EFFECTIVENESS AND ECONOMICS OF BOVINE SOMATOTROPIN USE TO ENHANCE CONCEPTION IN DAIRY HERDS EXPERIENCING SEASONAL HEAT STRESS

By

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To the most encouraging and inspirational people in my life:
Gale and Alison Bell

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There were two main objectives to the thesis. The first was to estimate the effects of bovine somatotropin (bST) on first insemination conception risk (CR) of lactating cows experiencing heat stress. The second objective was to estimate the economic value of increased first insemination CR as a result of bST administration and to identify the most beneficial time of the year to apply bST. To determine the biological effects of bST on first insemination CR, a field study was performed in the summer in Florida. Cows experiencing heat stress were subjected to an ovulation synchronization protocol for first insemination. Cows treated with bST received a single injection 3 days before insemination. Control cows received no bST. As expected, bST administration did not increase vaginal temperature. Bovine ST administration did not significantly increase the proportion of inseminated cows diagnosed pregnant although it was numerically greater for the bST group (24.2% vs. 17.8%, 124 vs. 132 cows per group). Fewer control cows tended to have high plasma progesterone concentrations ($\geq$ 1 ng/ml) at Day 7 after insemination than cows administered bST (72.6 vs. 81.1%). When only cows that were successfully synchronized were considered, the magnitude of the absolute difference in the

percentage of inseminated cows that were diagnosed pregnant between bST and control cows was reduced (24.8 vs. 22.4% pregnant for bST and control, respectively).

For the second objective, a computer model of a dairy farm was used to estimate the economic benefit of bST. Typical conditions in Florida were assumed, including seasonality of milk production and CR. Administration of a single injection of bST ($6 per dose) was incorporated into a first insemination TAI protocol. CR increases of 0, 4, 8, and 12 percentage points were compared to not using bST under various scenarios including changes in prices, management, and seasonal conditions. The scenarios simulated bST administration during individual months of the year. Months where bST administration resulted in gains in profit were combined to create extended administration periods of several months. The optimal extended administration period was identified for each scenario. Financial results and herd statistics were compared. The optimal extended administration period at the 4 percentage point level of CR increase for the scenario with all of the default inputs was February to June with a $0.80 per slot per year gain. The scenario with the greatest gain ($10.57) with its optimal extended administration period was the scenario simulating overall reduced CR by 5% at the 12 percentage point level of increase of first insemination CR. When no seasonality in milk production was assumed, administration of bST was profitable year round at any level of CR increase greater than or equal to 8 percentage points.

The results of the two studies indicate that bST administration to enhance conception risk is not successful, either biologically or economically, in dairy herds experiencing heat stress and with seasonal patterns of reproduction. More research should be conducted to clarify the economic benefits of improving reproductive efficiency in seasonal dairy herds.

CHAPTER 1
INTRODUCTION

Dairy cattle fertility is greatly reduced during times of heat stress (Faust et al., 1988; Ray et al., 1992; Thompson et al., 1996; Wolfenson et al., 2000) such as experienced during the summer months in Florida. Conception risk (CR) can decrease by as much as 30 to 40 percentage points in hot summer months (Cavestany et al., 1985). Consequences of decreased cow fertility include increased calving interval and decreased profitability (Plaizier et al., 1997).

Treatment of lactating cows with recombinant bovine somatotropin (bST) is used to increase milk yield under thermoneutral and heat-stress conditions (Soderholm et al., 1988; Zoa-Mboe et al., 1989; West et al., 1990; Jenny et al., 1992; Elvinger et al., 1992; Jousan et al., 2007). Bovine ST can also affect fertility, but the consequences are unclear. Several studies show a decrease in fertility associated with bST (Esteban et al., 1994a; Esteban et al., 1994b). Other studies show a benefit of bST (Moreira et al., 2000; Moreira et al., 2001) or no change (Santos et al., 2004; Blevins et al., 2006; Jousan et al., 2007) on first insemination CR when cows were inseminated using a timed artificial insemination (TAI) protocol. Treatment with bST CR for repeat-breeder cows bred at estrus (Morales-Roura et al., 2001).

Bovine ST might be particularly effective at increasing fertility during periods of heat stress. Insulin-like growth factor-1 (IGF-1), secreted in response to bST (McGuire et al., 1992; Jousan et al., 2007), has thermoprotective properties and can reduce the effect of elevated temperature on development and apoptosis of cultured bovine embryos (Jousan and Hansen, 2004; Jousan and Hansen, 2007). Even though administration of bST during heat stress increased IGF-1, there was no effect of bST on pregnancy rate in the one experiment that examined bST effects on fertility during heat stress (Jousan et al., 2007). The authors proposed that the repeated use of bST and subsequent increase in body temperature contributed to the lack of improvement of fertility (2007). The first objective, described in Chapter 3, was to determine the effect of a single injection of bST prior to first insemination on fertility during heat stress.

Increasing first insemination CR, through implementation of TAI, was shown to be more profitable during the summer than winter (Risco et al., 1998). Implementing TAI at first insemination during the summer to increase pregnancy rates increased net revenue by about $17.00 to 25.00 per cow per year (De la Sota et al., 1998; Risco et al., 1998). It was concluded that OvSynch had a greater impact on net returns during the summer because the value of a marginal increase of pregnancy rate was greater when fertility was low (Risco et al., 1998). De Vries (2007) showed that increasing pregnancy rate was more profitable when reproductive performance was low. The marginal value of increased pregnancy rates decreases at higher levels of pregnancy rates. After pregnancy rates reached 35% there was almost no benefit to net revenue (Risco et al., 1998).

The second objective of the study, described in Chapter 4, was to the estimate the profitability of bST administration at first insemination in lactating dairy cows submitted to a TAI program. The third objective, also in Chapter 4, was to determine the most profitable time period of the year to administer bST at first insemination when milk production and fertility are reduced in the summer as a result of heat stress.

CHAPTER 2
REVIEW OF THE LITERATURE

Decline in Reproductive Performance

Many indices have been used to evaluate reproductive function, including days to first service, estrus-detection rate, services per conception, calving interval, conception rate, pregnancy rate, and days open (also known as days to conception). There is extensive work to show that reproductive function in dairy cattle has declined in the last century within and outside the US. Days to first service has increased from 84 to 100 from 1985 to 1999 in Southeastern Holstein herds (Washburn et al., 2002) and from 90 to 94 days in Ohio from 1992 to 1998 (Rajala-Schultz and Frazer, 2003). Estrus-detection rate decreased from 51 to 42% in Southeastern Holstein herds from 1985 to 1999 and services per conception increased from 1.9 to 3.0 during the same time period (Washburn et al., 2002). Similar results were reported by Lucy in 2001. In addition, Lucy (2001) reported that calving interval increased from 13.4 to 14.8 mo during the period from 1970 to 1999. Conception rate also decreased in New York (Butler, 1998) and Kentucky (Silvia, 1998) as well as Australia (MacMillian, 1996), Ireland (Roche, 2000), and the United Kingdom (Royal, 2000). In addition, days open increased from 126 to 169 from 1976 to 1999 (Washburn et al., 2002) while days to conception increased from 136 to 151 between 1992 and 1998 (Rajala-Schultz and Frazer, 2003). Lucy (2001) suggested that reduced reproductive performance can be attributed to increased milk production, changes in management trending towards larger herds, inbreeding, and an increase in global warming and the effects of heat stress on lactating cows.

Economic Effects of the Decline in Reproductive Performance

Reduced reproductive performance has been associated with reduced profitability (Hady et al., 1994; Pecsok et al., 1994; Plaizier et al., 1998; Risco et al., 1998). Reduced reproductive performance results in increased days open which has been linked to reduced profitability (Louca and Legates, 1967; Schaeller and Henderson, 1971). Reduction in reproductive performance contributes to reduced milk per cow per day over herd life, reduced number of replacements produced, increased voluntary and involuntary culling, (Britt, 1985) and increased breeding costs (Plaizer, 1997). By reducing days open, the proportion of the cow's life spent in the most profitable part of the lactation curve can be maximized (Le Blanc, 2007). If artificial insemination is being utilized, as in most dairy herds, the rate of genetic progress for traits of economic importance is reduced (Plaizier, 1997).

Improving reproduction can have considerable value. Under French conditions, a 1 percentage point absolute change was estimated to increase profit between 10 and 20 FF per cow per year (Biochard, 1990). In Canada, value of a new pregnancy was estimated to be between $300-600 CDN (Le Blanc, 2007). In addition, the average value of a new pregnancy was estimated to be $278 (De Vries, 2006a) and the value of a 1 percentage point change in pregnancy rate was estimated to be between $3.31 and $32.04 per cow per year, depending on the level of reproductive performance of the herd. Herds with lower pregnancy rate to prior to the 1 percentage point improvement experienced greater gains (De Vries, 2007). Similarly, Le Blanc reports that Overton estimated that as PR increased from 10 to 12% there was a $66 benefit, as PR increased from 18 to 20% there was a $21 benefit, and as PR increased from 24 to 26% there was a $8 benefit (Le Blanc, 2007). Improving only estrus detection rate (and thus improving PR by about one third) by 1 percentage point increased net revenue by as much as $22.50 CDN per cow per year when estrus detection rate was 35% (Plaizier et al., 1998).

Effects of Seasonality of Reproduction

There is significant seasonal reduction of reproductive performance, especially during the summer months in the Southeastern United States (Gwazdauskas et al., 1975; Badinga et al., 1985; Cavestany et al., 1985; Al-Katanani et al., 1999; Oseni et al., 2003; De Vries and Risco, 2005). In addition, fertility of lactating dairy cows is reduced in other warm regions of the United States, such as Arizona (Ray et al., 1992) and Texas (Thompson et al., 1996), and other regions around the world, such as Australia (Orr et al., 1993), Spain (Lopez-Gatius, 2003), and Israel (Zeron et al., 2001). Reduction in reproductive performance is also seen in cool regions, such as Minnesota, during times of hot weather (Udomprasert and Williamson, 1987). One way that this reduction of reproductive performance manifests itself is through an increase in days open. The Southeastern region has the highest days open (155 d) compared to the average for all states (142 d) (Oseni et al., 2003). This increase in days open can be due to reduced reproductive performance but also managers' decisions to avoid breeding during this time of heat stress (Oseni et al., 2003).

Causes of Reduction in Reproductive Performance due to Heat Stress

Heat stress decreases conception risk and subsequent pregnancy rate through decreased estrus behavior, altered follicular and embryonic development, and changes to the reproductive tract. Elevated environmental temperatures decrease estrus behavior. Lactating Holsteins had decreased mounts per estrus from winter (8.6) to summer (4.5) (Nebel et al., 1997). In addition, there were more undetected estrus periods on a Florida dairy from June to September (76 to 82%) than October to May (44 to 65%) (Thatcher and Collier, 1986).

Exposure of lactating cows prior to AI to heat stress was associated with reduced conception risk (Chebel et al., 2004). This may be due to disrupted patterns of follicular development and dominance or oocyte competence. Heat stress can result in a smaller follicle (Badinga et al., 1993) and can decrease estrogen concentrations (Gilad et al., 1993; Wolfenson et al., 1995; Wilson et al., 1998). The luteinizing hormone surge associated with ovulation is also reduced during heat stress (Gwazdauskas et al., 1981). In addition, damage to the follicle from heat stress could affect the resultant corpus luteum and progesterone secretion. Progesterone concentration decreased during the summer months in lactating dairy cows (Wolfenson et al., 1993; Howell et al., 1994; Sartori et al., 2002a).

Heifers superovulated and exposed to heat stress prior to insemination had a reduced proportion of embryos classified as normal when the uterus was flushed (Putney et al., 1989c). Maturing oocytes are susceptible to damage from elevated temperature. Exposing *in vitro* matured oocytes to elevated temperature reduced the capacity of the resultant embryo to reach the blastocyst stage of development (Edwards and Hansen, 1996; Ju et al., 1999; Payton et al., 2004; Edwards et al., 2005; Ju et al., 2005). In other in vitro systems, fertilization rate was reduced by elevated temperature (Roth and Hansen, 2004a,b). Elevated temperature during maturation has resulted in alteration of normal development of the oocyte by reducing the proportion of oocycets that completed nuclear maturation (Payton et al., 2004; Roth and Hansen, 2005), increasing abnormal spindle formation (Ju et al., 2005; Roth and Hansen, 2005), and increasing the proportion that had apoptotic pronuclei (Roth and Hansen, 2004a,b; 2005). Furthermore, oocytes reached maturation more quickly after exposure to heat stress (Edwards et al., 2005).

The newly formed embryo is also susceptible to heat stress. Females exposed to heat stress during early pregnancy (Days 0-3 and Days 0-7 after insemination) had reduced embryonic survival (Dunlap and Vincent, 1971; Putney et al., 1989a). In addition, heat stress causes blood from the internal organs, including the ovary, oviduct, and uterus, to be redirected to the periphery resulting in decreased distribution of nutrients and hormone to the reproductive tract (Roman-Ponce et al., 1978).

