THE IMPACT OF REPRODUCTIVE TECHNOLOGIES ON BEEF CATTLE AND MANAGEMENT

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

DOCTOR OF PHILOSOPHY

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ABSTRACT

Two experiments were conducted to evaluate producer management decisions that may impact beef cattle reproductive efficiency. The over-arching hypothesis was that critical breeding management decisions would positively influence pregnancy rate, calving distribution, and calf weaning weights in crossbred beef cows. In experiment 1, the objectives were to assess two different breeding systems on reproductive and offspring outcomes in North Dakota beef herds, conduct partial budget analyses on each operation, and evaluate production, performance and profit outcomes within/across herds for each breeding system with the use of surveys, tests of knowledge, and focus group discussions. Cattle from 10 commercial beef herds were randomly assigned to one of two breeding systems: 1) only exposed to natural service herd bulls (CON), or 2) exposed to ovulation synchronization and fixed-time AI followed by natural service bulls (TAI, fixed-time artificial insemination). Producers were also enrolled in the Cow Herd Appraisal Performance Software and the Farm Business Management programs. A greater proportion of calves were born early in the calving season to cows exposed to TAI and subsequent calves were heavier at weaning compared to calves born from CON cows. Producer perceived understanding increased for every parameter tested by the end of the experiment. In experiment 2, the objective was to evaluate the use of an injectable trace mineral supplement on reproductive and offspring outcomes in North Dakota beef herds. Cattle from 4 commercial beef herds were randomly assigned to one of two treatments: 1) administered an injectable trace mineral supplement 30 d before breeding, or 2) administered no additional treatments prior to breeding. The injectable trace mineral supplement did not have any effect on pregnancy, weaning weights of calves at the side of cows, or calving distribution. Producers may be able to enhance profitability with the use of selected management strategies including the use of estrus

synchronization and AI, record keeping and performance programs, and the inclusion of injectable trace mineral supplements. Selection of management strategies that fit individual operations will be key in terms of increasing profitability as well as decreasing stress of producers.

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LIST OF ABBREVIATIONS

μL....................microliter

AI....................artificial insemination

CIDR....................controlled internal drug release

CL....................corpus luteum

CON....................control

TM....................trace mineral

d....................day

ES....................estrus synchronization

GnRH....................gonadotropin releasing hormone

hr....................hour

IM....................intramuscular

kg....................kilogram

kg/d....................kilogram per day

mg....................milligram

mg/kg....................milligram per kilogram

mL....................milliliter

$PGF_{2\alpha}$....................prostaglandin F2 alpha

SEM....................standard error

TMR....................total mixed ration

Cu....................copper

Co....................cobalt

Fe....................iron

Mn .... manganese

mg/mL .... milligram per milliliter

Mo .... molybdenum

Se .... selenium

Zn .... zinc

CHAPTER 1. LITERATURE REVIEW

Introduction

The beef industry is a diverse system that is unlike many others found in production agriculture. In contrast to the swine and poultry industries, the U.S. beef industry is not vertically integrated (Ward, 1997); one proprietor involved in two adjacent stages of an industry (Carlton and Perloff, 1994). North America's beef industry is comprised of 3 different segments, cow-calf, stocker/backgrounder, and feedlot operations (Galyean et al., 2011) with the cow-calf segment being by far the largest (McBride and Mathews, 2011). Commercial cattle, those primarily raised for consumption, make up 76.3 percent of all herds in the U.S. (NAHMS, 2009). Of commercial cattle, 48.7 percent were crossbred or hybrid in their breed type, meaning that genetics varies greatly and thus the beef produced has similar variability.

The cow calf segment of the beef industry is the most diverse, with a large variety of production sizes and management styles. Troxel and Simon, (2007) stated in a summary of the Arkansas Beef Audit that small cow-calf producers are more likely to manage their herds based on family legacy and give high priority to the lifestyle that cow-calf production offers. The future of cow-calf production on the small scale will have more opportunity to make genetic improvements while becoming more productive (Troxel and Simon, 2007). Larger operations, those consisting of 200 head of cows or more, have somewhat different characteristics. From a reproductive standpoint, herds of 200 or more are more likely to examine bulls for reproductive soundness including semen testing, scrotal measuring, and culturing for potentially harmful infections compared to smaller herds (NAHMS, 2009). Similarly, herds of 200 or more are increasing more likely to institute a reproductive technology compared to a smaller herd (19.3 and 5.7 for 200 or more and 1-49 head respectively (NAHMS, 2009).

Agricultural producers have distinct styles in which they conduct business based on values, mentality, economic standing, and personal views on agriculture (Schmitzberger et al., 2005). In addition, region, climate, feed sources, and breed type dictate a great deal about how cattle specifically are handled and cared for. Intensive management can be found both in all types of beef cattle production settings; however, "intensive" can have very different meanings to producers in each region. In a survey evaluating the management decision to calve during a specific time of the year, producers identified weather to be the largest factor (39.4 percent), while tradition (29.7 percent), forage availability (9.3 percent) and market cycle (5.7 percent) were less of a concern (Dargatz et al., 2004). Beef cattle raised in the northern climates are generally fed some type of stockpiled or stored forage to maintain body weight or lose minimal body weight during the winter months (Young, 1981). In addition, environmental modifications like shelters are often provided to increase rate of gain and reduce maintenance requirements during winter. Increased feeding costs, heavy snow cover, and cold external temperatures combined with increased maintenance expense of hauling equipment can lead to increased management for producers. Instead of snow cover, the Southeast contends with a lack of moisture as well as poorer quality forage and extreme temperatures. Cattle production is not the primary industry in the Southeast, as producers own less land than in other regions (Short, 2001). This variation in management styles can affect the productivity of an operation and therefore the profit generated from that enterprise.

Of the best management practices (BMP's), beef cattle producers are more likely to use those that would bring about the most economic benefits to their particular operation. Producers that adopt BMP's are generally exposed to a greater amount of information than producers that receive insufficient information and cannot analyze the effect of a practice (Gillespie et al., 2007). In addition, producers adopting BMP's are likely more familiar with proper methods of

BMP implementation. According to Gillespie et. al. (2007), producers being unfamiliar with BMP's is the second most cited reason for not adopting BMP's, identifying the cause to be information about different practices not reaching all producers. Of this group of non-adopters, a larger percent will not have attended college, will have another major source of income, and will rely less on others in extension or related fields (Gillespie et al., 2007). In a survey of North Dakota beef producers, the highest level of education reached by producers is a high school degree (44 percent), whereas 30.3 percent of producers have a bachelor's degree (Dahlen et al., 2014). Greater adoption will come from an increase in education as well as an economic incentive (Gillespie et al., 2007; Schmiztberger et al., 2005). Producers with plans of succeeding may have more intensive management in order to maintain the economic status for future endeavors (Schmitzberger et al., 2005).

While production practices change based on geographic location, in order for the propagation of beef cattle to continue, reproduction must be successful and a calf must be born. Therefore, the most important factor in any beef production setting is the birth of a live calf, and therefore, profit is based on cows becoming pregnant, calving, and raising a healthy calf to weaning (Ayers, 2011). From a management perspective, reproduction is key to any successful operation and can be affected in many different ways. Thus producers may be able to enhance overall reproductive efficiency and profitability by carefully selecting reproductive management strategies to implement on their operations. Choosing a breeding system, enrolling in record keeping and economic programs, or supplementing trace minerals are among the strategies that a producer may implement to enhance the reproductive efficiency of a beef herd.

Natural service breeding, in which a sire or several sires are placed in a pasture and allowed to breed a group of females, is the most commonly practiced breeding system among beef producers. Females in estrus will be bred throughout the breeding season time, without a great deal of influence from the producer. An alternative to strictly allowing herd bulls to breed females at any given time is artificial insemination (AI). When using AI, producers indicated the use of estrus synchronization as always (46 percent), usually (26 percent), sometimes (28 percent), rarely (6 percent), and never (4 percent) in a national survey targeted at identifying use of AI in beef herds (Johnson and Dahlke, 2016). While hopefully resulting in a calf born, AI offers potential advantages like increasing the number of calves born early in the calving season and increasing the weaning weight of calves as well as increasing the potential for genetic improvement (Rodgers et al., 2012, Steichen et al., 2013).

Nutritional status of cattle is a key factor in reproductive efficiency and is often regarded as a limitation in breeding programs (Short et al., 1990). Different functions in the body take priority over others; maintaining metabolism, activity, and growth are of higher priority than pregnancy and lactation (Short et al., 1990). In a study conducted by Day and others (1986), attainment of puberty was evaluated when prepubertal crossbred beef heifers (217 ± 14 kg average body weight at the start of the experiment) were fed a control or growing diet (formulated for 0.9 kg body weight gain/day) and when heifers were fed a restricted energy diet (formulated for 0.2 kg body weight gain/day) for a 175 d feeding period. The mean date of puberty occurred on d 120 ± 14 of the experiment for control heifers, whereas no heifers receiving the restricted diet reached puberty (Day et al., 1986). While whole animal nutrition is general measured by recording a body condition score, mineral needs can be overlooked. Animal performance can be greatly affected by mineral status with observable decreases in immunity and enzyme function as well as growth and fertility (Wikse, 1992).

This literature review will discuss some of the management tools currently available for producers that may impact reproduction. Section one will review concepts related to breeding systems and section two will review concepts related to mineral supplementation.

Section 1: Beef Cattle Breeding Systems

Infertility of the postpartum beef cow is caused by many factors, including general infertility, lack of involution of the uterus, shortened estrous cycles, and anestrus. Anestrus, or the quiescence of the estrous cycle, is a major factor contributing to postpartum infertility and can cause poor reproductive rates (Short et al., 1990). Decreases in efficiency of a beef production system can be very costly and attributed to poor reproduction and infertility. Lamb and others (2008) estimate the cost of infertility to be $165 per exposed cow or $11 per cow exposed for every 1 percent decrease in the proportion of females becoming pregnant. The interval from calving to resumption of estrous cycles is controlled by a number of factors. Influencing or altering the nutrient supply to females and calf suckling are two ways in which postpartum interval can be affected to reduce the time a female in anestrus (Short et al., 1990).

Nutritional status of cattle is a key factor in reproductive efficiency and is often regarded as a limitation in breeding programs (Short et al., 1990). For this reason, nutritional status must be evaluated and maintained by producers. Body condition scores (BCS) are the only current production method in which one can evaluate the nutritional standing of an animal based on observation alone, and can be a useful management tool to ensure reproductive efficiency (Randel, 1990). Proper nutritional status will help to obtain optimal BCS's for every stage of production based on the 1-9 scale, with 5-6 being ideal (Richards et al., 1986). Producers can use the BCS classification system to manage nutrient intake before and after calving, which are the most crucial times for reproductive efficiency (Bischoff et al., 2012). Energy intake, in all stages, affects BCS and the time between calving intervals. Because various bodily functions take priority over others (i.e. maintaining metabolism when compared to reproduction; Short et al., 1990), reproduction may falter due to inadequate nutrition, both over and under feeding. Cattle that remain in a moderate or ideal BCS during the postpartum interval are able to rebreed in a shorter amount of time due to a higher energy intake (Houghton et al., 1990). Shorter postpartum intervals are also observed when cows were consuming a low-energy diet prepartum followed by a high-energy diet postpartum (Houghton et al., 1990), maintaining a positive energy balance prior to the time of breeding. In contrast, 14 month old heifers of adequate BCS fed a high gain diet (1300 g/d gain) had poor embryo production and blastocyst yields when evaluating dietary intake on in vitro collection compared to heifers of adequate BCS on a more restricted diet (Freret et al., 2006). Cow pregnancy status was evaluated in respect to BCS and researchers found that decreased pregnancy rates were observed for cows with low BCS (≤ 3: 31 percent, 4: 60 percent, and ≥ 5: 89 percent; Rae et a., 1993). Similarly, dairy cows with a BCS of ≤ 2+ or ≥ 4- on a 1-5 scale had a greater incidence of hoof problems than did cows of adequate body condition (Gearhart et al., 1990).

In addition to increasing the plane of nutrition, calf sucking is another major factor related to postpartum anestrus. Cows with increased suckling intensity have a longer postpartum interval and decreased ovarian activity (Wettemann et al., 1978). In a study evaluating the effect of sucking versus milking stimulus, when calves were restricted but allowed to suckle two times per d, d to first ovulation were similar to cows with calves present continuously (33.9 and 34.7 d, respectively; Lamb et al., 1999). For cows with weaned calves, restricted calves, and cows that were milked two times per d (both restricted and weaned), d to first ovulation was decreased compared to cows that were suckled (14.6 and 34.3, respectively). Data suggests that it is not milking that prolongs anestrus but the maternal bond with the calf (Lamb et al., 1999). The maternal bond is forged during the increased sensitive period after parturition, in which cues made by the calf including tactile, olfactory, and auditory cues enhance the responsiveness of the dam to the calf (Poindron, 2005). It is suggested that the removal of this responsiveness decreases d to estrus.

Description of Breeding Systems

Natural Service

The most commonly utilized breeding system among cow-calf producers is natural service, or the use of bulls to breed females in the herd with roughly, 95.7 percent of beef operations using only natural service breeding in their herds (NAHMS, 2009). When utilizing this breeding method, herd sires are turned into pastures with females for a designated period of time (a breeding season) or indefinitely. Breeding seasons can be developed to ensure calves are born within a desired timeframe. Breeding seasons are used to decrease the variability in calf age and size within a herd and increase the uniformity for marketing or replacement purposes. Additionally, short breeding seasons can be used to more intensely monitor nutritional status of females as well as calving difficulties (NAHMS, 2009), potentially saving money. More than 50 percent of U.S. beef operations do not have a set breeding season, meaning that bulls stay with females 365 d a year (NAHMS, 2009). An economic evaluation of herds originating from Texas, Oklahoma, and New Mexico over a 10-year period, identified that the length of the breeding season, ranging from 11 to 365 d, negatively impacted the pounds weaned per exposed female (Ramsey et al., 2005). The remaining herds have 1 to 2 breeding seasons, with 34 percent having a single breeding season, generally during the months of May and June (NAHMS, 2009). Each operation may have their own desired breeding season in different regions of the U.S.

Bull Characteristics

The efficiency of natural service mating is dependent on the ability of a bull to effectively breed females. The bull:cow ratio is identified as the number of females that a bull is mated to (Chenoweth, 1981). Bulls are capable of servicing anywhere from 9-83 females in a 24-hr period, however, the ability for those females to become pregnant can be affected my many things including his libido and the social interactions of other bulls in the pasture (Chenoweth,

1981) as well as seminal traits (Pexton et al., 1990). National production averages of bull:cow ratios, as stated by APHIS (2009), are one mature bull per 25 females. Data collected from veterinarians over a two-year period confirms national results published by APHIS (2009) in which average number of bulls per female group were 1 bull per 24.8 females (Dahlen and Stoltenow, 2015). This number is slightly lower for yearling bulls; 1 bull per 17 females (APHIS, 2009). Greater pregnancy rates have been observed with older bulls (2 and 3+ year olds) when compared to yearlings in single sire mating groups (Pexton et al., 1990). In the same study, yearlings and mature (2 and 3+ years of age) bulls were observed for mountings in groups ranging from 1:7 to 1:51 bulls to cows with yearlings having significantly more mounts per cow compared to older bulls (Pexton et al., 1990). The selection of mature bulls by beef cattle producers is observed in a national survey where the ratio of young bull to mature bull for breeding purposes was 3.6 to 15.6, respectively for a herd size of 200 head or greater (NAHMS, 2009).

In addition to the number of bulls used per number of females, other factors must also be considered when using natural service breeding. Risks are involved in any breeding system due to the nature of animal production, however, bull maintenance risks can vary greatly. Risks associated with natural mating include failure to pass a breeding soundness exam, infertility of a dominant bull, lameness or injury during the breeding season, damage to property/facilities, or possible transmission of diseases (Vishwanath, 2003). The ability of the bull to breed a group of females is also dependent on semen quality, libido, and social ranking within contemporary groups in each herd (Chenoweth, 1981), factors included in the following section.

Breeding Soundness Exams

Bull selection in the cow-calf sector can be influential in terms of profit generated by a herd and for this reason, tools have been created in order to facilitate the choosing of the correct bulls. Breeding soundness exams are examinations done prior to the start of the breeding season that identify possible pitfalls that would make a bull unable to successfully breed. Guidelines for breeding soundness exams were established by the Society of Theriogenology (Ball et al., 1983) and include a physical examination, examination of the reproductive genitalia, and evaluation of semen morphology and motility. The physical examination evaluates overall health including eye and oral health, body condition, and conformation and body structure. Bulls should be in adequate condition, not overly fat or excessively thin as well as having proper posture, hoof health and structural integrity. The genital examination evaluates the prepuce for lesions, inflammation, and abscesses, the penis for any abnormalities, the scrotum for circumference and conformation, the testes and epididymis for size and tone, and finally the accessory sex glands including rectal palpation of the seminal vesicles. Bulls should be free of any lesions, abnormalities, and testicle conformation should be adequate (not a cryptorchidic) while meeting the necessary requirements for scrotal circumference. During the semen examination, there is a visual evaluation of the semen including volume and gross appearance, as well as gross and individual motility and morphology of semen. Bulls must have a gross motility rating of at least 30 percent (generalized oscillation) in order to pass the exam. Additionally, an ejaculate must contain at least 70 percent normal morphological sperm to pass an exam, for example less than 30 percent defects including acrosomal defects, nuclear defects and underdeveloped sperm (Barth and Oko, 1989).

The Society of Theriogenology classifies bulls as either satisfactory potential breeders, unsatisfactory potential breeders, or deferred (Ball et al., 1983). When data was reported for over 14,500 bulls, proportions of yearling bulls that failed a breeding soundness exam were greater than proportions of mature bulls failing an exam (22.1 percent and 11.6 percent, respectively; Underdahl et al., 2016). Bulls classified as deferred can be reevaluated at a later date while unsatisfactory breeders are recommended for culling due to one or more defects. If bulls, both yearling and mature, were being retested, greater proportions failed their retest exam than those that failed the initial exam (39.5 percent and 18.2 percent respectively). Yearling bulls were more likely to fail due to defects in semen morphology and penile warts whereas more mature bulls failed because of penile injuries/defects and issues with the conformation of their feet and legs (Underdahl et al., 2016). Bulls that are subfertile, meaning that they have reduced fertility, increase days to conception, prolong the calving season, and increase the number of culled females due to being open at the end of the breeding season (Kastelic and Thundathil, 2008).

Estrus Synchronization and Artificial Insemination

Estrus synchronization and artificial insemination are management techniques available for the advancement of herd genetics by selection of highly proven sires, without incurring the total costs of the advanced genetics of AI sires. As of 2009, use of AI in the beef industry was minimal with a reported 7.9 percent of operator implementation (NAHMS, 2009). Artificial insemination is used to a greater extent in heifers than in cows (12.4 percent and 4.1 percent, respectively; NAHMS, 2009). Bringing cattle through a chute to be AI bred required greater labor resources compared to natural service breeding, without or without the additional work brought on by estrus synchronization. Cited reasons for limited use of estrus synchronization and AI include labor and time (38.4 percent), cost (19.0 percent), and too difficult/complicated (16.6 percent; NAHMS, 2009). Although adoption is low, AI has the ability to offer potential advantages like increasing the number of calves born early in the calving season and increasing the weaning weight of calves (Rodgers et al., 2012, Steichen et al., 2013). While previously cited implementation is low, a North Dakota beef producer survey reported increased utilization of AI in herds that were planning to continue in the beef industry for the next 10 years (Schook et al., 2014). Additionally, while total implementation numbers reported by NAHMS (2009) reflect overall producer use, greater proportions of producers with herds of 200 head or more utilize estrus synchronization and AI when compared to smaller herds (NAHMS, 2009).

Estrus Synchronization

Estrus synchronization is the manipulation of the estrous cycle (Odde, 1990) to synchronize the ovulation of oocytes to facilitate insemination of a group of females at a predetermined time (Rathbone et al., 2001). Intensive research continues to be conducted in the area of estrus synchronization to increase the proportions of females that cycle for increased breeding efficiency (Foote, 2002). As synchronization of the estrous cycle is dependent on the manipulation of naturally occurring hormones (Twagiramungu et al., 1995), one must be familiar with those hormones and the normal cycle of that particular animal. Hormone functions and uses will be described in the following sections.

The development of estrus control and synchronization occurred in six phases (Patterson et al., 2003). The first, in the early 1960's, was based on the discoveries that progesterone inhibited ovulation and Prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) would regress a corpus luteum (CL) (Patterson et al., 2003 and Lamb et al., 2010). The next phase included the use of exogenous progesterone for the purpose of prolonging the luteal phase of the estrous cycle (Patterson et al., 2003). Subcutaneous progesterone implants paired with estradiol were the make-up of the progesterone-estradiol phase (Synchro-Mate-B; Lamb et al., 2010). Simultaneously, multiple injections of prostaglandin were utilized to reduce the number of d required to detect estrus. Next, progestins were used in combination with prostaglandin to delay estrus after spontaneous luteolysis (Lamb et al., 2010). In 1988, Fortune et al., concluded that ovarian follicles grow in wave-like patterns with one follicle, generally the largest, becoming dominant. The process of ovulation occurs as antral follicles are synchronously recruited in a cohort to grow past the point of being atretic (Fortune et al., 2004). Ovulation occurs when one follicle has been selected for dominance and is present at the time of luteal regression. In the cow, this wave like pattern occurs two to three times before concentrations of estradiol in the follicular fluid of the dominant follicle are great enough at luteal regression that the follicle can ovulate (Fortune et al., 2004). The next generation of estrus synchronization systems were developed with the idea of manipulating the follicular phase and the timing of ovulation (Lamb et al., 2010). To more accurately control estrus, both the luteal and follicular phases had to be manipulated, resulting in the GnRH-prostaglandin phase (Patterson et al., 2003).

