piglets. Increasing the nutrient supply of the gilt is recommended especially where pre-weaning mortality is a problem, because each foetus will gain approximately 40% of its final weight during the last 21 days of gestation and gilt feeding will need to respond to the requirements of the rapidly developing foetuses during late gestation (SPESFEED, 2006).

2.6.2 Nutrition and lactation

The length of lactation is at the control of the manager (Green, Wellock & Whittemore, 2006). Selection for leaner animals has caused a decrease in adiposity and voluntary feed intake of the female, which results in higher energy requirements during lactation and an inadequate intake to meet them (Eissen, Kanis & Kemp, 2000). Animals do not thrive without adequate feed intake, and those that do not efficiently utilise feed intake are not economically competitive (Hossner, 2005). This presents the challenge of production of a product that is satisfactory to the consumer for the most economical input of feed and other resources.

During lactation, it seems there are critical levels for both energy and protein below which WSI, rate of return to oestrus and pregnancy rate are affected especially in primiparous sows, which increases the number of replacement gilts required while decreasing the productivity per present sow (Dourmad, Etienne, Prunier & Noblet, 1994). Insufficient feed intake, leading to increased catabolism during the last week of lactation in the primiparous sow, has been shown to jeopardise embryo survival and development to day 30 of gestation in the subsequent litter owing to the decrease in the number and maturity of oocytes present at the time of weaning (Foxcroft, Vinsky, Paradis, Tse, Town, Putman, Dyck & Dixon, 2007). It was found that sows with low feed intake had high feed motivation (low satiety) and spent more time standing than lying down, with the result that piglets suckled by such a sow would spend more time nursing, not because of high milk production, but because of a high feed motivation due to lower milk production of their dam (van den Brand *et al.*, 2004).

It is important to supply essential amino acids in the diet (Boland, Lonergan & O'Callaghan, 2001) since pigs cannot synthesise these. Lysine is considered the first limiting amino acid in typical corn-soybean meal gestation and lactation diets and thus daily lysine intake is a primary determinant of sow performance (Yang, Heo, Jin, Yun, Choi, Yoon, Park, Yang & Chae, 2009). Cole (1982) stated that the level of feed intake during lactation may depend on protein nutrition during gestation. Feeding practices vary slightly for gilts and sows, but the levels of feeding for both vary according to the state of production the animal is in because the requirements for protein and energy change in response to the change in physiological status and level of production of the animal (Boland *et al.*, 2001). Yang *et al.* (2009) found that primiparous sows seemed to be more sensitive to lysine content of feed during gestation and lactation than multiparous sows and that the lysine requirements of the still-growing primiparous sows were greater than for multiparous sows during gestation.

Satiety maintains the energy balance of the animal ensuring metabolic homeostasis; and the regulation of appetite and food intake is ultimately regulated by the CNS, specifically the hypothalamus (Hossner, 2005). Energy homeostasis includes the regulation of nutrient levels in key storage organs, such as fat in adipose tissue and glycogen in the liver, as well as glucose in the blood (Woods, 2005).

2.7 Parameters of sow productivity

Reproductive performance is determined by various factors, namely age and size at puberty, OR, embryonic mortality, length of gestation, litter size and length of lactation anoestrus (Setchell, 1992); and the reproductive efficiency of the primiparous and multiparous sow is expressed in terms of farrowing rate, which is the number of litters produced per sow per annum. Reproductive efficiency is dependent on the proportion of gilts that reach puberty, have regular oestrous cycles and conceive at first breeding (Christenson & Ford, 1979). Reproductive performance is known to be affected by genotype, season, parity, lactation length and WSI (Belstra *et al.*, 2004).

Reproductive failure is the most common reason for culling sows from the herd (Stalder *et al.*, 2005) because sustaining high feed costs of maintaining non-productive animals is not financially sound. In addition to the maternal component of sow productivity, the quality and number of offspring born also has important economic consequences for efficient pork production (Foxcroft *et al.*, 2007).

2.7.1 Puberty

Puberty is defined as the age at the first expressed oestrus with ovulation and occurs when gonadotrophins, follicle stimulating hormone (FSH) and LH, are produced at levels high enough to inititiate follicle growth, oocyte maturation and ovulation (Bearden *et al.*, 2004).

Age at puberty is affected by environmental and genetic factors (Bearden *et al.*, 2004). Puberty in pigs usually occurs at 200 and 220 days of age but variation exists depending on internal (genetic) and management (environmental) factors (Evans & O'Doherty, 2001). Gilts born from primiparous sows were found to be slower growing, have thinner BF at 100kg body weight and were older at first mating than gilts born from multiparous sows (Tummaruk, Lundeheim, Einarsson & Dalin, 2000). Replacement gilts with high growth rates (GR) from birth to entry into the gilt pool and those with high GR from birth until entry into the breeding herd were reported to show signs of oestrus earlier than gilts with low GR (Tummaruk *et al.,* 2009). Ambient temperatures above 29 °C interfere with expression of behavioural oestrus, reduce feed intake and lower OR in cyclic gilts (Levis, 1997).

Nutritional management is the primary environmental factor determining the rate of growth of organs, bone, muscle, adipose tissue and total body lipid reserves and thus affects when sexual maturity is attained (Coetzee & Casey, 2009). It has been suggested that there is an advantage to promoting earlier onset of puberty in gilts because gilts selected for early puberty grow faster, have more BF and produce more litters per sow, as do their offspring, compared to those reaching puberty later (Nelson *et al.*, 1990). Earlier onset of puberty in gilts will in theory reduce the time and expense of feeding the animal before production of a saleable product (Nelson *et al.*, 1990). It has been shown that a minimum amount of body fat is required for onset of puberty and rapid return to oestrus after weaning (Barb *et al.*, 2005). Tummaruk *et al.* (2000) found that gilts with a thicker BF at 100kg body weight had younger AFS than gilts with less BF at the same weight. Coetzee and Casey (2009) found that puberty was reached within a close range of body fatness, even when growth had been restricted by nutritional influences and that genetic differences in mature size and growth rate resulted in very different chronological ages and liveweights at first ovulation between gilts of different genotypes. Similarly, Evans and O'Doherty (2001) stated that puberty only occurs when gilts reach a certain stage of physiological maturation, which is when the physiological development of the gilt is sufficiently able to support successful reproduction. The environmental and climatic conditions existing at the time when gilts approach sexual maturity have greater effects on AFS than the season in which gilts are born (Levis, 1997). This finding is supported by Christenson and Ford (1979) who found that gilts reaching puberty during winter and early spring were younger at first service than gilts reaching puberty during summer and early autumn.

2.7.2 Litter size

Litter size is a major component of sow productivity and it is a complex trait influenced by a paternal, maternal and foetal component (Hamann, Steinheuer & Distl, 2004). BA is a better indication of productivity than total number of piglets born (TB), because litter size is influenced by many factors from conception through the first hours after birth. The number of piglets weaned per sow is a function of OR of the sow, early embryonic survival, foetal survival during gestation and the perinatal period and finally pre-weaning survival of piglets (Lund, Puonti, Rydhmer & Jensen, 2002). Litter size, both BA and TB, may be influenced by genotype (Belstra *et al.*, 2004), as different breeds have different litter size potential and mothering abilities.

When gilts are bred at puberty rather than at second oestrus there is a reduction in litter size at first parity (Levis, 1997). Cunningham, England, Young and Zimmerman (1979) found that direct selection for OR would be expected to have little genetic effect on litter productivity and suggested that this was the result of a decrease in fertilization rate or embryonic survival with selection for increased OR. The increase in number of ovulations was found to be less important than increased embryo survival in producing increased number of embryos at day 30 of gestation (Foxcroft *et al.*, 2007). Milligan, Fraser and Kramer (2002) found that selection for increased litter size only had benefits when measures were undertaken to improve survival of the low-birth-weight piglets because an increase in TB is negatively correlated to birth weight of piglets. Sows producing more BA did not wean a significantly greater number of piglets than sows producing fewer piglets with heavier birth weights, due to lower survival percentages of the lighter birth weight piglets (Milligan *et al.*, 2002). Economically, an increase in litter size is only of interest if it increases the number of piglets weaned (van Rens, de Koning, Bergsma & van der Lende, 2005).

2.7.2.1 Pregnancy recognition

The theory on the mechanism of pregnancy recognition is that $PGF_{2\alpha}$ is secreted into the uterine lumen in the pregnant pig where it is sequestered to exert its biological effects to prevent luteolysis, whereas in the cyclic pig $PGF_{2\alpha}$ has a luteolytic effect when transported via the uterine vasculature to the CL (Bazer, Ott & Spencer, 1998). A minimum of four blastocysts must be present in the uterus on days 14 and 15 for successful pregnancy recognition (Bearden *et al.*, 2004). This is a function of both boar and sow fertility. Maximal reproductive performance is dependent on the total period during which capacitated spermatazoa are available in the correct concentrations at the ampullary-isthmic junction for fertilization of ova shed during ovulation (Vesseur, Kemp & den Hartog, 1996). It was found in an experiment by Stone (1982) that there is a critical value of spermatozoa concentration that enables fertilization to occur. Optimal time between first and follow-up insemination is dependent on the fertility of the boar, number of viable spermatazoa per dose, the quality of the processing and of the diluent used and on transport and storage of semen prior to insemination (Vesseur *et al.,* 1996). This indicates that maintenance of pregnancy, and litter size are not exclusively related to the OR of the sow, as it was previously thought.

2.7.2.2 Mortalities

Edwards (2002) suggests that a piglet mortality of 10-20% can be considered normal for the reproductive biology of the pig and that it is for this reason that attempts to reduce the mortality rate under domestic conditions have shown limited success. The incidence of pre-weaning mortality represents a significant source of economic loss to the pig industry (Lay, 2002). Leenhouwers, van der Lende and Knol (1999) reported a pre-weaning mortality of 11.1%, which was consistent with the National Animal Health Monitoring System value of 11% from data of 2000 reported by Lay (2002). It is, however, important to investigate the cause of piglet deaths, whether death occured prepartum, peripartum or postpartum, to determine whether it is due to disease in the sow, prolonged parturition and sow fatigue or crushing. The effect of chromosomal aberrations is not always obvious because it usually causes early embryonic death.

Piglet survival is the result of a complex interaction between the sow, the piglet and the environment (Edwards, 2002) and most pre-weaning piglet losses are the result of non-infectious causes (Lay, 2002). Mummified piglets (GA) are the result of enteroviral or parvo virus infections in the sow (van Halderen, 1993). Herd health management is essential in preventing disease-related piglet losses.

Gestational factors such as uterine environment and placental transfer of nutrients may affect the inherent viability of the piglet (Edwards, 2002). The variation in number of embryos surviving to the post-implantation period will affect both placental and foetal development (Foxcroft *et al.*, 2007). There is a negative relationship between litter size and birth weight (Roehe, 1999). Stillbirths (BD) account for approximately 30-40% of total mortality and crushing is the major cause of death in live born piglets (Edwards, 2002). It was reported that stillbirth rate increased with increasing TB (Holyoake, Dial, Trigg & King, 1995). With increasing litter size there is an increase in parturition time and increased number of stillborn piglets because piglets are more likely to be subjected to hypoxia (Lay, 2002). Piglets born alive in a large litter were found to have lower chances of survival in the pre-weaning period than piglets born alive in smaller litters (van Rens *et al.*, 2005). Litters with high numbers of stillborn piglets also showed higher chance of pre-weaning mortality for the piglets BA (Leenhouwers *et al.*, 1999).

Van Rens *et al.* (2005) reported that piglets with a low birth weight had lower survivability than litter mates with greater birth weights. Lay (2002) reported that piglets with large birth weight had a greater chance of becoming hypoxic due to inceased parturition time. It was found that the average birth weight of stillborn piglets was lower than that of the live-born piglets (Leenhouwers *et al.*, 1999). In apparent contradiction to the statements of van Rens *et al.* (2005) and Lay (2002) it was found that selection for improved piglet survival would lead to slightly smaller piglets that have improved ability to cope with the changes associated with the transition from intrauterine to extrauterine life (Leenhouwers, Knol, de Groot, Vos & van der Lende, 2002). Thus it is perhaps not the piglet birth weight *per se* that influences survival of piglets but rather the within-litter variation of birth weight, because a large variation in birth weight within a litter will promote competition and allows heavier litter mates to out-compete weaker siblings (Lay, 2002).

Neonatal piglets have low liver and muscle glycogen reserves and thus have a limited ability to maintain glucose levels during and after farrowing, and an impaired ability to maintain body temperature in situations of delayed colostrum intake (Leenhouwers *et al.*, 2002). Maternal factors affecting the availability and quality of colostrum will prevent the piglet from receiving adequate nutrition and passive immunity in the first hours of life (Edwards, 2002) which impedes the survival of the immunologically naive neonate piglet (Lay, 2002). Genetic differences in sow milk composition have been reported, where breeds producing larger litters and thus smaller piglets, produce milk with a greater concentration of fat to enable the smaller piglets to be more resistant to hypothermia (Lay, 2002).

Half of all pre-weaning mortalities of live-born piglets occur within the first three days postpartum with the majority of these is attributed to trauma (crushing) or low viability (Holyoake *et al.*, 1995). The ability of the piglet to establish regular and adequate nutrient intake and maintain body temperature long enough to achieve positive energy balance relates to its birth weight, position in birth order, speed of first suckling and ability to resist hypothermia (Edwards, 2002). Provision of heat lamps in the farrowing pen encourage piglets to move away from the warmth of the dam and so prevent crushing, but this attraction to the heat lamp is not solidified until three days after birth (Lay, 2002). It was shown that piglet mortalities were lower when sows were supervised during farrowing and early perinatal periods compared to litters farrowed in the absence of supervision (Holyoake *et al.*, 1995).

Maternal behaviour can affect piglet survival. Piglet-directed aggression is more common in primiparous sows and although a relatively minor cause of mortality (Edwards, 2002) it can be prevented by supervision, where piglets at risk can be removed from the aggresive sow until they can be either reintroduced to the dam or cross-fostered to other sows. It has been shown that females who savaged piglets in the first parity were more likely to be aggressive toward piglets in the second parity (Lay, 2002).

2.7.3 Number of piglets weaned

The number of pigs weaned per sow per year is considered to be a good measurement of reproductive efficiency at herd level during a specific period, but gives information only on the annual production and not the long term production (Tantasuparuk, Lundeheim, Dalin, Kunavongkrit & Einarsson, 2001). High milk production of the sow provides a high level of weaned pig output for subsequent growth and meat output (Butler, 2005). Improvements in the number of piglets weaned per litter are largely a consequence of increasing TB to offset the high piglet mortality (Edwards, 2002). The maximum number of pigs produced per sow per year occurs when litters are weaned at 28 days of age and the sows are rebred within one week (Britt, Szarek & Levis, 1983). Improvements in number of piglets weaned per litter can be made by having sows and their litters supervised during farrowing and early perinatal periods, but the cost benefits of reducing pre-weaning mortality can only be realised when sufficient space exists in the nursery/grower/finisher facilities to accomodate the additional pigs weaned (Holyoake *et al.*, 1995).

2.7.4 Litter weight at weaning

Litter weight at weaning is considered to be a good measure of sow productivity because it is the result of prolificacy and maternal ability (Omtvedt, Whatley & Willham, 1966). The direct and maternal genetic correlations between birth and weaning weight are positive (Kaufmann, Hofer, Bidanel & Künzi, 2000). Weaning weight is a better predictor for weight at slaughter than birth weight (Wilcock, 2009) because individual piglet weaning weight is more a function of pre-weaning gain than a reflection of birth weight (Omtvedt *et al*., 1966).

The number of piglets in a litter influences the pre-weaning growth rate of the piglets (Omtvedt *et al*., 1966). Litter weight at weaning gives an indication of sow milk production only when, through cross-fostering, sufficient opportunity was given for piglets to suckle and good pre-weaning growth of the piglets is achieved without excess BF loss of the sow. An increase in litter weaning weight was associated with a decrease in sow gain during lactation (Omtvedt *et al.*, 1966). Weaning weight is important for post-weaning performance and attention must be given to the lactating sow to ensure that high weaning weight for age of piglets is achieved (Wilcock, 2009). Litter weight at 21 days postpartum is often taken as an indicator of sow milk production and piglet growth, because this is the time when the sow is at peak lactation. There are ways to curb inadequate milk supply through provision of creep feed to the piglets, but this presents an extra cost and it is more economical to ensure adequate milk supply in the first weeks after birth and wean piglets with enough energy reserve to withstand the stress of weaning. It was shown that not only did a 1kg improvement on weaning weight result in the improvement of average daily gain (ADG) but also resulted in heavier live weights attained at 20 weeks of age in the finishing unit (Wilcock, 2009).

2.7.5 Weaning to service interval

The appropriate synchrony of post-weaning oestrus, ovulation and development of new CL in sows together with the correct timing of AI will secure conception of a second parity litter (Madej, Lang, Brandt, Kindahl, Madsen & Einarsson, 2005). Ovulation without obvious standing reflex at first oestrus after weaning is common in primiparous sows (Sterning, 1995). The major factors extending the WSI beyond a minimum of 4 days are maternal body condition, as indicated by the extent of maternal body fat, and protein depletion (Green *et al.*, 2006) as well as season, parity, lactation length and litter size. Significant positive correlations between weight loss, litter size, litter weight gain and WSI were found by Sterning, Rydhmer, Eliasson, Einarsson and Anderson (1990).