Timed Artificial Insemination

The proportion of cows pregnant can be improved by increasing number of cows submitted for breeding. One way to achieve this is through timed artificial insemination (TAI). The most well researched method to eliminate estrus detection and increase the number of inseminations is the implementation of a TAI protocol such as OvSynch (Rabiee et al., 2005). OvSynch uses exogenous hormones to synchronize ovulation. OvSynch allows producers to eliminate estrus detection and breed at a set time (Pursley et al., 1997). The basic OvSynch protocol (Pursley et al., 1995) is comprised of an initial gonadotropin releasing hormone (GnRH) injection to cause ovulation of any dominant follicles, initiating a new follicular wave. After 7 days, an injection of prostaglandin $F_{2\alpha}$ is administered, causing regression of any corpus lutea present on the ovary. Forty eight hours later, another GnRH injection is administered, causing ovulation of dominant follicles approximately 30 hours later. Insemination can be scheduled for 20 hours after this injection (Pursley et al., 1995). There are many variations on this protocol. One of the more frequently used modifications of OvSynch prescribes administration of the second GnRH concurrent with insemination (Portaluppi and Stevenson, 2005).

When using a TAI protocol, it is often helpful to insure tighter synchrony by preceding the OvSynch portion of the protocol with presychronization period of 2 injections of GnRH given 14 days apart with the second injection given 12 days prior to the first GnRH injection of the OvSynch (Portaluppi and Stevenson, 2005). While implementing TAI may initially decrease the conception risk, the number of cows submitted for breeding increases. Fetrow and Eicker created a partical budget outlining the change from estrus detection combined with estrus synchronization to TAI and calculated that when PR increases from 13 to 20% due to implementation of a TAI protocol, there is a $30/cow benefit (Le Blanc, 2007).

Strategies to Increase Pregnancy Rate during Heat Stress

There have been many methods and techniques presented to improve pregnancy rate during heat stress. Cooling has been widely adopted at the farm level to counteract or prevent the effects of heat stress. Reduction of heat stress via cooling has been shown to increase pregnancy rates (Thatcher et al., 1974; Roman-Ponce et al., 1977; Wolfenson et al., 1988; Ryan et al., 1993; Ealy et al., 1994; Khongdee et al., 2006). However, there are still large seasonal decreases in reproductive performance despite cooling methods (Hansen and Arechiga, 1999). Another attempt to increase fertility of lactating dairy cows during the summer is to increase the concentration of progesterone post-ovulation. This had been achieved by gonadotropin releasing hormone (GnRH) administration with mixed results. GnRH administration has increased pregnancy rates and progesterone levels (Ullah et al., 1996; Peters et al., 2000; Block et al., 2003; Wilard et al., 2003; Franco et al., 2006) but has also resulted in no improvement of pregnancy rates or reduced pregnancy rates (Schmitt et al., 1996; Franco et al., 2006).

Another suggested technique to improve pregnancy rate in the summer is to use embryo transfer (ET) or *in vitro* production (IVP) of embryos. Bovine embryos gain tolerance of heat stress as they mature (Ealy et al., 1993; Ealy et al., 1995; Edwards and Hansen, 1997). Therefore, performing ET can result in greater pregnancy rates in summer than artificial insemination or timed artificial insemination (Putney et al., 1989b; Ambrose et al., 1999; Drost et al., 1999; Al-Katanani et al., 2002a).

Actions of Bovine Somatotropin

Another proposed method to improve pregnancy rate is the use of bovine somatotropin. Bovine ST is available as a recombinant protein in a sustained release formulation (Posilac, Monsanto) and is administered every two weeks to increase milk yield (Lotan et al., 1993; Newbold et al., 1997; Tarazon-Herrera et al., 1999, 2000; Keister et al., 2002; Santos et al., 2004b). There are several direct and indirect actions of bST that lead to this increase in milk production. IGF-1 is produced in the liver as a response to GH (Newbold et al., 1997; Bilby et al., 1999; Cushman et al., 2001). After treatment with bST, more energy is taken up and used by the mammary system. Availability of glucose is increased by a decrease in storage of glucose in the muscle and by an increase of gluconeogenisis in the liver (Peel and Bauman, 1987; Miller et al., 1991; Bauman, 1992, 1999; Bauman and Vernon, 1993). In addition, there are changes in the adipose tissue as a result of bST that change the nutrient use over time. If there is a negative energy balance, glucose is released from glycerol during increased lipolysis (Peel and Bauman, 1987; Miller et al., 1991; Bauman, 1992, 1999; Bauman and Vernon, 1993). In addition, there is a reduction in lipogenesis in body tissue, allowing more free fatty acids to be used in milk fat production (Etherton et al., 1993; Etherton and Bauman, 1998). More amino acids are made available for milk protein synthesis by reducing protein turnover and amino acid oxidation (Peel and Bauman, 1987; Bauman, 1992, 1999; Bauman and Vernon, 1993). In addition, lactating cows treated with bST have increased feed intake (Peel and Bauman, 1987; Hartnell et al., 1991; Bauman, 1992, 1999; Gibson et al., 1992; Bauman and Vernon, 1993; Lotan et al., 1993; Renaville et al., 2002). All of these mechanism lead to net increases in milk production. Increased milk production and increased feed intake could result in increased body temperature. Lactating, bST-treated cows had increased rectal temperature (Vicini et al., 1990; West et al., 1990a; Elvinger et al., 1992; Jousan et al., 2007).

Effect of Bovine Somatotropin on Reproduction

Treatment with bST has been shown to reduce fertility caused by increased expression of silent estrus, increased incidence of cystic ovaries, increased proportion of cows with delayed uterine involution, and increased proportion of anestrus cows (Esteban et al., 1994b). However, more recent work has suggested that IGF-1 and bST can be beneficial to reproduction. ST has been partially implicated in the regulation of reproduction. Somatotropin in general works to regulate ovarian function, embryo development, and uterine function. The ovary responds to ST by altering patterns of follicular growth and development (de la Sota et al., 1993), increasing estrogen production (Lucy et al., 1993), and increasing the number of follicles smaller than 10 mm (Kirby et al., 1997). In addition, treatment of the cow with ST can result in a heavier corpus luteum (Lucy et al., 1995). IGF-1 increases *in vitro* progesterone secretion by luteal cells (Sauerwein et al., 1992). Effects on ST and IGF-1 on the formation of follicles and CL suggest the formation of a more competent embryo. Indeed, cows supplemented with bST and superovulated and inseminated, the proportion of embryos that developed to blastocyst stage were increased (Moreira et al., 2002b). *In vitro* studies performed by the same group found increased cell numbers of blastocyst produced under the influence of IGF-1 (Moreira et al., 2002a). Administration of IGF-1 to bovine embryos produced *in vitro* reduced the effects of heat stress on development and apoptosis (Jousan and Hansen, 2004; 2007). Effects of ST and IGF-1 on the embryo would suggest a more viable embryo with a greater potential for survival. In addition, bST treatment increased conceptus size and conceptus IFN-τ production at Day 17 post insemination (Bilby et al., 2004). Embryonic IFN- τ plays a role in establishment of pregnancy by inhibiting endometrial $PGF_{2\alpha}$ (Guzeloglu et al., 2004). Perhaps cows supplemented with bST would be more apt to form and maintain a pregnancy, decreasing early embryonic losses.

Practical Application of Bovine Somatotropin to Increase Conception Risk

While there is potential for bST and IGF-1 to affect reproduction at a cellular and an organism level, the results on a herd level are inconsistent. Early studies indicate bST is deleterious to reproduction, including decreased 305 d pregnancy rate and increased days to conception (Esteban et al., 1994a). Furthermore, pregnancy rate increased when bST administration was discontinued (Esteban et al., 1994a). Decreased estrus activity has been implicated as one of the reasons pregnancy rate is reduced in cows administered bST.

Recent studies of TAI combined with bST administration have shown increased conception risk (Moreira et al., 2000; 2001) or decreased pregnancy losses (Santos et al., 2004). Unfortunately, these studies have not been consistently repeated. Moreira et al. (2000) administered bST to first service cows at the beginning of a TAI protocol (OvSynch). The 45 d conception rate increased from 22.1% in the control group to 37.7% as a result of bST administration. In the follow-up study by the same group, cows were synchronized by either the OvSynch protocol or the OvSynch protocol preceded by a pre-synchronization period. bST was either administered 10 days prior to insemination (63d, same time period as previous study) or at the time of insemination (73d). While the initial Moreira study indicated that eliminating estrus detection through the use of OvSynch would be the key to harnessing the reproductive benefits of bST, this follow up study failed to support this hypothesis. There was no difference in conception risk in the control group (30.1%), the 63d bST group (29.4%), or the 73d bST group (28.1%). However, the addition of the PreSynch to the OvSynch proved to be valuable. In this study there was a PreSynch x bST interaction effect on conception risk: administration of bST increased conception risk at both 63 d (45.4%) and 73 d (48.6%) over the control (33.6%). In addition, when only cycling cows are considered, bST has a significant effect on conception risk, peaking at 58.2% for the OvSynch bST group (Moreira et al., 2001). The second Moreira study indicates that increasing the degree of ovulation synchronization caused more cows to respond favorably to the bST administration. A third study was conducted by Santos et al. (2004) comparing the PreSynch/OvSynch protocol to AI after estrus detection (ED). It was expected that bST would be more effective at increasing chance of conception in the TAI group than in the

ED group. However, there was no significant effect of bST on conception risk. In fact, the only beneficial effect of bST was actually exhibited in the ED group which experienced fewer early pregnancy losses between day 31 and day 45 (4.2% for ED/bST, 15.1% for ED/control, 12.2% for TAI/bST, 13.3% for TAI/control).

Blevins et al. (2006) administered bST biweekly as recommended to increase milk yield. There was no difference seen in conception risk between control and bST group. Cows were insemination after observation of estrus or at a specific TAI. Milk yield was increased by bST and may have prevented a positive effect of bST on conception risk.

Morales-Roura et al. (2001) administered bST to repeat breeder cows and increased conception risk. Repeat breeder cows were defined as cows with three or more unsuccessful inseminations. Cows were administered bST 12 hours prior to insemination and again 10 days later. Cows were inseminated 12 hours after first being observed in estrus. bST administration increased conception risk from 16.9% to 29.3%. bST was particularly effective in cows with eight or more previous inseminations and with between two and four inseminations. This study was performed in Mexico in a region were the climate is temperate and sub-humid.

Previous work *in vivo* and *in vitro* suggests that bST could be particularly effective in cattle experiencing heat stress. Jousan et al. (2007) hypothesized that administering bST during the summer months prior to insemination and continuing throughout gestation may increase conception risk, decrease embryonic loss, and ultimately increase the proportion of cows pregnant. bST was administered 17 days prior to insemination; between the PreSynch and OvSynch portions of the TAI protocol. In addition, body temperature was collected. Administration of bST increased both rectal and vaginal temperatures. Administration did not affect first service conception risk, second service conception risk, or pregnancy loss between day 36 and 45-80 at either service. It was speculated that bST did not increase conception risk or decrease pregnancy losses because effects of bST on body temperature counteracted beneficial effects on fertility.

It is suspected that bST could positively affect reproductive performance in heat stressed cattle because of the thermoprotective effects of bST and IGF-1 on the oocyte and embryo as well as positive effects on uterine environment and hormone function (Bilby et al., 2004). However, continuous administration of bST every two weeks as recommended may have deleterious effects on reproduction through the actions of increased temperature. Perhaps the negative effects of bST and body temperature could be minimized by a single administration of bST prior to insemination. This would minimize the period the oocyte and embryo would have to endure additional heat stress and still be able to take advantage of the protective effects of bST and IGF-1. This could result in increased conception risk which can decrease days open and decrease reproductive culling. Decreased days open and decreased culling should result in increased profitability.

Hypothesis

The hypothesis for this thesis is two-fold. The first was that a single injection of a sustained-release preparation of bST during the pre-ovulatory period could improve fertility of lactating dairy cows experiencing heat stress. This hypothesis was tested through a farm trial performed during the summer months on lactating Holsteins. The second hypothesis was that the improved fertility, and resultant increased conception risk could improve profitability of dairy herds when administered during the summer months in herds under influence of seasonal effects.

CHAPTER 3
PREGNANCY SUCCESS OF LACTATING HOLSTEIN COWS AFTER A SINGLE ADMINISTRATION OF A SUSTAINED-RELEASE FORMULATION OF RECOMBINANT BOVINE SOMATOTROPIN

Introduction

Treatment of lactating cows with recombinant bovine somatotropin (bST) can increase milk yield in thermoneutral and heat-stress environments (Soderholm et al., 1988; Zoa-Mboe et al., 1989; West et al., 1990; Jenny et al., 1992; Elvinger et al., 1992; Jousan et al., 2007). The consequences of bST treatment for fertility are not clear. In early studies, cows treated with bST had an increased calving to conception interval that was attributed, at least in part, to increased anestrus (Esteban et al., 1994a; Esteban et al., 1994b). In contrast, bST either increased (Moreira et al., 2000; Moreira et al., 2001) or had no effect (Jousan et al., 2007; Santos et al., 2004; Blevins et al., 2006) on pregnancy risk per insemination when cows were inseminated using a timed artificial insemination (TAI) protocol. Treatment with bST increased pregnancy rate per insemination for repeat-breeder cows bred at estrus (Morales-Roura et al., 2001).