Protocols are now available that allow producers to synchronize the estrous cycles of a group of females and breed cattle at a fixed time point. In an ideal situation, the synchronization of estrus would cause a fertile and tightly synchronized estrus response in a high percentage of the females that are treated (Odde, 1990). In order for the ideal situation to occur, the follicular stage of the estrous cycle must be synchronized (Patterson et al., 2003). With a tightly synchronized estrus and the ability to breed at a fixed time, pregnancy rates can resemble those found in bull breeding in the first 21-d period of the breeding season, roughly 65 percent of females; (Lauderdale, 2009). In addition to fixed time AI, other protocols exist and are updated annually by the Beef Reproductive Task force. Figures 1.1. and 1.2. detail the estrus synchronization protocols recommended by the BRTF including those focusing on heat detection, heat detection with timed-AI (TAI), and only TAI for both cows and heifers. Though several synchronization protocol options exist that facilitate the use of AI, compliance is critical in each case. If on any given d the compliance for giving the correct injection is done for 90 percent of the herd for an average of three working d, the appropriate response with not be

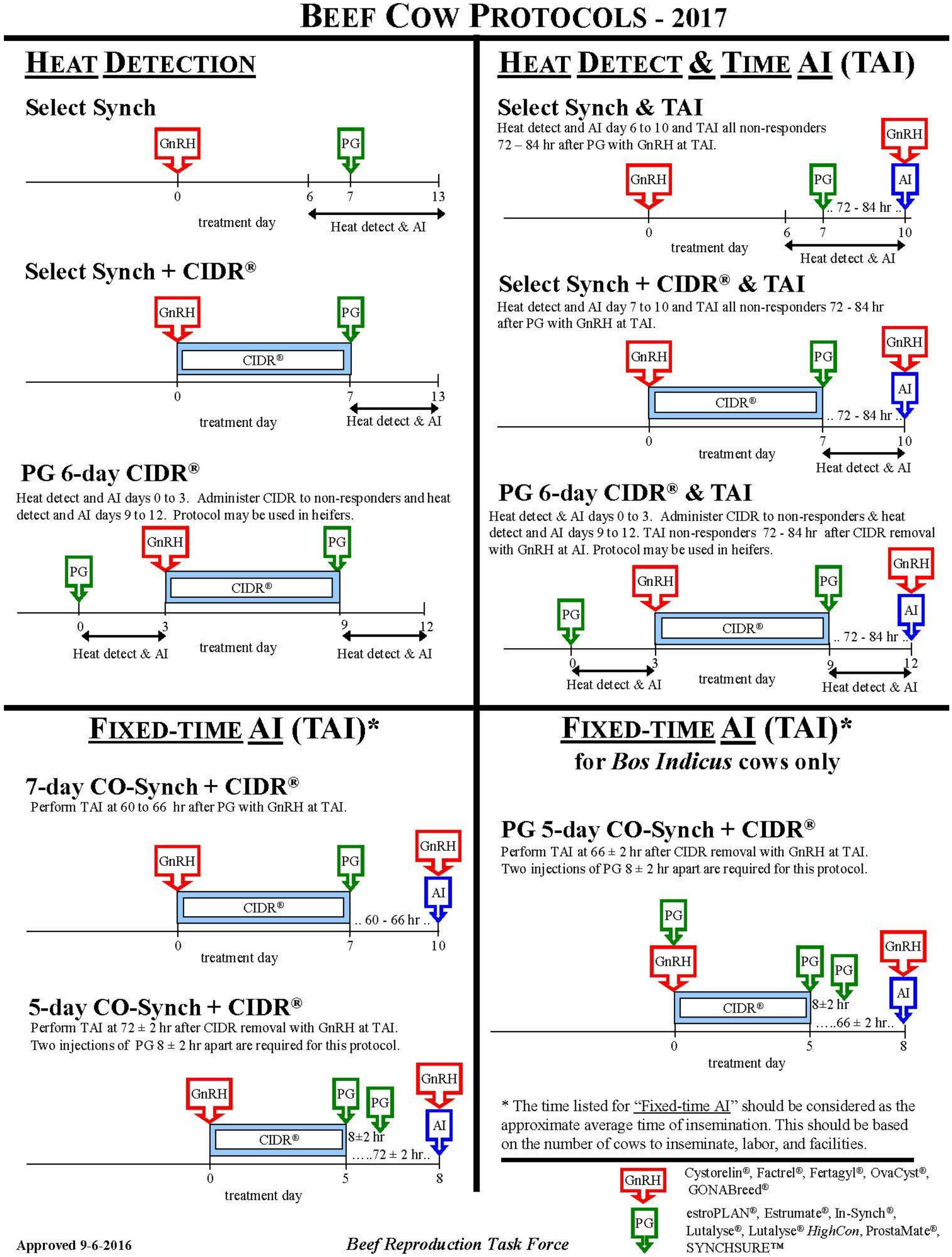

Figure 1.1. Estrus synchronization and AI protocols for beef cows as recommended by the Beef Reproductive Task Force, 2017

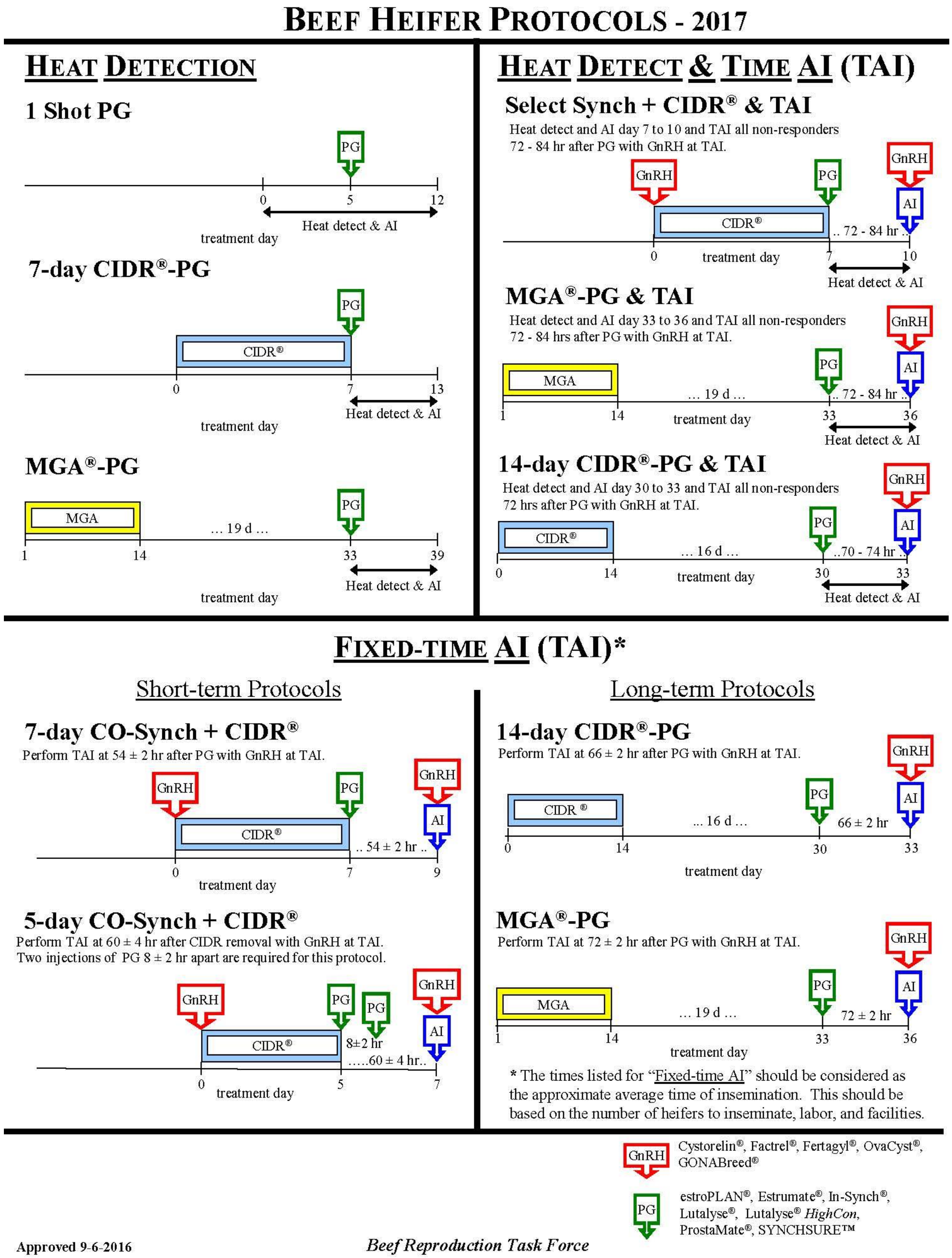

Figure 1.2. Estrus synchronization and AI protocols for beef heifers as recommended by the Beef Reproductive Task Force, 2017

obtained (0.90 x 0.90 x 0.90 = 72.9 percent). Taken together, a great deal of time and many resources have been spent to correctly synchronize females for the purpose of increasing reproductive efficiency. If followed correctly, ovulation synchronization protocols should yield a synchronized estrus among a group of females exposed to the protocol.

Artificial Insemination

Artificial insemination is the process in which semen is used to impregnate a female without the act of natural breeding. Understanding the procedure of AI requires a knowledge base of the anatomy of a species as well as the timing of events and estrus to successfully breed a female. The ability and knowledge to be able to perform AI has been known for many centuries, however, understanding and proper timing is still being researched today.

The development of AI began hundreds of years before it was commercially available for beef cattle, research was being done with other species. This viable reproductive technology has been rumored to have been used by Arabs to inseminate their mares (undocumented) however was first recognized as being successful in 1784 by Spallanzani who inseminated a dog (Foote, 2002). Nearly one hundred years passed before AI was reported successful again, this time in isolated studies involving dogs, rabbits, and horses (Foote, 2002). Research continued over the next century, finally focusing on the ability to understand the estrous cycle. Initial research and understanding of estrous began in the 1920’s at the University of Missouri by F. F. McKenzie. This work focused on the estrous cycle, ovulatory schedule and semen production of sheep. Between the 40’s and the 60’s, researchers began looking at hormones that may be manipulated in order to manage estrus in a cyclic cow (i.e. estrus synchronization). It is now known that many variables can affect successful AI.

Nutrition, postpartum interval, and bulls can all affect reproductive rates of females. When describing AI, it is important to also understand the variability that occurs with the application of techniques by different individuals. Factors such as handling cattle, detecting females when they come into heat, correctly handling semen, and working cattle in conditions that are favorable to breeding are all keys to success when utilizing AI (Dahlen et al., 2015). Cattle should be handled in a calm manner utilizing techniques that foster a low-stress environment. Additionally, weather conditions should be monitored, as adverse weather conditions such as heat, cold, or excess precipitation can impact the AI program results (Dahlen et al., 2015). Producers should be spending appropriate amounts of time with females if heat detecting is necessary for the accurate identification of females as they come into estrus. Proper heat detection should include a minimum three visits totaling at least three hrs total in a given day (Johnson et al., 2013). After a female is detected in heat, she should be inseminated six to 12 hours after she is first observed in standing estrus (Johnson et al., 2013).

Proper breeding techniques must be used when implementing AI. Semen used for AI is stored in a tank filled with liquid nitrogen. Before semen is implanted into a cow, a semen straw is thawed in a 35 ± 2 °C water bath for a minimum of 45 seconds (Dejarnette et al., 2004). After semen is thawed, it is thermally and hygienically protected while being loaded into an insemination rod. Once ready to inseminate, the semen gun is placed into the vagina with the technician’s dominant hand and is directed through the cervix to the uterine body, which is the site of semen deposition (Dejarnette and Nebel, 2012). Once the semen is deposited in the uterine body, the technician gently removes the instrument and proceeds to the next female.

Use of AI is often paired with an estrus synchronization protocol, that depending on the protocol selected will allow for breeding to occur after a period of heat detection or at a set time period (i.e. timed-AI). When timed AI is not used, the detection of estrus must be accurate to determine the proper time that females are receptive to breeding. In this case, the “AM/PM” rule is utilized and females that are observed in standing estrus are inseminated 12 hr after the initial mounted (Dejarnette et al., 2004). Following the "AM/PM" rule, if a female is observed in standing estrus at eight o'clock AM, she should be inseminated at eight o'clock PM of the same d. In a survey representing 42 states in the U.S., respondents synchronizing cows and heifers more commonly used heat detection protocols for heifers (heat detection: 59% and timed-AI: 41%) and timed protocols for cows (heat detection: 33% and timed-AI: 67%; Johnson and Dahlke).

Estrus Synchronization Protocol Selection

While many estrus synchronization protocols are currently recommended for use in both beef and dairy cattle, protocols recommended for use in beef cattle will be the primary focus for the remainder of this literature review. Specific synchronization protocols should be selected based on end goals, available financial resources, free or available time, and experienced labor. Based on compliance with the synchronization protocols, great variation can exist between pregnancy rates obtained for each operation, group of females and individual AI technician. In a study observing the variation among technicians of obtained pregnancy rates of cows from seven different operations, pregnancy rates ranged from 15 to 82% (Sá Filho et al., 2009). While variation exists, pregnancy rates obtained with proper protocol compliance and adequate technicians typically range anywhere from 15 to 70% of the females inseminated becoming pregnant to AI (Larson et al., 2006, Schafer et al., 2007, Busch et al., 2007, Steichen et al., 2013).

In some of the following chapters, the 7-d CO-Synch + CIDR (Larson et al., 2006) synchronization protocol was used, consisting of a GnRH injection given at the time of CIDR insertion, followed 7 d later by the removal of the CIDR and an injection of $PGF_{2\alpha}$. Timed-AI is preformed 54 or 60-66 hrs later (for heifers and cows, respectively) and includes a second injection of GnRH. In this protocol, the addition of progesterone, in the form of a CIDR, could potentially prevent the premature occurrence of estrus prior to the administration of $PGF_{2\alpha}$, which should improve pregnancy rates (Larson et al., 2006). Without the addition of a CIDR device, 10 to 20% of females exhibit estrus just before or immediately following the injection of $PGF_{2\alpha}$, causing females to not be in estrus at the time of TAI (Lamb et al., 2001). The increased number of cows coming into estrus due to the addition of progesterone would allow for more individuals to become synchronized and be more susceptible to fixed-time AI (Stevenson et al., 2000). The CO-Synch + CIDR protocol has been shown to have a wider application, based on time and labor constraints when compared to the MGA Select Synch protocol (Schafer et al., 2007).

Progesterone

Progesterone is a key component to not only the estrus cycle but also to the development and support of the calf while in utero. Progesterone is a steroid hormone produced by the corpus luteum (CL) of a cycling mammal. In ruminants, progesterone is also produced by the placenta during pregnancy (Senger, 2005). Progesterone receptors are expressed in the stroma and endometrial epithelium during the luteal phase in mammals and during pregnancy receptors are only found in the stroma and myometrium of the uterus (Spencer et al., 2004). A female is considered to be pubertal or cyclic and able to breed once the concentrations of progesterone have reached ≥ 1 ng/mL in blood serum (Perry et al., 1991). Concentrations of progesterone in the cyclic animal are the greatest during the luteal phase of the estrous cycle, which lasts for up to 80% of the cycle length (Senger, 2005).

After parturition, the first estrous cycle can vary in length and is often accompanied by a silent estrus, or females failing to show a behavioral estrus (Perry et al., 1991). Short estrous cycles are those less than 17 d in length with an average of 7 to 10 d and are generally observed between the first and second postpartum estrus (Odde et al., 1980). The CL formed after ovulation is short lived due to a premature uterine secretion of prostaglandin $F_{2\alpha}$ (Zollers, Jr. et al., 1993) and therefore produces progesterone for only a short period of time (Perry et al., 1991). Exposure to progesterone is a criterion for a normal behavioral estrus in many cases (Kyle et al., 1992) and it is thought that the progesterone produced during the short cycle is needed as a type of priming before the next ovulation and estrus cycle of normal length (Ramirez-Godinez et al., 1981). When breeding heifers, greater pregnancy rates were observed for females bred after their third estrus compared to their pubertal estrus, a potential sub-optimal fertility problem observed with the first estrus cycle (78 and 57 percent respectively; Byerley et al., 1987).

When exogenous progesterone is administered to females that have a regressing CL estrus is suppressed until the exogenous source is removed. In order for a female to cycle again, concentrations of progesterone must decrease and luteolysis must occur (Odde, 1990). Two forms of exogenous progesterone exist for the use of estrus synchronization, melengestrol acetate (MGA) and a controlled internal drug release (CIDR). Melengestrol acetate is an orally active progestin steroid (17-acetoxy-6-methyl-16-methyl-enepregna-4,6-diene 3,20-dione) developed to maintain pregnancy, promote endometrial proliferation, and delay estrus activity (Duncan et al., 1964). Melengestrol acetate is generally a pelleted product that has been established to be an effective method for synchronizing estrus in both cows (Patterson et al., 1989, Kojima et al., 2000) and heifers (Brown et al., 1988, Imwalle et al., 1998). While duration of feeding differs among protocols, a rate of 0.5 mg/(animal · d) is suggested per label recommendations (Zoetis, Parsippany, New Jersey). Melengestrol acetate is often fed to heifers in feedlot situations and is recommended for synchronizing estrus in heifers by the BRTF (Figure 1.2.). Problems with feeding MGA are observed when females do not consume the required amount necessary to suppress estrus and therefore estrus response is decreased (Patterson et al., 1989, Lamb, 2013). Adequate bunk space is recommended for use with MGA so animals have the opportunity to consume feed simultaneously with other females (Patterson et al., 2003). Controlled internal drug release devices (CIDR) on the other hand are exogenous progestin steroids that cross through the vaginal mucosa into the bloodstream at a controlled rate (FDA, 2012). Controlled internal drug release devices are comprised of a t-shaped nylon center covered by a silicone layer and contain around 10% progesterone (pregn-4-ene-3,20-dione) by weight (1.38 to 1.9 g of progesterone; Canada and the United States, respectively). Upon insertion of the CIDR device, plasma concentrations of progesterone rise quickly, reaching 4-6 ng/mL within the first few hr of administration (Rathbone et al., 2002, Dahlen et al., 2014). The amount of progesterone released should control plasma progesterone concentration levels adequately for about 7 d (Chenault et al., 2003), with concentrations ranging between 2-3 ng/mL by d 7 for pubertal heifers (Dahlen et al., 2014). After CIDRs are removed, plasma concentrations of progesterone decrease rapidly within 24 hr, falling to levels lower than 1 ng/mL (Dahlen et al., 2014).

Prostaglandin

Prostaglandins were discovered in human semen and sheep seminal vesicles in the 1930's and were shown to cause smooth muscle contraction and a change in blood pressure (Rathbone et al., 2001). The prostaglandin hormones are fatty acid bases with hormone like capabilities and were the first arachidonic acid products to be discovered (Senger, 2005). While several prostaglandins exist, prostaglandin $F_{2\alpha}$ will be the focus of discussion due to its role in the reproductive system. Prostaglandin $F_{2\alpha}$ is a prostaglandin secreted by the uterus in a series of short pulses with each pulse lasting roughly an hr with approximately five pluses occurring in a 24-hr period (McCracken et al., 1984). Receptors for $PGF_{2\alpha}$ are present on the luteal tissue of a CL, an endocrine gland formed by both large and small luteal cells (Arosh et al., 2004). The CL of the ovary is very sensitive to the pulse like fashion of $PGF_{2\alpha}$ and responds quickly (Silvia et al., 1991), causing luteolysis in the absence of pregnancy and allows for the regression and atresia of the CL (Odde, 1990), decreasing the amount of progesterone in the system (Silvia et al., 1991). Once luteolysis occurs and progesterone concentrations begin to decrease, the dominant or largest follicle on ovary, currently producing estradiol, increases its production of estradiol which stimulates an effect on the hypothalamic-pituitary axis, preparing the female for behavioral estrus (Rathbone et al., 2001). The increased production of estradiol stimulates a positive feedback system that causes the hypothalamus to release GnRH, stimulating the release of LH and FSH. The surge of LH and FSH causes the thecal and luteal cells to transform, releasing the oocyte from the follicle, causing ovulation and the formation of another CL (Rathbone et al., 2001).

For the purpose of estrus synchronization, $PGF_{2α}$ is administered to lyse a functional CL if present. If $PGF_{2α}$ is administered between d 5 to 15 or 16, of the estrous cycle, rapid luteolysis will occur (Rathbone et al., 2001). In a study evaluating the responsiveness of $PGF_{2α}$ on the CL's of 24 dairy cows, researchers found that serum progesterone levels decreased to lower than 1 ng/mL in 12 hrs for every 100% of cows (4/4) administered 30 mg $PGF_{2α}$ from days eight to 12 of the estrous cycle compared with cows administered estradiol, sterile saline or corn oil (Seguin et al., 1979). Similarly, when cows were administered $PGF_{2α}$ and GnRH simultaneously on d eight or 10 of the estrous cycle, concentrations of progesterone decreased 24 hr later in all treated females (Stevens et al., 1993). The time period between $PGF_{2α}$ release and luteolysis can be affected by age, breed, and other physiological factors and for this reason, it can be variable. In the case that a female does not have a functional CL, there are no luteal cells present and therefore no receptors for $PGF_{2α}$ to bind, causing an injection to have no effect (Rathbone et al., 2001).