The period from weaning to remating corresponds to the follicular phase of the oestrous cycle and so the response to feeding of the sow would be similar to that of the pre-pubertal gilt (Brooks & Cole, 1974). Sterning *et al.* (1990) found that the season in which the sow was weaned influenced the ability to show standing oestrus and ovulate within 10 days of weaning. Belstra *et al.* (2004) found that the number of weaned sows returning to oestrus within the expected time period was lower during summer. This delay in return to oestrus could be due to high daytime temperatures during summer months.

2.7.5.1 Weaning to service interval and parity

Primiparous sows usually have longer WSI than multiparous sows; and gilts that reach puberty late also tend to have longer WSI after the first litter (Tantasuparuk *et al.*, 2001). WSI decreases linearly with an increase in parity (Belstra *et al.*, 2004). Litter size was found to be reduced when primiparous sows had a WSI between 6-12 days (Poleze, Bernardi, Amaral Filha, Wentz & Bortolozzo, 2006).

The WSI of the primiparous sow could be used as a predictor of longevity and lifetime production (Tantasuparuk *et al.*, 2001) provided that management has been applied in such a way to optimise the expression of the potential of the gilt. The optimum WSI range was shown to be 3-5 days for both primiparous and mulitparous sows by Poleze *et al.* (2006).

2.7.5.2 Weaning to service interval and length of lactation

Lactation in the sow is demanding since all of the maternal dietary energy intake of the lactating sow may be required for milk synthesis and so the sow uses considerable body reserves to support the energy demands of lactation (Hartmann, Smith, Thompson, Wakeford & Arthur, 1997). Sows that nurse large litters tend to have longer WSI than those nursing smaller litters (Britt *et al.*, 1983) and this is most likely due to greater lactational condition loss in the sows with large litters, resulting from high milk production.

Strong suckling stimulus from a large litter suppresses gonadotrophin secretion in the lactating sow and effectively blocks ovarian function and oestrus until after weaning, at which time the suckling stimulus is removed and LH pulsatility is restored (Butler, 2005).

A decreased length of lactation should result in more pigs weaned per mated female per year because the period between weaning and re-mating, or WSI, is decreased, thus decreasing the farrowing interval (King, Koketsu, Reeves, Xue & Dial, 1998). WSI has an inverse relationship with duration of oestrus so that sows with a short lactation length will have a shorter duration of oestrus, which can impact insemination protocols (See, 2006). Weaning before 21 days postpartum does not offer great advantages because uterine involution is not yet complete at this stage, making conception and implantation less likely than at a later stage. Subsequent litter size is expected to be lower for sows with litters weaned at fewer than 18 days (See, 2006). A further advantage to weaning between 21 and 28 days is that piglets are more likely to be weaned at heavier weights than at 18 days (See, 2006).

Once the piglets have been weaned the sow should show oestrus (Butler, 2005) 5 to 6 days after weaning depending on the length of the preceding lactation (Brooks & Cole, 1974). WSI are shortest for sows weaned between 3 and 4 weeks (See, 2006) and weaning is optimal at 28 days postpartum because it makes planning and managing the weaning process more convenient.

2.8 Summer infertility syndrome

The effect of heat stress on reproductive efficiency of the pig herd is of great importance in South Africa, especially to those pig producers not making use of environmentally controlled housing. Summer infertility syndrome can result in high culling rates and thus high replacement costs.

It is proposed that the melatonin neuroendocrinological basis of seasonal reproduction in the pig does not differ from that of other seasonal breeders, but that the previous confusion was due to methodological problems (Peltoniemi *et al.*, 2000). Most bloodlines of domestic pig are descendents of the European wild pig, which usually produces only one litter per year (Kunavongkrit, Suriyasomboon, Lundeheim, Heard & Einarsson 2005). Hälli, Peltoniemi, Tast, Virolainen, Munsterhjelm, Varlos and Heinonen (2008) suggested that the impaired fertility of domestic pigs during the summer-autumn period is a vestige of seasonal breeding in the European wild boar.

Unlike sheep, which are short-day breeders, the breeding and non-breeding phases are not as clearly associated with different seasons in the domestic pig (Hälli *et al.*, 2008). Photoperiod can have an effect on fertility in Europe, as was found by Auvigne, Leneveu, Jehannin, Peltoniemi and Sallé (2010) in France, but can also have an effect in certain regions of South Africa where there is a large fluctuation in day length with changing seasons. The change in daylength rather than daytime light intensity is one reason for the occurrence of seasonal infertility (Tast, Love, Evans, Andersson, Peltoniemi & Kennaway, 2001). This effect is exerted through the hypothalamic-gonadal axis (Peltoniemi *et al.*, 2000) where melatonin secretion influences LH pulsatility. The photoperiod effect can be overcome by using closed house systems with artificial lighting. A study by Tast *et al.* (2001) showed that pigs are able to discern between day and night provided the difference in light intensity is 40lx and that extremely high light intensities (10000 lx) during the photophase provided no additional advantage over a comfortable light intensity of 200 lx when artificial lighting was used to counteract the effect of photoperiod on reproduction.

2.8.1 Summer infertility in the boar

In boars, summer infertility manifests as decreased semen volume, decreased sperm motility and increased abnormal sperm morphology (Kunavongkrit *et al.*, 2005). Decreased semen volume is not necessarily accompanied by decreased sperm concentration, but the quality is adversely affected by poor motility resulting from an increased incidence of spermatozoa with tail defects (Stone, 1982).

Sperm morphological defects are seen as sperm head abnormalities and presence of a proximal cytoplasmic droplet (Kunavongkrit *et al.*, 2005). The presence of a cytoplasmic droplet is the first indication that the animal is stressed and this is the last 'symptom' to disappear once the stressor is removed (Bearden *et al.*, 2004). Increased morphological aberrations are an indication of suboptimal environmental temperatures during spermatozoa production and development. Kunavongkrit *et al.* (2005) suggested that it is not heat per se that negatively affects fertility in boars, but rather great temperature fluctuations that may cause stress to the animal. The physiological response of the animal to stressors is the release of the glucocorticoid, cortisol, from the adrenal cortex in response to adrenocorticotrophin (ACTH) release from the anterior pituitary gland.

Hot weather and humidity could have a negative effect on boar reproductive efficiency due to depressed feed intake, which limits the quantity of protein available for spermatogenesis (Kunavongkrit *et al.*, 2005) and because spermatogenesis ceases when the internal temperature of the testes is elevated to normal body temperature (Bearden *et al.*, 2004). Increased ambient temperatures in the boar house beyond a critical temperature will compromise the heat regulating mechanisms of the animal to the extent that the scrotal surface temperature rises, adversely affecting spermatozoa production (Stone, 1982). Boars kept at ambient temperatures exceeding 32 ^{o}C for an extended period of time can become infertile for up to six weeks (Knoesen, 1993). High humidity levels in the houses can compound the effect of high temperatures by restricting the heat loss ability of the animal. When the animal is returned to a thermo-neutral zone, several weeks of decreased fertility follow the exposure to high temperatures because of the time required for spermatogenesis to be completed.

During spermatogenesis, FSH is required for the production of spermatozoa in the seminiferous tubules. The Sertoli cells are stimulated by FSH to produce androgen-binding protein, which is the carrier for testosterone once secreted into the lumen of the seminiferous tubules. The cells of Leydig in the interstitial tissue of the testes are stimulated by LH to produce androgens, mainly testosterone, providing a negative feedback mechanism to control GnRH secretion of the hypothalamus as well as FSH and LH release by the anterior pituitary gland. Testosterone has numerous functions, one of which is expression of male sexual behaviour or libido.

Glucocorticoids (cortisol) inhibit the pulsatile release of LH which can reduce libido in males (Bearden *et al*, 2004). Reduced libido could be a contributing factor to poor conception rate when natural mating is used on-farm.

2.8.2 Summer infertility in the sow

Peltoniemi *et al.* (2000) suggested that summer infertility in the sow is a manifestation of inadequate embryonic signal recognition by the dam resulting in an inability to maintain a pregnancy. This was termed seasonal disruption of pregnancy rather than seasonal infertility.

It has been shown in a study conducted in southern Brazil that the average rate of return to oestrus observed was higher between January through June, the data collection period, compared to that observed during July to December prior to the data collection period, and it was suggested that this was likely associated with seasonal infertility (Vargas, Bernadi, Bortolozzo, Mellagi & Wentz, 2009).

2.9 Heat stress

Heat stress is an environmental stressor that affects reproductive efficiency most dramatically of all the environmental stressors, resulting in anything from delayed puberty to seasonal infertility (Bearden *et al.*, 2004). Tummaruk, Tantasuparuk, Techakumphu and Kunavongkrit (2010) found in a study done in the tropical climate of Thailand that return to oestrus (repeat-breeders) was the most common cause for reproductive failure and was highest among gilts and primiparous sows compared to muliparous sows.

Heat-stressed female animals will likely secrete cortisol when heat regulation mechanisms become ineffective; glucocorticoids (cortisol) compromise normal LH pulsatility, which delays or prevents ovulation (Bearden *et al*, 2004). Any delay in production will affect profitability of a farm negatively, which emphasises the need to improve reproductive efficiency of the herd in any way possible. Heat stress has been shown to inhibit gonadotrophin secretion by way of exposure to high temperatures inhibiting hypothalamic GnRH secretion and possibly decreasing the reponsiveness of the pituitary gland to GnRH (Matteri, Carroll & Dyer, 2000).

A pig is an endotherm, like all mammals, able to regulate its core body temperature independent of environmental temperature. The heat production of a pig has a diurnal rhythm depending on the feed intake and activity level and is influenced by ambient temperature (Andersen, Jørgensen, Dybkjær & Jørgensen, 2008). Baldwin and Ingram (1968) stated that the thermoregulatory effects of changes in deep body temperature can be modified by the environmental temperature. The thermal equilibrium in the body is achieved through a balance between the metabolic heat production and heat loss from the body (Andersen *et al.*, 2008).

The pig has a sparse hair coat indicating that the skin plays an important role in thermoregulation mechanisms (Baldwin & Ingram, 1968) and it was assumed by Andersen *et al.* (2008) that pigs, like humans, felt thermally comfortable at a specific skin temperature. Unlike cattle, pigs do not sweat as a mechanism to increase heat loss when exposed to elevated environmental temperatures but rather resort to a change in lying behaviour and contact with pen mates (Andersen *et al.*, 2008) or to panting, in extreme cases, in an attempt to disperse excess heat. It is when this mechanism becomes ineffective that heat stress results.

It has been found that weaner pigs of modern genetic lines have a higher total heat production than those of traditional lines due to increased lean tissue deposition (Brown-Brandl, Eigenberg, Nienaber & Kachman, 2001) and it can thus be assumed that maternal lines of modern pigs will show a similar increase in total heat production. Gilts and sows mated in hot season in Thailand had the lowest farrowing proportion (FP) compared to gilts and sows mated in the rainy or cold seasons respectively, also on average gilts mated in the hot season had the lowest FP of all the female animals included in the study (Tummaruk *et al.*, 2010). This indicates that modern gilts are the most sensitive and modern sows are more sensitive to heat stress than previously.

2.10 Nutritional stress

Primiparous sows are especially vulnerable to the nutritional deficiency usually arising during lactation because they have larger body size and less body fat than pig genotypes used a decade ago (Yang *et al.*, 2009). The improvement of fertility and longevity in genetically lean young breeding sows can be achieved through use of nutritional strategies to increase body fat reserves (O'Dowd, Hoste, Mercer, Fowler & Edwards, 1997). Fertility is associated with successful feeding during lactation before mating as well as during early gestation (Virolainen, Peltoniemi, Munsterhjelm, Tast & Einarsson, 2005). It is important that the modern prolific sow consumes adequate amounts of nutrients for maintanence of a high level of weaned pig output over the reproductive life (Yang *et al.* 2009)

Nutritional stress is a serious challenge to homeostasis; as the release of glucocorticoids to restore disrupted homeostasis can affect reproductive processes by inhibiting gonadal steroid secretion and reducing the sensitivity of the target tissues to sex steroids (Matteri *et al.*, 2000). A stress response due to aspects of nutrition can be brought on directly as with mycotoxin contamination of the feed, or indirectly as indicated by changes in body condition of the animal. The latter may not necessarily be negative, provided it is not extreme.

In hot, wet months of the year there is a risk of mycotoxin contamination of the feed (Visser, 2005). Mycotoxins such as zearalenone, produced by *Fusarium*, have oestrogenic effects and have thus been associated with reproductive problems (Bearden *et al.*, 2004). Zearalenone has been known to cause vulvovaginitis and anoestrus and has also been found to interfere with the role of oxytocin in induction of parturition in gilts and sows (Morgavi & Riley, 2007). Pre-pubertal gilts and boars are the most susceptible animals to mycotoxicosis and in the latter group exposure to zearalenone can lead to a reduction in plasma testosterone and libido (Morgavi & Riley, 2007). Provision of fresh feed daily will prevent exposure to mycotoxins, and surplus feed must be stored in such a way to prevent contamination.

Based on previous research it has become generally accepted that high energy intake during early gestation is associated with increased embryo mortality and it was further found that this tended to be especially so in gilts (Varley & Prime, 1993). In sows it was found that high energy levels of feed during early gestation only negatively affected prolificacy when it followed a low energy level feed fed during the previous lactation (Varley & Prime, 1993). In contradiction to this finding it was suggested that restriction feeding of sows and gilts post-mating had a negative influence on the maintenance of pregnancy through insulin and glucose exerting an effect on LH pulse frequency (Peltoniemi *et al.*, 2000) through insulin and glucose providing metabolic signals to the brain about the metabolic state of the animal. Food deprivation during early gestation, specifically days 10 and 11 of gestation, was reported to result in increased plasma cortisol concentrations in gilts (Virolainen *et al.*, 2005).

The restriction-fed animal was thought to mimic the metabolic state of a starved animal, and LH pulsatiliy was reduced (Peltoniemi *et al.*, 2000). In the ‘starved’ metabolic state, glucocorticoids are secreted to increase the rate of gluconeogenesis by the liver and the rate of lipolysis from lipid tissue (Frandson, Wilke & Fails, 2003). It is likely that these glucocorticoids interfere with LH at the level of GnRH secretion from the hypothalamus. Changes in ovarian hormones as a result of starvation during early gestation have a profound negative effect on embryonic survival (Tsuma, Einarsson, Madej, Kindahl & Lundeheim, 1996). Consideration of this may be of importance where flush feeding is used.

It was inferred by Varley and Prime (1993) from results of another experiment, that changes in feeding level in sows could increase embryo mortality rate, thus there is a possibility that energy level per se has no direct effect on embryo mortality but rather it is changing body condition, as a result of changing energy level, that elicits a change in the hormonal balance of the animal. As Varley and

Prime (1993) suggest, this indicates body condition is an important link between nutrition and reproduction.

It was found that females at first parity (primiparous sows) were more likely to show reproductive failure especially in summer months and when only mated once, as a result of the less mature endocrine function and lower feed intake of the young animals compared with older sows (Takai & Koketsu, 2007). Feed intake was further depressed by high ambient temperatures (Takai & Koketsu, 2007).

Severe restriction of feed intake during lactation caused a marked reduction in litter growth during the fourth week of lactation, particularly in those sows with the least body reserves, but variation in body reserves at farrowing did not affect piglet growth when sows had a high feed intake during lactation (Hartmann *et al.*, 1997). When gilts were fed high energy, low protein diets during gestation mammogenesis was impaired, so it is undesirable to feed primiparous and multiparous sows a diet that restricts lean tissue growth during gestation (Hartmann *et al.*, 1997).

It was suggested to be beneficial to increase feeding beyond the recommended restriction feeding level to improve reproductive performance when seasonal infertility is expected to be a problem (Virolainen *et al.*, 2005) although the optimum allocation of feed per sow to prevent fighting caused by limited feed has yet to be established, since it differs depending on the breed, breed crosses and composite breeds used for production. Increasing the feed allocation for group housed sows is thought to somewhat counteract the depressed feed intake common in hot weather because there is more opportunity for the sows to have feed available for intake over a longer period of time without competition.

2.11 Social stress

It is common in most systems to regroup sows after weaning, causing the most intensive period of stressful confrontations to coincide with many important reproductive events, namely onset of standing oestrus, AI, ovulation and early embryo transport and development (Brandt, Einarsson, Ljung, Lundeheim, Rodríguez-Martínez & Madej, 2009). A shift toward group housing of sows in gestation to improve animal welfare has been shown to have advantages and disadvantages compared to the conventional individual or stall housing system (Karlen, Hemsworth, Gonyou, Fabrega, Strom & Smits, 2007). Pigs are social animals and social hierarchy or ‘pecking order’ plays a large role. Group housing has been used in conventional systems where non-lactating gilts and sows are grouped together for the duration of the production cycle (Hemsworth, Barnett, Hansen & Winfield, 1986).

Grouping of unfamiliar sows and gilts pre- and post-mating is a necessary procedure on many commercial farms (Barnett, Cronin, McCallum, Newman & Hennessy, 1996). It is important to detect as many primiparous sows showing standing reflex as possible after weaning, not only to prevent splitting established and stable sow groups, but also to promote efficiency of the batch-rearing system (Sterning, 1995). It was found that repeated regrouping of gilts in the short term had no effect on cortisol levels in the animals and did not result in depressed reproductive performance, whereas long-term regrouping proved stressful to the animals despite having encountered familiar pigs from previous regrouping (Soede, van Sleuwen, Molenaar, Rietveld, Schouten, Hazeleger & Kemp, 2006). In the absence of stable groups, where females remain together throughout gestation, it has been suggested that aggression linked to mixing affected recently introduced females that entered an existing social organisation and had to find their place in the group (Remience, Wavreille, Canart, Meunier-Salaün, Prunier, Bartiaux-Thill, Nicks & Vandenheede, 2008).