Bovine ST might be particularly effective at increasing fertility during periods of heat stress. This is because insulin-like growth factor-1 (IGF-1), whose secretion is stimulated by bST (Jousan et al., 2007; McGuire et al., 1992), has thermoprotective properties and can reduce the effect of elevated temperature on development and apoptosis of cultured bovine embryos (Jousan and Hansen, 2004; Jousan and Hansen, 2007). Indeed, the proportion of heat-stressed lactating cows receiving an in vitro produced embryo that became pregnant was higher when embryos were cultured in IGF-1 before transfer (Block et al., 2003; Block et al., 2007). This effect of IGF-1 was not seen for cows in cool weather (Block et al., 2007).

Despite the promise of using bST in the summer to increase IGF-1 and improve embryonic resistance to heat stress, there was no effect of bST on pregnancy rate in the one experiment that examined bST effects on fertility during heat stress (Jousan et al., 2007). In this experiment, cows received bST every 14 days beginning 13 days before TAI. The failure to observe an increase in fertility caused by bST may have been because bST also increased body temperature. Indeed, in this study and in others (Jousan et al., 2007; Elvinger et al., 1992), prolonged treatment of lactating cows with bST increased body temperature.

The hypothesis of the current study was that a single injection of a sustained-release preparation of bST during the pre-ovulatory period could improve fertility of lactating cows. The rationale for the hypothesis was that bST, directly or through an increase in IGF-1 secretion, would increase fertility by exerting beneficial effects on follicular function (Lucy, 2000; Quirk et al., 2004), oocyte function (Nuttinck et al., 2004; Wasielak et al., 2007) and embryonic development (Moreira et al., 2002; Kolle et al., 2004). In heat-stressed cows, bST would also be thermoprotective towards the embryo through actions of IGF-1 (Jousan and Hansen, 2004; Jousan and Hansen, 2007). Treatment with bST was limited to a single injection around the time of ovulation to exert effects on late follicular development, ovulation, and early embryonic development while avoiding milk yield responses during the peri-ovulatory period that could enhance hyperthermia or otherwise limit the possible beneficial effect of bST on fertility.

Materials and Methods

Animals, Housing, and Feeding

The experiment was conducted from June to November 2006 at a commercial 3000-cow dairy in Trenton, Florida, USA (29.36° N 82.49° W) utilizing 256 first-service, lactating Holstein cows. The climate is semi-tropical and humid. Meteorlogical measurements for the period of the study obtained from the Florida Automated Weather Network (http://fawn.ifas.ufl.edu) for nearby Alachua, Florida are shown in Table 3-1. Cows were housed in a free-stall barn equipped with cooling fans and an automatic sprinkler system. Cows were milked two times daily in the morning and afternoon and fed as a group after each milking. The diet was a total mixed ration containing corn silage and alfalfa as the main ingredients with 77 Mcal of net energy for lactation/kg and 17.4% crude protein on a dry matter basis.

Experimental Design and Timed AI

Cows were selected for the study because they were eligible for first service during the study period. A presynchronization-OvSynch protocol was utilized for first service TAI (Portaluppi and Stevenson, 2005). The protocol was initiated at an average of 37 d postpartum (range 30 to 50). For presynchronization, cows were administered 2 injections of 25 mg $PGF_{2\alpha}$, (Lutalyse, Pfizer Animal Health, New York, NY, USA, i.m.) at a 14 d interval. After another 14 d, an ovulation synchronization protocol was initiated consisting of 100 µg GnRH (Cystorelin, Merial Co., Athens, GA, USA, i.m.) followed 7 d later with 25 mg $PGF_{2\alpha}$ i.m., and a second injection of GnRH (100 µg) at 72 h following $PGF_{2\alpha}$ coincident with TAI (at an average of 75 days postpartum). All injections were given in the morning. Several cows were observed in estrus and inseminated prior to completion of the synchronization protocol. These cows were excluded from the analysis. Cows observed in standing estrus post-TAI were re-inseminated and considered non-pregnant to the TAI. Pregnancy diagnosis was conducted by rectal palpation at an average 45 d after TAI.

Cows were enrolled in the experiment each week (during a 12-wk period during June - September) and were assigned randomly within each week to receive bST or serve as controls within each week block. Treatment with a sustained-release formulation of bST (500 mg, s.c.; Posilac®, Monsanto Co., St Louis, MO, USA) was performed coincident with the last $PGF_{2\alpha}$ injection of the snychronization protocol. Treatment was administered by the researchers in the depression on either side of the tail head. Control cows received no injection.

Body Condition Score and Vaginal Temperature Measurements

Body condition score (BCS) was recorded for control and bST-treated cows at insemination using a scale of 1 to 5 in 0.25 increments (Edmonson et al., 1989). Each week, a random subset of cows in each treatment was fitted with a temperature data logger (HOBO Water Temp Pro v1, Onset Computer Co., Bourne, MA, USA) attached to a blank control internal drug release (CIDR) insert (Pfizer Animal Health) that was inserted into the vagina. The data logger recorded vaginal temperature at 15-min intervals beginning at 1100 h on Day 4 post-TAI for 3 days. Data were downloaded from the data logger onto a laptop computer after removal from the cow. Average vaginal temperature for each hour was calculated. A new subset of cows was enrolled each week so that vaginal temperatures were recorded from 21 control cows and 21 bST-treated cows. Note that results of a previous experiment indicated that insertion of HOBO devices into the vagina for 7 days did not affect fertility (Jousan et al., 2007).

Measurement of Plasma Progesterone Concentrations

Blood samples were collected from each cow at the time of insemination and at Day 7 after insemination to determine plasma progesterone concentration. Blood samples were collected by coccygeal venipuncture into evacuated heparinized 10-mL tubes (Becton Dickinson, Franklin Lakes, NJ, USA). Following collection, blood samples were placed in an ice chest until further processing in the laboratory (within approximately 2 to 6 h). Blood samples were centrifuged for 15 min at 4°C at 3000 x g. Plasma was separated and stored at -20°C until assayed for progesterone concentration using a commercial radioimmunoassay (Coat-a-Count, Diagnostic Products Corporation, Los Angeles, CA, USA). The intra- and interassay coefficients of variance were 6% and 9%, respectively and assay sensitivity was 0.11 ng/ml. Cows with low plasma progesterone concentrations (< 1 ng/ml) were considered to not have a functional corpus luteum while cows with high plasma progesterone concentrations (≥ 1 ng/ml) were considered to have a functional corpus luteum. Cows that had low progesterone concentration on Day 0 and high concentration on Day 7 were determined to be successfully synchronized in response to the ovulation synchronization regimen.

Statistical Analysis

Data on the proportion of cows pregnant after TAI were analyzed with the LOGISTIC procedure of SAS using a backward stepwise logistic model. Data were analyzed for all cows and for the subset of cows that were successfully synchronized. Variables were continuously removed from the model by the Wald statistic criterion if the significance was greater than 0.20. The initial mathematical model included the effects of bST, sire, technician, month of insemination, presence of a HOBO device, BCS class (< 2.5, ≥ 2.5), BST*BCS class, and BST*month. The final model included main effects of BST and month of insemination. The adjusted odds ratio (AOR) estimates and the 95% Wald confidence intervals (CI) from logistic regression were obtained from this analysis. The Wald chi-square statistic was used to determine the probability value for each main effect that remained in the reduced model (significance was considered as $P < 0.05$).

Effects on the proportion of cows that were successfully synchronized for TAI was also analyzed with the LOGISTIC procedure of SAS using a backward stepwise logistic model as described above. The final model included main effects of BST and month of insemination.

Treatment effects on BCS and vaginal temperature were analyzed using least-squares analysis of variance with the GLM procedure of SAS. Tests of significance were made using the appropriate error terms based on calculation of expected means squares. Cow was a random effect and other main effects were considered fixed. The model for effects on BCS included month of insemination, BST, and the interaction. The model for effects on vaginal temperature included BST, cow (BST), day, time of day, and all two way interactions.

Results

Vaginal Temperatures and Body Condition Scores

The 24-h pattern of vaginal temperatures is shown in Figure 3-1. Time of day affected vaginal temperature ($P < 0.001$). The peak temperature (least-squares mean) for both groups was 39.3^{o}C. Peak temperature occurred at 23:00 h for control cows and 18:00 h for bST-treated cows. The nadir, 38.6^{o}C for both control and bST-treated cows, occurred at 08:00 and 09:00 h, respectively. Vaginal temperature was not affected by bST treatment, day relative to TAI, or interactions between these main effects and other variables. Body condition score at TAI was not different between control and bST-treated cows (2.52 ± 0.03 vs. 2.54 ± 0.03).

Response to Ovulation Synchronization

Cows were considered to be successfully synchronized if progesterone concentration on the day of TAI (Day 0) was < 1 ng/ml and progesterone concentration on Day 7 after TAI was $\geq$ 1 ng/ml. Using this criterion, there was a tendency ($P = 0.100$) for a lower percent of control cows to be synchronized than bST-treated cows (77.3 vs 86.1%; Table 3-2). Further examination of progesterone concentrations revealed that, regardless of treatment, over 90% of cows had low progesterone concentrations (< 1 ng/ml) at Day 0. However, there was a tendency ($P=0.101$) for a smaller percent of control cows to have high progesterone ($\geq$ 1 ng/ml) at Day 7 than for bST-treated cows (72.6 vs 81.1%; Table 3-2). Thus, a smaller proportion of cows ovulated in response to TAI for control cows than for bST-treated cows. BCS at TAI also affected the successful synchronization rate ($P = 0.03$). Cows with BCS $\geq$ 2.5 were more likely to have been successfully synchronized (125/152, 87.5%) than cows with BCS < 2.5 (57/80, 71.3%) (AOR = 0.36, CI = 0.18 ± 0.710).

Pregnancy Rate

Results for pregnancy following TAI are presented in Table 3-3. Among all cows, the percent of cows pregnant following TAI was not statistically affected by treatment. Numerically, the percent of inseminated cows that were pregnant was lower for control cows (17.8 %) than for cows treated with bST cows (24.2%). This nonsignificant difference between groups was diminished in magnitude when percent of inseminated cows that were pregnant was calculated for the subset of cows that were successfully synchronized (22.4 vs 24.8%, treatment effect, P>0.10).

Discussion

Results from the present study failed to support the hypothesis that administration of a sustained-release form of bST near the time of first insemination improves fertility of lactating dairy cows. When cows were heat-stressed and timed AI was the sole method for breeding cows, there was a numerical increase in pregnancy rate in cows treated with bST as compared to control cows. However, this difference was not statistically different. Moreover, the numerical increase associated with bST was caused by effects on the response to ovulation synchronization rather than to fertility. Specifically, bST tended to improve the proportion of cows that ovulated after the ovulation synchronization protocol. The difference in percent cows pregnant after TAI between control and bST-treated cows was reduced when only successfully-synchronized cows were considered.

Experiments to evaluate the fertility-promoting effects of bST on ability of cattle to establish and maintain pregnancy after insemination have yielded variable results. Administration of a single injection of bST at insemination did not improve pregnancy risk per insemination in cows (largely beef cows) or beef heifers (Bilby et al., 1999). However, a single injection of bST at estrus increased the percent of repeat-breeder dairy cows pregnant following insemination (Morales-Roura et al., 2001). Injections of bST increased pregnancy success in dairy cows bred to TAI in some studies (Moreira et al., 2000; Moreira et al., 2001) but not in others (Jousan et al., 2007; Santos et al., 2004; Blevins et al., 2006). Differences in treatment regimens, reproductive management, cow type and issues related to sample size could explain some of this variation. For example, bST improved fertility for cows subjected to a Presynch-Ovsynch synchronization protocol but did not improve fertility for cows receiving an Ovsynch protocol without presynchronization (Moreira et al., 2001). Taken together, the lack of a consistent fertility-promoting effect of bST would contraindicate broad use of bST to improve fertility in lactating cows. Additional work is needed to confirm its efficacy in selected populations of cows, for example in repeat-breeder cows (Morales-Roura et al., 2001).

It was hypothesized that cows exposed to heat stress would be particularly likely to benefit from administration of bST because IGF-1, which is released in response to bST, can protect bovine preimplantation embryos from the deleterious effects of elevated temperature on development (Morales-Roura et al., 2001; McGuire et al., 1992). Nonetheless, bST did not improve fertility despite the fact that cows experienced vaginal temperatures characteristic of hyperthermia (greater than 38.6°C) throughout most of the day. There are several explanations for this lack of effect of bST during heat stress. For instance, it is possible that bST was not administered until damage to the oocyte had already occurred. Heat stress can compromise the follicle somewhere between 20-50 days before ovulation (Hansen, 2007) and administration of bST three days before ovulation, as performed here, would probably not reverse damage occurring earlier in follicular development. The bST was not administered earlier relative to ovulation because of the desire to avoiud effects of bST on milk yield that could possibly result in increased body temperature (Elvinger et al., 1992). In fact, the bST treatment did not increase vaginal temperature. Another possibility is that early embryos are refractory to the thermoprotective actions of IGF-1. The only stage of development at which IGF-1 has been shown to reduce negative effects of elevated temperature on embryos is at Day 5 after insemination (Morales-Roura et al., 2001; McGuire et al., 1992). Finally, it is also possible that treatment of bST may not change the bioavailable IGF-1 in the follicular, oviductal or uterine environment sufficiently to protect oocytes or embryos from elevated temperature. Treatment of lactating cows with bST increased amounts of IGF-1 in follicular fluid but not in uterine flushings (Lucy et al., 1995).