GnRH

Gonadotropin releasing hormone is a decapeptide hormone that is secreted by the hypothalamus (Senger, 2005). From the hypothalamus it is released in a pulse like manner into the anterior pituitary where it will bind to a specific G-protein and concludes with the stimulation of the release of follicle stimulating hormone (FSH) and luteinizing hormone (LH; Naor et al., 2000) from the anterior pituitary. Follicle stimulating hormone is responsible for the emergence of each follicular wave with concentrations peaking when the dominant follicle of a given wave reaches 4 mm (Ginther et al., 1996). When the dominant follicle diverges from all other growing follicles, concentrations of FSH decrease. During each follicular wave, recruited follicles produce gradually increasing levels of estradiol (Wiltbank et al., 2002). At the time of FSH decrease, concentrations of estradiol are sufficient enough to induce an LH surge, causing the ovulation of the dominant follicle within 24 to 32 hr (Wiltbank et al., 2002). Exogenous GnRH allows for the induction of ovulation by way of luteinizing the dominant follicle when injected into postpartum beef cows (Mapletoft et al., 2003). Luteinizing the dominant follicle allows any bovine females with a large follicle (10 to 15 mm) to ovulate and begin a new follicular wave Lucy et al., 1992). One to four waves occur during the follicular phase in cattle (Lucy et al., 1992) with increases in fertility observed with increased numbers of waves (Celik et al., 2005).

With regard to estrus synchronization, GnRH is administered for the purpose of causing ovulation in females with a dominant follicle. In a study evaluating the effect of a single injection of GnRH on ovulation at different stages of the estrous cycle in dairy cows, greater ovulation rates (86.5 percent) were observed for females in d 5-9 or 17-21 of the estrous cycle (Vasconcelos et al., 1999). When GnRH is administered to females with large dominant follicles (≥ 9 mm), the follicle either ovulates because of surging LH concentrations or regresses by atresia (Twagiramunhu et al., 1995). The follicles that ovulate with GnRH administration are healthy and functionally dominant. Females will dominant follicles of 12 mm or greater at the time of a second GnRH injection, relative to the Co-Synch and Co-Synch + $PGF_{2\alpha}$ protocols (Figure 1.1), had greater pregnancy rates compared to females with dominant follicles smaller than 12 mm (Lamb et al., 2001). Fewer females (23 percent) ovulated in response to GnRH when in d 1-4 of the estrous cycle (Vasconcelos et al., 1999). This is most likely due to the greater concentrations of FSH stimulating the growth of a new follicular wave to begin the estrous cycle.

Hormones Used Together

Understanding how each hormone works with regard to use in estrus synchronization is vital to realizing the potential when all three products are used together. Stevenson and others (1997) were interested in understanding the impacts on fertility when GnRH, $PGF_{2\alpha}$, and norgestomet (a steroidal progestin) were used in concert for synchronizing estrus. When both cyclic and noncyclic females were administered two $PGF_{2\alpha}$ injections 14 d apart (Control) or two $PGF_{2\alpha}$ injections 14 d apart followed by GnRH and a norgestomet implant (Treatment), conception rates were greater for cows in the treated group (60.1 percent) when compared to the control group (48.0 percent; Stevenson et al., 1997). Ovulation was either induced or synchronized with the inclusion of $PGF_{2\alpha}$, progesterone, and GnRH in both cycling and noncycling females. Furthermore, when the CO-Synch protocol was compared to the CO-Synch + CIDR protocol, the addition of progesterone increased pregnancy rates to AI (CO-Synch + CIDR: 54 percent and CO-Synch: 43 percent; Larson et al., 2006). Pregnancy rates to AI with use of the CO-Synch + CIDR protocol were similar when compared to those procedures including heat detection (Select Synch and TAI, Select Synch + CIDR and TAI, and a control consisting of a CIDR, $PGF_{2\alpha}$, and heat detection; Larson et al., 2006). Taken together, the addition of progesterone aided in nonclcyic females becoming pregnant, GnRH formed new luteal tissue by causing ovulation, and $PGF_{2\alpha}$ lysed the function CL of those females that were cyclic. In a recent national survey, the most frequently used estrus synchronization system for both heifers and cows was the 7-d CO-Synch + CIDR protocol, utilizing GnRH, progesterone, and $PGF_{2α}$ (Johnson and Dahlke, 2016).

Evaluation of Breeding Systems

Direct Comparisons of Breeding Systems

Accurately evaluating natural service and AI breeding systems requires assessing different areas of beef cattle production including pregnancy, calving, calf weaning weights, time, labor, costs, and overall management. Before a decision is made about which breeding system to implement the above listed factors must be considered.

Effects of AI on pregnancy rates when compared to those from natural service breeding vary in the published literature, with AI both increasing pregnancy rates as well as not changing pregnancy rates. Greater pregnancy rates were observed for both d 45 of the breeding season and the end of the breeding season in Nelore beef cows when the Syncro-Mate B estrus synchronization protocol was used, followed by TAI and natural service breeding for cleanup purposes compared to cows bred by natural service sires only (Sá Filho et al., 2013). In opposition, pregnancy rates did not differ in the first 21-d period of the breeding season for season ending rates when compared to cows exposed only to natural service (Lima et al., 2009). Cows enrolled in the aforementioned studies were of *Bos Indicus* and dairy breed types, respectively, as opposed to the *Bos Taurus* herds generally found in North Dakota. In a study evaluating AI and natural service breeding of angus-based commercial cows in ND, pregnancy rates did not differ between groups in the first 21-d of the breeding season; however, a greater proportion of females bred with TAI were pregnant on d 49 of the breeding season compared with natural service bred females (81.7 percent and 77.5 percent respectively; Steichen, 2013).

Proportions of cows calving in a calving season become quite important when evaluating breeding systems. When the calving season was distributed into 10 d calving intervals, the proportions of cows calving that were exposed to TAI were greater for the first and second 10-d intervals when compared to cows only exposed to natural service (TAI: 10 and 22 percent, respectively and NS: 6 and 16 percent; Rodgers et al., 2012). Similarly, after eight years of implementing such technologies as estrus synchronization and AI, Mercadante and others (2015) increased the number of calves born early from 50% in 90 d to 50% in less than 30d. It is also often theorized that AI can decrease the length of the calving season (Sprott, 1999, Larson et al., 2006, Lamb et al., 2010), however, the length of the calving season is not a function of calving, but of the length of time females are exposed to bull power. For example, if females are exposed to bulls for 45 d, the calving season will be shorter than if cows are exposed to bulls for 90 d (Rodgers et al., 2012).

Weaning weight can be affected by many factors, including geographic location of calves, genotype, postpartum environment, cow nutritional status and cow milk production (Spitzer et al., 1995). As previously stated, proportions of cows exposed to AI calved earlier in the calving season compared to cows exposed to natural service. The resulting calves born from AI are older and in published research these calves are heavier at weaning than their younger counterparts born to natural service (Rodgers et al., 2012, Steichen et al., 2013). When born from estrus synchrony and TAI, calves are older and heavier at marketing when they are compared to their herd mates born from NS (Sprott, 1999). Calves born earlier in the calving season may have a faster preweaning rate of gain and therefore may be able to utilize forage better than those born later in the calving season (Lesmeister et al., 1973). Additionally, increased calf weaning weights are attributed to calves being older in addition to improvements in genetic parameters related to growth (Johnson, 2002).

When comparing different breeding systems, producers are often more interested in whether or not they should put forth the time and effort to implement AI into their herds as opposed to tuning in herd sires, which require far less labor and time. Time, labor, difficulty of use and cost are the highest ranked reasons for producers not adopting the latest reproductive technologies (NAHMS, 2009). Artificial insemination as compared to natural service for breeding can offer some potential advantages including, improving calf uniformity, calf growth, weight at weaning, and overall genetic value (Odde, 1990). In natural service breeding, not only do producers purchase an entire bull, but also must feed and maintain that bull throughout its productive years on the ranch (Anderson et al., 2008). Investment costs include but are not limited to feed and labor (Gugelmeyer, 2010), as well as bull veterinary costs (breeding soundness exams, vaccines, other health costs; Lima et al., 2010). With the use of AI, a large number or potentially an entire herd of cattle can be bred in one d, however, generally not all females will become pregnant to AI. Average pregnancy rates to AI range from 40 to 70 percent of the females inseminated becoming pregnant to AI (Larson et al., 2006, Schafer et al., 2007, Busch et al., 2007, Steichen et al., 2013) in controlled experiments. To increase the proportion of females pregnant each year, clean-up bulls are often used after AI has been performed to breed those females that do not conceive to AI.

In addition to potential cost benefits, AI allows producers the opportunity to keep more accurate records and can increase herd management (Cooke and Marquezini, 2009). With the use of more efficient records, producers are able to assess the both production and financial operating systems independently as well as together to be more meaningful and useful for herd decisions. Records relative to breeding system include costs, proportions of females pregnant, calf weaning weights, and premiums possibly associated with calf sales (Pruitt et al., 2012). It is with these sounder records that judgments can be made on choosing specific bull genetics to enter into that production system while also allowing for better culling decisions.

3 P's of Sustainability

Sustainable agriculture can be defined as "practices that meet current and future societal needs for food and fibre, for ecosystem services, and for healthy lives, and all that do so by maximizing the net benefit to society when all costs and benefits of the practices are considered" (Tilman et al., 2002). Previous approaches to increase sustainability have included extension programming that strive to increase the acceptance and implementation of alternative production systems (Hinrichs and Welsh, 2003). In terms of herd management, success can be evaluated in a variety of ways, based on production, performance, and profit. For the following chapters, production, performance, and profit were defined to be the "3 P's of sustainability". Productiveness of a herd can include the proportion of females that became pregnant in a breeding season, the weight of the calves sold, etcetera. Sustainability is the measurement of production that allows for further evaluation of the entire herd. Producers may also evaluate their herd performance. Programs are available to aid in data collection and management of a herd to better analyze and summarize herd information (Ramsay et al., 2016). The Cow Herd Appraisal Performance Software (CHAPS) program is a management tool in which information can be collected, stored, and evaluated for benchmarking and herd performance purposes (Ramsay et al., 2016). Lastly, success can be evaluated in terms of profit. Similarly, to the performance record keeping system, programs are available to summarize and analyze returns and costs associated with farming and/or ranching (NDFME, 2011). Financial data can be used isolate specific techniques or management decisions that are either lucrative or draining financially. Production, performance, and profit will be evaluated in the following chapters with regard to different breeding systems when used on commercial beef operations.

Partial Budget Analysis

Various management alternatives have financial implications, either positive, negative, or both. Understanding the financial implications of alternative strategies is critical for producers to make sound management decisions. Management changes could be as small as implementing a different feed source or as large as utilizing artificial insemination (AI) to breed a large proportion of the female inventory. Understanding the financial implications of the respective alternatives could mean the difference between making money and losing money for a number of years, resulting in leaving the beef industry. Required labor, equipment, costs, and the additional income that could be generated must all be considered. Evaluating the success of a whole-farm operation includes completing some sort of budget or economic analysis. Understanding where their profit comes from, areas in which profits could be decreased, costs of the advancement, and savings made by implementing a new technique may be beneficial to increasing the productivity and profit of the operation. Partial budgets analyses are tools used to determine costs associated with making changes from standard practices in business, analyzed using the increased profit, decreased returns, cost of the advancement, and the saving made by the advancement (Alimi and Manyong, 2000).

In a partial budget analysis, total costs are subtracted from total revenues to analyze the economic effects of the change (Swinkles et al., 2005). This type of analysis can be used to determine the effects of substituting one enterprise for another, changing the level of a technology, or changing to a new technology all together. If making a change to an operation, a partial budget analysis can aid in determining if the change has the ability to truly increase the profit of an operation. Partial budgets can help producers understand the financial implications of the management strategies they would like to employ. A partial budget analysis does not evaluate the entire operation from a cost and revenue standpoint, but is more focused on the revenue gained or lost due to a new advancement (Roth, 2002). To complete a partial budget analysis, four specific components are necessary; additional income (A), reduced income (B), reduced expenses (C), and additional expenses (D; Table 1.1.; Ehui and Rey, 1992).

Table 1.1. The format of a partial budget analysis[1]

Increase Returns **(A)**	Decreased Returns **(B)**
-	-
-	-
-	-
Decreased Costs **(C)**	Increased Costs **(D)**
-	-
-	-
-	-

[1]Adapted from Rodgers et al., 2012

Increased Returns

The top left box (box **A**), relates to the increased returns or additional income generated from the addition of the advancement or technology applied. Items included here could consist of greater prices for animals sold (perhaps through heavier calf weights or more desirable phenotype), sale of more calves (a result of improved pregnancy rates), or a sale of more harvested crop (a result of greater yield for a particular crop). Income included here must include realistic yields and averaged prices as to not skew the results and lead to inaccurate decisions (Roth, 2002).

Decreased Returns

The top right box (box **B**), refers to income that is currently being generated by the operation that will cease with the implementation of the advancement or technology. In some scenarios this will be difficult to determine and may even not exist. Items included here would comprise the decreased income from selling cull animals, a reduction in yield or product, or the loss of rental income (Ehui and Rey, 1992).

Decreased Costs

The bottom left box (box **C**), relates to a decrease in costs and therefore represents profit saved from implementing the advancement or technology. The costs that are now incurred would be decreased or eliminated. An example of income saved includes the decision to hire out for the custom harvesting of a particular crop. The labor and time associated with harvest multiplied by the hourly wage needed to pay someone to complete the task would be reduced (Roth, 2002). This is similar to the veterinary cost decreased when animal numbers are reduced in a production setting.

Increased Costs

The bottom right box (box **D),** relates to the cost or expense of that advancement or technology (increased cost). The expense of the advancement would be a new or additional cost. Items included here would consist of the cost of a custom harvester or the additional supplies necessary to synchronize a group of females before breeding. This cost category can also include and interest charges not previously incurred.

After determining the income generated or saved as well as the costs associated with the addition of the advancement or technology, net profit or loss can be calculated. This occurs by adding the returns boxes together (**A** + **C**) and the cost boxes together (**B** + **D**). **A** + **C** is equal to the total income made and **B** + **D** is equal to the total costs. Total costs are then subtracted from the total income. If the number is positive, additional income was generated by the technology or advancement, whereas if the number is negative, income was lost (Rodgers et al., 2012). It is important to note that when evaluating the components of a partial budget, the units are the same; i.e. $/hr for labor, $/animal, or $/acre. All figures should be multiplied out, allowing for a total dollar figure for the operation.

Section 2: Mineral Supplementation

Mineral Classifications

Minerals are inorganic elements found within the Earth's crust that are defined as being essential or nonessential to one's diet. Essential minerals are those that must be in the diet of vertebrates as they serve well-define biochemical roles in health and productivity (NRC, 2005). Minerals can be separated into two classifications, macro and trace minerals (microminerals). Differences in the two classes lie in the amount of mineral the body depends on for normal function. Macrominerals are those required in larger amounts and include calcium (Ca), magnesium (Mg), phosphorus (P), potassium (K), sodium (Na), chlorine (Cl), and sulfur (S; NRC, 2000). Trace minerals are those required in lesser amount and consist of chromium (Cr), cobalt (Co), copper (Cu), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn; NRC, 2000). While all have specific functions, many major minerals are involved in a variety of different aspects in development and maintenance. Cobalt and Mo are generally involved in metabolism (NRC, 2000), Cr in immunity and blood sugar regulation (Burton, 1995), and Cu, I, Fe, Mn, Se and Zn in reproductive performance and growth (Hostetler et al., 2003). The National Research Council has established requirements of most of those minerals thought to be essential in beef cattle diets (Table 1.2).

Table 1.2. Mineral requirements and maximum tolerable levels for beef cattle[1]

Mineral	Units	Growing and finishing cattle	Gestating and dry cows	Lactating cows	Maximum tolerable level
Calcium	%				-
Chromium	ppm	-	-	-	1000.00
Cobalt	ppm	0.15	0.15	0.15	25.00
Copper	ppm	10.00	10.00	10.00	40.00
Iodine	ppm	0.50	0.50	0.50	50.00
Iron	ppm	50.00	50.00	50.00	500.00
Magnesium	%	0.10	0.12	0.20	0.40
Manganese	ppm	20.00	40.00	40.00	1000.00
Molybdenum	ppm	-	-	-	5.00
Nickel	ppm	-	-	-	50.00
Phosphorus	%				-
Potassium	%	0.60	0.60	0.70	2.00
Selenium	ppm	0.10	0.10	0.10	5.00
Sodium	%	0.06-0.08	0.06-0.08	0.10	-
Sulfur	%	0.15	0.15	0.15	0.30-0.50
Zinc	ppm	30.00	30.00	30.00	500.00

[1]Adapted from National Research Council (NRC). Nutrient requirements of beef cattle. 8th (revised) edition. Washington, DC. National Academy Press. 2016. p. 110.

Requirements of minerals are based on a threshold value in which normal bodily functions are maintained, however, mineral needs of individuals are variable based on breed type, growth, and reproductive function (McDowell, 1996). When individuals do not consume sufficient minerals to meet the minimum requirements, deficiency symptoms can arise. Inadequate intake of minerals can have severe negative effects including decreased intake, reduced reproductive efficiency, reduced disease resistance, and slow growth (Paterson and Engle, 2005). While seemingly observable symptoms are associated with mineral deficiencies, subclinical deficiencies often go unnoticed by livestock producers due to more broad symptomology (Spears, 1995). Deficiencies can occur in two ways with the first being dietary deficiencies, when individuals are not consuming adequate levels of a mineral or minerals. The second cause of mineral deficiency is by way of mineral interactions. In the case of mineral interactions, intake may be adequate, however bioavailability is lacking. Bioavailability refers to the degree that a nutrient is absorbed and becomes available for use by the required tissue, rather than just becoming a dietary ingredient (Miles and Henry, 2000). Common interactions that affect the bioavailability of minerals include Co, Cu, Fe, I, Mn, Se, and Zn (Corah and Ives, 1991). Interactions also include those between minerals and fiber compounds (Greger, 1999) as well as between Cu, Mo, and Se which will be discussed in the following sections.

Trace minerals can be broken down further into additional classifications including, inorganic and organically bound. Traditionally, supplemented minerals have been fed in the form of inorganic salts. Inorganic trace minerals are free ions that are not generally bound to a metal ion or any other type of substrate (Spears, 1996). Conversely, their counterpart, organically bound minerals, are known to be bound to an amino acid, a metal ion, a polysaccharide or to an organic molecule (Olson, 2007). Many minerals today are chelated. Chelate refers to the bond between a ligand and a metal ion via two or more donor atoms creating a heterocyclic ring with the metal (Spears, 1996; Andrieu, 2008). Due to their binding action, mineral chelates do not interact with vitamins and other ions and thus have been reported to have additional benefits due to availability. When heifers were fed an organic mineral mix, and inorganic mineral mix, or no mineral 23 d prior to embryo collection, fewer unfertilized ova were observed for organic chelated mineral fed heifers compared with inorganic and control heifers (Lamb et al., 2008). Organic minerals carry a neutral charge and are thought to be easily absorbed and more readily metabolized, so bioavailability is greater (McDowell, 1996).

Mineral Absorption and Metabolism

Most current mineral supplementation programs are based on an animal's intake of forage or feeds or to consume a targeted amount of supplement (Bowman and Sowell, 1997). Once ingested, minerals must be absorbed so they can be utilized by the body. After an injectable mineral supplement containing Cu, Mn, Se, and Zn was administered to beef steers, plasma concentrations of Mn, Se, and Zn began to rise within two hr post injection and gradually increased over the first 24-hr period (Pogge et al., 2012). Absorption of trace minerals generally takes place in the small intestine, however, for some minerals like Ca and P (Scott and McLean, 1981), absorption can also take place in the rumen (NRC, 2005). While the necessary amount of mineral can be taken in by the animal, based on requirements of that animal, availability of minerals can vary greatly. Nonruminant mineral absorption is generally greater than in ruminants. Absorption and availability can depend on the animal's age, overall intake, chemical form of the mineral, the environment, and the ability of the animal's cells to take up the nutrient (Underwood and Suttle, 1999). In addition, nutrients must also contend with factors in the stomach, more specifically the rumen, where microbial fermentation takes place in the ruminant animal. Enzymatic digestion of feeds may increase the availability for absorption, whereas an increase in the pH of the small intestine can result in decreased absorption of trace minerals (Waghorn et al., 1990). Mineral absorption can also be influenced by the formation of insoluble bonds formed with other elements.

Once an individual has absorbed various mineral compounds, they must be metabolized. Minerals that are absorbed enter the blood supply, are circulated and dispersed to cells in need and are then filtered through the liver (Suttle, 2010). After entering the liver, minerals are either stored for later use or are excreted (Suttle, 2010). For ruminants, several factors affect the ability for mineral to be metabolized including breed effects, gestational status, stress, agonists, and age (Paterson and Engle, 2005). Pogge et al., (2012) reported clearance rate differences between Angus and Simmental cattle when administered an injectable trace mineral supplement and speculated that different breeds of cattle may have different trace mineral requirements. Greater concentrations of Cu, Zn, and Se were observed in blood plasma of Angus steers when compared to Simmental steers. Additionally, greater Mn levels were observed in liver tissues of Simmental steers when compared to Angus steers (Pogge et al., 2012). Furthermore, when both Jerseys and Holsteins were supplemented with Cu for a period of 60 d, liver Cu concentrations were greater in Jerseys cows compared to Holstein cows (Du et al., 1996). When pregnant cows were intravenously administered a tracer dose of Zn, concentrations of Zn in the fetal liver and bone tripled in concentration while maternal liver concentrations decreased significantly (Hansard et al., 1968) signifying a change in the metabolism from dam to fetus. Additionally, in times of stress, metabolic adaptions must be made to accommodate the changes in environment. When livestock are entered into a thermal stressed environment, items such as electrolyte turnover, hormone production, and changes in mineral concentrations in the liver are altered (Beede and Collier, 1986). Agonists also affect metabolism as is the case with Cu, Mo and Se, where sulfide and Mo have the ability to bind to Cu to form insoluble compounds (Suttle, 1991, NRC, 2005). As described, the metabolism of minerals can be affected by many variables. The route of metabolism varies between mineral and such differences will be described for a select group of minerals in the following sections.