Evidence that suggests that the activation of the hypothalamic-pituitary-adrenal axis may impair normal gonadotrophin secretion, and consequently affect ovarian activity and related oestrus behaviour, was reported by Madej *et al.* (2005). Housing sows with low satiety levels in groups could pose some challenges for reproductive efficiency to be maintained especially when feeding is restricted, since the fighting during establishment of hierarchies causes stress in the short term and feeding restriction in the long term. This could potentially affect the occurrence or synchrony of hormonal events around the time of mating or in early pregnancy. This acute or chronic physiological stress response is likely to have a negative effect on reproduction (Barnett *et al*., 1996).

Although grouping is practical from a management perspective, the lower ranked sows within a group usually have the greatest number of returns to service owing to the high stress levels imposed by fighting early in gestation (Karlen *et al.*, 2007) and by possible underfeeding. The latter is a result of competition and the effects of which have been briefly discussed together with other nutritional stressors. Virolainen *et al.* (2005) also suggested it to be beneficial to increase feeding beyond the recommended restriction feeding level in group housed animals to reduce social stress at feeding. *Ad libitum* feeding for 48 hours after mixing was shown by Barnett, Cronin, McCallum and Newman (1994) to reduce aggression, which indicates that group stability may be affected by the degree of competition for resources (Arey & Edwards, 1998).

When individual housing was compared to group housing on deep litter for pigs in gestation it was found that there was an increase in culling due to locomotion (foot and leg) problems in stall-housed sows (Karlen *et al.*, 2007). This indicates a welfare problem for sows in confinement on solid floors in the last third of gestation and negatively affects herd reproductive efficiency due to high replacement rate.

Barnett, Hemsworth, Cronin, Newman and McCallum (1991) found that the design of cage stalls can affect the welfare of pigs. It was found that pigs in cage stalls with horizontal bars showed a chronic stress response whereas those housed in stalls with vertical bars showed more aggressive behaviour, with a cortisol concentration similar to that of group-housed pigs in the same study. With gilts reared in isolation from a boar, the effects of tethering and group housing on age at first ovulation and OR in the second oestrus were similar, although this was not the case when gilts were submitted to daily boar contact, where tethered gilts showed delayed first ovulation owing to restricted boar contact compared with group-penned animals (von Borell *et al.*, 2007). It is thus possible that group-penning of nulliparous sows (gilts) would promote earlier attainment of first ovulation, although the ideal AFS will differ slightly according to the breed used in production.

If group housing is used, it could be beneficial to provide partial feeding stalls to decrease fighting, since pigs fight more when feed restriction is practiced (Barnett *et al.*, 1996). Reduced fighting will reduce stress levels. It may be beneficial to group the repeat breeders of each group into a separate group, as these are usually the less dominant animals within a given group. Barnett *et al.* (1996) suggested that grouping of unfamiliar pigs after sunset decreased the acute stress response due to the animals settling down in a shorter time than pigs grouped during the day.

Overcrowding should be avoided at all cost in group housing systems. Wan, Hennessy and Cranwell (1994) found on one farm known to have a high occurrence of summer infertility that the increase of gilts in the mating shed to overcome the problem led to a higher incidence of depressed fertility because no space allowance was made for the extra animals. This overcrowding in conjunction with the heat stress of summer resulted in a chronic stress response manifesting as summer infertility. In a study by Hemsworth *et al.* (1986) gilts housed with a space allowance of 1m^2 per animal showed an increased plasma cortisol concentration and decreased oestrus detection compared with those housed with greater space allowances of 3m^2 per animal.

Sows housed in groups had a lower critical temperature (LCT) that was lower compared to those housed individually and were thus more tolerant to cold temperatures (Karlen *et al.*, 2007). Individually housed sows would thus be expected to have higher feed requirements than group housed sows and the inability to meet these requirements may exert nutritional stress on the animal. Tethered pigs showed an elevated total cortisol concentration compared with the group-housed pigs (Barnett *et al.*, 1991).

It has been suggested that pigs can be selected to be less responsive to stress i.e. stress resistant (Wan *et al.*, 1994). This is becoming increasingly important, as pigs bred to produce lean carcasses are those genotypes more susceptible to stress due to less selection pressure having been applied to social behaviour (van Putten, 1989).

2.12 Hypothesis

The null hypothesis of this study is that there are no seasonal differences in first parity productivity occuring in relation to seasonal temperature fluctuations and that there is no difference in seasonal productivity between production farms situated in different areas of the Highveld.

$$H_0: \bar{x}_1 = \bar{x}_2$$

$$H_A: \bar{x}_1 \neq \bar{x}_2$$

CHAPTER 3

MATERIALS AND METHODS

3.1 Farms

The herd records were obtained from two commercial units situated in different areas of the Highveld. Farm A was situated in the Cullinan area of Gauteng Province and Farm B was situated near Bela Bela in Limpopo Province. Both farms used naturally ventilated housing without cooling or heating systems. The roofs of the houses were insulated giving a measure of relief from the ambient temperatures, but the animals were still subjected to high summer temperatures. It was assumed that the peripheral management was basically the same on both herds.

All sows included in this evaluation originated from one of three Farms of Birth (FoB), namely Farm 1, 2 or 5. The FoB is geographically separate from Farm A and B but no further information about management or temperature conditions on the FoB was available at the time of the study.

3.2 Temperature data

Daily maximum and minimum outdoor temperature data, for the period between 1 January 2005 and 31 December 2007, were obtained from the South African Weather Service (SAWS) for the areas in which the farms are situated. Figure 2 presents the average daily minimum and maximum temperatures for each area for the period 2005-2007.

In this study, January, February, November and December were grouped as summer (Season 1); March and April were grouped as autumn (Season 2); May, June and July were grouped as winter (Season 3) and August, September and October were grouped as spring (Season 4).

3.3 Animals

The total pool of records used in various models corresponded to breeding records for 2600 sows, from both farms, born between 1 March 2004 and 28 February 2007. All sows from farms A and B included in this study were of the same synthetic genetic line.

Records of 2455 sows (1232 from Farm A and 1223 from Farm B) were used in the model for analysis of AFS as a dependent variable. Records of 2223 sows (1157 from Farm A and 1066 from Farm B) were used in the models for analysis of TB and BA (litter size) as dependent variables.

Records of 2373 sows (1187 from Farm A and 1186 from Farm B) were used in the model for analysis if WSI as a dependent variable. Only records concerning first parity reproductive performance were analysed. Records from sows failing to farrow, sows losing litters as a result of abortion and of sows having been served more than twice for cycle one, i.e. returning to oestrus for a third time in the first parity, were excluded from analysis.

3.4 Parameters of performance

The parameters of performance taken from the records were:

1) Date of birth (DoB) of gilt
2) Year of Birth (YoB) of gilt
3) Season of Birth (SB) of gilt
4) Age at first service (AFS)
5) Season of First Service (SS)
6) Year of First Service (YoS)
7) Number of Services (NoS)
8) Farrowing date (FD)
9) Year of Farrowing (YoF)
10) Season of Farrowing (SF)
11) Total number of piglets born (TB)
12) Number of piglets born alive (BA)
13) Number of stillborn piglets (BD)
14) Number of mummified piglets (GA)
15) Weaning date (WD)
16) Backfat thickness (BF) of the gilts at farrowing (BFF)
17) BF at weaning (BFW)
18) Weaning to service interval (WSI)

3.5 Statistical analysis

Multiple regression models were used for the analyses to test the overall significance of the effect of the main factors and the interaction between variables on each of the chosen dependent variables in which $y_{ij} = \mu + a_i + b_j + (ab)_{ij} + e_{ij}$

The dependent variables were: AFS, TB, BA and WSI. The P values and significant or non-significant effects for all factors and interactions between variables on the dependent variables were reported in the results. Means and standard deviations (SD) were calculated and significance of difference ($P \leq 0.05$) between means was determined by using the Bonferroni inequality. Results were reported as least square means ± SD.

$$y_{ijkl} = \mu + a_i + b_j + c_k + d_l + a_{i(j)} + (ac)_{ik} + (ad)_{il} + (cd)_{kl} + (acd)_{ijk} + e_{ijkl}$$

Where the dependent variable y_{ijkl} is AFS , a_i is the effects of Producer (A or B, $i = 1, 2$), $a_{i(j)}$ is Producer nested within FoB(b_j) (1, 2, 5, $j = 1, 2, 3$), c_k is the SB (Season 1, 2, 3, 4, $k = 1, 2, 3, 4$)), d_l is the YoB (2004, 2005, 2006, $l = 1, 2, 3$) and interactions of SB on YoB ($(cd)_{kl}$), Producer on SB ($(ac)_{ik}$), Producer on YoB ($(ad)_{il}$) and Producer on SB and YoB ($(acd)_{ijk}$) were evaluated using the GLM procedure of SAS (Statistical Analysis Systems, 2009). All main factors and interactions included in the model were significant ($P \leq 0.05$).

$$y_{ijkl} = \mu + a_i + b_j + c_k + d_l + (bc)_{jk} + (abc)_{ijk} + e_{ijkl}$$

Two models were run for analysis of litter size where TB and BA were the dependent variables respectively.

The main factors for both models were: a_i is the effect of Producer (A or B, $i = 1, 2$), b_j is the SS (Season 1, 2, 3, 4, $j = 1, 2, 3, 4$), c_k the YoS (2005, 2006, 2007, $k = 1, 2, 3$), d_l the Number of Services (NoS) (1 or 2, $l = 1, 2$) and the interactions of SS by YoS($(bc)_{jk}$) and Producer by SS and by YoS ($(abc)_{ijk}$).

These were evaluated using the GLM procedure of SAS (Statistical Analysis Systems, 2009). When TB was the dependent variable, NoS, SS and SS by YoS interaction were NS ($P > 0.05$), whereas all other factors and interactions were significant ($P \leq 0.05$). When BA was the dependent variable all main factors except NoS ($P > 0.05$) and SS ($P > 0.05$) were significant. All included interactions were found to have a significant influence on TB ($P \leq 0.05$). Boar line was excluded as a variable from this model due to insufficient variation in the dataset. Effects of Producer, SS and YoS on TB and BA reported in the results are not due to differences in AFS because it was included as a covariate in all models except the model used for the analysis of age at first service as a dependent variable.

$$y_{ijk} = a_i + b_j + c_k + (ab)_{ij} + (ac)_{ik} + (bc)_{jk} + (abc)_{ijk} + e_{ijk}$$

When the dependent variable was WSI, a_i the effects of Producer (A or B, $i = 1, 2$), b_j SF (Season 1, 2, 3, 4, $j = 1, 2, 3, 4$), c_k YoF (2005, 2006, 2007, $k = 1, 2, 3$) and the interactions of Producer by SF ($(ab)_{ij}$), Producer by YoF ($(ac)_{ik}$), SF by YoF ($(bc)_{jk}$), Producer by SF by YoF ($(abc)_{ijk}$) were evaluated using the GLM procedure of SAS (Statistical Analysis Systems, 2009). Only Producer, YoF and interaction of SF by YoF were found to be significant contributors to WSI ($P \leq 0.05$). All other main factors and interactions were not significant ($P > 0.05$). Effects of Producer, SF and YoF reported in the results are not due to differences in AFS, the number of piglets weaned, change in BF and lactation length because they were included as covariates in this model and were found not to be significant ($P > 0.05$) contributors to WSI despite having an additive effect on r^2.

CHAPTER 4

RESULTS AND DISCUSSION

Analysis of primiparous sow productivity is significant because gilts are immature animals entering the herd to replace the more mature, more productive sows. Any delay in productivity of the gilt beyond what is considered acceptable for an immature animal will lead to an increase in non-productive days and less income from saleable product with which to cover feeding and breeding expenses of the gilt. Owing to the immature reproductive system of the gilt, gilts should never make up the majority of the breeding herd because productivity is poor compared to that of multiparous sows. Tummaruk *et al.* (2000) found that gilts born from primiparous sows had slower GR, thinner BF at 100kg body weight and were older at first service compared to gilts born from multiparous sows. Gilts bred at first oestrus rather than at second oestrus showed a reduction in litter size at first parity (Levis, 1997). Primiparous sows usually have longer WSI than multiparous sows (Tantasuparuk *et al.*, 2001). It is important to recognise that primiparous sows kept under optimum conditions have potential to become good producers in later parities despite the lower productivity in the first parity reported by other authors. Should reproductive failure occur after first parity, despite optimal management of body condition, it can be used as a culling criterion as was found to be the case by Stalder *et al.* (2005).

The results from the current study show that environmental (exogenous) factors have an effect on AFS, litter size and WSI. It is shown that there were differences in production between seasons and years for farms pooled and between farms. Auvigne *et al.* (2010) stated that in addition to temperature, other environmental factors that may vary between years are feed quantity and quality, humdity, social factors and human behaviour to name a few, and all these may influence productivity of the breeding herd, thereby highlighting the importance of collecting data about management routines used by farmers as part of an analysis of their efficiency in an attempt to alleviate seasonal infertility.

4.1 Factors influencing age at first service

It is generally accepted by pig producers that gilts should attain a minimum percentage of mature body weight as well as a minimum age before first service. Failure to comply with this could result in gilts being removed from the breeding herd due to reproductive failure before they begin their productive lives.

4.1.1 Age at first service and farm of birth

Farm of origin or birth (FoB) of gilts (Farm 1, 2, 5) refers to the farm where gilts were born and raised prior to transfer to the farm, either Farm A or B, where they would enter the productive herd. All three farms where all gilts used for this study originated from are geographically separate from the production farms A and B.

Records of gilts were grouped into four groups based on FoB, namely gilts born and raised on Farm 1 and moved to Farm A (A1), gilts born and raised on Farm 2 prior to being moved to Farm A (A2), gilts born on Farm 2 and moved to Farm B (B2) and gilts born and raised on Farm 5 prior to being relocated to the production unit on Farm B (B5).

Table 1 Age at first service in days (least square means±SD) by farm of birth (1, 2, 5) and by farm of production (A, B)

Farm	Birth Farm	n	Age at first service (±SD)
A	1	780	216.7 ± 18.11^{a}
	2	452	218.8 ± 20.35^{a}
B	2	235	217.4 ± 20.42^{a}
	5	988	233.9 ± 19.63^{b}

^{ab} Column means with different superscripts differ ($P \leq 0.05$; Bonferroni)
n is number of gilts born

Overall, when AFS of gilts on a production farm (A or B) was considered within a specific FoB (A1, A2, B2, B5), the effect of Producer (A or B) on AFS was significant ($P < 0.0001$). It was found that B5 gilts were significantly older at first service than A1 gilts ($P < 0.0001$), older than A2 ($P < 0.0001$) and B2 gilts ($P < 0.0001$) respectively (Table 1). AFS usually falls in the range of 200 to 220 days of age (Evans & O'Doherty, 2001) and AFS of A1, A2 and B2 gilts were consistent with this range, whereas B5 gilts were much older than this at first service.

From Table 1 it can be seen that there was no significant (NS) difference in AFS of A1 and A2 gilts ($P = 0.1763$). Differences in AFS of A1 and B2 gilts ($P = 0.8011$) were NS (Table 1). Similarly, differences in AFS of A2 and B2 gilts ($P = 0.4829$) were also NS (Table 1).

4.1.2 Age at first service for farms pooled

The effects of Producer ($P < 0.0001$), SB ($P = 0.0005$) and YoB ($P < 0.0001$), as well as of the interaction of SB by YoB ($P < 0.0001$) on AFS were significant. The effects of interactions of Producer by SB ($P < 0.0001$) and Producer by YoB ($P < 0.0001$) on AFS were highly significant. The effect of Producer by SB by YoB interaction ($P < 0.0001$) on AFS was also significant. The indication that YoB has a significant effect on the variation of AFS support the statement of Auvigne *et al.* (2010) that environmental factors vary between year.

Table 2 Age at first service in days (least square means±SD) by season of birth and by year of birth for farms pooled

	Year							
Season	n	2004	n	2005	n	2006	n	Season Average
Summer	109	$218.8\pm14.05^{a}_{1}$	203	$223.7\pm15.22^{a}_{12}$	259	$226.1\pm16.75^{a}_{2}$	571	222.9 ± 16.41^{ab}
Autumn	276	$220.5\pm20.80^{a}_{12}$	111	$215.1\pm12.50^{b}_{1}$	139	$224.6\pm16.82^{a}_{2}$	526	220.1 ± 18.82^{a}
Winter	233	$229.7\pm24.02^{b}_{1}$	226	$220.0\pm34.32^{ab}_{2}$	232	$224.4\pm17.07^{a}_{2}$	691	224.7 ± 26.18^{b}
Spring	166	$223.1\pm25.32^{a}_{12}$	206	$222.2\pm14.61^{a}_{1}$	295	$227.3\pm15.41^{a}_{2}$	667	224.2 ± 18.29^{b}
Year Average	784	$223.0\pm23.08_{1}$	746	$220.2\pm22.63_{1}$	925	$225.6\pm16.52_{2}$		

^{ab} Column means with different superscripts differ ($P \leq 0.05$; Bonferroni)
$_{12}$ Row means with different subscripts differ ($P \leq 0.05$; Bonferroni)
n is number of gilts born

Season

From Table 2 it can be seen that for the season average of AFS across years, differences in AFS between gilts born in summer and gilts born in autumn ($P = 0.0346$), winter ($P = 0.1352$) and spring ($P = 0.2839$) were NS. Gilts born in autumn were younger at AFS than gilts born in winter ($P < 0.0001$) and spring ($P = 0.0008$) (Table 2). This is consistent with the findings that gilts born in autumn (reaching puberty in winter and early spring) reached puberty at a younger age than gilts born in spring (reaching puberty during summer and early autumn) suggesting that gilts maturing during summer are exposed to conditions which delay the rate of sexual maturity (Christenson & Ford, 1979). The seasonal infertility period is considered to last from late summer through autumn (Hälli *et al.*, 2008). There was no difference in AFS of gilts born in winter and spring ($P = 0.6313$) (Table 2).