The proportion of cows that ovulated following the ovulation synchronization protocol tended to be greater for cows treated with bST. This possible effect of bST did not reflect a difference in luteolysis following administration of $PGF_{2\alpha}$ because there was no difference between control and bST-treated cows in the proportion of cows with low progesterone concentrations on the putative day of ovulation (Day 0). Perhaps bST increased luteinizing hormone (LH) release in response to GnRH or increased the rate of follicular development so that preovulatory follicles were more likely to respond to LH. The literature is equivocal as to whether bST affects LH secretion (Dalton and Marcinkowski, 1994; Schemm et al., 1990) but it is well established that bST can enhance follicular growth (Block and Hansen, 2007).

In conclusion, results failed to indicate a beneficial effect of bST treatment on fertility of lactating dairy cows. There was a tendency for bST to increase ovulatory response in cows bred by TAI and further studies to evaluate this action of bST are warranted.

Table 3-1. Average daily minimum and maximum dry bulb temperatures and average daily humidity during the experiment.[a]

Month	Average daily minimum dry bulb temperature (°C)	Average daily maximum dry bulb temperature (°C)	Average daily relative humidity(%)
June	12.6	34.4	74
July	13.4	35.4	75
August	18.2	34.5	76
September	10.9	33.7	76
October	-0.7	31.3	70
November	-0.4	29.6	74

[a] Obtained from Florida Automated Weather Network, collected in nearby Alachua, Florida.

Table 3-2. Effect of bovine somatotropin administered 3 d before insemination on plasma progesterone concentrations on d 0 and 7 relative to timed artificial insemination and on the percent of cows successfully synchronized.[a]

Item	Treatment[b] Control	Treatment[b] bST	P	AOR	CI
Low progesterone (<1 ng/ml) on d 0	112/124 (90.3%)	123/132 (93.2%)	NS	1.45	0.58 to 3.58
High progesterone (≥ 1 ng/ml) on d 7	90/124 (72.6%)	107/132 (81.1%)	0.10	1.66	0.91 to 3.03
Synchronized (low on d 0 and high on d 7)	85/110 (77.3%)	105/122 (86.1%)	0.10	1.78	0.89 to 3.58

[a] Abbreviations are bST; bovine somatotropin; AOR, adjusted odds ratio; CI, confidence interval; NS, non-significant

[b] Data are the number of cows with that classification/total cows inseminated and, in parentheses, percent.

Table 3-3. Effect of bovine somatotropin administered 3 d before insemination on proportion of cows pregnant after first service.[a]

Pregnancy rate, first service	Treatment[b]		P	AOR	CI
	Control	bST			
All cows	22/124 (17.8%)	32/132 (24.2%)	NS	1.50	0.81 to 2.76
Synchronized cows[c]	19/85 (22.4%)	26/105 (24.8%)	NS	1.12	0.51 to 2.20

[a] Abbreviations are bST; bovine somatotropin; AOR, adjusted odds ratio; CI, confidence interval; NS, non-significant

[b] Data are the number of cows pregnant/total cows inseminated and, in parentheses, percent pregnant.

[c] Cows where progesterone concentration on the day of timed artificial insemination (Day 0) was < 1 ng/ml and progesterone concentration on Day 7 after TAI was ≥ 1 ng/ml.

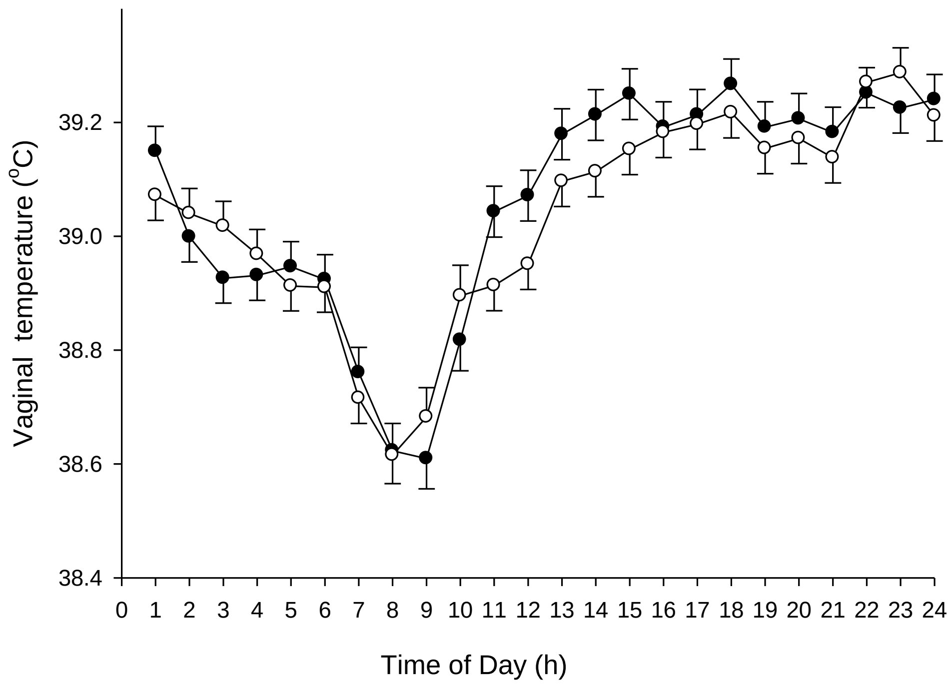

Figure 3-1. Effect of bovine somatotropin on vaginal temperature. Data represents least-squares means ± SEM. There was an effect of time ($P<0.001$) but no difference between control (open circles) and bST-treated cows (closed circles) and no time x treatment interaction.

CHAPTER 4
PROFITABILITY OF BOVINE SOMATOTROPIN ADMINISTRATION TO INCREASE FIRST INSEMINATION CONCEPTION RISK IN SEASONAL DAIRY HERDS

Introduction

Dairy cattle fertility is greatly reduced during times of heat stress (Faust et al., 1988; Ray et al., 1992; Thompson et al., 1996; Wolfenson et al., 2000). Conception risk (CR) may drop from 40 to 60% in the cool winter months to 10 to 20% in hot summer months (Cavestany et al., 1985). As cow fertility decreases, the calving interval increases and profit decreases (Plaizier et al., 1997).

Bovine somatotropin (bST) has been used to increase CR in lactating dairy cows. Administration of bST can increase CR to timed artificial insemination (TAI) (Moreira et al., 2000; Moreira et al., 2001). In these studies, the percent of cows pregnant to first insemination increased from 22 to 38% (Moreira et al., 2000) and 34 to 45% (Moreira et al., 2001). Both of the previous studies were performed in Florida from February to May (Moreira et al., 2000) and February to June (Moreira et al., 2001). Bovine ST can improve follicular function (Lucy 2000), oocyte function (Nuttinck et al., 2004; Waiselak and Bogacki, 2007), and embryonic development (Moreira et al., 2002; Kolle et al., 2004) either directly or indirectly through the action of IGF-1. It maybe that bST administration during the summer has additional benefits due to the thermoprotective actions of insulin-like growth factor 1 (IGF-1) (Jousan and Hansen, 2004; Jousan and Hansen, 2007) which is increased by bST administration (McGuire et al., 1992; Jousan et al., 2007). In a recent study, bST administration prior to first insemination in the summer increased CR numerically from 18 to 24% (Bell et al., 2008).

Increasing first insemination CR through implementation of TAI was shown to be more profitable during the summer than winter (Risco et al., 1998). Implementing TAI at first insemination during the summer to increase pregnancy rates increased net revenue by about

$17.00 to 25.00 per cow per year (De la Sota et al., 1998; Risco et al., 1998). In the study by Risco and colleagues, the only difference between the control scenario and the TAI group was application of an OvSynch protocol to the first inseminations during summer. This small change in the breeding protocol resulted in a reduction in days open of 18 days and increased net revenue of $25.36 per cow. In addition, there was a loss in net revenue of approximately $30 when no cows where bred during the summer. It was concluded that OvSynch had a greater impact on net returns during the summer because the value of a marginal increase in pregnancy rate was greater when fertility was low (Risco et al., 1998). De Vries (2007) also showed that increasing pregnancy rate was more profitable when reproductive performance was low. This increase in profit was mainly due to reduction of culling rates and increased milk production. The marginal value of increased pregnancy rates decreases at higher levels of pregnancy rates. After pregnancy rates reached 35% there was almost no benefit to a further increase in pregnancy rate (Risco et al., 1998).

The profitability of increased first insemination CR through bST administration will depend on the size of the increase in CR and inputs such as heifer and milk prices. Further, bST administration to increase CR could be more profitable during certain times of the year than others in seasonal herds.

The objective of this study was to estimate the profitability of bST administration at first insemination in lactating dairy cows submitted to a TAI program. The second objective was to determine the most profitable time period of the year to administer bST at first insemination when milk production and fertility are reduced during the summer as a result of heat stress. Effects of variations in heifer price, milk price, milk yield, fertility, and magnitude of seasonality of reproduction and milk production were studied was well.

Materials and Methods

Approach

The dynamic probabilistic computer simulation program DairyVIP (Dairy Value Iteration Program; De Vries, 2006a,b) was used to study the effects of bST administration in this study. DairyVIP can be used to evaluate the effects of changes in management strategies and prices, such as various breeding programs, on individual dairy cow breeding and culling decisions on the resulting herd statistics such as profit per cow per year. DairyVIP has the ability to calculate optimal breeding and voluntary replacement decisions for individual dairy cows with the objective to maximize profitability per slot (De Vries, 2006b; 2007). The program consisted of 3 modules: 1) a bio-economic module to enter and calculate cow performance data and prices; 2) an optimization module based on dynamic programming to determine (optimal) future breeding and replacement decisions for individual cows; and 3) a herd performance module based on Markov chains to calculate summary results for subgroups of cows or for the entire herd. The program used monthly time steps (30.4 d). Results in this study were calculated for a herd in steady state as determined by the herd performance module.

In the current study, the effect of bST administration and increased conception risk at first insemination in a herd using TAI was simulated. In addition, patterns of profit were investigated over time and under different management and market scenarios. The simulation of this protocol could easily be extrapolated to any treatment with a similar costs associated with implementation.

Default Input Values

Input values for the bio-economic module were chosen to represent a general Holstein dairy herd in Florida.

Milk yield

Average daily milk yield for non-pregnant cows per lactation was predicted from data from the Southeast Dairy Herd Improvement Association (De Vries, 2004). The lactation curves used in this study were adjusted to reflect an increased daily milk yield (Figure 4-1). For first lactation cows, minimum daily peak milk weight was 26.3 kg for a heifer calving in September. The maximum daily peak milk weight for a heifer was 30.6 kg for a heifer calving in February. For second lactation cows, cows calving in September had the lowest peak at 31.4 kg. Cows calving in March had the highest peak at 36.6 kg. Third lactation cows or later had a minimum daily peak in milk weight of 32.5 kg when calving occurred in September. The same cows had a maximum daily peak in milk weight of 37.8 kg when calving occurred in April. It was assumed that a single administration of bST at first insemination did not affect milk production.

Breeding strategy

Cows were eligible for breeding after 61 DIM until the end of the 15th month in lactation (d 456), unless the cow was culled earlier. The probability of being inseminated during the 21-d estrous cycle was 100% for the first insemination and 50% for all inseminations after the initial insemination (representative of a TAI protocol with good compliance). CR was seasonal and averaged 29% throughout the year (Figure 4-2). CR peaked in February at 40% and reached its lowest value at 19% in July. There was no change in CR based on parity or days in milk. Breeding decisions were not optimized. Therefore, all eligible cows after a voluntary waiting period of 2 months were subject to first insemination.

The risk of abortion by month of gestation (n = 2 to 8) was set to 3.5, 2.5, 1.5, 0.5, 0.3, 0.1, and 0.1% respectively (data adapted from Santos et al., 2004a). Consequently, the total probability of abortion after the first month, if the cow was not culled, was 8.2%. The probability of fetal loss during the first month of pregnancy was set at 0% because the CR was defined as the probability that the cow was pregnancy 1 mo after breeding.

Culling strategy

Replacement decisions in this study were optimized. The supply of replacement heifers was assumed to be unlimited. Risk of involuntary culling was the same as described by De Vries (2006a). Risk of involuntary culling was determined by parity (with greater parity resulting in increased involuntary culling) and month in milk. Involuntary culling was greatest in the first month of lactation (1.7% per month) and lowest in mid lactation (maintained at 0.6% per month). However, as months in milk increased past 14 months, the risk of involuntary culling steadily increases, peaking again at 1.4% in the 24th month of lactation. No seasonality in the risk of involuntary culling was assumed.

Other inputs

Other inputs included body weights, labor needs and feed intake as described by De Vries (2006a).