Due to the variety of factors that can effect both the absorption and metabolism of minerals, fed tags and mineral supplementation tags are not an entirely reliable source for determining the amount of mineral used by an animal (Kincaid, 1999). For this reason, testing of feed and animal tissues can be done to evaluate the nutrient status of animals. Blood, both serum and plasma, and liver tissue are the most common tissues available for testing. Based on the type of analysis needed, the timeframe of mineral evaluation and ease of collection, either sample can be evaluated. While collecting blood samples is a rather inexpensive task that is minimally invasive in most cases, concentrations of mineral in the blood change at very slow rates due to the long lifespan of a red blood cell (Kincaid, 1999). Mineral concentrations of blood can be highly variable and signify a mineral status of up to 160 d before sampling (Kincaid, 1999). On the other hand, liver samples are often used to determine changes in mineral status, often after treatments are applied (Kincaid, 1999). Mineral status can be evaluated, a change can be made, and then the status can be reevaluated. No matter the type of sampling, it is important to understand how minerals are absorbed and metabolized in the body to understand the limitations of evaluating both mineral and nutritional status (Herdt and Hoff, 2011).

Trace Minerals Supplemented to Ruminants

Copper

Copper is a naturally occurring mineral found in the Earth's crust, generally found in one of two oxidative states, cuprous (Cu^{+1}) or cupric (Cu^{+2}). Cuprous is more so found in solution and is colorless, whereas cupric is more abundant and blue or green in color (NRC, 2005; Arredondo and Nunez, 2005). Sources of Cu for nonsupplemented animals, specifically ruminants, include water, soil, forages, and concentrate diets, however, all sources vary in form and bioavailability. Copper is typically not abundant in water, most forages (i.e. grasses and hay) and feeds of animal origin. Legumes and soil, especially from areas where smelting and mining take place, are generally greater sources of Cu (Underwood and Suttle, 1999).

Copper is an essential trace mineral for the multitude of functions and enzymes in which it activates (Underwood and Suttle, 1999). Requirements for Cu for growing and/or finishing cattle, gestating or dry cattle, and lactating cattle are reported in Table 1.2. Copper functions in iron metabolism and cellular respiration, crosslinking for the formation of bone and blood vessels, pigmentation of hair and wool, the synthesis of myelin in the central nervous system, and as a protector against free radicals (Underwood and Suttle, 1999). In addition to protection from free radicals, during fetal development, Cu is taken up by human placental trophoblast cells and it is thought to bind to a membrane bound protein that binds ceruloplasmin (Hilton et al., 1995). Greater than 95 percent of the Cu found in the plasma of an individual is in the form of a serum ferroxidase, ceruloplasmin. Ceruloplasmin functions as a regulator of Fe homeostasis and is involved in the mobilization and oxidation of Fe from the liver (Hellman and Gitlin, 2002).

The absorption rate of Cu for nonruminants is roughly 30-70 percent (Linder, 2002) and 1-3 percent for ruminants with both occurring in the small intestine (Underwood and Sutle, 1999). After ingestion or intravenous administration of Cu, plasma concentrations gradually increase within the first 24 hr (Turnlund, 1998). The small intestine is the major site for absorption and the percent absorbed is greater when the intake of Cu is marginal or low. Absorption is also greater for young animals, especially ruminants. As the gut becomes more fully developed, absorption decreases (NRC, 2000). When ingested, Cubinds to metallothionein in the gut mucosa (Linder, 2002). Metallothionein is a protein with an affinity to bind Cu that functions as storage and transportation. Metallothionein also functions as detoxification in cases of copper toxicity. Copper binds to metallothionein as opposed to binding to the intestinal mucosa, and is then excreted. Once absorbed into the blood, Cu binds to albumin and is transported to the liver. The liver is the site of Cu homeostasis which contains highly polarized epithelial cells, liver hepatocytes, which metabolize Cu (Hellman and Gitlin, 2002). Liver hepatocytes regulate Cu to be excreted into the bile, stored, or used by various metolloenzymes, including ceruloplasmin and superoxide dismutase (NRC, 2005). Excretion of Cu occurs through fecal and urinary pathways with fecal excretion increasing with greater absorption and urinary excretion remaining consistently low, as it is not a factor of Cu regulation (Turnlund, 1998). Most Cu is stored in the skeleton and the muscle, however, roughly a third is stored in the liver for maintaining Cu homeostasis (National Academy Press, 2000a). Stored Cu is mainly bound to metallothionein where it can also function as a detoxifier.

Absorption is highly influenced by form and by interactions with other minerals; particularly the interaction of Cu with Mo and S in ruminants (Suttle, 1991; Underwood and Suttle, 1999; NRC, 2000; and NRC, 2005). Microbial fermentation and degradation in the rumen facilitate the breakdown of S amino acids to sulfide. Sulfide has the ability to bind to Cu to form insoluble Cu sulfide (Suttle, 1991) as well as the ability to interact with Mo and form thiomolybdates (NRC, 2005). Thiomolybdates also have the ability to bind to Cu, and too can form insoluble complexes that are resistant to acidic conditions and affect absorption (NRC, 2005). Increased Mo and S in the diet of a ruminant can decrease the availability of Cu and create a deficiency as well as the opposite; decreased Mo and S can increase the availability of Cu to a toxic level (Suttle, 1991).

In recognizing the potential absorptive issues associated with Cu, deficiencies and toxicities are of importance to livestock species. Deficiency symptoms include anemia, increased heart size, lameness, hair pigment loss, neonatal ataxis, and delayed or depressed estrus (Underwood and Suttle, 1999; NRC, 2000). Deficiencies of this kind could be fatal if sustained for an extended period of time and could cost a beef producer unnecessary costs. While Cu deficiencies are a worldwide problem (NRC, 2000), Cu poisoning or toxicity is also of concern. Monogastrics are generally highly tolerant, whereas ruminants, more specifically sheep, are highly intolerant to excess Cu (Underwood and Suttle, 1999). High death rates were observed when high Cu and low or no Mo/S diets were feds to lambs over a period of several weeks (Suttle, 1977). Toxicity symptoms include hemolysis, jaundice, necrosis, and often death (NRC, 2000). Toxicosis is greatly affected by Mo and S but can also be affected by exposure length, age, previous Cu levels, dietary toxins that may affect the liver, and concentrations on Zn and Fe (NRC, 2005).

Manganese

Manganese is an essential mineral that although being spread widely throughout the body, is the least abundant trace mineral (Herdt and Hoff, 2011). Requirements of Mn for growing and finishing cattle, gestating or dry cattle, and lactating cattle are reported in Table 1.2. Manganese is found in two oxidation states, Mn (0) and Mn^{+2} and does not occur naturally as a mineral, but as a part of many other minerals (NRC, 2005). Sources of Mn include forages, grains, and protein supplements, however, can vary drastically based on plants, type of soil, and treatment of the soil (NRC, 2005). While little concentrations are available in the air and also drinking water, cattle have the ability to consume three to six times their requirement for Mn (NRC, 2005).

Manganese functions are linked to the metalloenzymes in which they activate. Manganese is involved in cartilage development via glycosyl transferase, blood clotting with the formation of prothrombin, lipid and carbohydrate metabolism, sex hormone synthesis, and CL function (Underwood and Suttle, 1999). With regard to reproduction, a major function of Mn is decreasing free radical protection via superoxide dismutase (Lequarre et al., 2001). Free radical production and the increase of peroxides are thought to cause oxidative stress to embryo development. In culture, Mn superoxide dismutase was found in both morulas and blastocysts, suggesting that manganese is required for embryo development (Lequarre et al., 2001). Manganese is also thought to be a factor in the production of squalene, a precursor of steroid hormone production (Hostetler et al., 2003).

Relatively low amounts of Mn are absorbed relative to the larger amounts found in supplements or in feed rations (Underwood and Suttle, 1999). Manganese is absorbed in the gut and is carried by transferrin (Anderson et al., 1999), albumin, and α2-marcoglobulins to the liver. Once at the liver, Mn can be distributed to the pancreas and kidney (NRC, 2005; Herdt and Hoff, 2011). Previously, it was thought that Ca and P decreased the absorption of Mn, however, after many studies, it was determined to be based on P alone (Underwood and Suttle, 1999). Without an overabundance of P being supplemented, influence on Mn concentration is not likely to be of much consequence. Iron on the other hand, while interacting with P, also interacts with concentrations of Mn. Plasma P as well as kidney and heart Mn decreased when greater levels of Fe were fed to beef steers (Standish et al., 1971). Once tissues are saturated and the requirement has been met, Mn is then excreted via the bile and urination very rapidly with the majority or excretion occurring through the bile (National Academy Press, 2000a). There is no known storage tissue for Mn (Underwood and Suttle, 1999).

Manganese deficiencies are described by two methods, biochemical and clinical. Biochemical deficiency symptoms occur when alkaline phosphatase activities decrease (Underwood and Suttle, 1999). Clinical deficiency symptoms are observed mostly in avian species, with deficiencies in cattle being minimal (Herdt and Hoff, 2011). In early fetal and embryonic development, Mn deficiencies cause skeletal abnormalities. Manganese deficiency symptoms also include abnormalities in lipid and carbohydrate metabolism, dermatitis of the skin, growth retardation, and reproductive issues (NRC, 2005; Herdt and Hoff, 2011). With regards to reproduction, abnormal ovulation and testicular degeneration were observed in mice and delayed or depressed estrus has been observed in cattle with Mn deficiencies (Underwood and Suttle, 1999). Toxicities are far less common, as Mn is considered to be the least toxic trace mineral. Symptoms include decreased Fe concentrations and hemolytic changes associated with reduced Fe (Herdt and Hoff, 2011).

Selenium

Selenium is an essential trace mineral that was once studied and most well-known for its toxic effects. Selenium is a semimetal with four different oxidation states, -2 (selenocyctine), 0 (elemental Se), +4 (selenite), and +6 (selenate) (NRC, 2005). The most common form of Se in physiological functions occurs in the +2 oxidation state. Concentrations of Se can vary greatly depending on the plant species, the part of the plant, season of the year and Se soil content (Underwood and Suttle, 1999). In Se adequate soils, grasses supply more Se than do grains, both of which contain less Se than animal sources.

Selenium is found to be an essential nutrient because of its presence in selenoproteins, (Lu and Holmgren, 2009). There are currently more than 50 known selenoprotein families, of which 25 genes encode the human selenoproteome (Labunskyy et al., 2014). Eighteen selenoproteins have been purified, allowing for further evaluation of their functions (Labunskyy et al., 2014). Glutathione peroxidases (GPX1-4), deiodinases (ID1-3), thioredoxin reductases (TR1-3), selenoprotein P and selenoprotein W are among the families and proteins in which functions are understood and studied (Underwood and Suttle, 1999; Brown and Arthur, 2001; Mehdi et al., 2013; Labusnskyy et al., 2014; and Chauhan et al., 2014). A major role of selenoproteins, including the GPX's and TR's found throughout the body, are to act as antioxidants to control peroxidation (Underwood and Suttle, 1999). Selenium and erythrocyte GPX1-4 were observed to be highly correlated in blood, indicating that GPX can be used to evaluate Se levels (Koller et al., 1984). As observed with Mn, reduction of free radicals may contribute to embryo survival during fetal development. Deiodinases, found in the liver, kidneys, and thyroid, function in thyroid metabolism and are involved in the conversion of T_4 to T_3 (Mehdi et al., 2013). Selenoprotein P is most abundant in plasma and plays a role in Se transport to various tissues. Less is known about the function of selenoprotein W, however, it has been linked with muscle disorders like white muscle disease (Lescure et al., 2009). Selenium also enhances the function of vitamin E and the two work synergistically together to prevent radical proliferation (Chauhan et al., 2014). A group of immune cell known as CD4 T-cells similarly require Se to activate an immune response, with the need becoming greater in times of disease and immune failure as seen with acquired immunodeficiency syndrome (Brown and Arthur, 2001).

Absorption of Se occurs in the small intestine and, depending on the form, up to 98 percent can be absorbed by both ruminants and nonruminants (NRC, 2005). Requirements for various stages of beef cattle production and maximum tolerable levels for Se can be found in Table 1.2. Both organic and inorganic forms for Se can be absorbed. The organic forms of Se are those bound to amino acids, being selenocysteine and selenomethionine. Inorganic forms include selenite, selenide, selenate, and the Se element (Mehdi et al., 2013). Amino acid bound Se is absorbed by active amino acid transport, whereas selenate is absorbed through a Na mediated carrier and selenite though simple diffusion (Thomson and Robinson, 1986). Selenium is transported in the blood as selenoprotein P to the liver. Although absorbed in various forms, all selenoprotein genes contain the UGA selenocysteine codon and the selenocysteine insertion sequence (Labunksyy et al., 2014). Selenocysteine not immediately used by the body is stored in the liver, muscle, kidney, and plasma in the form of selenomethionine. Selenomethionine reserves can be used in times of low selenium intake (Mehdi et al., 2013), however, use of reserves is dependent on selenomethionine turnover, rather than the immediate need of the individual (National Academy Press, 2000). Additionally, through Se turnover, excretion takes place mainly through the urine and in cases of Se toxicity, through the breath (National Academy Press, 2000b).

The absorption of selenium involves more metabolic pathways than is required by most or all other elements. Heavy metals and dietary sulfate can also affect Se absorption (NRC, 2005). Sulfur and Se are in the same family of elements and compete against one another (Mehdi et al., 2013). Heavy metals increase the excretion rate of Se and therefore decrease absorption (NRC, 2005).

As stated previously, Se was once studied because of its ability to cause toxicity, however, deficiencies have the potential to be dangerous as well. Like other trace minerals, deficiency symptoms can be classified as biochemical and clinical. Biochemical manifestations of deficiency include decreased glutathione peroxidase activity and therefore a reduction in antioxidant activity and storage of selenoproteins, muscle enzyme leakage due to damaged muscle tissue, and an increase in free radical production (Underwood and Suttle, 1999). Decreased glutathione peroxidase activity can cause severe damage to mammalian tissue from the buildup of free radicals in the body as well as disruptions in the metabolism of lipids, proteins and DNA that can cause cellular dysfunction (Sordillo and Aitken, 2009). Observable Se deficiency symptoms include muscular degeneration or white muscle disease, in which lesions form on striated muscles from free-radical damage (Arthur, 1998). Other symptoms include exudative diathesis, atrophy of the pancreas, myocardial lesions, Heinz-body anemias (hemoglobin denaturation; Rifkind and Danon, 1965), decreased resistance to disease and infections, poor conception, reduced litter size, and endometritis (Underwood and Suttle, 1999). Toxicity on the other hand can occur due to one of three possible situations; grazing in an area with high Se levels, like in the Great Plains of the U.S., drinking contaminated water from an industrial or mining water source, or experiments with supplementation or poor management (NRC, 2005). Toxicity varies from acute to chronic symptoms which take account for strong garlic breath, labored respiration, “blind staggers” (wandering, stumbling, visual impairment), alkali disease, liver atrophy, and sloughed hooves (NRC, 2005).

Zinc

Zinc is the second most abundant mineral in the body, preceded only by Fe (Herdt and Hoff, 2011). Zinc requirements for beef cattle in the growth and finishing phase, gestating or dry, and lactating as well as maximum tolerable levels can be found in Table 1.2. In biological functions and systems, Zn is found in the divalent state (NRC, 2005). Zinc is also an electron acceptor and for these reasons, Zn readily binds to amino acids, proteins, and peptides (NRC, 2005). Sources of Zn include items found in the diet and drinking water. Cereal grains and pasture forage are generally low, being exceeded by legumes and various high protein meals, like meat and fishmeal (NRC, 2005). Concentrations of Zn are high in young, less mature plants (Hambidg et al., 1986).

Zinc is a component of over 300 enzymes and supports structural, catalytic, and regulatory functions (Herdt and Hoff, 2011). Zinc functions in gene expression including DNA replication and transcription (NRC, 2005) by way of Zn fingers and the binding of various steroid complexes to DNA, cell division and interpretation of genetic code, and the regulation of appetite, growth and immune function (Herdt and Hoff, 2011). Similar to Cu and Mn, Zn superoxide dismutase scavenges free radical to reduce peroxide damage (Hostetler et al., 2003), a potential aid in embryo development. One of the most important roles of Zn is its interaction with vitamin A. Retinene reductase and alcohol dehydrogenase are metalloenzymes involved in the interconversion of vitamin A alcohol (retinol) to vitamin A (retinene), necessary for vison. Zinc is required for this conversion (Underwood and Suttle, 1999). Zinc is also involved in the formation of prostaglandins because of its role in the arachidonic acid pathway, necessary for normal estrous cycles (Hostetler et al., 2003). When rats were made to be deficient in Zn, plasma levels of 6-keto-$PGF_{2\alpha}$ were decrease compared with rats that were pair fed or fed ad libitum (Chanmugam et al., 1984).

The absorption of Zn is based on the need of the individual and is an active process mediated by a carrier (Underwood and Suttle, 1999). The main site of absorption is the small intestine, however, in ruminants' absorption can also occur in the gut. Zinc binds to plasma albumin and is transported to the portal blood stream. Roughly 70 percent of Zn is bound to albumin while the other 30 percent is bound to α-2 macroglobulins and metallothionein (NRC, 2005). During the synthesis of metallothionein by Zn arriving at the liver, Zn is removed from the blood plasma and distributed to various tissues for use (Underwood and Suttle, 1999). If Zn concentrations are at an excess after tissue distribution, it is thought that pools of Zn form in tissues not readily affected by dietary Zn intake (Swinkels et al., 1994). Zinc storage tissues are muscle and bone (Underwood and Suttle, 1999). Due to storage only occurring in storage pools, much of ingested Zn is excreted via feces (1 mg to 5 mg per d for humans; National Academy Press, 2000a) or urine (NRC, 2005).

Absorption of Zn is greatly influenced by phytate in the diet. Phytate, a component and major source of P in plant material, forms insoluble complexes with Zn, decreasing absorption (Underwood and Suttle, 1999). Phytate interactions occur more in monogastrics than ruminants due to microbial fermentation breakdown (Herdt and Hoff, 2011). Interactions can also occur with iron, as well as calcium. Elevated concentrations of dietary Ca and Fe have the ability to decrease Zn absorption (Underwood and Suttle, 1999; NRC, 2005). Although they have the potential to alter Zn absorption, Ca and Fe do not influence Zn as much as phytate.

Although regulation of Zn homeostasis is tightly regulated by the body, deficiencies and toxicities are still observed. Deficiencies are more commonly seen in monogastrics versus ruminants due to their ability to digest phytate via microbial fermentation (Herdt and Hoff, 2011). Like Mn, deficiency symptoms are observed in two different methods; one being as biochemical manifestations of deficiency, and two being as clinical manifestations of deficiency

(Underwood and Suttle, 1999). Zinc functions are also prioritized in a hierarchal fashion, allowing for some to be less sensitive to deficiency than others (Herdt and Hoff, 2011). Biochemical symptoms include reduced Zn in the blood and body tissues, reduced enzyme function, and an increase in the uptake of heavy metals (Underwood and Suttle, 1999). Clinical deficiency symptoms of Zn include anorexia or loss of appetite, thickening of skin, stiffness and swelling of joints, reduction of spermatogenesis, reduced secretion of GnRH, and reduction of humoral immunity (Underwood and Suttle, 1999; NRC, 2005; Herdt and Hoff, 2011). Zinc toxicity is noted by the National Resource Council as being feed or water related. Acute toxicity of Zn can cause gastrointestinal distress like diarrhea, vomiting, and abdominal cramps (NRC, 2005), whereas chronic toxicity causes reduced immune function and high density lipoprotein cholesterol (Cousins, 1996). Chronic Zn toxicity also causes more copper to be bound to metallothionein, thus decreasing Cu absorption (NRC, 2005). Table 1.3. illustrates recommended ranges, maximum tolerable levels, symptoms of deficiency and toxicity, as well as recommended tissues for analysis of the 4 minerals outlined.

Table 1.3. Summary of mineral information

Mineral	Requirements	Maximum tolerable levels[2]	Symptoms of deficiency[3]	Symptoms of toxicity[4]	Recommended samples for mineral analysis[5]
Copper	10.0	40.00	Decreased growth, anemia, delayed estrus, depigmentation of hair/wool	Jaundice, hemolysis, widespread necrosis	Liver, blood serum
Manganese	20.00-40.00	1000.00	Irregular estrus cycles, low conception, abortions	Decreased iron concentrations	Liver, whole blood
Selenium	0.10	5.00	White muscle disease, stiffness, lameness, exudative diathesis	Blind staggers, hoof sloughing, labored breathing, liver cirrhosis	Liver, whole blood, blood serum
Zinc	30.00	500.00	Anorexia, stiffness, depressed growth, excessive salivation	Reduce immune function, vomiting, diarrhea	Liver, blood serum

[1,2,3,4]Mineral ranges adapted from National Research Council (NRC). Nutrient requirements of beef cattle. 8th (revised) edition.; values presented as mg/kg. Requirements = values found necessary to optimize animal health and performance, Maximum tolerable levels = values found that if fed cause detrimental effects to animal health and performance, Symptoms of deficiency = symptoms associated with animal not consuming or not absorbing adequate amounts of a certain mineral, Symptoms of toxicity = symptoms associated with the over consumption of a certain mineral, Recommended samples for mineral analysis = samples identified as sufficient for mineral analysis by Herdt and Hoff, 2011. NRC identifies that many essential minerals are found in adequate or sufficient amounts in practice feedstuffs, however, supplementation may be required for others.