During 2004, gilts born during winter were older at AFS than those born during summer ($P < 0.0001$), autumn ($P < 0.0001$) and spring ($P = 0.0012$) (Table 2). Differences in AFS between gilts born during the summer and autumn ($P = 0.4989$) and summer and spring ($P = 0.1103$) of 2004 were NS (Table 2). Similarly there was no difference in AFS of gilts born in autumn and spring ($P = 0.2296$) (Table 2).

During 2005, gilts born during the autumn were younger at AFS than those born during the summer ($P < 0.0001$) and spring ($P = 0.0013$), but were not younger at AFS than gilts born in winter ($P = 0.0296$) (Table 2). Differences between AFS of gilts born during the summer and winter ($P = 0.0630$) and summer and spring ($P = 0.4184$) of 2005 were NS (Table 2). There was no difference in AFS between gilts born in winter and spring ($P = 0.2695$) of 2005 (Table 2).

Seasonal differences found in AFS between gilts born during the summer and autumn ($P = 0.4429$), winter ($P = 0.3107$) and spring ($P = 0.4719$) during 2006 were NS (Table 2). There was no difference in AFS between gilts born in autumn and winter ($P = 0.8978$) or autumn and spring ($P = 0.1677$) (Table 2). Similarly there was no seasonal difference in AFS between gilts born in winter and spring ($P = 0.0842$) (Table 2).

Year

In Table 2 it can be seen that for the year average of AFS across all seasons, gilts born during 2006 were found to be older at AFS than those born either in 2004 ($P = 0.0146$) or 2005 ($P < 0.0001$), but differences in AFS between gilts born during 2004 and 2005 ($P = 0.0182$) were NS. Between years there were differences in AFS for 2004 and 2005 but not 2006 and this supports the statement by Auvigne *et al.* (2010) that environmental factors change from year to year. The AFS was within the normal range as stated by Evans andO'Doherty (2001).

There was no difference in AFS found between gilts born during the summer of 2004 and 2005 ($P = 0.0581$), differences in AFS between gilts born in summer of 2005 and 2006 ($P = 0.1663$) were NS (Table 2). Gilts born in summer 2004 were younger at AFS than gilts born in summer 2006 ($P = 0.0032$) (Table 2).

Gilts born during autumn of 2004 were not older at AFS than those born during autumn of 2005 ($P = 0.0177$); these same gilts were not younger at AFS than those born during autumn of 2006 ($P = 0.0517$) (Table 2). Gilts born during autumn of 2005 were significantly younger at AFS than those born during autumn of 2006 ($P < 0.0001$) (Table 2).

Gilts born during the winter of 2004 were older at first service than those born during the winter of 2005 ($P < 0.0001$) and 2006 ($P = 0.0041$) respectively (Table 2). Differences between AFS of gilts born during the winter of 2005 and 2006 ($P = 0.0265$) were NS (Table 2).

Gilts born during spring of 2004 were not older than those born during the spring of 2005 ($P = 0.6501$) at first service, nor did they have younger AFS than those born during the spring of 2006 (P =

0.0262) (Table 2). Gilts born during the spring of 2005 were younger than gilts born during the spring of 2006 (P = 0.0041) (Table 2).

Evans and O'Doherty (2001) stated that age at puberty, which is a term usually used interchangably with AFS in practice, is affected by environment. This is supported by the finding in this study where the FoB (Table 1), the SB as well as the YoB of gilts (Table 2) were shown to significantly influence AFS. This contradicts the statement by Levis (1997) that season of birth has less influence on AFS than the climatic conditions existing at the time when gilts approach sexual maturity. As there was no further information available on the management practices used on the farms of birth, nor information on the area in which these farms are situated, no further conclusions could be made on the factors influencing AFS specifically within FoB.

4.1.3 Age at first service for Farm A

Table 3 Age at first service in days (least square means±SD) by season within year and between years of birth for Farm A

	Year							
Season	n	2004	n	2005	n	2006	n	Season Average
Summer	87	$212.8 \pm 12.14^{a}_{1}$	89	$219.9 \pm 13.82^{a}_{2}$	136	$225.7 \pm 18.40\ ^{a}_{2}$	312	219.5 ± 16.41^{a}
Autumn	124	$210.0 \pm 11.76^{a}_{1}$	55	$211.4 \pm 11.87^{bc}_{1}$	68	$223.8 \pm 18.00^{ab}_{2}$	247	215.0 ± 14.97^{b}
Winter	81	$222.2 \pm 29.46^{b}_{1}$	61	$202.4 \pm 16.80\ ^{b}_{2}$	151	$218.6 \pm 16.25^{b}_{1}$	293	214.4 ± 21.81^{b}
Spring	111	$224.2 \pm 27.40^{b}_{1}$	110	$215.2 \pm 8.90\ ^{ac}_{2}$	159	$228.1 \pm 17.43^{a}_{1}$	380	222.5 ± 19.74^{a}
Year Average	403	$217.3 \pm 22.24\ _{1}$	315	$212.2 \pm 13.95\ _{2}$	514	$224.1 \pm 17.77_{3}$		

^{ab} Column means with different superscripts differ ($P \leq 0.05$; Bonferroni)
$_{12}$ Row means with different subscripts differ ($P \leq 0.05$; Bonferroni)
n is number of gilts born

Season

It was shown in Table 3 that for the season average of AFS across years, gilts born during summer were not younger at AFS than those born during spring (P = 0.0443), but were older than those born during the autumn (P = 0.0071) and winter (P = 0.0015) respectively. Gilts born during autumn were not older at first service than gilts born during the winter (P = 0.7106) but were significantly younger at AFS than gilts born in spring (P < 0.0001) (Table 3). There was a significant seasonal difference in AFS between gilts born in winter and spring (P < 0.0001) (Table 3).

During 2004 (Table 3), differences in AFS between gilts born during the summer and autumn (P = 0.2861) and between gilts born during the winter and spring (P = 0.4888) respectively were NS. Gilts born during summer were younger at first service than those born during winter (P = 0.0010) and spring (P < 0.0001) respectively (Table 3). Similarly gilts born in autumn 2004 were significantly younger at AFS than gilts born in winter (P < 0.0001) and spring (P < 0.0001) (Table 3).

During 2005 it was shown that gilts born during summer were older at first service than gilts born in autumn (P = 0.0072) and winter (P < 0.0001), but not older than gilts born during spring (P = 0.0820) (Table 3). Gilts born during the autumn of 2005 were not older at AFS than gilts born during the winter of the same year (P = 0.0097), nor were they younger at first service than gilts born during spring (P = 0.2143) (Table 3). There was a significant seasonal difference in AFS between gilts born in winter and spring (P < 0.0001) (Table 3).

As seen from Table 3, differences between AFS of gilts born during the summer and autumn (P = 0.4727), and summer and spring (P = 0.2686) of 2006 were NS. Gilts born during winter were younger at AFS than those born during both summer (P = 0.0014) and spring (P < 0.0001) (Table 3). Gilts born during the autumn of 2006 were not older at first service than gilts born during winter (P = 0.0590) or spring (P = 0.1035) (Table 3).

Year

From Table 3 it can be seen that for the year average of AFS across seasons, gilts born during 2004 were older at AFS than gilts born in 2005 (P = 0.0027) and younger than gilts born in 2006 (P < 0.0001). Gilts born in 2005 had a significantly younger AFS than gilts born during 2006 (P < 0.0001) (Table 3).

Gilts born during the summer of 2004 had younger AFS than gilts born in summer of 2005 (P = 0.0122) and 2006 (P < 0.0001) (Table 3). There was no difference between AFS of gilts born during summer of 2005 and 2006 (P = 0.0277) (Table 3).

Gilts born during autumn of 2004 showed no difference in AFS compared with gilts born in autumn 2005 (P = 0.6633) (Table 3). There was a significant difference in AFS between gilts born in autumn 2004 were younger at AFS than gilts born in autumn 2006 (P < 0.0001); similarly gilts born in autumn 2005 were younger at AFS than gilts born in autumn 2006 (P = 0.0004) (Table 3).

Gilts born during the winter of 2004 had older AFS than gilts born during the winter of 2005 ($P < 0.0001$), but not older than gilts born in winter 2006 ($P = 0.1629$) (Table 3). Gilts born in winter 2005 were significantly younger at first service than gilts born in winter 2006 ($P < 0.0001$) (Table 3).

Gilts born during the spring of 2005 were younger than gilts born during the spring of 2004 ($P = 0.0005$) and 2006 ($P < 0.0001$) respectively (Table 3). Differences in AFS between gilts born during the spring of 2004 and 2006 ($P = 0.0894$) were NS (Table 3).

4.1.4 Age at first service for Farm B

Table 4 Age at first service in days (least square means±SD) by season within year and between years of birth for Farm B

		Year						
Season	n	2004	n	2005	n	2006	n	Season Average
Summer	22	$222.3\pm11.37^{ac}_{1}$	114	$225.0\pm13.76^{a}_{1}$	123	$224.1\pm13.75^{a}_{1}$	259	223.8 ± 13.54^{a}
Autumn	152	$228.7\pm24.28^{ab}_{1}$	56	$216.3\pm9.53^{b}_{2}$	71	$223.1\pm14.58^{a}_{12}$	279	222.7 ± 20.11^{a}
Winter	152	$234.7\pm18.20^{b}_{1}$	165	$235.2\pm34.52^{c}_{1}$	81	$227.8\pm11.86^{a}_{2}$	398	232.6 ± 25.44^{b}
Spring	55	$219.6\pm20.52^{c}_{1}$	96	$226.7\pm13.44^{a}_{1}$	136	$224.0\pm12.23^{a}_{1}$	287	223.4 ± 14.71^{a}
Year Average	381	$226.3\pm21.89_{1}$	431	$225.8\pm23.93_{1}$	411	$224.7\pm13.11_{1}$		

^{ab} Column means with different superscripts differ ($P \leq 0.05$; Bonferroni)
$_{12}$ Row means with different subscripts differ ($P \leq 0.05$; Bonferroni)
n is the number of gilts born

Season

In Table 4 it was shown that for the season average of AFS across years, gilts born during winter were significantly older at AFS than gilts born during either summer ($P < 0.0001$), autumn ($P < 0.0001$) or spring ($P < 0.0001$). There was, however, no difference in AFS between gilts born during summer and autumn ($P = 0.5877$) or spring ($P = 0.8381$) respectively (Table 4). Seasonal differences in AFS of gilts born in autumn and spring ($P = 0.6892$) were NS (Table 4).

During 2004, there was no seasonal difference in AFS of gilts born in summer and autumn ($P = 0.1640$) and of gilts born in summer and spring ($P = 0.5558$) (Table 4). Similarly seasonal differences in AFS between gilts born in autumn and winter ($P = 0.0108$) of 2004 were NS (Table 4). Gilts born in summer 2004 were younger at AFS than gilts born in winter ($P = 0.0037$) of the same year (Table

4). Gilts born in autumn 2004 were older at AFS than gilts born in spring 2004 (P = 0.0070), similarly gilts born in winter were older than gilts born in spring (P < 0.0001) in 2004 (Table 4).

During 2005 (Table 4), there was no difference in AFS between gilts born during summer and spring (P = 0.4995). Gilts born during summer 2005 were older at AFS than gilts born in autumn (P = 0.0043) and were younger at AFS than gilts born in winter (P < 0.0001) (Table 4). Gilts born in autumn 2005 were younger at AFS than gilts born in winter (P < 0.0001) and spring (P = 0.0009) of 2005 (Table 4). Gilts born in winter 2005 were older at AFS than those born in spring (P = 0.0006) of the same year (Table 4).

Differences in AFS between gilts born during summer and autumn (P = 0.7131), winter (P = 0.1712) or spring (P = 0.9569) of 2006 were NS (Table 4). Similarly there was no seasonal difference in AFS between gilts born in autumn and winter (P = 0.1232) or spring (P = 0.7427) of 2006; and no significant seasonal difference in AFS between gilts born in winter and spring (P = 0.1490) of 2006 (Table 4).

Year

In Table 4 it can be seen that for the year average of AFS across all seasons, differences in AFS of gilts born during 2004 and 2005 (P = 0.7546) or 2006 (P = 0.3503) or between gilts born during 2005 and 2006 (P = 0.4333) were NS.

There were no differences in AFS between gilts born in summer of 2004 and 2005 (P = 0.5386), or 2006 (P = 0.6764) nor any difference of AFS between gilts born during summer 2005 and 2006 (P = 0.7201) (Table 4).

From Table 4 it is evident that gilts born during the autumn 2004 were older at first service than gilts born in autumn 2005 (P = 0.0002), but not older than gilts born in autumn 2006 (P = 0.0778). Gilts born during autumn 2005 were not younger than gilts born in autumn 2006 (P = 0.0414) (Table 4).

Gilts born in the winter of 2005 (Table 4) were not older at first service than gilts born in the winter of 2004 (P = 0.8124), but were older than gilts born in winter 2006 (P = 0.0041). Gilts born in winter 2004 were older at first service than gilts born in winter 2006 (P = 0.0077) (Table 4).

Differences in AFS between gilts born in spring of 2004 and those born in spring 2005 (P = 0.0236) and 2006 (P = 0.1357) were NS (Table 4). Similarly there was no difference in AFS of gilts born in spring 2005 and 2006 (P = 0.2782) (Table 4).

When considering year and season averages of AFS, it can be seen that gilts in production on Farm A (Table 3) were younger at AFS than gilts in production on Farm B (Table 4) for 2004, 2005 but not for 2006. Also AFS of gilts born in summer, autumn and winter, but not those born in spring, had markedly younger AFS on Farm A than on Farm B. This could be the result of the majority of gilts on Farm B originating from Farm 5, where AFS was significanlty older than in gilts originating from FoB 1 and 2 (Table 1).

4.2 Factors influencing litter size

In this study AFS was used as a covariate in the models for litter size and was shown not to have any significant effects on either the TB or BA per litter in the first parity and was thus excluded from the results.

The study by Vargas *et al.* (2009) in southern Brazil, found an increased return to oestrus between January through June, which is equivalent to the period of summer to early winter in this study. In contrast, it was shown in this study that there was a trend of higher return rates during summer decreasing towards autumn (Fig.1). This suggests that the higher temperatures may be the cause of this trend in this study rather than a change in day length.

Table 5 Sows served and percentage returns to service by year by season for farms pooled

Year	Services*	Summer	Autumn	Winter	Spring
	1	213	94	166	107
2005	2	25	5	14	10
	% Return	**10.5**	**5.1**	**7.8**	**8.5**
	1	232	154	184	196
2006	2	29	14	19	17
	% Return	**11.1**	**8.3**	**9.4**	**8.0**
	1	126	129	257	163
2007	2	17	16	22	13
	% Return	**11.9**	**11.0**	**7.9**	**7.4**

*Number of services for first parity

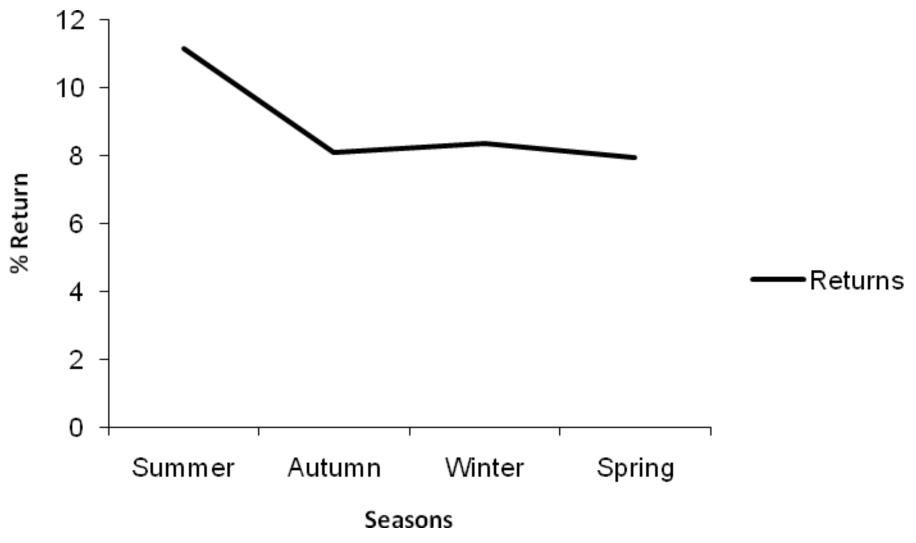

Figure 1. Percent return to service for each season for two farms averaged over 2005 to 2007

Levis (1997) stated that the proportion of gilts reaching sexual maturity was lower in the months June through September (summer for the northern hemisphere) than during any other months of the year and suggested increasing the number of gilts selected for mating in summer to compensate for the lower number of gilts reaching sexual maturity. From Table 5 and Figure 1 it can be seen that overall there is a tendency for the sows to return to service during the summer months more than in any other season. The results of this study support the statement made by Levis (1997).