Prices and costs

The default milk price was set to $0.35/kg. The replacement heifer price was set at $1,600 per head. Prices for culled cows were set at $0.90/kg of body weight. Fixed costs were $1.25/slot/day. Other variable cost for dry cows was $1.00/cow/day and other variable cost for lactating cows was $1.00/cow/day. Feed cost for dry cows was $0.15/kg dry matter (DM) intake and feed cost for lactating cows was $0.20/kg DM. Labor cost was $9.00/hr. Veterinary cost was between $1.00 to39.00 depending on month of lactation. Breeding cost was $15.00/breeding. These additional cost values are all derived from De Vries (2006a). The program assumed no additional labor cost as a result of the administration of bST because administration would occur simultaneously with a scheduled injection prostaglandin $F_{2\alpha}$ three days prior to insemination.

Experimental Design

The simulation runs consisted of four steps. First, the default scenario was established. The default scenario was defined as a simulation with all of the default inputs but no bST administration. The default scenario serves to model a herd utilizing a TAI breeding protocol.

Second, sensitivity analysis was performed to create the 10 other scenarios. Simulated conditions included variations in milk and heifer price, milk yield, reproductive performance, and seasonality of milk yield and reproduction. The effects of changing conditions on the profit per slot per year were measured. The effect of milk price was evaluated at $26 and $44 per 100 kg. The effect of heifer price was evaluated at $1,200 and $2,000 per heifer purchased. Daily milk yield was increased and decreased by 10% from the lactation curves shown in Figure 4-1. The effect of overall reproductive performance was simulated by increasing and decreasing CR by ± 5 percentage points above the default CR (Figure 4-2).

A reduction in seasonality was simulated by averaging daily yield for each month of lactation and months within each lactation curve that were less than the average were reduced by 50% of the difference between that month and the monthly average (Figure 4-2). As a result of this method, lactation curves above the average had the same peak milk while anything below the average had an increased peak. For first lactation cows, the new minimum peak was 27.5 kg for heifers calving in September. Second lactation cows had a new minimum peak of 32.7 kg when calving was in September. Third lactation cows had a new minimum peak of 34.0 kg when calving was in September. In addition, the effect of seasonality of milk yield alone was evaluated by removing all seasonality of milk yield while maintaining the normal, seasonal pattern of CR.

To simulate a reduction of CR during the summer/warmer months, the annual average CR was calculated and each month below this average the CR was increased by 50% of the difference between the individual month and the average. The adjusted months were May to October. The new monthly CR curve maintained its peak at 40% in February but increased CR during the summer, resulting in a higher minimum of 24% in July. The annual average of the adjusted monthly CR was 31%.

Third, bST was administered in single calendar months to all scenarios and the effect on profit per slot per year was observed. These results would give an initial idea of the months in which bST administration would be profitable. The 4 levels of first insemination CR due to bST administration were 0 percentage point (PP) change, and increases of 4, 8, or 12 PP compared to the default CR. The cost per bST administration was $6.00. Months in which there was a gain in profit per slot per year after bST administration where identified.

Finally, the calendar months in which bST administration was profitable were combined into extended administration periods. For example, if bST administration during the single months of April and May was profitable, bST administration was simulated for both months simultaneously. The extended administration period was then expanded and contracted by adding months to or removing months from the extended period and evaluating the change in profit from these changes to ensure the extended administration period was optimal. If the months of February through July were identified as the extended administration period, the following combinations would also be modeled: January to July (addition of one previously negative month), February to August (addition of one previously negative month), January to August (addition of two previously negative months), March to July (reduction of one previously positive month), February to June (reduction of one previously positive month), and March to June (reduction of both previously positive months).

Three scenarios with bST administration were compared to the default scenario without bST in more detail to determine the underlying factors of changes in profitability. Specifically, factors examined included culling and reproductive indices and cow population statistics, such as percent first lactation cows at a given time.

Results

Simulation of Default Farm

The default dairy farm simulated by DairyVIP with only the default inputs had a total profit of $192 per slot per year, as shown in Table 4-1. Total revenue was $3,449 and total cost was $3,258 per slot per year. Total revenue of the default scenario was composed of milk sales (90% of total revenues), cow sales (4% of total revenues), and calf sales (6% of total revenues) sales. Total cost of the default condition was made up of feed cost (43% of total costs), breeding supply cost (1% of total costs), heifer purchase cost (15% of total costs), veterinary cost (2% of total costs), labor cost (13% of total costs), and other costs (25% of total costs). Other herd statistics included milk yield of 8896 kg/cow/yr, calving interval of 13.1 months, 126 days to conception, 19% pregnancy rate, and an overall annual cull rate of 31%.

Sensitivity Analysis without bST Administration

Simulation of new scenarios yielded new profits, as shown in Table 4-1. In general, as costs increased, as simulated by increased heifer price, or revenue was decreased, as simulated by lower milk price and milk yield, profit decreased. For example, when heifer price was increased to $2000, there was a loss of $116 per slot per day. Inversely, as costs decreased, as simulated by decreased heifer price, or revenue was increased, as simulated by greater milk prices and yield, profit increased. For example, when heifer price was reduced to $1200, there was a gain of $142 per slot per year. When revenue decreased, profit followed. For example, when milk price was reduced to $35 per 100 kg, there was a loss of $796 per slot per year. Increased CR increased profit and reduced reproductive performance decreased profit. When the amount of seasonality (both reproductive and milk yield) was reduced profitability increased.

Bovine ST Administration: Single Month Values

Default scenario

Figures 4-3 shows the effect on profit per slot per year when first insemination CR was increased one month at a time. There were no months with a postive profit when there was no change in CR. Increased CR of 4 PP resulted in gain in the months of Feburary through June. Increased CR of 8 PP resulted in gain in the months of January through June. Increased CR of 12 PP due to bST administration resulted in increased profit in the months of January through July.

Heifer price

At a heifer price of $1200, as seen in Figure 4-4, the months with gain at a CR of 4 PP were March to May. The months of gain at CR of 8 PP were January to June. Increased CR from 8 to 12 PP resulted in the addition of July to the positive months. There was no change in the positive months at the 0 PP level. When heifer price was $2,000, the positive months after an increase of CR of 4 PP were February to June. The positive months at a CR of 8 PP were December to June. The positive months at a CR of 12 PP were December to July. In general, decreasing heifer price reduced the number of positive months while maintaining the magnitude and the timing of the peak of profitability. Increasing heifer price maintained the number of positive months and maintained the timing of the peak of profitability but increased the overall magnitude of the peak of profitability.

Milk price

When milk price was $26.00 per 100 kg as seen in Figure 4-5, the positive months at a CR of 4 PP were February to May. The positive months at a CR of 8 PP were December to July. The positive months at a CR of 12 PP were December to July. There was no change in the positive months at the 0 PP level. When milk price was $44.00 per 100 kg as seen in Figure 4-5, the positive months at the 4 PP level of CR were February to June. Increasing CR by 8 PP added the month of January to the positive months of the 4 PP level. Increasing CR by 12 PP added July to the positive months of the 8 PP level. There was no change in the positive months at the 0 PP level. Lower milk price resulted in lower profit and increased milk price resulted in high profit.

Milk yield

For both milk yield levels when CR was changed by 0 PP the pattern of positive months was the same as the default condition (Figure 4-6). When milk yield was reduced by 10%, the CR increase of 4 PP resulted in positive months of February to May. However, at the 8 and 12 PP levels the positive months were the same as the default. When milk yield increased by 10%, the positive months were the same as the default at all three levels.

Overall conception risk

When overall CR was increased or decreased by 5 percentage units, positive months at the 0 PP level were the same as the default condition (Figure 4-7). When overall CR was decreased by 5%, the positive months at the 4 PP level were February to June. Positive months at 8 and 12 PP and decreased overall CR were December to July. When overall CR was increased by 5%, at the 4 PP level positive months were March to May and the 8 PP level positive months were the same as the default. However, increasing CR to 12 PP only added the month of July to the positive months at the 8 PP level. In general, increasing first insemination CR proved to be more profitable when overall CR was low. This resulted in more profit and the addition of more positive months at all levels.

Seasonality of milk yield and reproduction

When seasonality of milk yield and reproduction were both reduced by 50%, maximum profit was similar to the other scenarios (Figure 4-8). There were no positive months at the 0 PP change in CR. The positive months at 4 PP change in CR were February to May. The positive months at the 8 PP change in CR were January to June. The positive months at a 12 PP change in CR were December through July. When seasonality of milk yield was eliminated (Figure 4-9), the effect of increase in first service CR is reduced. The ranges of profits were narrower throughout the year at the 4, 8, and 12 PP levels of change in CR. At the 8 and 12 PP level CR changes all of the months were positive. At the 4 PP increase of CR, February to May were positive months.

In general, the most profitable months of bST administration at first insemination were in the winter. Further, the positive months were sequential. Variations in heifer price, milk price, overall CR, milk yield, and reducing seasonality did not affect the way in which profit changed as a result of bST administration and increase in first insemination CR. In fact, the profit gained or lost by bST administration changed very little, between -$1.50 and $2.50 per slot per year. Total reduction of seasonality of milk yield had the most dramatic effect on which months during the year an increase in profit was shown. After reduction of seasonality, bST administration was profitable in every month when CR increased by at least 8 PP. The magnitude of the resulting change in profit was similar to the previous scenarios.

Optimal Sequence of Months of bST Administration

Table 4-2 shows the change in profit resulting from bST administration for each extended administration period. In the majority of scenarios the optimal extended administration period was the same months as the single months that resulted in an increased profit. The exceptions to this trend were when heifer price was changed at 8 and 12 PP. When heifer price was $1,200 and change in CR was 12 PP, all the positive months were January through July but the most profitable months, although only by $0.03, were February through July. In addition, when heifer price was $2,000 and the change in CR was set at 8 PP, the positive months were December through June while the optimal extended administration period was December through July. An advantage of $0.83 was gained through the addition of July to the time period bST was administered.

The administration of bST during the default scenario resulted in gain of profit in the months of February to June when CR was increased by 4 PP (Table 4-2). Applying this administration plan resulted in additional profit of $0.80 per slot per year. Several of the scenarios at the 4 PP level had the same extended administration period as the default scenarios: heifer price of $2000, milk price of $44, and milk yield increasing 10%. Decreasing default CR by 5% resulted in positive months expanding to include January at the 4 PP increase in CR. This expansion of the default extended administration period resulted in the highest profit of any of the scenarios at the 4 PP level at $1.38 per slot per year. The remainder of the scenarios resulted in decreasing the range of the default scenario's extended administration period: heifer price of $1200, milk price of $26, milk yield decreases 10%, CR increases 5%, and both of the changing seasonality scenarios. At the CR 8 and 12 PP level, the optimal extended treatment plan covered more months than the default and overall profit was increased.

Income, expenses, and selected herd statistics are shown for selected scenarios (Table 4-3). Milk sales were highly associated with gain in profit. Despite changes in inputs or decreases in CR, as long as milk sales were maintained, profit was maintained. The changes in CR across scenarios did not affect the overall pregnancy rate to a great degree. This is due to the limited number of cows that received bST at any given month. This resulted in small increases in pregnancy rate and contributed to small changes in profit per slot per year. It seems that profit is more driven by changes in milk price, heifer price, and milk yield. In general, breeding supply expenses were increased. However, total expenses were hardly affected because of decreased costs due to fewer inseminations per conception. Calf sales and milk sales increased. Decreased culling lowered heifer purchase costs and decreased cow sales.

Detailed Analysis of Effect of bST Administration on Various Indices

The optimized extended administration period for 8 PP change in CR with default inputs (bST administered from January to June) was compared to the default scenario with no bST administration. Several indices were evaluated. Pregnancy rate (Figure 4-9A) peaked in January with a minimum in July for both scenarios. The default scenario without bST administration had lower pregnancy rates from January to June with the greatest difference in January. Pregnancy rate is a direct reflection of the differences in the CR of the two scenarios because there was no difference in insemination rate. The percent lactating cows was greatest in April for both scenarios and lowest in September (Figure 4-9B). While the magnitude of the peak was the same for both scenarios, the scenario without bST administration did not reach the same magnitude of negative profits as the scenario with bST administration. The greatest variation between the two scenarios was from September to December with the default scenario maintaining a greater proportion of lactating cows during this time. Milk yield per slot peaked in March and reached a low in September in both scenarios (Figure 4-9C). Milk sales differed between the two scenarios (Table 4-4) with bST administration resulting in increased milk revenues. This difference was due to the proportion of cows in the herd lactating, not milk yield changes between the two scenarios. Total culling was slightly changed between the two scenarios (Figure 4-10A). While there are distinct peaks in October and a distinct minimum in July for both scenarios, the most difference between the two scenarios was observed in December, February, and March. In the month of December, the no bST administration scenario with default inputs had a greater total cull rate. In the months of February and March, the bST administration scenario resulted in increased total culling. A portion of the total culling can be attributed to involuntary culling. Both scenarios exhibit a peak of involuntary culling in December and a minimum in July (Figure 4-10B). The greatest difference in involuntary culling between the two scenarios occurred from December to April, during this time the bST administration protocol culled a greater proportion of cows. Proportion of calvings saw a minimum for both scenarios in June while the peak was October for the no bST administration scenario and shifted to November for the bST administration scenario (Figure 4-10C). The greatest difference between the scenarios was in the month of November when the bST treated group entered a greater proportion of new cows into the herd. There were slight changes in December to March when the bST treated group entered a greater proportion of new cows into the herd.