[5]Herdt and Hoff, 2011

Mineral Supplementation Needs

Cattle diets that consist of mostly grazed forage often require additional supplementation of minerals in order to avoid deficiency. A National Animal Health Monitoring System survey reported that 5.2 percent of responding beef producers, representing 9.7 percent of beef cows, identified mineral deficiencies as the cause for poor reproduction or health problems in the herd (NAHMS, 1997). The need for trace mineral supplementation is greatly dependent on geographical location and physiological stage of production (Lalman and McMurphy, 2004). Mineral concentrations are highly variable based on soil type, fertilization type and level, and fertility of the soil within a given geographic location (Soder and Stout, 2003).

While supplementation needs may change due to growth stage or physiological state, palatability and individual requirements may be animal dependent. Geographically, mineral requirements are subject to differences in soil and forage type, fertilization and precipitation. Areas with sandy soils leach more nutrients compared to heavier clay soils, and different soil types can produce different species of forage that may contain varying compositions of nutrients (Greene, 2000). In order to increase the mineral concentrations of forages for the purpose of supplementing animals, fertilization of forages with mineral components must only be done when a deficiency is occurring following proper testing of fertilization type, mineral content of the location, and soil and forage type (Soder and Stout, 2003).

Physiological state of an individual animal also determines mineral needs. Soder and Stout (2003) reported that mineral compositions of forages are highly variable and adequacy of a particular forage will change based on physiological state of production of an animal. In the case of mineral concentrations, adequacy can be defined as there being no expected reason to anticipate a clinical response for an individual not receiving enough or receiving too much mineral (MSU-DCPAH). In dairy cattle, differences in mineral needs are subject to d in milk or lactation. Increased trace mineral status from parturition to peak milk production optimizes the immunity and health of the females in times of increased milk production demand and stress due to their antioxidant properties (Andrieu, 2007). Additionally, due to the vast reproductive functions of trace minerals (i.e. Cu, Mn, Se, and Zn) a reduction or deficiency of mineral status may negatively affect the many function and cause poor reproductive efficiency. The inadequate transfer of minerals from dam to fetus may cause abnormal fetal growth and development (Widdowson et al., 1974).

Mineral Supplementation Methods and Intake Variability

The use of clinical signs to determine an animal's adequate mineral consumption is not always realistic. While mammals are able to conserve varying amounts of nutrients within their fluid stores and tissues, the extent to which this is done for each nutrient is unknown (Olson, 2007). Mineral supplements are available in direct or indirect forms (McDowell, 1996). Direct supplementation consists of the immediate consumption of mineral by way of water additives, drenching, free-choice, energy-protein feeds, and injection (Greene, 2000). As is apparent from the many different methods of application, intake regulation of direct mineral supplementation can quite easy or challenging. Indirect methods include altering soil pH, fertilizing, and planting non-native forage species for increased uptake by the animal at time of grazing (McDowell, 1996).

Free-choice Mineral

Intake of free-choice mineral, a widely used source of commercial mineral, is often greatly variable among individual animals (McDowell, 1996). Free-choice mineral supplements include loose mineral, mixes, compressed blocks, and protein supplements (Arthington, 2012).

Free-choice mineral feeders are designed to be a self-feeding system. Animals are more likely to choose a feed source that is palatable rather than a feed source that is less palatable (McDowell, 1996). In the case of free-choice mineral supplements, palatability is driven by the inclusion of salt, as animals will crave salt, however, other sources of sodium will reduce free-choice mineral consumption (Greene, 2000).

Due to the nature of free-choice mineral, intake is highly variable. In large enough quantities, intake of free-choice mineral may be reduced due to increased mineral concentrations in drinking water (Wright, 2007). In many parts of the U.S., minerals such as S, Mn, Fe, Ca, and Mg have been found in drinking water of animals and contribute to daily intake. In a study by Manzano and others (2012), no mean differences were observed between steers consuming a free-choice mineral supplement in the spring and fall months, however, large variability in average mineral supplement intake among calves was observed during the spring to summer period compared with the fall period with lower variability (77.7 g/d average mineral intake) observed from spring to summer and greater variability (104.3 g/d average mineral intake) observed from the summer to fall period. Researchers speculated that attendance at the mineral feeder was related to amount of daylight and daily temperature (Manzano et al., 2012). Similarly, Garossino et al. (2005) reported the proportions of one yr old steers visiting a mineral feeder containing a mineral supplement containing fenbendazole (for giardia control). Within two 14-d treatment periods, average proportions of steers visiting the mineral feeders on a given day were 17 percent and 25 percent of steers visiting the feeders (treatment periods one and two, respectively; Garossino et al., 2005).

Mineral Boluses

Mineral supplements are also available as boluses, or long acting, slow release supplements (Sprinkle et al., 2006). Boluses can be fed to a ruminant for placement in the reticulum (the second forestomach; Caja et al., 1999). Mineral blouses are most commonly utilized in areas of rough terrain or when agonists are present in the consumed soil or forage (Sprinkle et al., 2006). Use of the bolus system in the study completed by Sprinkle and others (2006) targeted three mineral compounds, Cu, Co, and Se, for use during late gestation when nutritional requirements were greater when compared to maintenance. When reticulorumen boluses containing Cu, Se, and Co were used during gestation, liver Cu concentration of cows were greater for bloused cows compared to control/nonbolused cows (120 ppm and 71 ppm, respectively). Similarly, whole blood Se concentrations of calves from bloused cows were greater than calves from control/nonbolused cows (0.135 ppm and 0.118 pm, respectively; Sprinkle et al., 2006). Intake is not an issue for mineral bolus supplements, however, use of a bolus system is reserved for a more targeted supplementation of specific minerals in much of the published literature. General use of a mineral boluses for supplementation including macrominerals is not recommended due to the large amount of macrominerals required for normal physiological function (Greene, 2000).

Injectable Mineral

To combat the intake variability of enteral supplementation, influences of variability can be managed with injectable trace mineral supplementation products. Injectable supplementation advantages include the targeted delivery of known trace mineral elements (Arthington et al., 2014). An injectable product is currently available that is not a blanket nutrient supplement or broad spectrum, but contains only a few trace minerals: Cu, Mn, Se, and Zn.

In contrast to other direct supplementation methods, injectable trace mineral supplements offer rapid transport to the blood. When an injectable mineral supplement containing Cu, Mn, Se, and Zn was injected into beef calves at nine months of age, plasma concentrations of Mn, Se, and Zn were greater than untreated controls during the first 24 hr after which concentrations dropped to similar values of the controls for the remainder of the 15-d post-injection evaluation period (Pogge et al., 2012). In the same study, liver concentrations of Cu, Se, and Ze were greater for mineral treated calves when compared to untreated control while Mn concentrations tended to be treated for mineral treated calves throughout the 15-d post-injection evaluation period. Concentrations of Se in the liver of calves remained greater for treated calves compared to control calves for the entire 15-d post-injection period (Pogge et al., 2012). At the time of administration, all calves were receiving a trace mineral supplement meeting all NRC (1996) recommendations for Cu, Zn, Mn and Se as a part of a total mixed ration, in addition minerals found in the diet (Pogge et al., 2012). Mineral concentrations of blood are highly variable and it is for this reason that liver concentrations of minerals are more widely accepted, due to the nature of metabolism of minerals.

Effect of Mineral Products on Reproduction

Free choice mineral is the most popular form of commercial supplementation despite variable intake due to season, individual intake, palatability, and requirement. Critical time points such as in reproduction are highly influenced by the amount and kind of minerals consumed. Muehlenbein et al. (2001) reported that cows not supplemented with any type of free-choice Cu (n = 22) had greater pregnancy rates (86%)in the first 30 d of the breeding season when compared to those that were supplemented with free-choice inorganic mineral (n = 23; 57%), with cows supplemented with organic mineral (n = 24) being an intermediate (75%). At the start of the study, all cows had similar Cu and Zn concentrations based on liver biopsy results obtained from 15 cows/treatment group before the initiation of individual supplementation. The following year, a replicate study was completed with the same cow groups and treatments. After year two of the study, cows that were supplemented with organically bound Cu had greater pregnancy rates in the first 30 d of the breeding season, when compared to those not supplemented with organically bound Cu (85% and 61%, respectively), with inorganic mineral supplemented cows being an intermediate (80%; Muehlenbein et al., 2001). Differences in years were thought to be caused by Cu status at the beginning of the treatment period, as year 2 liver concentrations of Cu were reduced compared with year 1, meaning supplementation of year 2 was more beneficial (40 mg/kg and 58 mg/kg, respectively). In a similar study, Ahola and others (2004) reported no difference in the proportion of females fed no supplement, inorganic supplements, or organically bound supplements of Cu, Mn, and Zn that became pregnant to AI (65%, 67%, and 52%, respectively). In year two of a replicate study, a smaller proportion of females became pregnant to AI from the control treatment than did either of the supplemented treatments (34%, 57%, and 58%, control, inorganic, and organically bound respectively; Ahola et al., 2004). In contrast, a study was completed comparing the pregnancy rates of cows not receiving supplement, receiving inorganic supplement, or organically bound supplement containing Cu, Co, Mo, and Zn for a 60 d feeding period with results indicating that supplements (inorganic, organically bound, or neither) hindered reproduction; both resulted in a decrease in the proportion of females that became pregnant in a 70 d breeding season, when combined over two years (No supplement: 0 cows not pregnant, Organic: 11 cows not pregnant, and inorganic: 11 cows not pregnant; Olson et al., 1999). Previous research is highly variable and adequate supplementation may or may not lead to improvements in reproductive efficiency.

Cows administered injectable trace mineral supplements 105 d before the first expected calving date and 30 d before breeding, gained more body condition between parturition and AI compared with unsupplemented cows (0.38 and 0.26, respectively; Mundell et al., 2012). A greater proportion of those females receiving the injectable supplement became pregnant to AI (60.2%), compared with to those not receiving injectable supplement (51.2%); however, no differences were observed among treatments in the final season ending pregnancy rates (93.0% and 89.9% for trace minerals cows and control cows, respectively; Mundell et al., 2012). Furthermore, when heifers were treated with the same injectable trace mineral supplement 17 d prior to embryo transfer, conception rates (embryo survival) at 23 (ITM: 48% and Control: 36%) and 48 d (ITM: 43% and Control: 30%) after timed embryo transfer were greater when compared to untreated controls (Sales et al., 2011). Heifers receiving the injectable trace mineral supplement 30 d prior to breeding had greater season ending pregnancy rates when compared to untreated controls, however pregnancy to AI did was not affected by mineral treatment (Season ending: 92.7% and 83.3% and TAI: 63.6% and 61.1%, respectively; Brasche et al., 2015). In contrast, when a single dose of injectable trace mineral supplement containing Cu, Mn, Se, and Zn, was administered 38-45 d prior to AI breeding in a well-managed dairy herd, conception to AI was not affected when compared to untreated controls (Vanegas et al., 2004). Similarly, when a double dose was given, one administered prior to calving (263 to 271 d of gestation) and the other administered prior to AI breeding (38-45 d in lactation), pregnancy rate to AI was not affected (Vanegas et al., 2004).

A summary of the effects of mineral supplementation on reproductive performance can be found in Table 1.4. Results indicate that mineral supplementation does affect the proportion of females that become pregnant to AI, both positively and negatively, while having no effect on

Table 1.4. Summary of mineral data with regard to reproduction

Study	Class of cattle	n	Minerals supplemented[1]	Mineral form	PG to AI[2, 5]	SE PG[3]	Estrus response[4]
Muehlenbein et al., 2001			Cu				
Year 1 of study	Crossbred primiparous	75	Control, organic, inorganic	Free-choice	C: ↑ O: ↔ I: ↓	C: ↔ O: ↔ I: ↔	C: ↔ O: ↔ I: ↔
Year 2 of study	Crossbred primiparous	120	Control, organic, inorganic	Free-choice	C: ↓ O: ↑ I: ↔	C: ↔ O: ↔ I: ↔	C: ↔ O: ↔ I: ↔
Ahola et al., 2004			Cu, Mn, Zn				
Year 1 of study	Crossbred multiparous	178	Control, organic, inorganic	Free-choice	C: ↔ O: ↔ I: ↔	C: ↔ O: ↔ I: ↔	C: ↔ O: ↔ I: ↔
Year 2 of study	Crossbred multiparous	178	Control, organic, inorganic	Free-choice	C: ↓ O: ↑ I: ↑	C: ↔ O: ↔ I: ↔	C: ↔ O: ↔ I: ↔
Olson et al., 1999	Crossbred	236	Cu, Co, Mn, Zn: Control, organic, inorganic	Mineral-protein feed sup.	-	C: ↔ O: ↔ I: ↔	C: ↔ O: ↔ I: ↔
Mundell et al., 2012	Crossbred	460	Cu, Mn, Se, Zn: Control, ITM	ITM- 2x dose[6]	C: ↓ ITM: ↑	C: ↔ ITM: ↔	C: ↔ ITM: ↔
Brasche et al, 2015	Crossbred	109	Cu, Mn, Se, Zn: Control, ITM	ITM- 1x dose	C: ↔ ITM: ↔	C: ↓ ITM: ↑	-
Vanegas et al., 2004			Cu, Mn, Se, Zn				
Experiment 1	Dairy primi & multiparous	417	Control, ITM	ITM- 1x dose	C: ↔ ITM: ↔	-	-
Experiment 2	Dairy primi & multiparous	408	Control, ITM	ITM- 2x dose	C: ↔ ITM: ↔	-	-

[1] Minerals supplemented = control, inorganic or ITM (injectable trace mineral) supplement as described by corresponding authors
[2]PG to AI = pregnancy rate to artificial insemination
[3]SE PG = season ending pregnancy rate
[4]Observed estrus response as described by corresponding authors
[5]Results: C = control, O = organic, I = inorganic, ITM = injectable trace mineral, ↑ = increase, ↓ = decrease, ↔ = no change
[6]Dose: 1x dose = a single dose administration at a single time point (pre-breeding), 2x dose = a single dose administration at 2 different time points (pre-calving and pre-breeding)

the estrus response of females. Additionally, injectable mineral supplementation has increased the proportion of females to become pregnant by the end of the breeding season.

Conclusions

The most important factor for a cow-calf operator is the birth of a live calf and the ability of a dam to raise that calf to weaning. Therefore, reproduction is a vital component of producer profitability. While individual management strategies vary by operation, understanding factors that affect the reproductive efficiency of a herd are very important. Management techniques and technologies are currently available have potentially have the ability to impact reproductive performance.

Natural service breeding is the most commonly practiced breeding method among beef producers, however, other options are available. Estrus synchronization and AI create the opportunity for increasing the proportion of females calving early in the calving season and can increase weaning weights of calves. While potential benefits exist, it is currently unclear what effect AI will have on commercial operations, including impacts on season ending pregnancy rates and profitability components when compared with natural service breeding. The following chapters seek to identify the true difference between use of AI and natural service on commercial beef herds in terms of reproductive parameters as well as producer profitability by evaluating the effect of natural service and AI on commercial beef operations.

With regard to mineral nutrition, many effects are known. Minerals are required for many process and without, death likely occurs, minerals need to be supplemented when concentrations in forages are not meeting requirements, and mineral supplements are available in many forms as intake of mineral is highly variable. Current supplementation of minerals, specifically trace minerals, and their effects on reproduction are also highly variable with pregnancy rates increasing and decreasing between studies, supplementation type, and mineral form. There does not seem to an overall product that is best suited for all animals with consistent results across the board. As far as additional products are concerned, little research has been done to evaluate the effects of an injectable trace mineral supplement on reproductive parameters on commercial beef herds when only natural service breeding is used. The final chapter of this dissertation will look to identify the differences in pregnancy rate, weaning weights of calves, and calving date for cows administered either an injectable trace mineral supplement or nothing at all.

The following chapters include information relative to management strategies available for implementation (natural service and AI breeding systems, the CHAPS program, the FBM program, and injectable trace mineral supplementation) and their effects on pregnancy, weaning, calving, producer perceptions, and quality of life.

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CHAPTER 2. EFFECTS OF BREEDING SYSTEM (NATURAL SERVICE OR ARTIFICIAL INSEMINATION) ON PREGNANCY RATES, DISTRIBUTION OF CALVING, AND CALF WEANING WEIGHTS OF COMMERCIAL BEEF COW HERDS IN NORTH DAKOTA

Abstract

Objectives of this study were to compare pregnancy rates, calving distribution, and calf weaning weights of commercial beef cows exposed to two different breeding systems. In addition, partial budget analysis was used to evaluate the economic impacts of estrus synchronization and timed artificial insemination (TAI). Within each herd (n = 10), cows were randomly assigned to one of two breeding system treatments; 1) only exposed to natural service herd bulls (CON; n = 1,114), or 2) exposed to ovulation synchronization and fixed-time AI followed by natural service bulls (TAI, fixed-time artificial insemination; n = 1,285). Females exposed to TAI were subject to the 7-d CO-Synch + CIDR protocol with fixed-time AI at 60-66 h after CIDR removal. Clean-up bulls were placed in breeding pastures 1 d after AI and remained with females until the end of the producer defined breeding season. Presence of a viable fetus was determined at least 45 d after the conclusion of the breeding season. At parturition, birth date and calf sex were recorded. No differences ($P = 0.54$) were observed in the proportion of females pregnant at the end of the breeding season between CON (93.1%) and TAI (93.2%) treatments. Cows in the TAI treatment calved 7.7 d earlier ($P < 0.001$) in the calving season compared with CON cows. A greater proportion ($P < 0.001$) of TAI cows (45.6%) gave birth in the first 21 d of the calving season compared with CON cows (24.7%). From d 22 to 42, a greater proportion ($P < 0.001$) of CON cows (41.9%) gave birth compared to TAI cows

(27.3%), and a greater proportion of CON cows (24.7%) gave birth from d 42 to the end of the calving season compared with TAI cows (18.6%). Proportions of cows confirmed pregnant at the end of the breeding season that did not calve in the calving season were similar between treatments. Greater ($P < 0.001$) weaning weights were observed for the calves born from dams exposed to TAI when compared to cows only exposed to CON (249.9 ± 1.6 kg and 242.7 ± 1.7 kg, respectively). Calculated 205-d weights, however, were not different ($P = 0.703$) between treatment groups (CON: 243.6 ± 1.7 kg and TAI: 244.9 ± 1.7 kg). A treatment ×calving group interaction was present for weaning weight. Greater ($P = 0.002$) weaning weights were observed for calves born from TAI cows in the first 21 d of the calving season (269.3 ± 1.82 kg) compared with calves born from CON cows (257.6 ± 2.65 kg). Calves born from TAI cows were also 4 d older than CON calves (9.6 d and 13.6 d, respectively) when evaluating calves born in the first 21-d period of the calving season. During the second 21-d period, weaning weights were greater ($P = 0.05$) for calves born from CON exposed cows (246.7 ± 2.30 kg) when compared to calves born from cows exposed to AI (239.7 ± 2.48 kg). Weaning weights for calves born after d 42 of the calving season were similar between treatments ($P = 0.762$). When utilizing AI, increased profit was observed for producers if bull:cow was increased (i.e. bull number was decreased; $48.81/cow). If bull number was not reduced, a loss was observed ($33.55/cow). Use of TAI in commercial beef herds increased the number of calves born earlier in the calving season and increased the weaning weights of calves. Additionally, if bull number was reduced in terms of clean-up bulls needed, a profit was observed.

Keywords: AI, beef cattle, breeding systems, natural service

Introduction

Reproductive performance is a vital component of any profitable cow-calf production system (Dziuk and Bellows, 1983; Payne et al. 2013). The most important factor in any beef production setting is the birth of a live calf, and therefore, profit is based on cows successfully becoming pregnant, calving, and raising a healthy calf to weaning (Ayers, 2011). Estrus synchronization and artificial insemination (AI) are management techniques available for the advancement of herd genetics by selection of highly proven sires. Previous research has identified that estrus synchronization and AI offer potential benefits and attributes including shortening the breeding and calving seasons, increasing the number of calves born early in the calving season resulting in older and heavier calves at weaning (Odde, 1990; Rodgers et al., 2012). In addition, pregnancy rates could be affected, as *Bos indicus* cows exposed to timed-AI had greater pregnancy rates compared with those only exposed to natural service herd sires (Sá Filho et al., 2013). While offering potential benefits for the commercial cattleman, less than 8 percent of the beef industry utilizes AI, citing labor, time, and difficulty of use as major deterrents (NAHMS, 2009).

Our previous research has revealed that incorporating AI into a management scheme lead to older and heavier calves at weaning, compared with a breeding system that relied solely on natural service breeding (Steichen et al., 2013), however, did not evaluate the costs and returns and therefore profitability associated with implementing AI, and were also conducted at university research facilities rather than commercial operations. While limited studies are available that compare the use of natural service with AI on commercial operations, Rodgers et al., (2012) determined that a profit could be realized when utilizing AI, however, did not evaluate factors such as pregnancy rate. A more complete study evaluating the profitability and effects of breeding systems is warranted. Additionally, although limited implementation is observed on a national level, a North Dakota survey, mailed to 2,500 randomly selected beef producers, determined that over 51 percent of producers staying in the beef industry for at least the next 10 years were likely to utilize AI on their operations (Schook et al., 2014). In addition, 42 percent of operators were willing to hire outside labor to accomplish farming/ranching tasks. Tasks associated with AI can be performed by trained professionals, often by individuals working for semen distribution companies (personal communication; Dan Donnelly, Beef Business Manager for Minnesota Select Sires Co-Op, Inc.).

With an increase in potential adoption of AI in North Dakota, the objectives of this study were to compare the effects of artificial insemination and natural service breeding systems on 1) pregnancy rates, calving distribution, and calf weaning weights of commercial beef cow-calf operations, and 2) conduct partial budget analysis to determine the economic effect of the breeding systems with operators lacking previous experience utilizing TAI in their herds.