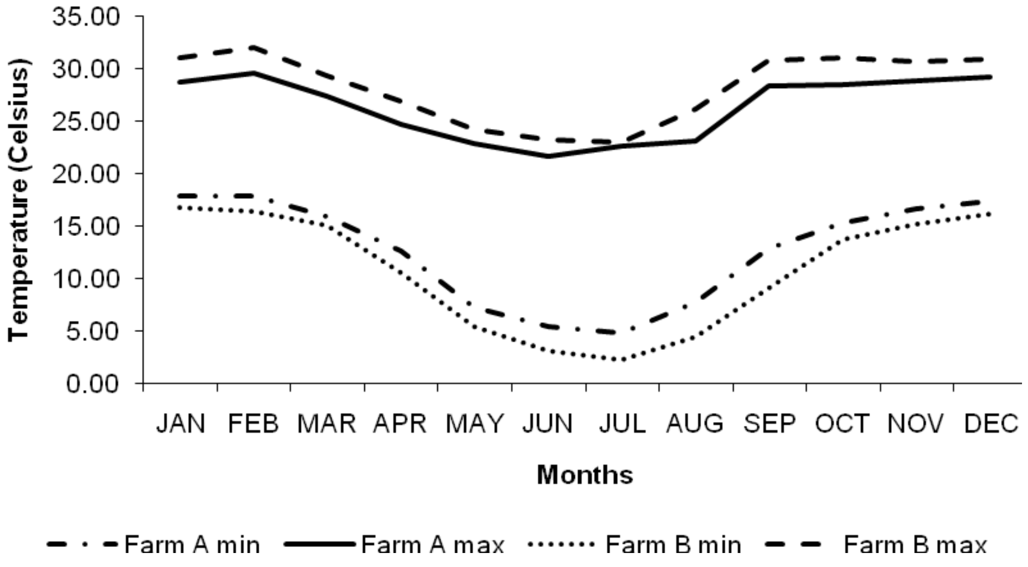

Figure 2. Average daily minimum and maximum temperatures in the areas close to Farms A and B between 2005 and 2007.

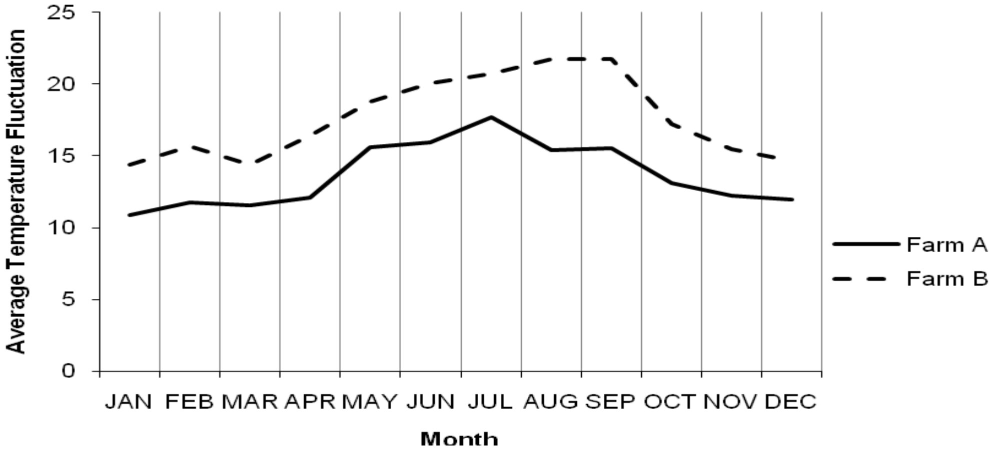

Figure 3. Monthly temperature fluctuations averaged over 2005 to 2007 for the areas close to Farms A and B

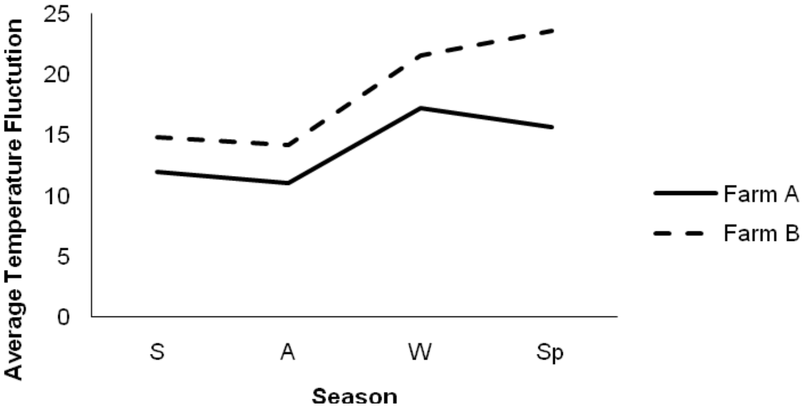

Figure 4. Average temperature fluctuation for two areas for 2005

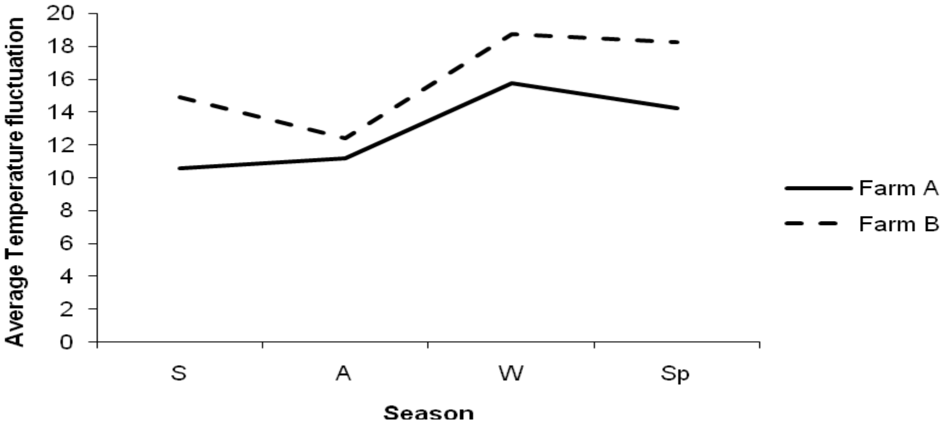

Figure 5. Average temperature fluctuation for two areas for 2006

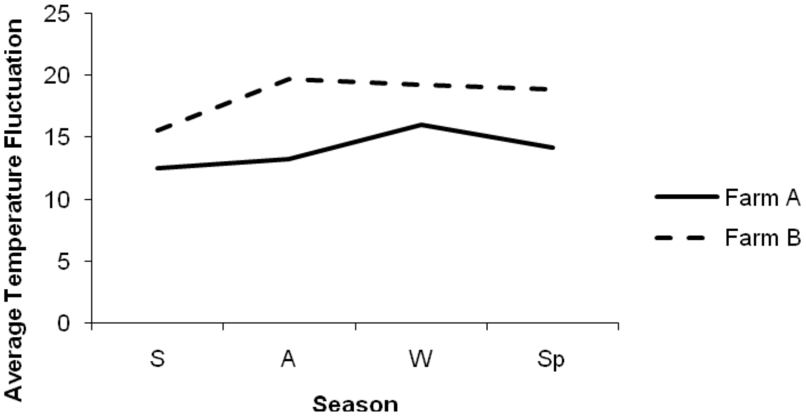

Figure 6. Average temperature fluctuation for the areas for 2007.

A higher percentage of returns to service (Table 5) in the summer is presumably due to hotter temperatures occuring during summer than during other seasons (Fig.2). Tummaruk *et al.* (2010) found that return to oestrus was the most common cause of reproductive failure and was highest among primiparous sows when compared with multiparous sows. Takai and Koketsu (2007) found that primiparous sows were more likely to show reproductive failure in summer months, which is consistent with the results of the current study. An exception to the trend is apparent in the high return percentage reported for the autumn of 2007 (Table 5). When compared to Figures 4 and 5 it can be assumed that the greater difference in autumn temperature fluctuation between farms seen for 2007 (Fig. 6) was unusual. The data reported in Table 5 are the average return percentages for farms A and B pooled and thus the high return percentage found during the autumn months of 2007 may be attributed to the unusually high temperature fluctuation that occured during the same period in the area in which Farm B is situated (Fig. 6). This may have resulted in higher return percentages occuring on Farm B, in turn affecting the overall results. Kunavongkrit *et al.* (2005) suggested that it is not heat per se that negatively affects fertility in boars, but rather great temperature fluctuations that may cause stress to the animal. It is possible that the same is true for female breeding stock. This could, however, not be conclusively explained in this study because the information on the individual farm return percentage rates was not considered here and thus could not be compared to the temperature data available.

4.2.1 Total number of piglets born

Table 6 indicates that there was no significant difference in TB from sows receiving either one or two services before successful conception (P = 0.8679). This is consistent with the results of Leenhouwers *et al.* (1999) that reported an average TB of 10.77 piglets.

Table 6 Total number of piglets born per litter (least square means±SD) related to number of services per sow for farms pooled

Sows conceiving at service 1	Number of piglets born from first service	Sows conceiving service 2	Number of piglets born from second service	% Returns
2022	10.7±2.68 $_{1}$	201	10.7±2.69 $_{1}$	9.0

$_{12}$ Row means with different subscripts differ (P ≤ 0.05; Bonferroni)

4.2.1.1 Total number of piglets born for farms pooled

The effects of Producer (P < 0.0001), YoS (P = 0.0001) and the interaction of Producer by SS by YoS (P = 0.0047) on TB were significant (P≤0.05). The influence of SS (P = 0.6263) (Table 7) and the interaction of SS by YoS (P = 0.3274) on TB was NS.

Table 7 Total number of piglets born per litter (least square means±SD) by season by year of service for farms pooled

	Year of Service							
	2005		2006		2007			
Season	n	Piglets born per litter	n	Piglets born per litter	n	Piglets born per litter	n	Season Average
Summer	238	10.7±2.80$^{a}_{12}$	261	10.4±2.57$^{a}_{1}$	143	11.2±2.60$^{a}_{2}$	642	10.8±2.67^{a}
Autumn	99	11.0±2.95$^{a}_{1}$	168	10.7±2.67$^{a}_{1}$	145	10.6±2.43$^{a}_{1}$	412	10.8±2.66^{a}
Winter	180	11.0±2.52$^{a}_{12}$	203	10.3±2.77$^{a}_{1}$	280	10.9±2.60$^{a}_{2}$	663	10.7±2.64^{a}
Spring	117	10.8±2.90$^{a}_{12}$	213	10.1±2.65$^{a}_{1}$	176	10.8±2.69$^{a}_{2}$	506	10.6±2.74^{a}
Year Average	634	10.9±2.76 $_{1}$	845	10.4±2.67 $_{2}$	744	10.9±2.59 $_{1}$		

^{ab} Column means with different superscripts differ (P ≤ 0.05; Bonferroni)
$_{12}$ Row means with different subscripts differ (P ≤ 0.05; Bonferroni)
n is the number of gilts served

Season

Table 7 indicates that for the season average of TB across years, there was no seasonal difference of TB between gilts first served in summer and autumn (P = 0.9203), winter (P=0.8089) or spring (P = 0.2231). Seasonal differences in TB between gilts served in autumn and winter (P = 0.9067) or spring (P = 0.3174) were NS (Table 7). Similarly there was no difference in TB between gilts served in winter and spring (P = 0.3324) (Table 7).

In 2005, there was no seasonal difference in TB between gilts served in summer and autumn (P = 0.4193), winter (P = 0.3305) or spring (P = 0.7905) (Table 7). Seasonal differences in TB between gilts served in autumn and winter (P = 0.9377) or spring (P = 0.6202) of 2005 as well as between gilts served in winter and spring (P = 0.5413) of 2005 were NS (Table 7).

In 2006, seasonal differences in TB between gilts served in summer and autumn (P = 0.4122), winter (P = 0.5519) or spring (P = 0.1434) were NS (Table 7). There was no seasonal difference in TB between gilts served in autumn and winter (P = 0.1916) or spring (P = 0.0374) of 2006; similarly differences in TB between gilts served in winter and spring (P = 0.4187) of 2006 were NS (Table 7).

In 2007, there was no seasonal difference in TB between gilts served in summer and autumn (P = 0.0920), winter (P = 0.3477) or spring (P = 0.2844) (Table 7). Seasonal differences in TB between gilts served in autumn and winter (P = 0.3151) or spring (P = 0.4911) of 2007 and between gilts served in winter and spring (P = 0.7962) of 2007 were NS (Table 7).

Year

For the year average of TB across seasons, there were fewer TB from gilts served during 2006 than from gilts served during either 2005 (P = 0.0007) or 2007 (P = 0.0002) (Table 7). Differences in TB from gilts served during 2005 and 2007 (P = 0.9957) were NS (Table 7).

There was no difference in TB between gilts served in summer of 2005 and 2006 (P = 0.2482) or 2007 (P = 0.1259) (Table 7). Gilts served in summer of 2006 produced fewer TB than gilts served in summer 2007 (P = 0.0098) (Table 7).

Differences in TB between gilts served in autumn 2005 and 2006 (P = 0.3441) or 2007 (P = 0.3097) and between gilts served in autumn of 2006 and 2007 (P=0.9141) were NS (Table 7).

Differences in TB between gilts served in winter 2005 and 2006 (P = 0.0182) or 2007 (P=0.7008) were NS, whereas gilts served in winter 2006 produced fewer TB than gilts served in winter 2007 (P = 0.0131) (Table 7).

Differences in TB between gilts served in spring 2005 and 2006 (P = 0.0189) or 2007 (P = 0.9184) were NS but gilts served in spring 2006 produced fewer TB than gilts served in spring 2007 (P = 0.0060) (Table 7).

4.2.1.2 Total number of piglets born for Farm A

Table 8 Total number of piglets born per litter (least square means±SD) by season and year of service for Farm A

	Year of service					
	2005		2006		2007	
Season	n	Piglets born	n	Piglets born	n	Piglets born
Summer	88	$10.5 \pm 2.63^{a}_{12}$	126	$10.0 \pm 2.46^{a}_{1}$	82	$11.0 \pm 2.66^{a}_{2}$
Autumn	59	$11.3 \pm 3.11^{a}_{1}$	67	$9.9 \pm 2.78^{a}_{2}$	84	$10.4 \pm 2.41^{a}_{12}$
Winter	141	$10.7 \pm 2.62^{a}_{1}$	94	$9.5 \pm 2.84^{a}_{2}$	142	$11.0 \pm 2.42^{a}_{1}$
Spring	64	$10.6 \pm 2.98^{a}_{12}$	104	$9.9 \pm 2.78^{a}_{1}$	106	$10.8 \pm 2.74^{a}_{2}$

^{ab} Column means with different superscripts differ ($P \leq 0.05$; Bonferroni)
$_{12}$ Row means with different subscripts differ ($P \leq 0.05$; Bonferroni)
n is the number of gilts served

Season

In Table 8 it was shown that differences in TB from gilts first served during summer and autumn (P = 0.0770), winter (P = 0.5084) or spring (P = 0.7716) of 2005, between gilts served in autumn and winter (P = 0.1795) or spring (P = 0.1654) of 2005 and between gilts served in winter and spring (P = 0.7795) of 2005 were NS (Table 8).

In Table 8 it was shown that differences in TB from gilts first served during summer and autumn (P = 0.8508), winter (P = 0.1358) or spring (P = 0.7058) of 2006, from gilts served in autumn and winter (P = 0.2740) or spring (P = 0.8905) of 2006 and from gilts served in winter and spring (P = 0.2812) of 2006 were NS (Table 8).

In Table 8 it was shown that there was no significant difference in TB from gilts first served during summer and autumn (P = 0.1613), winter (P = 0.9861) or spring (P = 0.5969) of 2007. Differences in TB between gilts served in autumn and winter (P = 0.1200) or spring (P = 0.3423) of 2007 and between gilts served in winter and spring (P = 0.5569) of 2007 were NS (Table 8).

Year

Gilts served during the summer of 2006 produced fewer TB than gilts served during the summer in 2007 (P = 0.0073), but not fewer TB than from gilts served during summer in 2005 (P = 0.1772)

(Table 8). There was no difference in TB for gilts served in summer 2005 and 2007 (P = 0.2076) (Table 8).

It is evident from Table 8 that gilts served during the autumn 2005 produced more TB than gilts served in autumn 2006 (P = 0.0041), but not more than gilts served in autumn 2007 (P = 0.0588). Differnces in TB between gilts served in autumn 2006 and 2007 (P = 0.2392) were NS (Table 8).

Gilts served in winter 2005 produced more TB than gilts served in winter 2006 (P = 0.0003), but not fewer TB than gilts served in winter 2007 (P = 0.3952) (Table 8). Gilts served in winter 2006 produced significanlty fewer TB than gilts served in winter 2007 (P < 0.0001) (Table 8).