Discussion

The results of this study suggest that the profitability of increasing first insemination CR is greater in the winter than in the summer. This is the opposite results of a similar study comparing estrus detection and OvSynch during the summer to increase pregnancies (Risco et al., 1998). Risco and colleagues found that there was greater benefit from improving reproductive efficiency in the summer because of reduced fertility. These same authors also commented that at certain levels of conception risk, there is less value to improving fertility (Risco et al., 1998). Perhaps, the conditions modeled in this study represented a level of fertility that could not be improved upon to such a degree that profit would increase. In addition, in the

Risco model, there was no change in culling as a result of OvSynch (1998) while in the current study there was variation in culling patterns. Perhaps these changes in culling could attribute for some of the summer months not showing gains after bST administration.

De Vries (2006a) found that value of new pregnancy is lower early in lactation and increases as cows approach mid to late lactation and become repeat breeders. Bovine ST has been shown to have a positive effect on CR of cows remaining open after 5 or more previous inseminations (Morales-Roura et al., 2001). Bovine ST administration later in lactation when both the value of pregnancy is greater and the effect of bST is more pronounced could result in greater profit than what was realized in the current experiment.

A major driver is the seasonality of milk production that characterized the current study. Cows conceiving in the summer have decreased potential for future milk production than cows achieving pregnancy in the cooler months. In addition, cows becoming pregnant at the first breeding after the end of the voluntary waiting period might have a shorter calving interval than optimal. This may be particularly true for first parity and high producing cows that may have a longer optimal calving interval (Le Blanc; 2007). This has implications for applying other treatments during the summer that are intended to increase CR. For example, it has been suggested that embryo transfer (ET) could be utilized during the summer to increase pregnancy rates (Hansen and Arechiga, 1999). This is a much more costly protocol than the bST protocol investigated in the current study. Perhaps implementing a program during the summer, such as ET, would not be profitable even if CR was significantly increased.

Cycling status prior to treatment has been identified as an indicator of success in field trials where bST was evaluated as a treatment to increase proportion of cows pregnant after insemination (Moreira et al., 2000; Moreira et al., 2001). In the current study there were no criteria for submission to bST administration other than days in milk. Cycling state was assumed to be the same for all cows. If a selection criterion, such as cycling status, was used to select animals more likely to respond the total number of animals submitted for treatment would be smaller. While this would allow CR to increase, the absolute number of animals conceiving would potentially stay the same and pregnancy rate would not be expected to increase. In this study it was assumed that all cows submitted for breeding were enrolled and inseminated as a part of a TAI protocol. Bovine ST has also been shown to increase CR at comparable levels when estrus detection was employed (Santos et al., 2004b).

Utilizing bST administration, or any other treatment, to increase CR in the winter, will result in a herd with a more seasonal calving pattern. This many not be ideal for all herds. For instance, increased seasonality may cause problems when certain resources are constrained, for example parlor capacity and barn capacity, and may put a strain on cash flow as milk receipts will decline during this period.

Results from the current study can be applied to many different breeding systems as long as cost of implementation of the breeding system itself is included. Assumptions of this study include submitting all cows to the same TAI protocol for second or greater inseminations.

In the current study, bST was only administered prior to first insemination. bST is traditionally administered to increase milk production and is administered every two weeks. Depending on management conditions, eliminating bST use as a lactogen and only applying it for its reproductive effects may not be economically prudent. In addition, it is increasingly more common for dairy producers to discontinue bST use because of personal preference or at the request of their milk processors. Obviously, attempting to harness the effects of bST for reproductive gain would be not make sense if it would mean eliminating a market for milk.

However, results from this study can be extrapolated to any treatment of management change to increases first inseminations in seasonal herds with similar costs and expected outcomes.

In conclusion, administration of bST to increase first insemination CR was the most profitable during the winter. Administration of bST during the summer did not result in increased profit under the assumptions and conditions of this study Applying this protocol in the winter months would increase seasonality over time. Eliminating seasonality did result in increased profits during the summer months.

Table 4-1. Default herd statistics and effects of sensitivity analysis without bST administration.

	Default	Heifer price		Milk price		Milk yield		CR[1]		Seasonality	
Herd Statistics	$/slot/year	$1,200	$2,000	$44	$26	Plus 10%	Minus 10%	Plus 5%	Minus 5%	50% MY[2]+ 50% Repro	0% MY[2]+ 100% Repro
		---------- Δ $/slot/year from default ----------									
Milk sales	3114	77	-46	844	-832	323	-322	-1	2	30	183
Cow sales	124	58	-24	22	-21	7	-6	-8	13	-3	3
Calf sales	211	18	-7	7	-6	2	-1	5	-5	2	2
Total revenue	3449	154	-77	874	-859	333	-329	-4	10	28	488
Feed cost	1398	9	-5	5	-5	63	-62	-1	2	6	36
Breeding supply cost	41	0	0	0	0	0	0	-4	5	0	1
Heifer purchase cost	501	-2	47	61	-56	18	-17	-18	30	-9	9
Veterinary cost	81	5	-2	2	-2	1	0	2	-1	1	1
Variable labor cost	415	1	0	0	0	0	0	-2	2	-1	0
Variable other cost	365	0	0	0	0	0	0	0	0	0	0
Fixed other cost	456	0	0	-111	0	0	0	0	0	0	0
Total cost	3258	12	39	67	-64	81	-80	-25	37	-4	45
Total profit	192	142	-116	805	-796	251	-250	19	-28	31	142
Milk yield (kg)	8896	222	-130	99	-118	925	-918	-3	6	525	6
Calving interval (months)	13.1	-0.4	0.2	-0.1	0.2	-0.1	0.1	-0.3	0.3	0	0.3
Days to conception (days)	126	-10	5	-4	4	-2	1	-8	9	-1	9
Pregnancy rate (%)	19	1	0	0	0	0	0	4	-3	0	-3
Overall cull rate (%)	31	11	-4	4	-3	1	-1	-1	2	1	2

[1]Conception risk

[2]Milk yield

Table 4-2. Total increase in profit from default scenario (prior to bST administration) for months with positive change.

	----------- 4 PP[1] -----------		----------- 8 PP[1] ----------		---------- 12 PP[1] ---------	
	All positive months	ΔProfit ($/slot/year)	All positive months	ΔProfit ($/slot/year)	All positive months	ΔProfit ($/slot/year)
Default	Feb-Jun	0.80	Jan-Jun	4.13	Dec-Jul	7.96
Heifer price $1,200	Mar-May	0.37	Jan-Jun	2.99	Jan-Jul[4]	6.18
Heifer price $2,000	Feb-Jun	0.96	Dec-Jun[3]	4.64	Dec-Jul	8.86
Milk price $44/100 kg	Feb-Jun	0.95	Jan-Jun	4.89	Jan-Jul	8.23
Milk price $26/100 kg	Feb-May	0.54	Dec-Jul	3.72	Dec-Jul	7.42
Milk yield increase 10%	Feb-Jun	0.86	Jan-Jun	4.26	Dec-Jul	8.05
Milk yield decrease 10%	Feb-May	0.72	Jan-Jun	3.09	Dec-Jul	7.84
CR[2] increase 5%	Mar-May	0.45	Jan-Jun	3.25	Jan-Jul	6.41
CR[2] decrease 5%	Jan-Jun	1.38	Dec-Jul	3.34	Dec-Jul	10.57
50% Seasonal. of repro & MY[3]	Feb-May	0.48	Jan-Jun	3.35	Dec-Jul	6.80
Seasonality of repro only	Feb-May	0.19	Jan-Dec	4.16	Jan-Dec	9.29

[1]Percentage point

[2]Conception risk

[3]Milk yield

[4]Profit increased when bST was administered from February to July (+$0.03).

[5]Profit increased when bST was administered from December to July (+$0.83).

Table 4-3. Changes in factors related to profitability during the extended administration protocol as conditions change. Heifer price (HP), milk price (MP), milk yield (MY), probability of conception (PC), and seasonality (NS)

	Default		$2,000 HP	$26 MP	Minus 10% MY	Minus 5% PC	50% of NS	No Seasonality of MY
	No bST	bST Jan-Jun	bST Dec-Jun	bST Dec-Jul	bST Jan-Jun	bST Dec-Jul	bST Jan-Jun	bST Jan-Dec
Milk sales	3113.67	1.77	-43.45	-829.85	-319.46	3.06	31.06	182.62
Cow sales	124.38	-1.43	-25.27	-22.45	-7.46	10.06	-5.29	-0.32
Calf sales	211.41	2.48	-4.77	-3.39	0.63	-1.51	3.55	5.69
Total revenue	3449.45	2.82	-73.50	-855.69	-326.29	11.60	29.33	187.99
Feed cost	1398.40	-0.58	-6.30	-6.09	-62.96	0.78	4.91	33.67
Breeding supply cost	41.17	1.38	1.77	1.85	1.32	6.63	0.20	3.40
Heifer purchase price	501.00	-2.27	44.78	-57.86	-18.51	25.24	-11.37	2.85
Veterinary cost	81.15	0.78	-1.21	-0.87	0.24	-0.45	1.11	1.85
Variable labor cost	415.02	-0.62	-0.78	-0.90	-0.67	1.05	-1.12	-1.19
Fixed other cost	456.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Variable other cost	364.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total costs	3257.53	-1.31	38.26	-63.87	-80.58	33.26	-6.25	40.59
Total profit	191.92	4.13	-111.76	-791.83	-245.70	-21.65	35.58	147.40
Pregnancy rate (%)	19%	1%	1%	2%	1%	-2%	2%	3%
Overall cull rate (%)	31%	-0.1%	-4%	-4%	-1%	2%	-1%	0.2%
Days to conception (d)	126	-5	-1	-2	-4	2	-7	-10

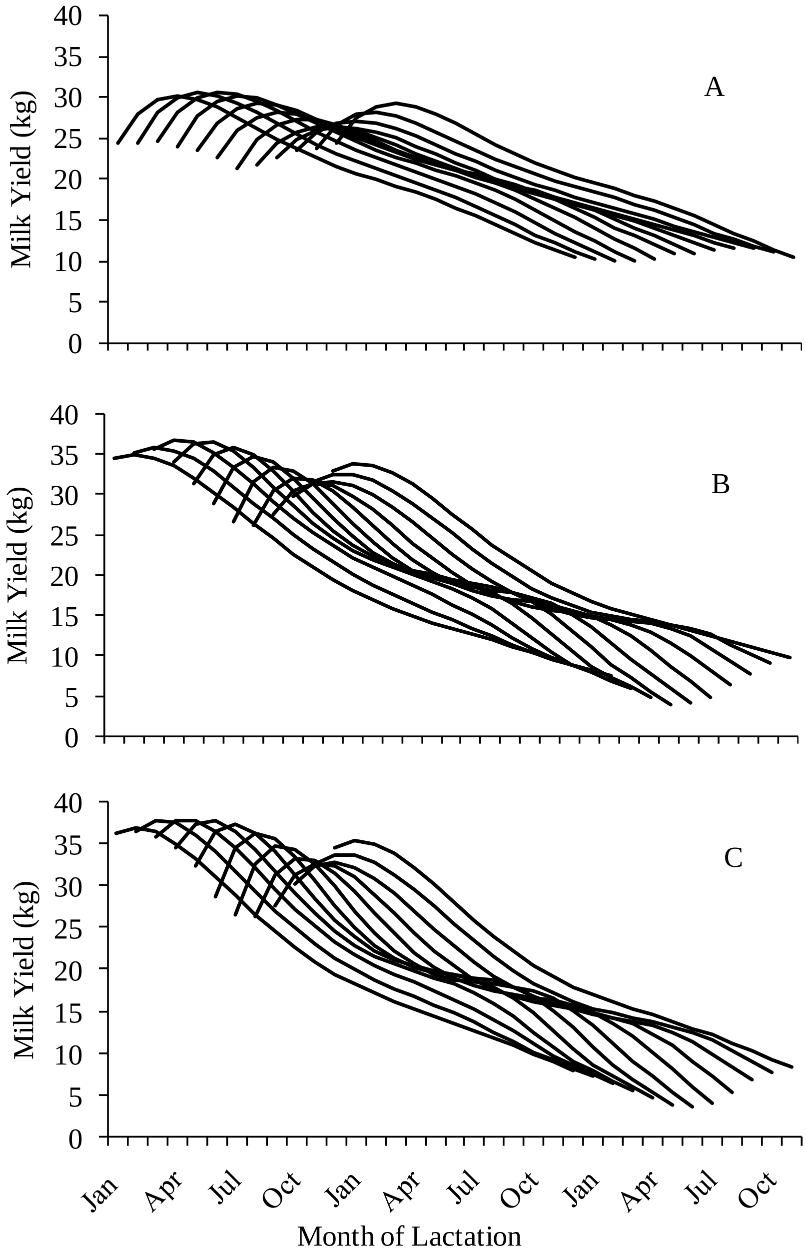

Figure 4-1. Default lactation curves by month of initiation of lactation. A. First lactation. B. Second lactation. C. Third and later lactations.