Materials and Methods

All cattle were managed according to the Federation of Animal Science Guide for the Care and Use of Agricultural Animals in Agriculture Research and Teaching (FASS, 1999). All procedures were reviewed and approved by the Institutional Animal Care and Use Committee of North Dakota State University.

Treatments

Two thousand three hundred and ninety-nine crossbred commercial cows originating from 10 commercial beef herds in the state of North Dakota were used to compare pregnancy rates, calving distribution, and calf weaning weights of beef cows exposed to two different breeding systems. County Extension Agents from the North Dakota State University system identified commercial cattle producers who did not use breeding systems that incorporated estrus synchronization or AI as a part of their management strategy for participation in this experiment. Within each herd, females were stratified by d postpartum and randomly assigned to one of 2 treatments (Figure 2.1); 1) only exposed to natural service herd bulls (**CON**; n = 1,114) or 2) exposed to ovulation synchronization and fixed-time AI followed by natural service bulls (**TAI**, n = 1,285).

All TAI females were exposed the 7-d CO-Synch + CIDR (Larson et al., 2006) consisting of inserting a controlled internal drug releasing insert (CIDR,1.38 g Progesterone, Zoetis, Inc., Florham, NJ, USA) and 100 µg Gonadotrophin Releasing Hormone (GnRH) i.m. (2 mL Factrel, Zoetis, Inc.), followed in 7 d by CIDR removal and 25 mg $PGF2_{\alpha}$ i.m. (5 mL Lutalyse, Zoetis, Inc.), followed in 60-66 hr by 100 µg GnRH i.m. and fixed-time artificial insemination (AI). At the time of CIDR insertion, body condition scores (BCS) were recorded on all TAI females. Body condition scores are a visual method for evaluating the nutritional status of an animal and are based on a 1-9 scale, with 1 being emaciated and 9 being obese (5-6 being ideal; Richards et al., 1986).

Participating producers were responsible for the selection of AI sires to be bred to females in the TAI treatment group. Criteria for selection included a maximum cost of $20 per unit of semen and bull breeds would be similar to those used as clean-up for TAI and bulls for NS matings.

Within each herd, females from both treatments were comingled on common pastures and managed together. Bulls were placed into breeding pastures a minimum of 1 d after TAI. The presence of a viable fetus was determined by the herd veterinarian of each operation, at least 45 d after the conclusion of the producer defined breeding season. Birth date and calf sex were recorded at parturition and individual calf weights were collected at weaning. Calves born from cows exposed to TAI will be referred to as TAI calves and calves born from dams only exposed to NS will be referred to as NS calves.

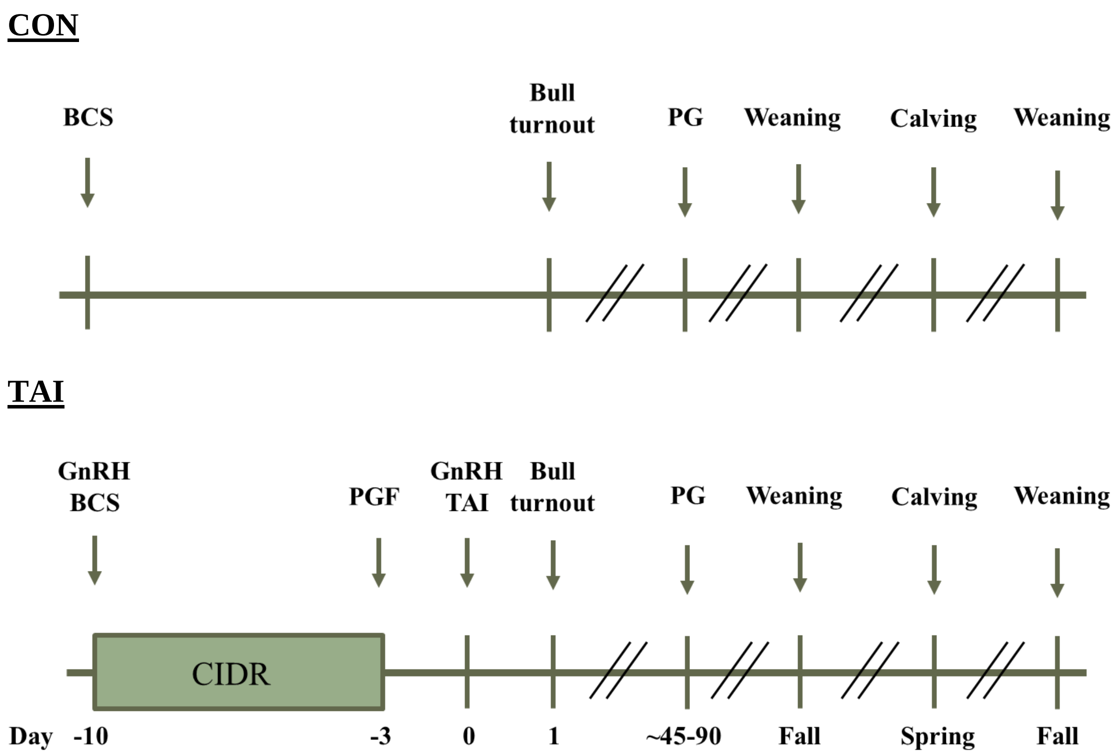

Figure 2.1. Experimental protocol for the assigned breeding systems (natural service or timed-artificial insemination). BCS = body condition score; CIDR = controlled internal device release; PGF = prostaglandin $F_{2\alpha}$; TAI = timed AI; PG = pregnancy diagnosis.

In the current study, the start of the calving season was defined as the date that the third calf from within a herd was born to remove any early born outliers in the calving season. Calves were then divided into three 21-d interval calving groups based their respective date of birth: born in the first 21 d of the calving season (≤ 21), born from d 22 to 42 (22-42), and born after d 42 of the calving season (≥ 42). If a female was determined to be pregnant at the end of the breeding season but failed to calve the calving group was referred to as no calf. The proportion of cows in the TAI group in the first 21 d of the calving season will serve as a proxy for cows that became pregnant to TAI.

Calf body weights were recorded at the time of weaning at each producer location. Due to the variation in timeframe of when calves were weaned at each location, adjusted weights were calculated. Calf weaning weight was divided by the difference in weaning date and birth date and then multiplied by 205. Weaning weight per cow exposed was also calculated where the weaning weight recorded for cows that did not calve was entered as a zero.

Herd Descriptions

Herd 1 was comprised of 228 Angus based crossbred cows. Females in the TAI group were bred on June 3, 2013. The first calf was born on March 3, 2014, and the last calf was born on June 20, 2014. Weaning events took place on November 2nd and 9th for year 1 (2013) and year 2 (2014), respectively.

Herd 2 consisted of 190 Red Angus and Simmental based crossbred cows. Females in the TAI group were bred on June 24, 2013. The first calf was born on March 19, 2014 and the last calf was born on June 20, 2014. Weaning events took place on October 16th and November 7th, for years 1 and 2 respectively.

Herd 3 included 385 Angus and Simmental cows. Females in the TAI group were bred on June 20, 2013. The first calf was born on March 10, 2014, and the last calf was born on July 16, 2014. Weaning events took place on November 16th and 9th for year 1 (2013) and year 2 (2014), respectively.

Herd 4 was comprised of 216 Angus based crossbred cows. Females in the TAI group were bred on June 22. The first calf was born on March 17, 2014, and the last recorded calf birth date was May 3, 2014. Weaning weights were not collected in year one, however, in year 2, calves were weaned and weights were collected on September 26. 2014.

Herd 5 included 197 Simmental based crossbred cows. Females in the TAI group were bred on June 17, 2014. Calf birth records were collected and then lost before the retrieval of the research team. Weaning events took place on November 3^{rd} and October 14th for year 1 (2014) and year 2 (2015), respectively.

Herd 6 consisted of 227 Angus and Simmental based crossbred cows. Females in the TAI group were bred on July 4, 2014. The first calf was born on February 23, 2015, and the last calf was born on August 10, 2015. Weaning events took place on February 7^{th} and October 21^{st} for year 1 (2014) and year 2 (2015), respectively.

Herd 7 Herd 1 was comprised of 202 Angus, Hereford, and Charolais based crossbred cows. Females in the TAI group were bred on June 26, 2014. The first calf was born on March 6, 2015, and the last calf was born on July 5, 2015. Weaning events took place on November 19^{th} and 28^{th} for year 1 (2014) and year 2 (2015), respectively.

Herd 8 included 277 Angus based crossbred cows. Females in the TAI group were bred on July 2, 2014. The first calf was born on March 1, 2015, and the last calf was born on June 3, 2015. Weaning events took place on October 19^{th} in year 1 and at 3 different time points in year 2, September 29^{th}, October 3^{rd}, and October $19^{th,}$ for year 1 (2014) and year 2 (2015), respectively.

Herd 9 consisted of 76 Angus based crossbred cows. Females in the TAI group were bred on May 30, 2014. The first calf was born on February 20, 2015, and the last calf was born on May 29, 2015. Weaning events took place on November 1^{st} and December 19^{th} for year 1 (2014) and year 2 (2015), respectively.

Herd 10 included 309 Angus based crossbred cows. Females in the TAI group were bred on June 20, 2014. The first calf was born on March 11, 2015, and the last calf was born on July 10, 2015. Weaning events took place on November 14th and 9th for year 1 (2014) and year 2 (2015), respectively.

Partial Budget Analysis

A partial budget analysis (Tigner, 2006) was completed for each operation to determine the economic implications of estrus synchronization and TAI. To calculate each partial budget, factors related to the operations income with regards to the cow herd were considered. Profits and costs were sectioned into four quadrants; A) increased returns, increased profit due to the addition of a technology or change, B) decreased returns, due to the addition of a technology or change, C) decreased costs, of production due to the addition of a technology or change, and D) increased costs, due to added expenses of a technology or change (Tigner, 2006). Specific factors related to the inclusion of AI can be overserved in Table 2.1. Once returns and costs were identified for each operation, the increased returns (A) and decreased costs (C) are added together to become the income generated from the change and the decreased returns (B) and the increased costs (D) are added together to become the costs associated with the change (Tigner, 2006). After determining the income generated or saved as well as the costs associated with the addition of estrus synchronization and TAI, net profit or loss was calculated. In terms of the current study, some factors that may affect increased returns will not be included in the analysis (i.e. values associated with improvement in herd genetics and/or calf uniformity). Improvements in genetics can be made by breeding to high quality AI sires that are highly proven with the use of expected progeny differences (EPD's). Additionally, because females are bred at a single time point with timed AI and often times to a small number of bulls, calves may appear more uniform in their phenotype, allowing producers to sell calves in large groups.

For each operation, partial budget scenarios for alterations in natural service bull numbers were also evaluated. For each operation, two scenarios were used to evaluate the cost/profit differences: 1) clean-up bull numbers remained similar to previous years when TAI was not utilized (stocking rate of 1 bull per 25 cows), and 2) clean-up bull numbers were reduced to the mean number used in the industry after AI is implemented (1 bull per 39 cows; Dahlen and Stoltenow, 2015).

Increased returns (A) were calculated by determining the average calf weaning weights for both cow treatments (CON or TAI). Natural service weaning weights were subtracted from TAI weights to evaluate the increased size and gain of calves from each respective treatment group. Average weaning weights for each operation were multiplied by the average price/pound received for calves.

Table 2.1. Partial budget overview for AI use on commercial beef operations[1]

Increased returns (A)	Decreased returns (B)
- heavier calves[2]	- fewer cull bulls[3]
Decreased costs (C)	**Increased costs (D)**
- bull:cow ratio[7] - improved calving ease[9]	- labor for working d[8] - supplies (drugs, gloves, etc.)[10] - technician[11] - semen[12]

[1]Table adapted from Rodgers et al., 2012.
[2]Calves born earlier in the calving season may be heavier.
[3]Fewer cull bulls attributed to fewer bulls in the herd.
[4]Increased in weaning weight may be attributed to improved genetic potential derived from the artificial insemination sire.
[5]More pregnant cows due to additional estrous cycles per breeding season. Fewer open cows culled.
[6]Calves more uniform in weight attributed to a shorter calving season.
[7]Reduction in the bull:cow ratio attributed to pregnancies from TAI.
[8]Labor requirements increase attributed to TAI protocols.
[9]Incidence of dystocia decreased and attributed to sires with a greater calving ease direct expected progeny difference value.
[10]Increased costs associated with semen, pharmaceuticals, and other supplies.
[11]Increased costs associated with hiring a technician to perform AI.
[12]Increased cost attributed to the price paid per straw of semen for each female inseminated.

Bull number utilized is a direct factor related to decreased costs (C). If bull number is unchanged after AI (scenario 1), decreased costs does not change and remains a factor of zero. If bull number is decreased (scenario 2), bull purchase price, feed, veterinary services, interest, and death loss are calculated for the change in bull numbers (1:25 to 1:39). Average bull price, feed costs, veterinary costs, interest, and death loss were calculated by individual operation as opposed to being an assumed cost. The difference between the bull:cow ratio reduction is determined to be the decreased costs (calculator obtained from J. McGrann, Department of Agricultural Economics, Texas A&M University, College Station, TX.).

Decreased returns (B) for the partial budgets were calculated by determining the average number of cull bulls sold each year per operation. In a year in which TAI is used and bull numbers are reduced, less bulls would be necessary and therefore less bulls would need to be culled and sold. Salvage value was determined by multiplying an average bull weight (2,000 lbs.) by the price per pound received for cull bulls (calculator obtained from J. McGrann, Department of Agricultural Economics, Texas A&M University, College Station, TX.). Average cull numbers were multiplied by the salvage value/bull.

Costs of all supplies required for TAI were included in the increased cost category (D). Semen, pharmaceuticals, and supplies were calculated on a per cow basis. Semen costs were calculated at $15.00 per straw (or female) as producers were allocated to that amount. Pharmaceuticals included two doses of GnRH at $2.00/dose, one dose of $PGF_{2\alpha}$ at $3.00/dose, and one CIDR insert priced at $12.00/CIDR. Supplies included gloves, needles, syringes, and lubricant, totaling roughly $0.62/cow. Prices for pharmaceuticals and supplies were obtained from a local purveyor, Stockmen's Supply, West Fargo, ND on 4/5/2016. Labor was calculated individually for each herd by adding the additional time necessary for implanting CIDRs and administering GnRH, removing CIDRs and administering PGF2α, and breeding females and multiplying the number of extra hr by the increased number of people required to complete the work. The product of hr and individuals was then multiplied by the price per hr each producer would pay someone to complete the work. Final calculations were then divided by the number of cows in the herd and then added to the overall increased cost figure. Additional work associated with TAI increased time spent with a range of six to 12 hr, required 4 additional people. Lastly, technician costs were defined to be the cost per cow for an AI technician to breed females and determined to be $7.00/females for each operation (Dan Donnaley, Select Sires, personal communication).

After determining increased returns and costs as well as the decreased returns and costs associated with the addition of the advancement or technology, net profit or loss was calculated. Income boxes were added together (**A** + **C**), and the cost boxes were added together (**B** + **D**). **A** + **C** is equal to the total income made and **B** + **D** is equal to the total costs. Total costs are then subtracted from the total income. If the number is positive, additional income was generated by the technology or advancement, whereas if the number was negative, income was lost.

Statistical Analysis

The MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) was used to analyze all continuous data (calf birth date and calf weaning weights). The GENMOD procedure of SAS was used to analyze the binomial data (pregnancy rate and calving distribution). Each model included the effect of treatment (natural service or fixed-timed AI breeding systems) and producer operation (ranch). In addition, another model for weaning weight was evaluated that included the effects of calving distribution.

When analyzing the effects of DPP and BCS, categories were created to determine differences in groups of data and included in the model. For DPP, groups were defined as ≤ 40, 41-70, 71-100 or > 100 d based on the interval from calving until breeding. Groups used for analysis of BCS data were < 4, 4, 5, or > 5 based on their condition at the time of treatment administration. Statistical models for pregnancy included the categories for both DPP and BCS. Significance was declared at $P \leq 0.05$.

Results and Discussion

Pregnancy

In the current study, breeding system did not affect the proportion ($P = 0.54$) of cows that were pregnant at the end of the producer defined breeding season (TAI: 93.2 ± 0.01 and NS: 93.1

± 0.01). Pregnancy rate did, however, differ by herd (*P* = 0.01), where Herd 7 had the smallest proportion of females pregnant (89.1%) and Herd 6 had the greatest (96.3%; Figure 2.2.). The CIDR included in the use of the 7-d CO-Synch + CIDR protocol provides increased concentrations of progesterone for the period of time in which it is inserted. The greater concentrations of exogenous progesterone found in the blood during the synchronization protocol from the CIDR device is speculated to increase the length of proestrus and increase the development of the follicle, allowing for accurately timed ovulation relative to TAI and increases in the chances for conception (Echternkamp et al., 2011). The addition of a CIDR with an estrus synchronization protocol provided supplementary progesterone that improved pregnancy rates to TAI when compared to a CO-Synch protocol without the use of a CIDR (Larson et al., 2006). Even with increased concentrations of progesterone presumably occurring with the use of a CIDR (as concentrations of progesterone were not evaluated) during the synchronization of our TAI cows, pregnancy was not increased over females receiving no source of exogenous progesterone.

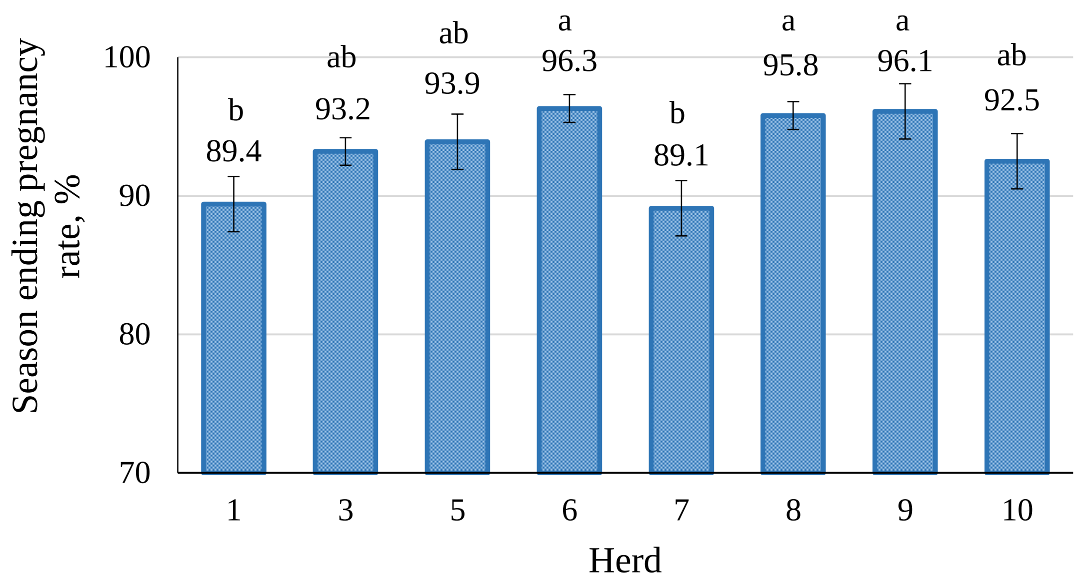

Figure 2.2. The proportion of cows that became pregnant by the end of the breeding season by herd. [a,b]Means with uncommon superscript differ ($P < 0.05$).

Effects of AI on pregnancy attainment vary in the published literature. Previous research in *Bos indicus* cattle demonstrated an increase in pregnancy rates to TAI compared with those from natural service breeding (Sá Filho et al., 2013). Similarly, when *Bos taurus* cattle were evaluated for the first 21-d period of the calving season, pregnancy rates did not differ for TAI and natural bred cows, however, by d 49 greater proportions of cows bred to TAI were pregnant compared with cows bred with natural service breeding (81.7 and 77.5 percent respectively; Steichen, 2013). In the study by Steichen et al., (2013), pregnancy rates were again similar between TAI and natural service bred females by the end of the breeding season. Season ending pregnancy rates for the study by Steichen (2013) are similar to those observed in dairy cattle when both TAI and natural service breeding were evaluated, pregnancy rate was not different (Lima et al., 2009). To date, limited studies are available that evaluate season ending pregnancy rates for *Bos taurus* cattle bred to TAI or natural service. The current study includes crossbred cattle on commercial beef (76 percent of the beef industry) operations which represent a large proportion of the U.S. beef industry (NAHMS, 2009).

Season ending pregnancy rates were not affected by the interval from calving to breeding when evaluated between treatments, as rates were similar (P = 0.34) between cows exposed to TAI and those only exposed to natural service breeding (CON), with an average of 65.2 ± 0.69 d. When categorized as previously described, DPP affected (P = 0.05) pregnancy rate, with the pregnancy rate increasing as DPP increased (< 40 DPP: 85.1% ± 0.03; 41-70 DPP: 93.4% ± 0.01; and 71-100 DPP: 94.8% ± 0.01; Figure 2.3.). Rutter and Randel (1984) concluded that cows that could maintain their body condition after calving had a shorter postpartum interval of anestrus. Cows that were able to maintain body condition also had greater GnRH-induced LH release than those losing condition after calving (Rutter and Randel, 1984). Although maintenance of body condition score was not evaluated in the current study, greater pregnancy rates were observed for those females with greater BCS. For TAI cows, a greater proportion (P = 0.01) of those with greater BCS became pregnant compared with cows with lower BCS (<4: 87.1% ± 0.01; 4: 92.4% ± 0.01; 5: 95.7% ± 0.01; and > 5: 97.8% ± 0.0.1; Figure 2.4.). Likewise, Larson and others (2006) reported that for every unit increase in BCS over the value of 3, the proportion of cyclic cows increases 11.5 percent. In contrast, BCS recorded at breeding identified higher conception rates in those cows that were moderate or thinly conditioned (BCS 3 to 4) compared with fleshy cows (BCS ≥ 5; Houghton et al., 1990). Our data may align more closely to that published by Richards et al., (1986) in which cows calving with a BCS > 5 became cyclic earlier than those calving with a BCS < 4. Earlier cyclicity of cows with a greater BCS may explain greater pregnancy rates for heavier conditioned cows in the current study.