There was no difference in TB of gilts served in spring 2005 and 2006 (P = 0.0727) or 2007 (P = 0.6678), but gilts served in spring 2006 produced fewer TB than gilts served in spring 2007 (P = 0.0106) (Table 8).

4.2.1.3 Total number of piglets born for Farm B

Table 9 Total number of piglets born per litter (least square means±SD) by season and year of service for Farm B

	Year of service					
	2005		2006		2007	
Season	n	Piglets born	n	Piglets born	n	Piglets born
Summer	150	11.0±2.89 $^{a}_{1}$	135	10.9±2.61 $^{ab}_{1}$	61	11.3±2.52 $^{a}_{1}$
Autumn	40	10.7±2.68 $^{a}_{1}$	101	11.4±2.44 $^{a}_{1}$	61	10.8±2.46 $^{a}_{1}$
Winter	39	11.3±2.08 $^{a}_{1}$	109	11.1±2.48 $^{ab}_{1}$	138	10.8±2.78 $^{a}_{1}$
Spring	53	11.0±2.81 $^{a}_{1}$	109	10.3±2.52 $^{b}_{1}$	70	10.9±2.64 $^{a}_{1}$

^{ab} Column means with different superscripts differ (P ≤ 0.05; Bonferroni)
$_{12}$ Row means with different subscripts differ (P ≤ 0.05; Bonferroni)
n is the number of gilts served

Season

In Table 9 it was shown that differences in TB from gilts first served during summer and autumn (P = 0.5732), winter (P = 0.4718) or spring (P = 0.9344) of 2005 were NS. There was no difference in TB between gilts served in autumn and winter (P = 0.3076) or spring (P = 0.5881) of 2005; nor were differences in TB between gilts served in winter and spring (P = 0.5818) of 2005 significant (Table 9).

In Table 9 it was shown that there was no significant difference in TB from gilts first served during summer and autumn (P = 0.1430), winter (P = 0.4758) or spring (P = 0.0870) of 2006. Differences in TB between gilts served in autumn and winter (P = 0.4647) were NS, but gilts served in autumn 2006 produced more TB than gilts served in spring (P = 0.0028) of 2006 (Table 9). There was no difference in TB between gilts served in winter and spring (P = 0.0212) of 2006 (Table 9).

In Table 9 it was shown that differences in TB from gilts first served during summer and autumn (P = 0.3060), winter (P = 0.2115) or spring (P = 0.3402) of 2007 were NS. There was no difference in TB between gilts served in autumn and winter (P = 0.9650) or spring (P = 0.9167) of 2007; similarly there was no difference in TB between gilts served in winter and spring (P = 0.8644) of 2007 (Table 9).

Year

Differences in TB of gilts served in summer 2005 and 2006 (P = 0.8431) or 2007 (P = 0.3671) and in TB of gilts served in summer 2006 and 2007 (P = 0.2983) were NS (Table 9).

There was no difference in TB of gilts served in autumn 2005 and 2006 (P = 0.1492) or 2007 (P = 0.7987), nor was there any difference in TB of gilts served in autumn 2006 and 2007 (P = 0.1799) (Table 9).

There was no difference in TB of gilts served in winter 2005 and 2006 (P = 0.7437) or 2007 (P = 0.3091), nor were differences in TB of gilts served in winter 2006 and 2007 (P = 0.3354) significant (Table 9).

There was no difference in TB of gilts served in spring 2005 and 2006 (P = 0.1249) or 2007 (P = 0.8124) and differences in TB of gilts served in spring 2006 and 2007 (P = 0.1628) were also NS (Table 9).

Tummaruk *et al.* (2010) defined FP as the number of farrowings per number of inseminations and found that gilts served in the hot season in the tropical climate of Thailand had the lowest FP compared with gilts mated in either the rainy or cold seasons respectively as well as the lowest FP of all the female animals included in the herd. For farms pooled, overall more gilts were served in summer and winter than in autumn and spring and this may indicate an attempt of producers to compensate for an anticipated seasonal reproductive failure as was found by Wan *et al.* (1994) where famers increased the number of gilts in the mating shed to compensate for seasonal infertility.

4.2.2 Number of piglets born alive

There was no significant difference in BA from sows receiving either one or two services before successful conception (P = 0.9153) (Table 10).

Table 10 Number of piglets born alive per litter (least square means±SD) related to number of services per sow

Sows conceiving at service 1	Number of piglets born from first service	Sows conceiving at service 2	Number of piglets born from second service	% Returns
2022	$9.9\pm2.69_{1}$	201	$9.9\pm2.60_{1}$	9.0

$_{12}$ Row means with different subscripts differ ($P \leq 0.05$; Bonferroni)

4.2.2.1 Number of piglets born alive for farms pooled

The effects of Producer (P = 0.0465), YoS (P = 0.0101) and the interactions of SS by YoS (P = 0.0429) and Producer by SS and by YoS (P = 0.0090) on BA were significant. SS did not have a significant effect on BA (P = 0.3004) as is reported in Table 11.

Table 11 Number of piglets born alive per litter (least sqaure means±SD) by season and year of service for farms pooled

	Year of service							
	2005		2006		2007		Season Average	
Season	n	Piglets born per litter	n	Piglets born per litter	n	Piglets born per litter	n	Piglets born per litter
Summer	238	$9.9\pm2.76^{a}_{1}$	261	$9.6\pm2.63^{ab}_{1}$	143	$10.2\pm2.73^{a}_{1}$	642	9.9 ± 2.70^{a}
Autumn	99	$10.5\pm2.99^{a}_{1}$	168	$10.1\pm2.62^{a}_{12}$	145	$9.5\pm2.38^{a}_{2}$	412	10.0 ± 2.66^{a}
Winter	180	$10.2\pm2.58^{a}_{1}$	203	$9.8\pm2.67^{ab}_{1}$	280	$10.1\pm2.60^{a}_{1}$	663	10.0 ± 2.62^{a}
Spring	117	$10.0\pm2.68^{a}_{1}$	213	$9.3\pm2.61^{b}_{1}$	176	$10.0\pm2.88^{a}_{1}$	506	9.8 ± 2.74^{a}
Year Average	634	$10.1\pm2.74_{1}$	845	$9.7\pm2.65_{2}$	744	$10.0\pm2.66_{12}$		

^{ab} Column means with different superscripts differ ($P \leq 0.05$; Bonferroni)
$_{12}$ Row means with different subscripts differ ($P \leq 0.05$; Bonferroni)
n is the number of gilts served

Season

For the season average of BA across years, as is evident from Table 11, there was differences in BA between gilts served in summer and autumn (P = 0.3397), winter (P = 0.3142) or spring (P = 0.4883) were NS. There was no difference in BA produced from gilts served in autumn and winter (P = 0.9661) or spring (P = 0.1247); nor was there any difference in BA produced by gilts served in winter and spring (P = 0.1022) (Table 11).

In 2005, there was no difference in BA between gilts served in summer and autumn (P = 0.0683), winter (P = 0.2765) or spring (P = 0.7585) (Table 11). Differences in BA produced from gilts served in autumn and winter (P = 0.4609) or spring (P = 0.1736) of 2005 and between gilts served in winter and spring (P = 0.5003) of 2005 were NS (Table 11).

In 2006, there was no difference in BA between gilts served in summer and autumn (P = 0.0431), winter (P = 0.4254) or spring (P = 0.3338) (Table 11). Differences in BA produced from gilts served in autumn and winter (P = 0.2255) of 2006 were NS, but there were more BA from gilts served in autumn than from gilts served in spring (P = 0.0052) of 2006 (Table 11). There was no difference in BA between gilts served in winter and spring (P = 0.0950) (Table 11).

In 2007, differences in BA between gilts served in summer and autumn (P = 0.0470), winter (P = 0.8724) or spring (P = 0.5111) were NS (, similarly there was no difference in BA produced from gilts served in autumn and winter (P = 0.4523) or spring (P = 0.1563) of 2007 and differences in BA between gilts served in winter and spring (P = 0.5482) of 2007 were NS (Table 11).

Year

For the year average of BA across all seasons, as was reported in Table 11, gilts served in 2005 produced more BA than gilts served in 2006 (P = 0.0034), but not more than gilts served during 2007 (P = 0.2592). There was no difference in BA between gilts served in 2006 and 2007 (P = 0.0550) (Table 11).

BA produced by gilts served in summer 2005 did not differ from BA produced by gilts served in summer 2006 (P = 0.1957) or 2007 (P = 0.3039) (Table 11). Differences in BA from gilts served in summer 2006 and 2007 (P = 0.0288) were NS (Table 11).

There was no difference in BA produced by gilts served in autumn 2005 and 2006 (P = 0.2828), but gilts served in autumn 2005 produced more BA than gilts served in autumn 2007 (P = 0.0085) (Table 11). Differences in BA produced by gilts served in autumn 2006 and 2007 (P = 0.0679) were NS (Table 11).

BA produced by gilts served in winter 2005 did not differ from BA produced by gilts served in winter 2006 (P = 0.1474) or 2007 (P = 0.7945) (Table 11). There was no difference in BA from gilts served in winter 2006 and 2007 (P = 0.1356) (Table 11).

BA produced by gilts served in spring 2005 did not differ from BA produced by gilts served in spring 2006 (P = 0.0355) or 2007 (P = 0.9960) (Table 11). Differences in BA from gilts served in spring 2006 and 2007 (P = 0.0183) were NS (Table 11).

4.2.2.2 Number of piglets born alive for Farm A

Table 12 Number of piglets born alive per litter (least square means±SD) by season and year of service for Farm A

	Year					
	2005		2006		2007	
Season	n	Born Alive	n	Born Alive	n	Born Alive
Summer	88	9.9±2.66 $^{a}_{1}$	126	9.3±2.54 $^{a}_{1}$	82	10.0±2.85 $^{a}_{1}$
Autumn	59	10.9±3.14 $^{a}_{1}$	67	9.5±2.72 $^{a}_{2}$	84	9.7±2.29 $^{a}_{2}$
Winter	141	10.0±2.61 $^{a}_{1}$	94	9.0±2.79 $^{a}_{2}$	142	10.2±2.61 $^{a}_{1}$
Spring	64	9.9±2.71 $^{a}_{1}$	104	9.3±2.88 $^{a}_{1}$	106	10.0±2.96 $^{a}_{1}$

^{ab} Column means with different superscripts differ ($P \leq 0.05$; Bonferroni)
$_{12}$ Row means with different subscripts differ ($P \leq 0.05$; Bonferroni)
n is the number of gilts served

Season

As can be seen from Table 12, there was no significant seasonal difference in BA from gilts served during summer and autumn (P = 0.0431), winter (P = 0.8109) or spring (P = 0.9086) for 2005. Differences in BA between gilts served in autumn and winter (P = 0.0467) or spring (P = 0.0462) of 2005 were NS and there was no difference in BA between gilts served in winter and spring (P = 0.7331) of 2005 (Table 12).

Seasonal differences in BA from gilts served during summer and autumn (P = 0.6345), winter (P = 0.4380) or spring (P = 0.0363) for 2006 were NS (Table 12). There was no difference in BA between gilts served in autumn and winter (P = 0.2668) or spring (P = 0.5746) of 2006 and differences in BA between gilts served in winter and spring (P = 0.5687) of 2006 were also NS (Table 12).

There was no significant seasonal difference in BA from gilts served during summer and autumn (P = 0.3847), winter (P = 0.7239) or spring (P = 0.9992) for 2007 (Table 12). Differences in BA between gilts served in autumn and winter (P = 0.1815) or spring (P = 0.3561) of 2007 and between gilts served in winter and spring (P = 0.7016) of 2007 were NS (Table 12).

Year

Differences in BA between gilts served in summer of 2005 and 2006 (P = 0.0770) or 2007 (P = 0.8417) and between gilts served in summer 2006 and 2007 (P = 0.0515) respectively were NS (Table 12).

Gilts served in autumn of 2005 produced more BA than gilts served in autumn of 2006 (P = 0.0040) and 2007 (P = 0.0088) whereas differences in BA between gilts served in autumn 2006 and 2007 (P = 0.6710) were NS (Table 12).

Gilts served in winter of 2005 produced more BA than gilts served in winter 2006 (P = 0.0040) but there was no difference in BA when compared with gilts served in winter of 2007 (P = 0.6917) (Table 12). Gilts served in winter of 2006 produced fewer BA than gilts served in winter 2007 (P = 0.0012) (Table 12).

Differences in BA between gilts served in spring of 2005 and 2006 (P = 0.1263) or 2007 (P = 0.7551) and between gilts served in spring of 2006 and 2007 (P = 0.0343) respectively were NS (Table 12).

4.2.2.3 Number of piglets born alive for Farm B

Table 13 Number of piglets born alive per litter (least square means±SD) by season and year of service for Farm B

	Year					
	2005		2006		2007	
Season	n	Born Alive	n	Born Alive	n	Born Alive
Summer	150	9.8±2.82 $^{a}_{1}$	135	9.8±2.69 $^{ab}_{1}$	61	10.3±2.57 $^{a}_{1}$
Autumn	40	10.1±2.74 $^{a}_{12}$	101	10.7±2.45 $^{a}_{1}$	61	9.4±2.50 $^{a}_{2}$
Winter	39	10.4±2.48 $^{a}_{1}$	109	10.5±2.36 $^{a}_{1}$	138	10.1±2.60 $^{a}_{1}$
Spring	53	10.0±2.68 $^{a}_{1}$	109	9.4±2.35 $^{b}_{1}$	70	9.9±2.78 $^{a}_{1}$

^{ab} Column means with different superscripts differ ($P \leq 0.05$; Bonferroni)
$_{12}$ Row means with different subscripts differ ($P \leq 0.05$; Bonferroni)
n is the number of gilts served

Season

As can be seen from Table 13, seasonal differences in BA from gilts served during summer and autumn (P = 0.5529), winter (P = 0.2368) or spring (P = 0.5761) for 2005 were NS and there was no difference in BA between gilts served in autumn and winter (P = 0.6342) or spring (P = 0.9381) of 2005 (Table 13). Differences in BA between gilts served in winter and spring (P = 0.5588) of 2005 were also NS (Table 13).

There was no significant seasonal difference in BA from gilts served during summer and autumn (P = 0.0113), winter (P = 0.0476) or spring (P = 0.2069) for 2006. (Table 13). Differences in BA between gilts served in autumn and winter (P = 0.5700) were NS but gilts served in autumn produced more BA than those served in spring (P = 0.0003) of 2006 (Table 13). Gilts served in winter produced more BA than gilts served in spring (P = 0.0021) of 2006 (Table 13).

Seasonal differences in BA from gilts served during summer and autumn (P = 0.0614), winter (P = 0.5923) or spring (P = 0.3911) for 2007 were NS and the differences in BA between gilts served in autumn and winter (P = 0.0953) or spring (P = 0.2815) of 2007 were also NS (Table 13). There was no difference in BA between gilts served in winter and spring (P = 0.6437) of 2007 (Table 13).

Year

There was no difference in BA between gilts served in summer of 2005 and 2006 (P = 0.9369) or 2007 (P = 0.2077) and differences in BA between gilts served in summer of 2006 and 2007 (P = 0.2382) were NS (Table 13).

Differences in BA between gilts served in autumn of 2005 and 2006 (P = 0.2039) or 2007 (P = 0.2136) were NS whereas gilts served in autumn of 2006 produced more BA than gilts served in autumn 2007 (P = 0.0025) (Table 13).

There was no difference in BA between gilts served in winter of 2005 and 2006 (P = 0.7810) or 2007 (P = 0.5676) (Table 13) and differences in BA between gilts served in winter of 2006 and 2007 (P = 0.2250) were NS (Table 13).

Differences in BA between gilts served in spring of 2005 and 2006 (P = 0.1477) or 2007 (P = 0.7913) and in BA between gilts served in spring of 2006 and 2007 (P = 0.2047) were NS (Table 13).

4.2.3 Piglet production between farms

Table 14 shows the difference of least square means calculated from means of TB (Table 12) and BA (Table 13) respectively and the results of this calculation are expressed as the difference in production between production farms A and B, for gilts served in every season (1, 2, 3 and 4) for 2005, 2006 and 2007.

Table 14 Seasonal difference in number of piglets produced per litter between farms

	2005		2006		2007	
Season	Total Born	Born Alive	Total Born	Born Alive	Total Born	Born Alive
Summer	0.5	0.1*	0.9**	0.5	0.3	0.3
Autumn	0.6*	0.8*	1.5**	1.2**	0.4	0.3*
Winter	0.6	0.4	1.6**	1.5**	0.2*	0.1*
Spring	0.4	0.1	0.4	0.1	0.1	0.1*

* indicates that Farm A produced more piglets per litter than Farm B, all other values indicate that Farm B produced more piglets than Farm A
** indicates differences in means are significant ($P \leq 0.05$; Bonferroni)

Total number of piglets born per litter

On Farm A gilts served in summer produced 0.5 piglets per litter TB less than on Farm B in 2005 (P=0.2020); 0.9 piglets per litter TB less than on Farm B in 2006 (P = 0.0068) and 0.3 piglets per litter TB less than on Farm B in 2007 (P = 0.4967) (Table 14).

On Farm A gilts served in autumn produced 0.6 piglets per litter TB more than on Farm B in 2005 (P=0.2682); 1.5 piglets per litter TB less than on Farm B in 2006 (P = 0.0004) and 0.4 piglets per litter TB less than on Farm B in 2007 (P = 0.3855) (Table 14).