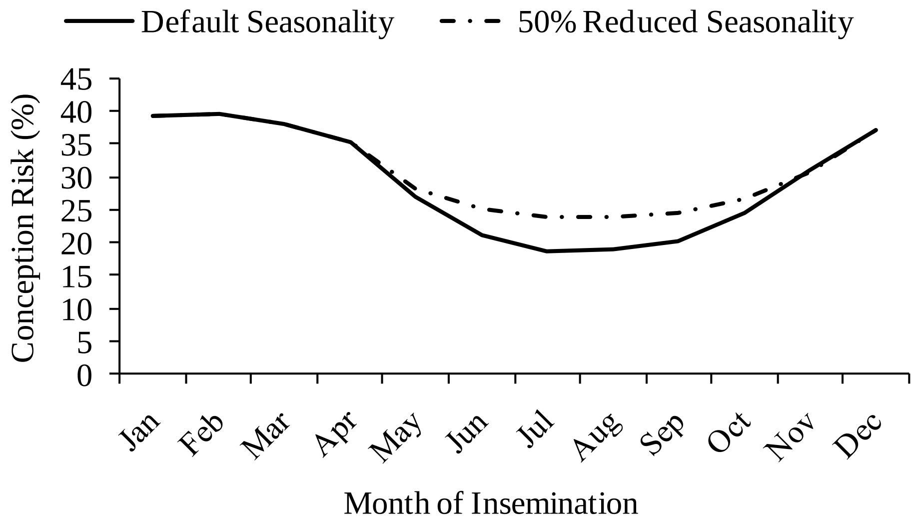

Figure 4-2. Conception risk by month of insemination at the default level of seasonality and at 50% reduction of seasonality.

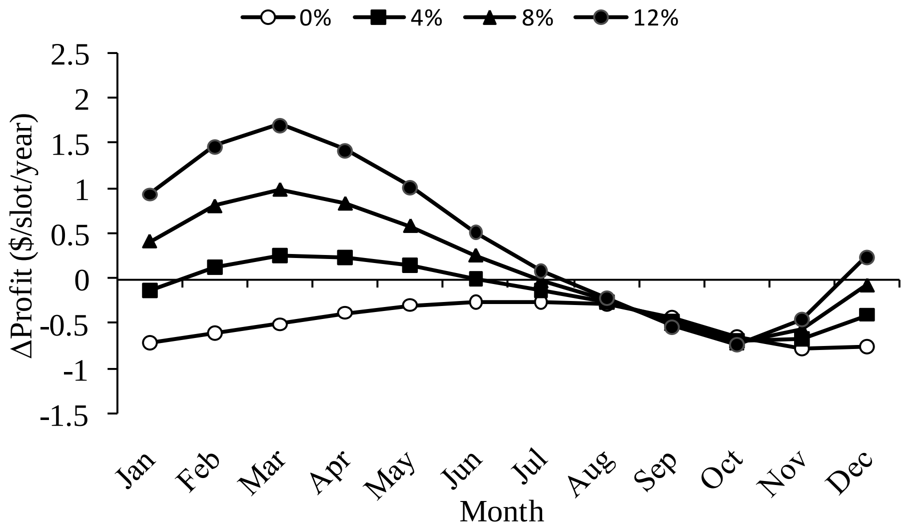

Figure 4-3. Change in profit per slot per year by month from bST administration prior to first service at 0, 4, 8, and 12 percentage point increases in conception risk.

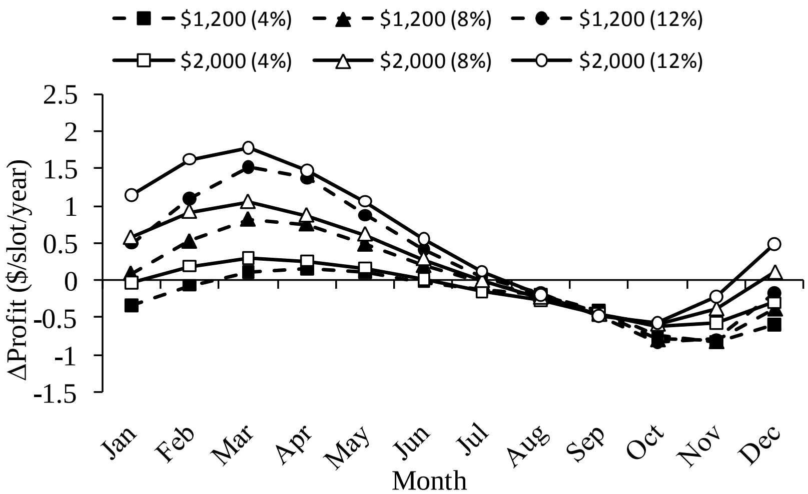

Figure 4-4. Change in profit per slot per year by month of bST administration at 4, 8, and 12 percentage point increases in conception risk under influence of change in heifer price.

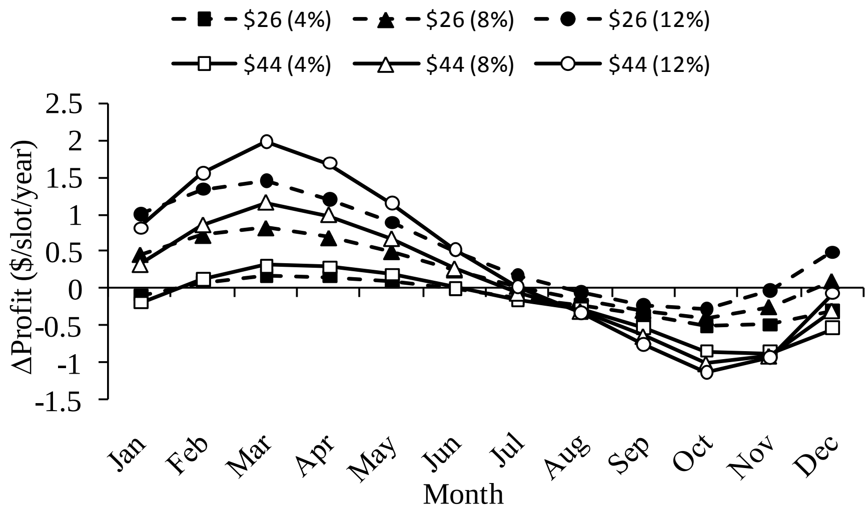

Figure 4-5. Change in profit per slot per year by month of bST administration at 4, 8, and 12 percentage point increases in conception risk under influence of change in milk price.

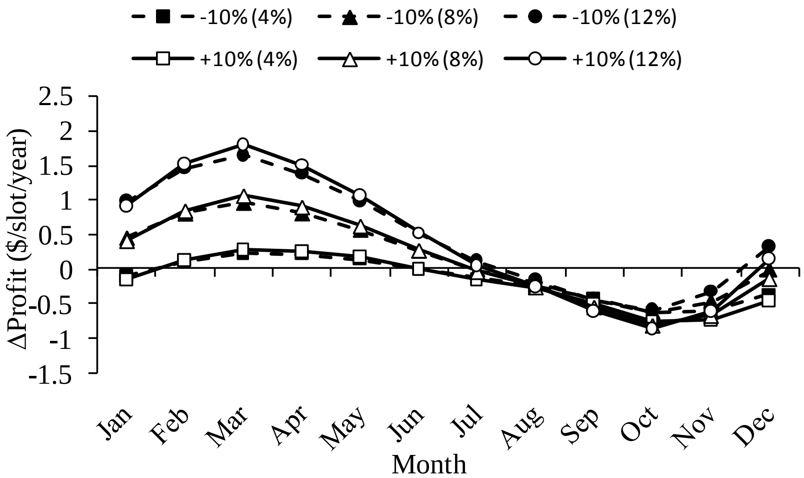

Figure 4-6. Change in profit per slot per year by month of bST administration at 4, 8, and 12 percentage point increases in conception risk under influence of change in milk yield.

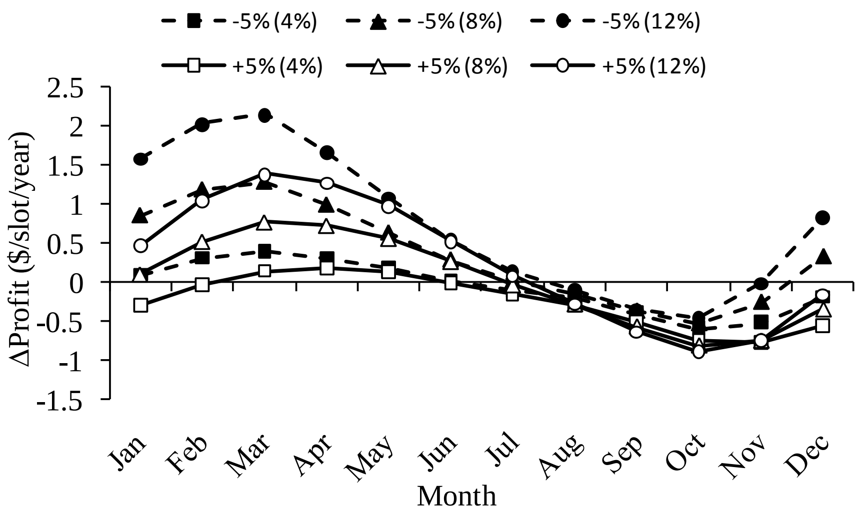

Figure 4-7. Change in profit per slot per year by month of bST administration at 4, 8, and 12 percentage point increases in conception risk under influence of change in overall probability of conception.

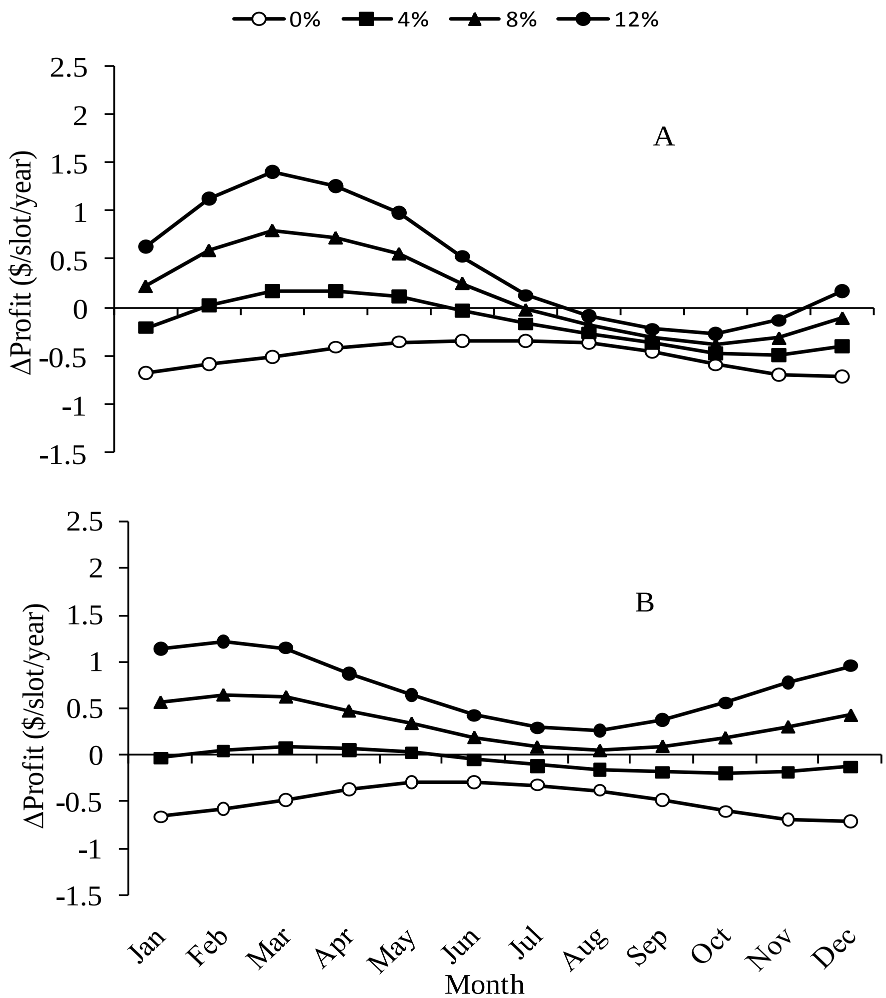

Figure 4-8. Change in profit per slot per year by month of bST administration at 4, 8, and 12 percentage point increases in conception risk under influence of change in seasonality of milk yield and reproduction (A) and milk yield alone (B).