Advantages of TAI in terms of pregnancy rate were not observed in the current study, however, provided further evidence in the importance of greater body condition scores and increased intervals between calving and breeding. Although DPP cannot be increased indefinitely, as females need to have a calf each year, greater proportions of cows that calve earlier in the calving season will become pregnant compared with those calving later in the calving season. Culling females that calve late in the calving season may increase the DPP of a herd, increasing reproductive performance.

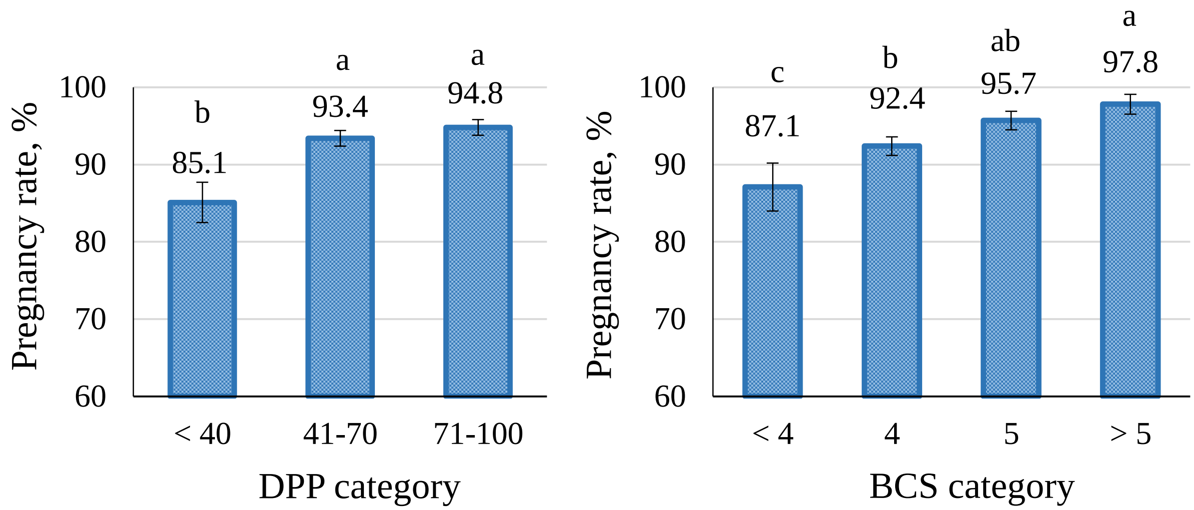

Figure 2.3. The proportion of cows that became pregnant by the end of the breeding season by days postpartum (DPP) and body condition scores (BCS) when categorized. [a,b]Means with uncommon superscript differ ($P < 0.05$).

Calving Distribution

In the current study, cows exposed to TAI calved 7.7 d earlier ($P < 0.001$) than CON cows (27.1 ±0.81 and 34.8 ± 0.82, respectively). Cows bred to TAI were exposed to ovulation synchronization and bred on a single d compared to cows only exposed to natural service which were serviced by herd bulls as they came into estrus any time during the breeding season. Steichen et al. (2013), reported similar findings, with cows bred to TAI calving six d earlier than those bred to natural service. A greater ($P < 0.001$) proportion of TAI cows (45.6 ± 0.02%)

calved in the first 21 d of the calving season period compared with CON cows (24.7 ± 0.02%; Figure 2.4.). In contrast, more (*P* < 0.001) CON cows calved from d 22-42 and from d 42 to the end of the calving season compared with TAI cows (when evaluating the second and third 21 d periods, a greater proportion of CON females calved in each respective period (21-42: 41.9 ± 0.02 and 27.4 ± 0.02 and > 42: 24.7 ± 0.02 and 18.6 ± 0.01, CON and TAI, respectively). Finally, there was no difference in the proportion of cows that did not calve (*P* = 0.59).

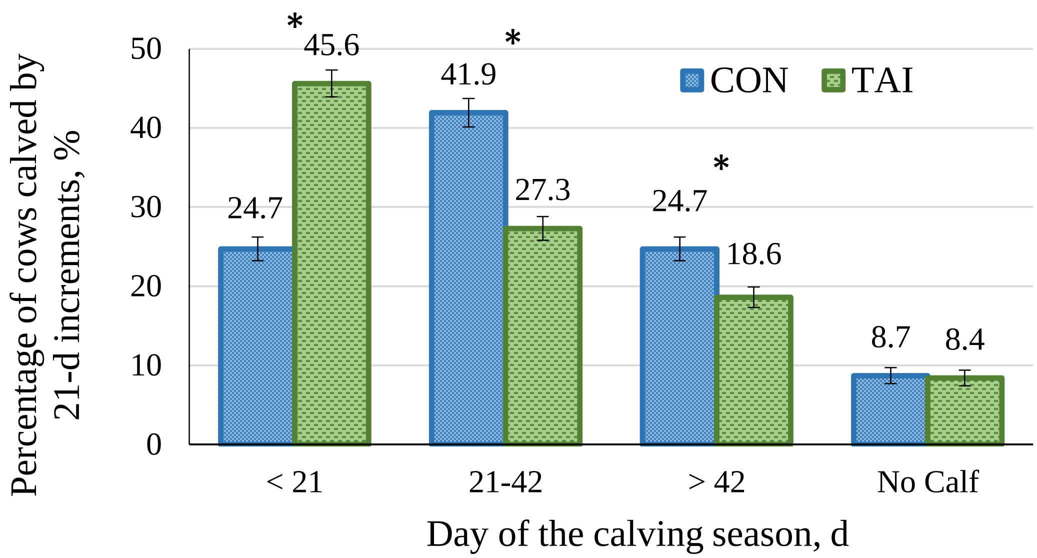

Figure 2.4. The proportion of cows calving by 21-d increments of the calving season. CON = dams were exposed to natural service breeding, TAI = dams exposed to ovulation synchronization with the 7-d CO-Synch + CIDR protocol and TAI. *Treatments differ within d (*P* < 0.05).

To determine the mean age of calves within 21-d increments, the effects of treatment and calving group were evaluated. A calving group × treatment interaction was present for birth date (Table 2.2.). Within the first 21 d period, calves born to TAI dams were born four d earlier (*P* < 0.001) than calves born from CON dams (TAI: 9.6 and CON: 13.6). In the second 21-d interval, CON born calves tended (*P* = 0.07) to be born earlier than TAI born calves (CON: 30.4 and TAI: 32.0). Mean age was similar within the third 21 d period of the calving season.

Table 2.2. Mean age of calves within 21-d calving intervals of the calving season

Item	Mean calf birth date			
Calving group[2]	CON[1]	TAI	SEM	P-value[3]
1	13.6	9.6	0.38	< 0.001
2	30.4	32.0	0.34	0.070
3	63.6	63.0	1.46	0.603

[1]Treatment: CON = dams were exposed to natural service breeding, TAI = dams exposed to ovulation synchronization with the 7-d CO-Synch + CIDR protocol and TAI.
[2]Calving group: 1 = calf born ≤ 21 d in calving season, 2 = calf born from 22-42 d of calving season, 3 = calf born > 42 d of calving season.
[3]Means within treatment differ at (P = 0.05)

Incorporation of estrus synchronization and AI increase the number of calves born early in the calving season in previous literature. A similar distribution to the one observed in the current study was observed when the calving season was distributed into 10 d calving intervals, as greater proportions of cows bred with TAI calved earlier than cows bred with natural service (Rodgers et al., 2012). It is often theorized that AI can decrease the length of the calving season (Sprott, 1999, Larson et al., 2006, Lamb et al., 2010). The length of the calving season is, however, mostly a function of bull exposure and the amount of time a bull is with females (i.e. the longer a bull is exposed to females, the longer the calving season). Rodgers et al., (2012) reported no change in calving season length with similar treatment assignments. After eight years of implementing estrus synchronization and AI, Mercadante and others (2015) altered the proportions of calves born from 50% born in 90 d to 50% born in less than 30 d. In this study mean calving d decreased by 20 d in the first year of AI implementation with a continual progression of decreasing d over the next 6 calving seasons (Mercadante et al., 2015). In the current study, over 85% of the cows calved by 42 d in the calving season, however, calving season length remained the same. Numbers of calves born in each d of the calving season are illustrated in Figure 2.5.

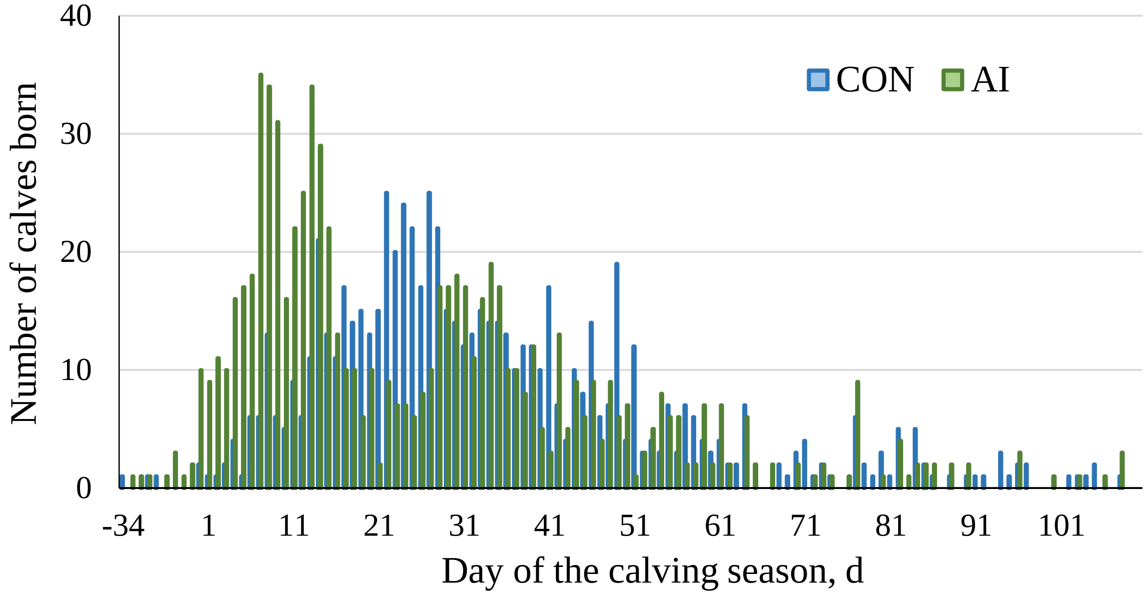

Figure 2.5. The number of calves born by individual d of the calving season. CON = dams were exposed to natural service breeding, TAI = dams exposed to ovulation synchronization with the 7-d CO-Synch + CIDR protocol and TAI. N = 1,522 (99.1 percent of calving cows).

Calves born from dams exposed to TAI were born nearly 8 d earlier in the calving season with an overall greater proportion of TAI calves being born in the first 21 d of the calving season. If cattle producers wish to increase the proportion of females calving earlier, the ability to breed a large group of females at a single time point is a way to accomplish this goal. Aside from being older, calves born earlier in the calving season may also have advantages in weight and growth due to an increased growth period (Cushman et al., 2013).

Weaning Weights

Weights of calves born from each breeding systems were recorded at each producer location at the time of weaning. Greater ($P < 0.001$) weights were observed for the TAI calves compared with CON calves (249.9 ± 1.6 kg and 242.7 ± 1.7 kg, respectively). Calculated 205-d weights, however, were not different ($P = 0.703$) between treatment groups (CON: 243.6 ± 1.7 kg and TAI: 244.9 ± 1.7 kg). When including calving group in the statistical model, a treatment

× calving group interaction was also present for weaning weight. Greater (*P* < 0.001) weaning weights were observed for TAI calves born in the first 21 d of the calving season (269.3 ± 2.1 kg) compared with CON calves born during the same period (257.6 ± 3.0 kg; Figure 2.6.). A treatment × calving group interaction was also present for calculated 205-d weights, where larger weights were observed for TAI calves born in the first 21 d of the calving season compared with CON calves (252.9 ± 2.3 and 245.1 ± 3.3, respectively; Figure 2.6). Increased calf weaning weights of calves born from AI exposed females are attributed to calves being older in addition to improvements in genetic parameters related to growth (Johnson, 2002). When 205-d weights were calculated, age is not a factor, thus giving probable cause for an additive genetic value when calves were born from cows bred using TAI. Results are similar to those observed by Rodgers et al. (2012), where weaning weights per cow exposed were greater for cows exposed to estrus synchronization and TAI compared with natural service. Calves born earlier in the calving season may have a faster preweaning rate of gain and therefore, may be able to utilize forage better than those born later in the calving season (Lesmeister et al., 1973). Greater (*P* = 0.05) weaning weights were observed for CON calves born in the second 21-d period of the calving season compared with TAI calves (246.7 ± 2.3 kg and 239.7 ± 2.8 kg, respectively). No differences (*P* = 0.23) were present in the third 21-d period of the calving season when evaluating weaning weights of calves as well as the second and third 21-d period of the calving season when evaluating calculated 205-d weaning weights.

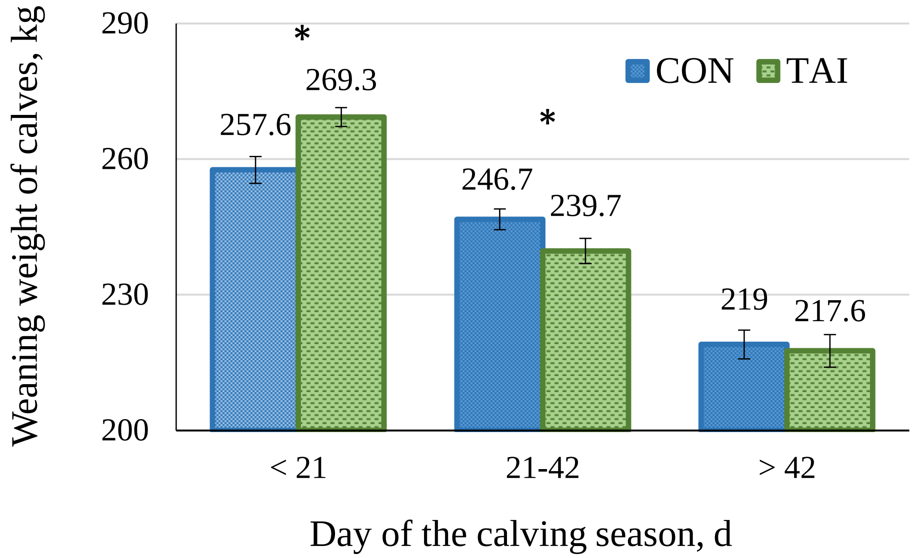

Figure 2.6. Effect of breeding system of origin on actual calf weaning weights within 21-d periods of the calving season (weaning weight × calving season interaction). CON = dams were exposed to natural service breeding, TAI = dams exposed to ovulation synchronization with the 7-d CO-Synch + CIDR protocol and TAI. *Treatments differ within d ($P < 0.05$).

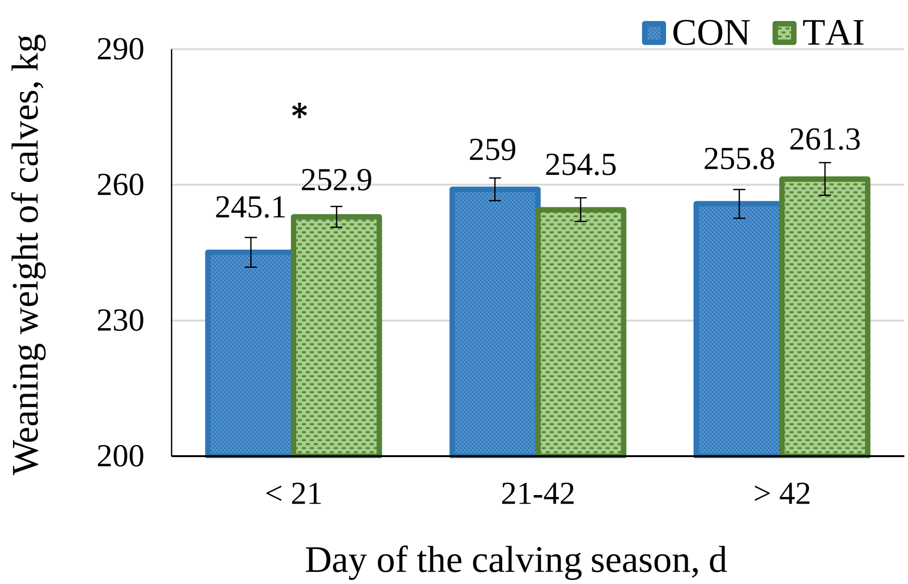

Figure 2.7. Effect of breeding system of origin on calculated 205-d calf weaning weights within 21-d periods of the calving season (weaning weight × calving season interaction). CON = dams were exposed to natural service breeding, TAI = dams exposed to ovulation synchronization with the 7-d CO-Synch + CIDR protocol and TAI. *Treatments differ within d ($P < 0.05$).

An effect of DPP during the year of breeding on calf weaning weight the following year was observed. When categorized, greater ($P < 0.001$) calf weaning weights were observed when cows had a greater number of d between calving and breeding (41-70: 246.4 ± 1.8 kg and 71-100: 251.5 ± 1.9 kg) compared with cows with a lower number of d between calving and breeding (< 40: 233.0 ± 3.9 kg). Additionally, greater ($P < 0.001$) weaning weights were observed for calves born from cows with greater BCS (5: 258.7 ± 3.0 kg, 4: 245.0 ± 2.1 kg, and < 4: 229.4 ± 4.0 kg). In the current study, DPP was similar between treatments, as previously discussed. Therefore, observed advantages in DPP are based on increased in time from calving to breeding. Body condition scores in the current study were recorded at the time of CIDR insertion (just before breeding) and not at parturition. In contrast to observed results in the current study, Spitzer and others (1995) found no differences in calf weaning weights from cows originating from a 4, 5, or 6 BCS at the time of calving in a multistate sttudy. Researchers did, however, report heavier calf weaning weights from cows fed to gain 0.9 kg/d (high) compared to cows fed to gain 0.45 kg/d (moderate; Spitzer et al., 1995).

Partial Budget Analysis

Partial budget analyses were created to evaluate the costs and returns associated with estrus synchronization and AI. Budget analyses were independently generated for each herd. Partial budgets were created to signify a change in bull number (1:39 bull to cow ratio) or to signify that no change in bull number was made (1:25 bull to cow ratio). The following data is only descriptive data and cannot be used to make statistical inferences.

In the analysis that included a bull to cow ratio of 1 to 25, an average loss of -$12.04 per cow ($/cow) was generated by implementing estrus synchronization and AI (Figure 2.3.). However, net profit was increased in 5 of the 9 herds evaluated. The analysis included zero decreased costs and zero decreased returns as the number of bulls needing to be purchased and maintained would not change as well as the number of bulls culled each year. A loss was recorded for 4 of 9 herds ranging from -$0.28/cow to -$90.28/cow. For herds 2, 6, 7, and 10, the increased returns based on increases in weaning weight were not great enough to offset the cost of purchasing and raising bulls for natural service breeding.

Table 2.3. Partial budget analysis for cows exposed to estrus synchronization and TAI compared with those exposed to natural service with a bull to cow ratio of 1 to 25 ($/cow)

Herd	Increased returns[1]	Decreased costs[2]	Decreased returns[3]	Increased cost[4]	Profit or loss[5]
1	80.35	0.00	0.00	45.36	34.99
2	3.58	0.00	0.00	45.68	-42.10
3	116.38	0.00	0.00	43.97	72.41
5	94.14	0.00	0.00	45.93	48.21
6	46.02	0.00	0.00	46.30	-0.28
7	37.02	0.00	0.00	47.00	-9.98
8	55.14	0.00	0.00	44.57	10.57
9	64.65	0.00	0.00	51.09	13.56
10	-45.90	0.00	0.00	44.38	-90.28
Overall[6]	33.18	0.00	0.00	45.22	-12.04

[1]Additional weights calculated by subtracting the natural service treatment sired calves from the TAI treatment sired calves and average weights for each herd x selling price.
[2]Average price paid for natural service sires plus feed costs, veterinary services, interest, and death loss (adapted from McGrann). If bull number is not decreased, no decreased costs are associated and figure becomes a zero.
[3]Average number of bulls culled and sold per year to calculate salvage value.
[4]Increased costs associated with supplies and labor required for estrus synchronization and TAI; GnRH = $4.00 per dose x 2 doses, PGF = $3.00 per dose, CIDR = $12.00, miscellaneous (gloves, syringes needles) = $1.00, semen = $15.00 per straw, technician = $7.00 per head, labor = 0.41 hr per cow x 12 per hr (Rodgers et al., 2012).
[5]Profit or loss = (increased returns + decreased costs) – (decreased returns + increased costs).
[6]Overall = average of each column (average of all herds)

In the analysis including a bull to cow ratio of 1 to 39, an average profit of $13.84 per cow was generated with the implementation of estrus synchronization and TAI (Table 2.4.). Due to the increased bull to cow ratio, decreased costs were included in the analysis as well as a reduction in returns caused by culling and selling fewer bulls. All other aspects of the analysis were similar to those calculated by the previous analysis. In contrast to the analysis in which no change in bull number was made, only one operation (herd 10) incurred a loss due to the implementation of AI. It is important to note that Herd 10 incurred a loss regardless of management scenario. Herd 10 had pronounced variation in weaning weight over the two recorded years which may be observed in the financial analysis. Figure 2.8. illustrates the differences in profit or loss for each herd relative to the respective bull to cow ratio.