On Farm A gilts served in winter produced 0.6 piglets per litter TB less than on Farm B in 2005 (P=0.2441); 1.6 piglets per litter TB less than on Farm B in 2006 (P < 0.0001)and 0.2 piglets per litter TB more than on Farm B in 2007 (P = 0.5329) (Table 14).

On Farm A gilts served in spring produced 0.4 piglets per litter TB less than on Farm B in 2005 (P=0.4616); 0.4 piglets per litter TB less than on Farm B in 2006 (P = 0.2288) and 0.1 piglets per litter TB less than on Farm B in 2007 (P = 0.8677) (Table 14).

Number of piglets born alive

On Farm A gilts served in summer produced 0.1 piglets per litter BA more than on Farm B in 2005 (P=0.7042); 0.5 piglets per litter BA less than on Farm B in 2006 (P = 0.0994) and 0.3 piglets per litter BA less than on Farm B in 2007 (P = 0.5164) (Table 14).

On Farm A gilts served in autumn produced 0.8 piglets per litter BA more than on Farm B in 2005 (P=0.1623); 1.2 piglets per litter BA less than on Farm B in 2006 (P = 0.0031) and 0.3 piglets per litter BA more than on Farm B in 2007 (P = 0.5759) (Table 14).

On Farm A gilts served in winter produced 0.4 piglets per litter BA less than on Farm B in 2005 (P=0.4754); 1.5 piglets per litter BA less than on Farm B in 2006 (P < 0.0001) and 0.1 piglets per litter BA more than on Farm B in 2007 (P = 0.8567) (Table 14).

On Farm A gilts served in spring produced 0.1 piglets per litter BA less than on Farm B in 2005 (P=0.7581); 0.1 piglets per litter BA less than on Farm B in 2006 (P = 0.6739) and 0.1 piglets per litter BA more than on Farm B in 2007 (P = 0.7936) (Table 14).

In Table 14 it can be seen that for the most part the difference in production was not significant except for production from sows served during summer, autumn and winter of 2006. This is contrary to expectations because Farm B experienced greater temperature fluctuations than Farm A during summer, autumn and winter 2006 (Fig. 5). These results could not be explained by temperature fluctuations alone in this study and further research which will take into account management aspects is required. These results illustrate that the quality and number of offspring have economic consequences, as was pointed out by Foxcroft *et al.* (2007).

4.2.4 Piglet mortality

Table 15 shows the difference in LS means of TB (Table 8 for Farm A and Table 9 for Farm B) and BA (Table 12 for Farm A and Table 13 for Farm B) expressed as the number of piglets lost per litter as BD or GA within each of the farms, A and B, for gilts served in all seasons for 2005, 2006 and 2007. TB included the number of BA, GA and BD piglets.

Table 15 Number of piglets lost as Born Dead and Mummified by season and year of service by farm

	Farm A			Farm B		
Season	2005	2006	2007	2005	2006	2007
Summer	0.6	0.7	1.0	1.2	1.1	1.0
Autumn	0.4	0.4	0.7	0.6	0.7	1.4
Winter	0.7	0.5	0.8	0.9	0.6	0.7
Spring	0.7	0.6	0.8	1.0	0.9	1.0

Gilts served in summer 2005 had a loss of 0.6 piglets per litter on Farm A and a loss of 1.2 piglets per litter on Farm B (Table 15). Gilts served in summer 2006 had a 0.7 piglets per litter loss on Farm A compared with a loss of 1.1 piglets per litter on Farm B (Table 15). Gilts served in summer 2007 had a loss of 1.0 piglet per litter on Farm A and a loss of 1.0 piglet per litter on Farm B (Table 15).

Gilts served in autumn 2005 had a loss of 0.4 piglets per litter on Farm A and of 0.6 piglets per litter on Farm B (Table 15). Gilts served in autumn 2006 had a loss of 0.4 piglets per litter on Farm A compared with a loss of 0.7 piglets per litter on Farm B (Table 15). Gilts served in autumn 2007 had a 0.7 piglets per litter loss on Farm A and a loss of 1.4 piglets per litter on Farm B (Table 15).

Gilts served in winter 2005 had a loss of 0.7 piglets per litter on Farm A and a loss of 0.9 piglets per litter on Farm B (Table 15). Gilts served in winter 2006 had a loss of 0.5 piglets per litter on Farm A compared with a loss of 0.6 piglets per litter on Farm B (Table 15). Gilts served in winter 2007 had a loss of 0.8 piglets per litter on Farm A and a 0.7 piglets per litter loss on Farm B (Table 15).

Gilts served in spring 2005 had a loss of 0.7 piglets per litter on Farm A and a loss of 1.0 piglet per litter on Farm B (Table 15). Gilts served in spring 2006 had a loss of 0.6 piglets per litter on Farm A compared with a loss of 0.9 piglets per litter on Farm B (Table 15). Gilts served in spring 2007 had a 0.8 piglets per litter loss on Farm A and a loss of 1.0 piglet per litter on Farm B (Table 15).

In this study the piglet mortality figures are mostly higher than the 0.57 BD piglets per litter reported by Leenhouwers *et al.* (1999) depending on the season in which the gilts were served. From Table 15 it can be seen that there was a tendency for more piglets per litter lost as BD and GA from gilts served in summer than in autumn, winter and spring for both Farm A and B. It can also be seen that there is a greater number of piglets lost per litter from gilts served in summer on Farm B than on Farm A (Table 15) and this could be the result of consistently higher summer temperature fluctuations in the area around Farm B than the area around Farm A (Fig. 3).

The greatest loss for the three year period 2005 to 2007 was a loss of 1.4 piglets per litter for Farm B for gilts served in autumn 2007 compared with the loss of 0.7 piglets per litter for Farm A for gilts served in the same season and year (Table 15). This loss could be attributed to the temperature fluctuations that occured during autumn 2007 (Fig. 6) which were higher than any temperature fluctuations for autumn 2005 (Fig. 4) and 2006 (Fig. 5) for the area surrounding Farm B.

Holyoake *et al.* (1995) found that the BD rate increased with increasing TB but this statement is not supported by current results because the season of largest TB for Farm A (Table 8) and Farm B (Table 9) did not consistenly correspond to the season with the highest reported mortalities (Table 15). Although it was found that there were no significant seasonal differences in TB (Table 7) and BA (Table 11) for Farms A and B pooled, the piglet losses per litter reflected in Table 15 require attention. For Farm A, if there were a consistent loss of only 0.4 piglets per litter as BD or GA throughout the year as was found for autumn of 2005 (Table 15) it would translate into a loss of 352 piglets per sow per year. This calculation was based on 352 gilts in production for 2005 on Farm A, each gilt producing 2.5 litters per year. Similarly for Farm B, the smallest loss of 0.6 piglets per litter as BD or GA reported for autumn 2005 (Table 15) would translate into a loss of 423 piglets per sow per year. These calculations are based on 282 gilts in production for Farm B in 2005, producing 2.5 litters per sow per year. These results emphasize the importance of reducing piglet mortalities in litters from primiparous sows.

A loss of 0.1 piglets born alive per litter for Farm A compared to Farm B as was reported for spring 2005 and 2006 respectively (Table 14) would translate into Farm A having a production of approximately 88 piglets born alive per sow per year less than Farm B. These calculations are based on 352 gilts for 2005 on Farm A producing 2.5 litters per gilt per year. This shows that even the smallest difference in production between farms can have an economical impact. Table 14 shows that the difference in production can occur between seasons. Seasonal infertility, although not the only reason for piglet mortality and differences in production, can thus present an economical problem despite the absence of significant statistical evidence and therefore management should be adjusted to alleviate the problem as much as possible.

4.3 Factors influencing weaning to service interval

Tantasuparuk *et al.* (2001) found that gilts reaching AFS at a later age tended to have a longer WSI at first parity than gilts reaching AFS at a younger age. AFS was included in the model for WSI and was found not to have a significant influence on length of WSI (P = 0.9208).

King *et al.* (1998) suggested that a shorter lactation length could shorten WSI. Lactation length was included as a covariate in the model for WSI and was found not to have a significant influence on WSI length (P = 0.3604).

Maes *et al*. (2004) and Stalder *et al.* (2005) stated that body condition plays a role in the ability of the gilt to conceive post-weaning. Primiparous sows are more sensitive to reduced voluntary feed intake during lactation than older sows due to lower body fat reserves (Eissen *et al.,* 2000); reduced feed intake during lactation will negatively affect return to oestrus and lead to a decrease in conception rate (Whittemore, 1996). Sows that are either under- or over-conditioned at weaning will have longer WSI than those in optimal condition (Thaker & Bilkei, 2005). Change in BF was included in the model for WSI and was found not to have a significant influence on WSI length (P= 0.0502) although tending towards significance. The number of piglets weaned was added included in the model of WSI and was found not to have a significant influence on WSI (P = 0.1866), which does not support the findings of Britt *et al.* (1983). The results of the current study also do not support that there is a positive correlation between litter size and WSI as was found by Sterning *et al.* (1990).

4.3.1 Weaning to service interval for farms pooled

Producer (P = 0.0052) and the interaction of SF by YoF (P = 0.0464) had significant effects on WSI, whereas YoF (P = 0.0524) did not significantly influence WSI. The effects of SF (P= 0.4946) and the interactions of Producer by SF (P = 0.3595), Producer by YoF (P = 0.5947) and Producer by SF and by YoF (P = 0.1522) on WSI were NS. This is shown in Table 16.

Table 16 Weaning to service interval in days (least square means±SD) by season and year of farrowing for farms pooled

	Year							Season
Season	n	2005	n	2006	n	2007	n	Average
Summer	191	$7.6 \pm 7.22^{ab}_{1}$	187	$6.1 \pm 6.07^{a}_{1}$	270	$6.6 \pm 7.56^{a}_{1}$	648	6.8 ± 7.06^{a}
Autumn	222	$8.3 \pm 7.43^{a}_{1}$	119	$6.4 \pm 7.09^{a}_{2}$	155	$5.9 \pm 7.90^{a}_{2}$	496	6.8 ± 7.50^{a}
Winter	157	$5.7 \pm 4.31^{b}_{1}$	182	$7.0 \pm 7.26^{a}_{1}$	217	$6.0 \pm 4.85^{a}_{1}$	556	6.2 ± 5.65^{a}
Spring	168	$6.8 \pm 6.68^{ab}_{1}$	230	$6.0 \pm 5.65^{a}_{1}$	275	$6.6 \pm 5.89^{a}_{1}$	673	6.4 ± 6.02^{a}
Year Average	738	$7.1 \pm 6.68_{1}$	718	$6.3 \pm 6.44_{1}$	917	$6.3 \pm 6.59_{1}$		

^{ab} Column means with different superscripts differ ($P \leq 0.05$; Bonferroni)
$_{12}$ Row means with different subscripts differ ($P \leq 0.05$; Bonferroni)
n is number of primiparous sows farrowed

Season

For the season average of WSI across years, the seasonal differences between primiparous sows farrowed in summer and autumn (P = 0.8603), winter (P = 0.2149) or spring (P = 0.3942) were NS (Table 16). There was no difference in WSI between primiparous sows farrowed in autumn and winter (P=0.1990) or spring (P = 0.3519), nor was there any difference in WSI between primiparous sows farrowed in winter and spring (P = 0.6406) (Table 16). The results of the present study do not support the statement made by Hälli *et al.* (2008) that first heat after farrowing in sows is delayed during summer through autumn, or the seasonal infertility period, because overall the seasonal differences in WSI are not statistically significant. The variation in WSI was too large to show significance due to year effect.

In 2005 the differences in WSI between primiparous sows farrowed in summer and autumn (P = 0.3202), winter (P = 0.0109) or spring (P = 0.2816) were NS (Table 16). Primiparous sows farrowed in autumn 2005 had longer WSI than primiparous sows farrowed in winter 2005 (P = 0.0004), but there was no difference in WSI when compared to primiparous sows farrowed in spring 2005 (P = 0.0431) (Table 16). Differences in WSI between primiparous sows farrowed in winter and spring of 2005 (P = 0.1577) were also NS (Table 16).

In 2006 there was no seasonal difference in WSI between primiparous sows farrowed in summer and autumn (P = 0.7066), winter (P = 0.2833) or spring (P = 0.8634) (Table 16). Differences in WSI between primiparous sows farrowed in autumn and winter (P = 0.5002) or spring (P = 0.5897) in 2006 and between primiparous sows farrowed in winter and spring (P = 0.2152) of 2006 respetively were NS (Table 16).

In 2007 differences in WSI between primiparous sows farrowed in summer and autumn (P = 0.2884), winter (P = 0.3185) or spring (P = 0.9105) and between primiparous sows farrowed in autumn and winter (P = 0.8463) or spring (P = 0.3349) in 2007 were NS (Table 16). Similarly there was no difference in WSI between primiparous sows farrowed in winter and spring (P = 0.3747) of 2007 (Table 16).

Year

For the year average of WSI across seasons, differences between primiparous sows farrowed in 2005 and 2006 (P = 0.0571) or 2007 (P = 0.0256) and in WSI between primiparous sows farrowed in 2006 and 2007 (P = 0.8736) were NS (Table 16).

There was no difference in WSI between primiparous sows farrowed in summer of 2005 and 2006 (P= 0.0327) or 2007 (P = 0.1472) (Table 16). There was no difference in WSI between primiparous sows farrowed in summer 2006 and 2007 (P = 0.3646) (Table 16).

Primiparous sows farrowed in autumn of 2005 had a longer WSI than primiparous sows farrowed in either autumn 2006 (P = 0.0136) or 2007 (P = 0.0021) whereas differences in WSI between primiparous sows farrowed in autumn 2006 and 2007 (P = 0.5714) were NS (Table 16).

There was no difference in WSI between primiparous sows farrowed in winter of 2005 and 2006 (P=0.1388) or 2007 (P = 0.6317) (Table 16). Differences in WSI between primiparous sows farrowed in winter 2006 and 2007 (P = 0.2574) were NS (Table 16).

There was no difference in WSI between primiparous sows farrowed in spring of 2005 and 2006 (P=0.2579) or 2007 (P = 0.7787) and differences in WSI between primiparous sows farrowed in spring 2006 and 2007 (P = 0.3136) were NS (Table 16).

In Table 16 it can be seen that WSI length ranged from 5.7 to 8.3 days depending on the SF and YoF. The generally accepted optimum WSI for multiparous sows is 3 to 5 days according to Poleze *et al.* (2006). The results in Table 16 are consistent with the statement of Tantasuparuk *et al.* (2001) that primiparous sows usually have longer WSI than multiparous sows.

Although not significant, the season average of WSI for farms pooled (Table 16) showed the WSI to be longer for summer and autumn than for winter and spring. This is consistent with the findings of Belstra *et al.* (2004) where number of sows returning to oestrus within the expected time post weaning was lower in summer.

4.3.2 Weaning to service interval for Farm A

Table 17 Weaning to service interval in days (least square means±SD) by season and year of farrowing for Farm A

	Year							
Season	n	2005	n	2006	n	2007	n	Season Average
Summer	110	$7.0\pm5.92^{a}_{1}$	98	$6.3\pm5.08^{a}_{1}$	142	$7.5\pm8.11^{a}_{1}$	350	6.9 ± 6.71^{a}
Autumn	76	$9.0\pm8.29^{a}_{1}$	49	$7.6\pm6.80^{a}_{12}$	94	$5.6\pm9.49^{a}_{2}$	219	7.4 ± 8.53^{a}
Winter	57	$6.6\pm5.50^{a}_{1}$	60	$7.0\pm6.39^{a}_{1}$	131	$6.9\pm5.63^{a}_{1}$	248	6.8 ± 5.77^{a}
Spring	120	$7.1\pm6.75^{a}_{1}$	106	$6.8\pm7.32^{a}_{1}$	144	$8.0\pm7.42^{a}_{1}$	370	7.3 ± 7.17^{a}
Year Average	363	$7.4\pm6.71_{1}$	313	$6.9\pm6.42_{1}$	511	$7.0\pm7.65_{1}$		

^{ab} Column means with different superscripts differ ($P \leq 0.05$; Bonferroni)
$_{12}$ Row means with different subscripts differ ($P \leq 0.05$; Bonferroni)
n is number of primiparous sows farrowed

Season

For the season average of WSI across years, there was no seasonal difference between primiparous sows farrowed in summer and autumn (P = 0.4351), winter (P = 0.8629) or spring (P = 0.4685) (Table 17). Differences in WSI between primiparous sows farrowed in autumn and winter (P=0.3939) or spring (P = 0.8755) and in WSI between primiparous sows farrowed in winter and spring (P = 0.4222) respectively were NS (Table 17).

In 2005 there was no difference in WSI between primiparous sows farrowed in summer and autumn (P = 0.0367), winter (P = 0.6424) or spring (P = 0.9164) (Table 17). There was no difference in WSI between primiparous sows farrowed in autumn and winter (P = 0.0262) or spring (P = 0.0.432) of 2005, similarly differences in WSI between primiparous sows farrowed in winter and spring of 2005 (P = 0.5738) were NS (Table 17).

In 2006 differences in WSI between primiparous sows farrowed in summer and autumn (P = 0.2514), winter (P = 0.4828) or spring (P = 0.5967) were NS (Table 17). There was no difference in WSI between primiparous sows farrowed in autumn and winter (P = 0.6640) or spring (P = 0.4837) of

2006, nor was there any difference in WSI between primiparous sows farrowed in winter and spring of 2006 (P = 0.8110) (Table 17).