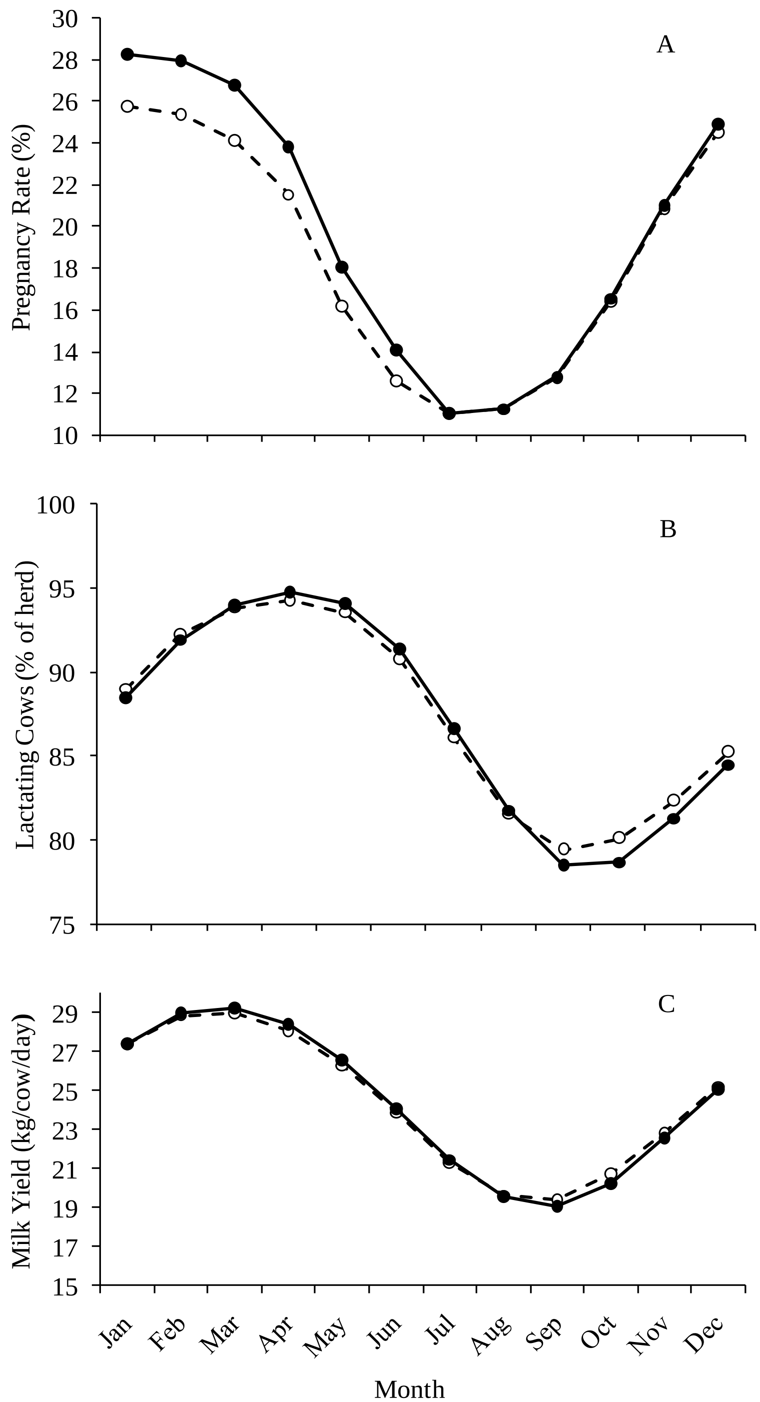

Figure 4-9. Comparison of herd statistics between default protocol with no bST (- - ○ - -) and protocol of bST administration optimized for positive months (January-June) under default conditions and conception risk increase of 8 PP (—●—). Pregnancy rate (A), lactating cows by month (B), and milk yield (C).

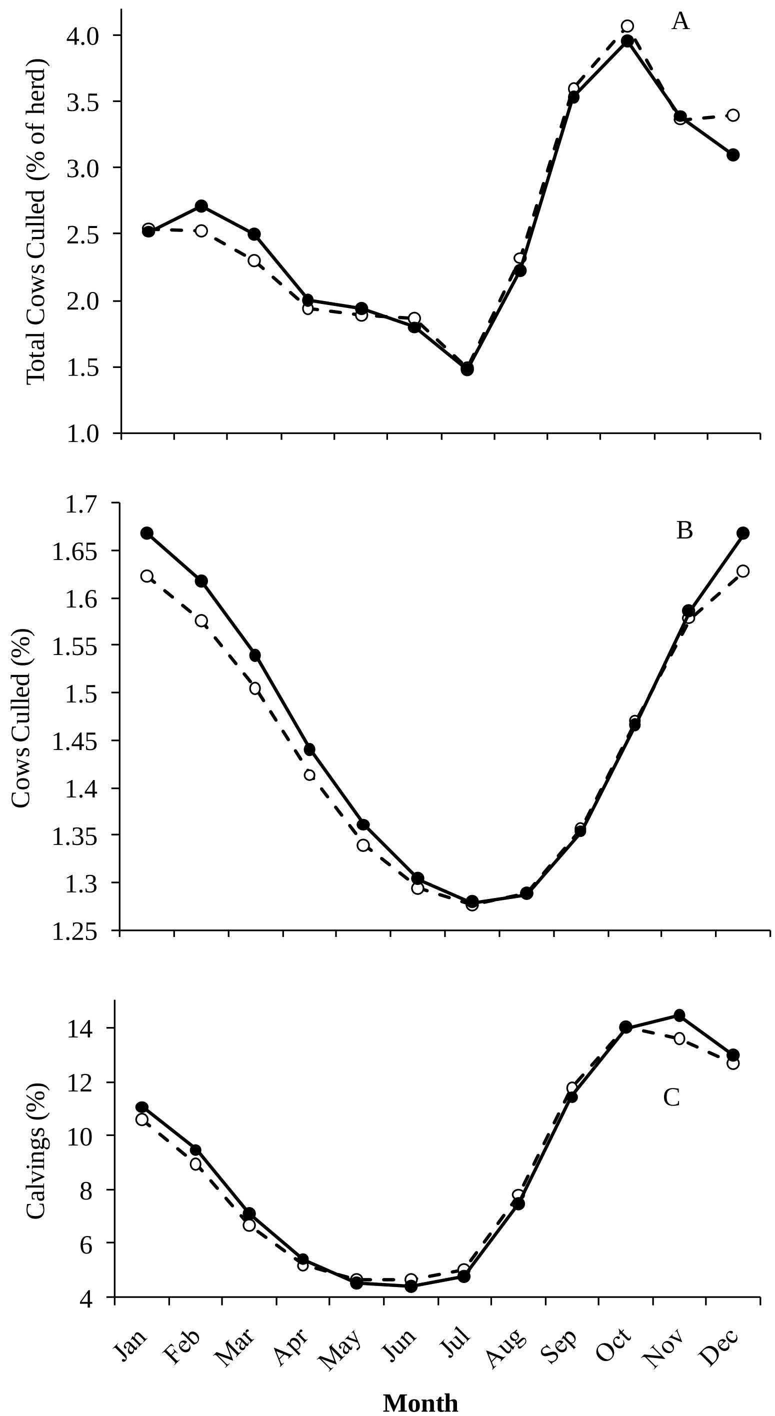

Figure 4-10. Comparison of herd statistics between default protocol with no bST (- - ○ - -) and protocol of bST administration optimized for positive months (January-June) under default conditions and conception risk increase of 8 PP (—●—). Total cows culled (A), involuntary culling (B), and calvings by month(C).

CHAPTER 5
GENERAL DISCUSSION

The long term goal of this research is to develop strategies for improving fertility in lactating dairy cattle experiencing heat stress to improve profitability of dairy farms. One such method proposed to combat the effects of heat stress on reproduction is the administration of a single injection of bST prior to insemination (Jousan et al., 2007). However, the value of such a strategy to increase fertility is unknown.

The study described in Chapter 3 of this thesis tested the hypothesis that administration of a sustained-release form of bST near the time of insemination improves fertility of lactating dairy cows. Results from the present study failed to support the hypothesis. When cows experienced heat-stress and were synchronized and inseminated in a timed AI protocol, there was a numerical increase in pregnancy rate in cows treated with bST as compared to control cows. However, this difference was not statistically different. The numerical increase in pregnancy rate associated with bST was caused by effects on the response to ovulation synchronization rather than to fertility. Bovine ST tended to increase the proportion of cows that ovulated after the ovulation synchronization protocol. The difference in percent cows pregnant after TAI between control and bST-treated cows was reduced when successfully synchronized cows were considered.

The rationale of the hypothesis for the study in Chapter 3 was that cows exposed to heat stress would benefit from administration of bST because of IGF-1. IGF-1 is released in response to bST and can protect bovine preimplantation embryos from the damaging effects of elevated temperature on development (Morales-Roura et al., 2001; McGuire et al., 1992). However, bST did not improve fertility despite the fact that cows experienced vaginal temperatures characteristic of hyperthermia (greater than 38.6°C) throughout most of the day. It is possible that damage to the oocyte was already completed prior to bST administration. Administration of bST was delayed until 3 days prior to insemination to avoid the increase in milk yield that could increase body temperature (Elvinger et al., 1992). By administering only a single injection of bST, this was avoided, as vaginal temperature was not elevated in bST cows when compared to control cows. Another reason for the absence of an effect of bST on fertility could be that early embryos are not protected by IGF-1. Research has only shown that IGF-1 can act as a thermoprotectant at Day 5 after insemination (McGuire et al., 1992).

Experiments to evaluate the potential of bST to enable cows to better establish and maintain pregnancy after insemination have yielded variable results. Administration of a single injection of bST to cows (large proportion of beef cows) and heifers at insemination did not improve pregnancy rate per insemination (Bilby et al., 1999). However, a single injection of bST at estrus increased the percent of repeat-breeder dairy cows pregnant following insemination (Morales-Roura et al., 2001). Injections of bST increased pregnancy success in dairy cows bred to TAI in some studies (Moreira et al., 2000; Moreira et al., 2001) but not in others (Jousan et al., 2007; Santos et al., 2004; Blevins et al., 2006). Differences in treatment regimens, reproductive management, cow type and issues related to sample size could explain some of this variation. For example, bST improved fertility for cows subjected to a Presynch-Ovsynch synchronization protocol but did not improve fertility for cows receiving an Ovsynch protocol without presynchronization (Moreira et al., 2001). Taken together with the results of this study, the lack of a consistent fertility-promoting effect of bST would contra-indicate broad use of bST to improve fertility in lactating cows. Additional work is needed to confirm its efficacy in selected populations of cows, for example in repeat-breeder cows (Morales-Roura et al., 2001).

In conclusion, results failed to indicate a beneficial effect of bST treatment on fertility of lactating dairy cows during the summer. There was a tendency for bST to increase ovulatory response in cows bred by TAI and further studies to evaluate this action of bST are warranted.

The results of the study in Chapter 4 suggest that even if bST increases first insemination CR the profitability of increasing first insemination CR is greater in the winter than in the summer. This contradicts the results of a similar study comparing profitability in dairy herds using estrus detection or OvSynch during the summer to increase pregnancies. It was more profitable to improve reproductive efficiency in the summer because of reduced fertility (Risco et al., 1998). The authors also commented that at higher levels of conception risk, there is less value to improving fertility (Risco et al., 1998). Perhaps, the seasonal nature of milk production and reproduction modeled in this study resulted in sufficiently high level of fertility (for this specific model) that could not be improved upon to such a degree that profit would increase.

Eliminating seasonality of milk production greatly changed the profitability in the current study. Cows conceiving in the summer have decreased potential for future milk production than cows achieving pregnancy in the cooler months. In addition, cows becoming pregnant at the first breeding after the end of the voluntary waiting period might have a shorter calving interval than optimal. This may be particularly true for first parity and high producing cows that may have a longer optimal calving interval (Le Blanc; 2007).

Using bST, or any other fertility enhancing strategy, to increase CR in the winter, will result in a herd with a more seasonal calving pattern. This many not be ideal for all herds under all management conditions. For instance, increased seasonality may cause problems when certain resources are constrained, for example parlor capacity and barn capacity, and may put a strain on cash flow as milk receipts will decline during this period.

Taken together, the results of Chapter 3 and 4, indicate that bST is not a biologically or economically efficient fertility enhancing agent for use in heat stressed dairy cattle. However, more research should be completed to fully understand the effect of bST on response to synchronization systems during heat stress. In addition, more research should be completed to identify the value of increasing seasonality or improving summertime fertility in lactating dairy cows.

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BIOGRAPHICAL SKETCH

Adriane Bell was born in Columbia, South Carolina. She resided in Irmo, South Carolina and graduated from Dutch Fork High School in 2001. She then enrolled at Clemson University and graduated in 2005 with a Bachelor of Science in Animal and Veterinary Science. While at Clemson, Adriane was active as an officer in the Dairy Science Club and also as a student leader with the university wide organization, Central Spirit. Next, Adriane began working with Albert De Vries and Peter J. Hansen at the University of Florida. She is currently a student at the University of Florida. In addition to her research and course work at the University of Florida, Adriane held the position of Graduate Advisor to the Dairy Science Club, was active in the Animal Science Graduate Student Association (ASGSA), and participated in various departmental activities. As a result of her various roles as a graduate student, Adriane was selected by a committee of faculty and students as the ASGSA Master's Student of the Year for 2007. Upon completion of her degree, Adriane plans on pursuing a career in animal agriculture.