In 2007 there was no difference in WSI between primiparous sows farrowed in summer and autumn (P = 0.0332), winter (P = 0.4934) or spring (P = 0.5279) (Table 17). Differences in WSI between primiparous sows farrowed in autumn and winter (P = 0.1527) or spring (P = 0.0090) of 2007 and between primiparous sows farrowed in winter and spring of 2007 (P = 0.2113) respectively were NS (Table 17).

Year

For the year average of WSI across seasons, differences primiparous sows farrowed in 2005 and 2006 (P = 0.3198) or 2007 (P = 0.3395) and between primiparous sows farrowed in 2006 and 2007 (P = 0.8815) respectively were NS (Table 17).

There was no difference in WSI between primiparous sows farrowed in summer of 2005 and 2006 (P= 0.3938) or 2007 (P = 0.5809), nor was there any difference in WSI between primiparous sows farrowed in summer 2006 and 2007 (P = 0.1519) (Table 17).

Differences in WSI between primiparous sows farrowed in autumn of 2005 and 2006 (P=0.2181) were NS (Table 17). Primiparous sows farrowed in autumn 2005 had a longer WSI than primiparous sows farrowed in autumn 2007 (P = 0.0008), but there was no difference in WSI between primiparous sows farrowed in autumn 2006 and 2007 (P = 0.0868) (Table 17).

There was no difference in WSI between primiparous sows farrowed in winter of 2005 and 2006 (P=0.6911) or 2007 (P = 0.7232) and differences in WSI between primiparous sows farrowed in winter 2006 and 2007 (P = 0.9216) were also NS (Table 17).

There was no difference in WSI between primiparous sows farrowed in spring of 2005 and 2006 (P = 0.6916) or 2007 (P = 0.2891), nor was there any difference in WSI between primiparous sows farrowed in spring 2006 and 2007 (P = 0.1720) (Table 17).

Table 18 Percentage return to oestrus by day 10 post-weaning by season by year of farrowing for Farm A

	2005		2006		2007		Season Average	
Season	n	Percentage returned	n	Percentage returned	n	Percentage returned	n	Percentage returned
Summer	110	30	98	31	142	28	350	29
Autumn	76	21	49	16	94	18	219	18
Winter	57	16	60	19	131	27	248	21
Spring	120	33	106	34	144	28	370	31
Total	363	-	313	-	511	-	1187	-

n is the number of sows farrowed

Table 18 shows the percentages of weaned sows returning to oestrus by day 10 post-weaning based on the number of sows farrowed reported in Table 17. Belstra *et al.* (2004) found that the percentages of weaned sows returning to oestrus by day 7 and day by 10 post-weaning were lower in the summer and spring compared to autumn and winter. Results from this study for Farm A (Table 18) are not consistent with the findings of Belstra *et al.* (2004). Across all years the percentages of weaned sows returning to oestrus were lowest in autumn and winter (Table 18). This is also true when 2005, 2006 and 2007 are considered individually and may be explained by the inceased temperature fluctuation for the period between autumn and winter for 2005 (Fig. 4), 2006 (Fig. 5) and 2007 (Fig 6.) for Farm A.

4.3.3 Weaning to service interval for Farm B

Table 19 Weaning to service interval in days (least square means±SD) by season and year of farrowing for Farm B

	Year							
Season	n	2005	n	2006	n	2007	n	Season Average
Summer	81	$8.1 \pm 8.72^{a}_{1}$	89	$5.8 \pm 7.02^{a}_{1}$	128	$5.8 \pm 6.87^{a}_{1}$	298	6.6 ± 7.46^{a}
Autumn	146	$7.5 \pm 6.90^{a}_{1}$	70	$5.2 \pm 7.31^{a}_{1}$	61	$6.2 \pm 4.38^{a}_{1}$	277	6.3 ± 6.54^{a}
Winter	100	$4.8 \pm 3.41^{b}_{1}$	122	$6.9 \pm 7.66^{a}_{1}$	86	$5.1 \pm 3.18^{a}_{1}$	308	5.6 ± 5.56^{a}
Spring	48	$6.4 \pm 6.49^{ab}_{1}$	124	$5.1 \pm 3.49^{a}_{1}$	131	$5.2 \pm 2.86^{a}_{1}$	303	5.6 ± 3.90^{a}
Year Average	375	$6.7 \pm 6.63_{1}$	405	$5.8 \pm 6.46_{1}$	406	$5.6 \pm 4.76_{1}$		

^{ab} Column means with different superscripts differ ($P < 0.05$; Bonferroni)
$_{12}$ Row means with different subscripts differ ($P < 0.05$; Bonferroni)
n is number of primiparous sows farrowed

Season

For the season average of WSI across years, seasonal differences between primiparous sows farrowed in summer and autumn (P = 0.6394), winter (P = 0.1369) or spring (P = 0.0912) were NS (Table 19). There was no difference in WSI between primiparous sows farrowed in autumn and winter (P=0.3301) or spring (P = 0.2612), nor was there any difference in WSI between primiparous sows farrowed in winter and spring (P = 0.9440) (Table 19).

In 2005 differences in WSI between primiparous sows farrowed in summer and autumn (P = 0.5797) or spring (P = 0.1714) were NS, whereas primiparous sows farrowed in summer had a longer WSI than primiparous sows farrowed in winter (P = 0.0019) (Table 19). Primiparous sows farrowed in autumn 2005 had a longer WSI than primiparous sows farrowed in winter (P = 0.0040), but there was no difference in WSI when compared to primiparous sows farrowed in spring (P = 0.3249) of 2005 (Table 19). Differences in WSI between primiparous sows farrowed in winter and spring of 2005 (P = 0.1686) were NS (Table 19).

In 2006 there was no difference in WSI between primiparous sows farrowed in summer and autumn (P = 0.5372), winter (P = 0.4155) or spring (P = 0.4717) (Table 19). Differences in WSI between primiparous sows farrowed in autumn and winter (P = 0.1952) or spring (P = 0.9708) of 2006 and between primiparous sows farrowed in winter and spring (P = 0.1597) of 2006 respectively were NS (Table 19). The percentages of weaned sows returning to oestrus by day 10 post weaning were lower in summer and autumn compared to winter and spring of 2006 (Table 20) unlike the results reported by Belstra *et al.* (2004) which showed lower percentages of weaned sows returning to oestrus in summer and spring compared to autumn and winter.

In 2007 there was no difference in WSI between primiparous sows farrowed in summer and autumn (P = 0.7412), winter (P = 0.4686) or spring (P = 0.4589) (Table 19). There was no difference in WSI between primiparous sows farrowed in autumn and winter (P = 0.3939) or spring (P = 0.3810) of 2007, nor were differences in WSI between primiparous sows farrowed in winter and spring (P = 0.9461) of 2007 significant (Table 19).

Year

For the year average of WSI across seasons, there was no difference between primiparous sows farrowed in 2005 and 2006 (P = 0.0971) or 2007 (P = 0.0322), nor was there any difference in WSI between primiparous sows farrowed in 2006 and 2007 (P = 0.7271) (Table 19).

Differences in WSI between primiparous sows farrowed in summer of 2005 and 2006 (P= 0.0403) or 2007 (P = 0.0203) and between primiparous sows farrowed in summer 2006 and 2007 (P = 0.9622) respectively were NS (Table 19).

There was no difference in WSI between primiparous sows farrowed in autumn of 2005 and 2006 (P=0.0199) or 2007 (P = 0.2369), nor was there any difference in WSI between primiparous sows farrowed in autumn 2006 and 2007 (P = 0.4220) (Table 19).

There was no difference in WSI between primiparous sows farrowed in winter of 2005 and 2006 (P = 0.1018) or 2007 (P = 0.7457), nor were differences in WSI between primiparous sows farrowed in winter 2006 and 2007 (P = 0.1719) significant (Table 19).

Differences in WSI between primiparous sows farrowed in spring of 2005 and 2006 (P = 0.2644) or 2007 (P = 0.2702) and between primiparous sows farrowed in spring 2006 and 2007 (P = 0.9425) were NS (Table 19).

Table 20 Percentage return to oestrus by day 10 post-weaning by season by year of farrowing for Farm B

	2005		2006		2007		Season Average	
Season	n	Percentage returned	n	Percentage returned	n	Percentage returned	n	Percentage returned
Summer	81	22	89	22	128	32	298	25
Autumn	146	39	70	17	61	15	277	23
Winter	100	27	122	30	86	21	308	26
Spring	48	13	124	31	131	32	303	26
Total	375	-	405	-	406	-	1186	-

n is the number of sows farrowed

Table 20 shows the percentages of weaned sows returning to oestrus by day 10 post-weaning based on the number of sows farrowed reported in Table 19. Results from this study for Farm B (Table 20) are not consistent with the findings of Belstra *et al*. (2004). The season average across all years the percentages of weaned sows returning to oestrus were numerically lowest in autumn (Table 20).

For 2005 (Table 20) the results are consistent with the findings of Belstra *et al.* (2004). These results cannot be explained by temperature fluctuations, since the temperature fluctuation was lowest during summer and greatest in spring with increased fluctuation in temperature occuring between autumn and winter of 2005 (Fig. 4).

For 2006 and 2007, the lowest percentages of weaned sows returning to oestrus post-weaning occured in autumn and winter (Table 20) unlike the results of Belstra *et al.* (2004). For 2006, this may be explained by the inceased temperature fluctuation for the period between autumn and winter for that year (Fig. 5), but the temperature fluctuation was relatively stable during autumn, winter and spring during 2007 for the area surrounding Farm B (Fig. 6), therefore no obvious conclusions about the percentages of weaned sows returning to oestrus post-weaning could be drawn based on outdoor temperature fluctuations alone.

Although it has been established that gilts are the most sensitive group within the breeding herd, the lack of literature focusing solely on early partity productivity was apparent during this study. Much of the literature investigating the factors influencing sow productivity only included the measurement of first parity productivity in the context of investigating how management of the a gilt could promote longevity within the productive herd through the comparison of gilt productivity with the productivity of multiparous sows.

CHAPTER 5

CONCLUSION

The objective of this study was to analyse first parity productivity records over a determined time period of three years from two selected commercial pig production units on the Highveld, one situated in the Cullinan area of Gauteng Province and the other situated near Bela Bela in Limpopo Province, and to determine whether seasonal differences in productivity occur in relation to seasonal temperature fluctuations, and whether there is a difference in seasonal productivity between farms.

A limiting factor of this study was the absence of other data of nutrition and general management procedures. The analytical observations made and conclusions drawn were on the noted parameters only and could not be placed in perspective to these influences. It was assumed that the peripheral management was basically the same on both herds.

There were seasonal differences in productivity between years, within years and between farms of production but were not necessarily directly linked to the seasonal temperature fluctuations in all cases. It was found that the farms on which gilts were raised prior to entering the productive herd (FoB) influenced AFS significantly and that gilts born in autumn were younger at first service than gilts born in winter and spring.

Litter size was not influenced by the number of services before successful conception nor the season in which the gilts were first served. There were fewer piglets born (TB) from gilts served in 2006 than from gilts served in 2005 or 2007, but there was no difference in number of piglets born alive (BA) between years. The production of piglets differed between farms for seasons and years. There was a seasonal difference in first parity productivity although contrary to expectations, it was not necessarily related to the seasonal temperature fluctuations of the area surrounding the farms. This was apparent from the lower litter size recorded on Farm A compared to Farm B, despite the area in which Farm B is situated having overall higher day temperatures and greater temperature fluctuations than the area in which Farm A is situated.

There were no significant seasonal differences in WSI reported but the results of this study showed an increase in return rate of gilts served during summer more than in any other season. This is consistent with expectations that productivity can be compromised during the hot months of the year.

Based on the results of this study, the null hypothesis of this study is that there are no seasonal differences in first parity productivity occuring in relation to seasonal temperature fluctuations was not rejected, whereas the null hypothesis stating that there is no difference in seasonal productivity between production farms situated in different areas of the Highveld was rejected.

CHAPTER 6

CRITICAL EVALUATION AND RECOMMENDATION

6.1 Critical evaluation

This study was limited to an attempt at drawing links between seasonal temperature fluctuations in two areas on the Highveld and the first parity productivity on the farms situated in the respective areas, as well as investigating the difference in productivity between farms. Aspects of management surrounding feeding, grouping and herd health were not included in this study and further research is required to determine the impact of management on productivity.

Differences in productivity between production farms could have been due to differences in oestrus detection efficiency, which was not included as a parameter in this study. Comparison of productivity of production units in Limpopo province and in the Western Cape may reveal an effect of photoperiodism and summer infertility on first parity productivity. Ideally further study using controlled lighting and temperature conditions is required to determine the impact of seasonal temperature and light fluctuations on reproductive performance of sows.

Feed compostition and feed intake were not the focus of this study and thus information on feeding management was not included in the parameters of this study. Due to the lack of this additional information, no meaningful conclusions could be made from this study about what influence feeding practices may have had on the reproductive parameters of the primiparous sows.

The potential implications of selecting for an animal with high voluntary intake and low fat deposition are that management strategies must be adapted to allow these genetically lean animals to reach their genetic potential as well as allowing for the economic production of offspring with great potential for growth. The increased feed intake of the sow during lactation is beneficial in preventing excessive loss of body condition, which is important in maintaining a short WSI. It should be mentioned that there is a possibility that genetically lean gilts and sows could be more sensitive to seasonal infertility than conventional pig breeds, thus requiring greater attention especially in the hotter months of the year. In this study all gilts were of the same synthetic genetic line thus sufficient information was not available to investigate whether genetically lean gilts are more sensitive to seasonal infertility than conventional pig breeds under the production conditions found in these specific areas in the Highveld.

In the tropics, where high temperatures and high humidity are the main problems, efficient cooling systems were advised to prevent boar reproductive efficiency from decreasing during hot months

(Kunavongkrit *et al.*, 2005). It was found that ambient temperature above 29 ^{o}C adversely affected the ability of the heat transfer mechanisms of boars and affected normal sperm output (Stone, 1982). Cooling mechanisms are generally restricted to AI facilities and stud farms owing to the high input costs of such housing facilities. Boar line was excluded from the models due to insufficient variation in the data set and so it was not possible to test for the seasonal influence of boar line on litter size. Differences in litter size and its components (TB, BA, BD and GA) could have been due to boar effect as well as a boar by year interaction. Further study including boar line as a parameter is needed to determine the effect of boar line on litter size.

6.2 Recommendations

To promote production of consistently large litters of viable piglets and heavy weaners, replacement gilts should be selected from dams with good temperament, having farrowed large litters, and through an adequate milk production having weaned heavy litters.

With open-sided housing there is not much one can do to reduce the ambient temperature of the house at a low cost. It is recommended that management be adjusted to promote efficient oestrous detection, since strong oestrous behaviour is not always obvious in the gilt (Sterning, 1995). It was reported by Levis (1997) that a greater proportion of gilts showed standing oestrus at 6:00 than at noon or 18:00, so checks should be done in the morning and where possible, gilts should be scheduled for AI during the cooler hours of the day to avoid overheating. Anticipating the problem of seasonal infertility and increasing the service protocol from two services to three services per gilt during the hotter months may improve conception rates. It is also important to ensure that there is sufficient space per gilt in the pen, access to fresh water at all times and gentle handling especially pre- and post-service to reduce stress as much as possible in an effort to promote successful conception and avoid embryo loss. Increasing the pool of replacement gilts to compensate for a high return rate during summer may be an option, provided there is enough space to prevent overstocking of the gilt pens and to cope with the additional number of piglets that will be farrowed and weaned.

Gestational nutrition for gilts should be such to promote healthy development and attainment of healthy birth weights of the piglets, as well as ensuring adequate BCS of the gilt at farrowing without compromising appetite during lactation.

In the farrowing house, provision of heating for the piglets will allow the ambient temperature to be kept optimal for sow comfort and thus WSI is not expected to be delayed due to heat stress (Kemm, 1993). It was found that provision of chilled water of 15^{o}C to lactating sows during periods of high ambient temperatures improved the performance of the sow and the litter, presumably through promoting better appetite and voluntary feed intake by the sow during lactation (Jeon, Yeon, Choi, Min, Kim, Kim & Chang, 2006).

Further research is recommended to investigate the high piglet mortality rate on Farm A, with a focus on feeding and breeding management as well as herd health in addition to temperature and seasonal effects. On-farm historical minimum and maximun daily temperatures were unavailable for this study and thus temperature data from SAWS of the areas surrounding the production units was used. This could have accounted for the non-significant seasonal differences in productivity observed in this study. It is recommended that for further studies, the outdoor and indoor daily minimum and maximum temperatures are recorded for the specific location of the production unit used in the study, across the period of time coinciding with the period of production of the herd studied. This is to allow for more meaningful conclusions to be drawn about seasonal infertility within a herd in a specific area over a specific period of time.

Inclusion of parity may be useful in addressing whether piglet mortality is a problem in first-parity sows alone or whether it occurs in multiparous sows, or even if it recurs in a particular sow in later parities. Results of such a study have the potential to be useful in improving management of the ‘high-risk’ sow groups to reduce piglet losses. Supervised farrowing during the perinatal period may help to improve piglet survival during and immediately after birth by ensuring each piglet is breathing, receives adequate colostrum and is guided toward the heat source to prevent crushing.

CHAPTER 7

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