Table 2.4. Partial budget analysis for cows exposed to estrus synchronization and TAI compared with those exposed to natural service with a bull to cow ratio of 1 to 39 ($/cow)

Item	Increased returns[1]	Decreased costs[2]	Decreased returns[3]	Increased costs[4]	Profit or loss[5]
1	80.35	38.23	9.28	45.36	63.94
2	3.58	59.52	10.06	45.68	7.36
3	116.38	30.45	8.74	43.97	94.12
5	94.14	28.42	5.33	45.93	71.30
6	46.02	34.59	8.40	46.30	25.91
7	37.02	39.86	9.97	47.00	19.91
8	55.14	27.27	7.31	44.57	30.53
9	64.65	39.31	14.04	51.09	38.83
10	-45.90	38.96	10.26	44.38	-61.58
Overall[6]	33.18	34.08	8.21	45.22	13.84

[1]Additional weights calculated by subtracting the natural service treatment sired calves from the TAI treatment sired calves and average weights for each herd x selling price.
[2]Average price paid for natural service sires plus feed costs, veterinary services, interest, and death loss. Reduced from 1:25 bull:cow to 1:39 bull:cow (adapted from McGrann; Dahlen and Stoltenhow, 2015).
[3]Average number of bulls culled and sold per year to calculate salvage value.
[4]Increased costs associated with supplies and labor required for estrus synchronization and TAI; GnRH = $4.00 per dose x 2 doses, PGF = $3.00 per dose, CIDR = $12.00, miscellaneous (gloves, syringes needles) = $1.00, semen = $15.00 per straw, technician = $7.00 per head, labor = 0.41 hr per cow x 12 per hr (Rodgers et al., 2012).
[5]Profit or loss = (increased returns + decreased costs) – (decreased returns + increased costs).
[6]Overall = average of each column (average of all herds)

Variation was observed in increased returns due to the sale price of calves and weight differences between natural service and TAI born calves. Increased returns per female ranged from $116.38 to a loss of $45.90. Variation was caused by differences in prices received for calves and the weight differences observed for calves in each herd. If additional weight due to treatment was increased in combination with a high average price received for calves, a greater increased return was observed. If an increase in calf weaning weight was not observed, a loss was incurred no matter the price per pound received for calves. Herds 1, 3, 5, 8 and 9 had increased profit with the change in breeding system from natural service to TAI. Herds 2, 6, 7, and 10 were at a loss due to smaller advantages in weaning weight of calves and decreased returns attributed to the sale of cull bulls each year.

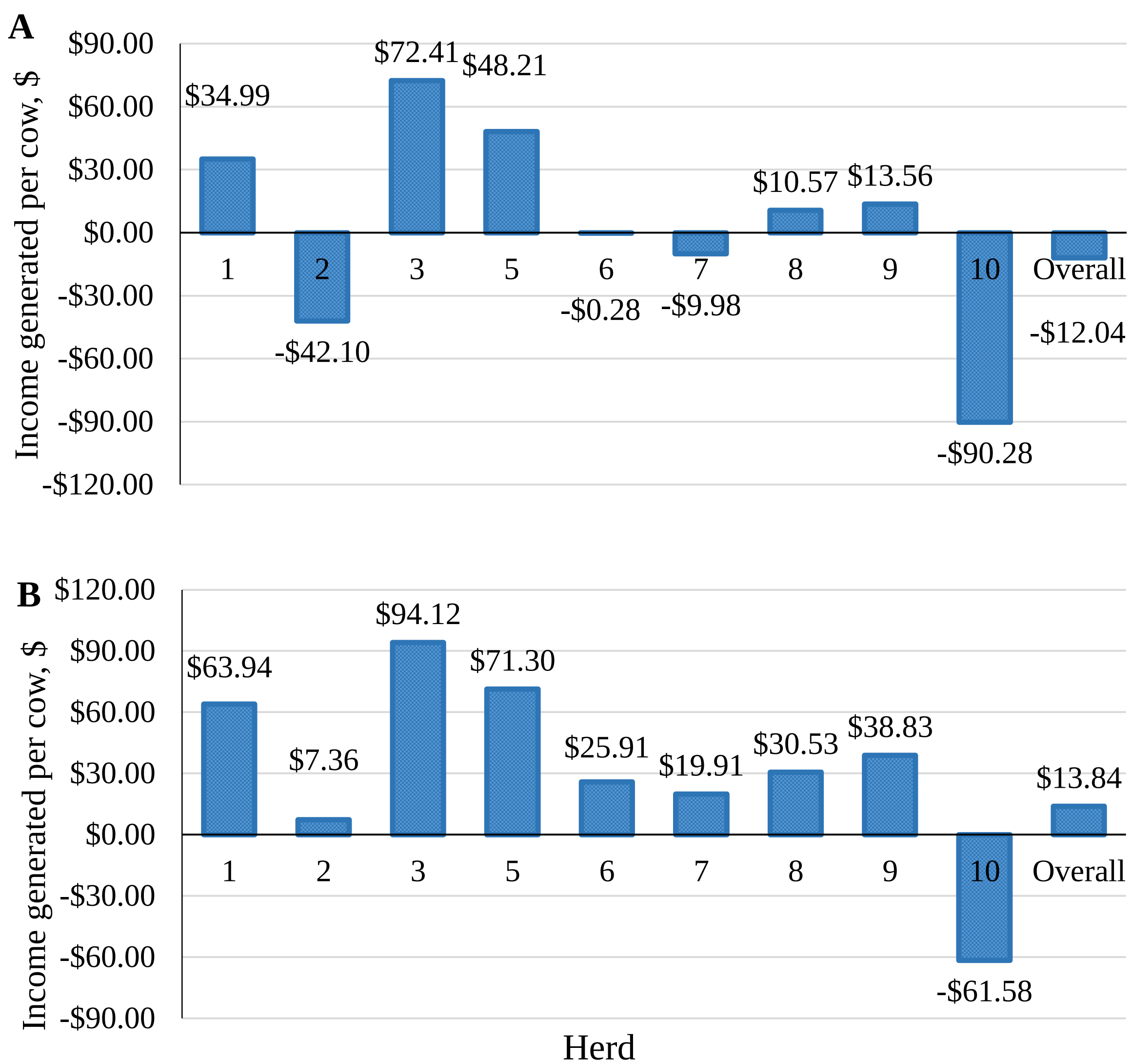

Figure 2.8. Effect of estrous synchronization and TAI on partial budget analysis when bull:cow ratio remained the same (1:25; A) and when bull:cow ratio was reduced (1:39; B).

Results from the current study indicate that a greater proportion of cows calve in the first 21-d of the calving season when exposed to TAI compared with cows bred only using natural service breeding and the resulting TAI calves are therefore older at the time of weaning compared to calves born from natural service exposed females. Weaning weights for calves born in the first 21-d from TAI exposed females were also greater than weights of calves born from natural service bred females when born in the same 21-d period. The increase in weaning weight for TAI calves was true for actual body weight as well as 205-d weight. The increase in weight may therefore be a factor of increased genetic potential due to calves being treated similarly from birth to weaning. An advantage observed with the use of AI is the ability to select sires with highly proven performance records (EPD's). In addition to a short postpartum interval, producers have the ability to select sires with increased growth characteristics that may increase weaning weights when compared to bulls selected for natural service breeding (Rodgers et al., 2012). An advantage in increased growth due to genetic potential could not be segregated from an advantage in age and the ability to gain weight over more days in this study.

Although not included in the analysis of the current partial budgets, uniformity of calves as well as quality of replacement females are of great importance to producers considering implementing an AI program (Crosswhite et al., unpublished focus group data). Calves born from dams exposed to AI may be more uniform in their phenotype and may be more marketable (Johnson, 2002), as producers may be able to sell calves in larger contemporary groups. Producers enrolled in the current study were very interested in the ability to increase the quality of heifers retained in the herd because of the ability to introduce improved genetics through the selection of highly proven sires. In a study evaluating the effect of calving period on heifer progeny, researchers found that heifers born in the first 21 d of the calving season had greater pre-breeding weights and greater proportions were cyclic at the beginning of the breeding season compared to heifers born in the second or third 21-d periods (Funston et al., 2012). Additionally, in a study in which heifers were fed varying amounts (low, medium, or high gain) over the winter months, heifers fed to reach higher gains became pregnant earlier in the breeding season compared with lighter weight heifers or those fed to a lower gain threshold (Short and Bellows, 1971). Of heifers calving in the first 24 d of the calving season, a greater proportion remained in the herd long enough to produce a fifth calf (Cushman et al., 2013). Females that calve in the first 21 d period of the calving season will also raise more kg of calf in their lifetime than those that calve in the second or third 21 d period of the calving season (Lesmeister et al., 1973). Greater weaning weights were observed for the first 6 calves born to heifers calving in the first 24 d of the calving season compared with heifers calving in the second or third 24 d period of the calving season (Cushman et al., 2013).

Decreased costs in the current study are a significant driver of producer profitability. The cost of feeding, raising, and housing bulls required to breed a herd of cows is a costly endeavor. Because conception to AI is not an absolute guarantee, natural service breeding bulls may still be needed for clean-up purposes. A reduction in the cost of maintaining bulls by decreasing the number of natural service sires may decrease costs. One possible way of decreasing costs can be observed in the following scenario; assuming pregnancy rates to estrus synchronization and AI are greater than 50 percent (Larson et al., 2006, Schafer et al., 2007, Busch et al., 2007, Steichen et al., 2013), the number of bulls necessary to breed the remaining 50 percent could be lower than the bulls necessary to breed an entire herd, based on personal preference. Therefore, the number of clean-up bulls could be reduced to accommodate the proportion of females that would become pregnant to TAI. Producers could purchase fewer bulls, spending less upfront cost by decreasing their stocking rate of 1 bull per 39 cows (Dahlen and Stoltenow, 2015). While ideal if utilizing AI, in some herds the decrease of bull numbers is not possible based on pasture layout and accessibility. In pastures that have limited cow stocking rate potential, for clean-up purposes at least one bull would be recommended in each pasture. If the pasture can only accommodate 25 head of cows, a reduction in bull numbers would not be possible. Reproductive management strategies must fit that of the facilities, labor, and time of an operation.

Implications

In conclusion, the incorporation of estrus synchronization and AI did not affect the proportion of cows becoming pregnant, however, did increase the number of calves born early in the calving season. Due to the increase in calf age by more calves being born early in the calving season, TAI calves were heavier at weaning compared with CON calves. While an adjusted 205-d weaning weight was not different for CON and TAI calves, producers have the ability to select sires with increased genetic potential, regardless of weaning weight. Furthermore, the incorporation of TAI was not profitable for all herds represented, a significant increase in profit is associated with reducing the number of herd sires used for clean-up purposes. The partial budgets show the importance of increased weaning weights as a great deal of income generated from TAI comes from the increases in weaning weight and therefore the increases in dollars made per calf sold. Additionally, more profit can be generated by decreasing costs associated with the purchase and maintenance of natural service herd sires. For these reasons, the use of estrus synchronization and AI could have potential benefits for producers.

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CHAPTER 3. ANALYSIS OF VARIATION IN A TWO-YEAR MULTI-HERD STUDY EVALUATING THE EFFECT OF NATURAL SERVICE AND ARTIFICIAL INSEMINATION BREEDING SYSTEMS

Abstract

Objectives were to compare mean calving date and calculated weaning weights of calves born from dams exposed to either natural service or artificial insemination breeding systems across years and within year to determine appropriate data comparisons. Within each herd (n = 10), cows were randomly assigned to one of two breeding system treatments; 1) only exposed to natural service herd bulls (CON; n = 1,114), or 2) exposed to ovulation synchronization and fixed-time AI followed by natural service bulls (TAI, fixed-time artificial insemination; n = 1,285). Females exposed to TAI were subject to the 7-d CO-Synch + CIDR protocol with fixed-time AI at 60-66 h after CIDR removal. Clean-up bulls were placed in breeding pastures 1 d after AI and remained with females until the end of the producer defined breeding season. Presence of a viable fetus was determined at least 45 d after the conclusion of the breeding season. At parturition, birth date was recorded. Weaning weights were recorded both for year 1 (year of treatment administration) and year 2 (year following treatment administration). Data comparisons included: 1) cows that were bred via natural service were compared over a two-year period, 2) cows that were bred via TAI in year two were compared to themselves in year one with no intervention, and 3) cows in the natural service group and the TAI groups for year 2 were compared. For natural service bred cows across years, mean calving date was increased ($P = 0.04$; cows calved later) in four of eight herds (50%) and calculated weaning weights both increased ($P = 0.05$) and decreased within herds in 75% and 25% of herds, respectively. For cows bred utilizing AI in year 2, mean calving date was decreased ($P = 0.03$) in three of eight herds (37.5%) and greater in two of eight (25%) herds in year 2 compared with year 1. Calculated weaning weights were greater (*P* = 0.05) for year 2 compared with year 1 for the majority of herds (62.5%). Within herd, cows in the AI treatment calved earlier than natural service cows in 75% of herds. Calculated weaning weights were greater for AI claves in two of eight (25%) herds compared with natural service calves whereas in one of eight herds (12.5%), weights were greater for NS calves compared with AI calves. A great deal of variation was observed within herd across year and within year for cows exposed to two different breeding systems. Due to the variation observed in comparisons 1 and 2, comparison 3 (across treatments within a single year, is the most appropriate comparison for the data set.

Keywords: AI, beef cattle, breeding systems, natural service

Introduction

Reproductive performance is a vital component of any profitable cow-calf production system (Dziuk and Bellows, 1983; Payne et al. 2013). The most important factor in any beef cattle production setting is the birth of a live calf, and therefore, profit is based on cows successfully becoming pregnant, calving, and raising a healthy calf to weaning (Ayers, 2011). For producers interested in making a change to increase reproductive performance, management techniques are available. Before suggesting a change in management or the adoption of a new technique or technology, understanding potential changes over time can aid in deciding if that change is a proper fit. It is also key that a producer make appropriate comparisons on available data. A North Dakota survey, mailed to 2,500 randomly selected beef producers, determined that over 51 percent of producers staying in the beef industry for at least the next 10 years were likely to utilize AI on their operations (Schook et al., 2014). In addition, 42 percent of operators were willing to hire outside labor to accomplish farming/ranching tasks, an available option.

When designing experiments, it is important to understand the variations that a single variable can have on the test parameters. In the case of producers making decisions about the implementation of a technology, anticipating and understanding how a new technology may change aspects of their farm and/or ranch can be very important. If accurate comparisons of data are not made available so a producer may understand the ramification of a change in production, results for the effects of the change in production may be invalid. Evaluations of data over multiple years in which data are compared across and within years are not currently available. Therefore, the objectives of these analyses were to compare mean calving date and calculated weaning weights of calves born from dams exposed to either natural service or artificial insemination breeding systems across years and within year to make appropriate data comparisons.

Materials and Methods

All cattle were managed according to the Federation of Animal Science Guide for the Care and Use of Agricultural Animals in Agriculture Research and Teaching (FASS, 1999). All procedures were reviewed and approved by the Institutional Animal Care and Use Committee of North Dakota State University.

Treatments

The materials and methods section of this chapter is similar to that of Chapter 2 (see Chapter 2: Effects of breeding system (natural service or artificial insemination) on pregnancy rates, distribution of calving, and calf weaning weights of commercial beef cow herds in North Dakota). All originating data was similar, however, the analysis of data was different of that presented in Chapter 2.

Statistical Analysis

The current study was designed as a randomized complete black design where within herds, cows were stratified by DPP and randomly assigned to one of two treatments, AI or NS breeding systems. The focus of the study was to evaluate variables across years (Figure 3.2.) to determine the effect of breeding system on a herd when systems are altered, as well as within years. Various data comparisons were made to determine the most correct way of analyzing the information based on two years of producer data. Calves born from a natural service breeding program were evaluated the year of breeding (i.e. year 1) against calves born from a natural service breeding program from year 1 breeding (i.e. year 2; Comparison 1). Similarly, Calves born from a natural service breeding program were evaluated the year of breeding (i.e. year 1) against calves born from the TAI breeding program from year 1 breeding (i.e. year 2; Comparison 2). Finally, cows in the natural service group and the TAI groups for year 2 were compared (comparison 3).

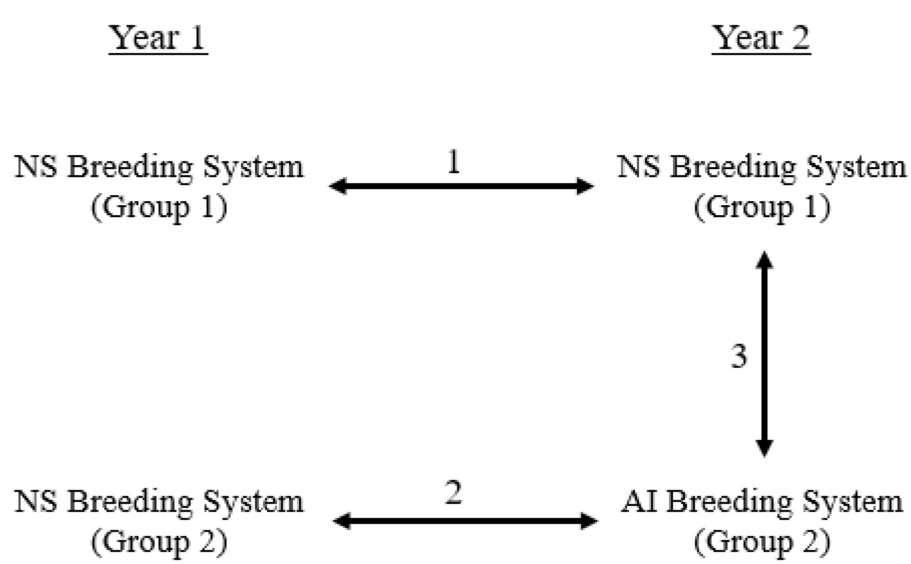

Figure 3.1. Data comparisons made between years and treatment groups. Numbers 1, 2, and 3 denote the three respective comparisons made.

The MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) was used to analyze all continuous data which included date of birth in the calving season and calculated 205-d weaning weight. Data was separated by herd and analyzed independently to determine effect within herd. Each model included year, both within and between years. Means were separated using the LSMeans procedure of SAS and significance was declared at $P < 0.05$).

Results

Comparisons 1 and 2

When evaluating the time of calving for cows bred utilizing natural service breeding over a two-year time period, mean calving date was increased ($P = 0.04$; cows calved later) in four of eight herds (50%) from year 1 to year 2 (Table 3.1.). Cows bred with natural service over the two-year time period experienced no intervention of breeding system and were subject to the same management as in the previous year. Variation across years for the natural service bred cows was also observed for calculated weaning weights as greater ($P = 0.05$) calf weights were observed in six of eight herds (75%) for year 2 calves compared to year 1 calves (Tables 3.2.). Lastly, in two of eight herds (25%), calculated weaning weights were decreased ($P < 0.01$) for year 2 calves compared with year 1 calves.

Table 3.1. Effect of breeding system on mean calving date across years (d of calving season)

	CON		AI		
Herd	Year 1	Year 2	Year 1	Year 2	SEM
1	30.6	32.1	31.9[a]	25.4[b]	2.0
2	18.2[b]	32.1[a]	18.8[b]	29.4[a]	1.7
3	30.5[b]	41.2[a]	27.4[b]	35.2[a]	1.9
6	48.0	44.9	34.4[a]	25.1[b]	2.8
7	26.7[b]	34.5[a]	32.8	26.8	2.2
8	24.1[b]	27.3[a]	19.3	21.0	1.3
9	21.7	26.8	31.8[a]	12.9[b]	3.6
10	32.2	32.4	32.4	28.4	1.6

[1]Treatment: CON = dams were exposed to natural service breeding, TAI = dams exposed to ovulation synchronization with the 7-d CO-Synch + CIDR protocol and TAI.
[a,b]Year within treatment differ ($P < 0.05$).

Table 3.2. Effect of breeding system on calculated 205-d weaning weight (kg) across years[2]

	CON		AI		
Herd	Year 1	Year 2	Year 1	Year 2	SEM
1	237.2[b]	243.8[a]	239.4[b]	248.2[a]	3.0
2	261.9[a]	233.3[b]	265.8[a]	229.8[b]	3.2
3	218.4[b]	250.7[a]	219.1[b]	266.9[a]	3.3
6	188.3[b]	235.5[a]	169.2[b]	237.5[a]	4.7
7	217.9[b]	225.0[a]	222.6	227.7	3.0
8	265.9[b]	303.8[a]	286.8[b]	315.2[a]	3.8
9	306.1[a]	217.6[b]	314.2[a]	220.3[b]	6.8
10	258.7[b]	271.5[a]	244.1[b]	255.0[a]	3.0

[1]Calculated weaning weights represented as kg of body weight
[2]Treatment: CON = dams were exposed to natural service breeding, TAI = dams exposed to ovulation synchronization with the 7-d CO-Synch + CIDR protocol and TAI.
[a,b]Year within treatment differ ($P < 0.05$).

Comparisons across years were also made for cows exposed to estrus synchronization and AI in year 2. Mean calving date was decreased ($P = 0.03$) in three of eight herds (37.5%) while being greater ($P < 0.01$) in two of eight (25%) herds in year 2 compared with year 1. Calculated weaning weights were greater ($P = 0.05$) for year 2 compared with year 1 for five of eight (62.5%) herds while being decreased in two of eight herds.

Comparison 3

The comparison of breeding systems within year two was done to evaluate the effects of estrus synchronization and AI compared with natural service breeding systems in a given year as well as to evaluate the differences in results based on analysis. Within herd, cows in the TAI treatment calved earlier than NS cows in six of eight herds (75%; Table 3.3.). Calculated weaning weights were greater for AI calves in two of eight (25%) herds compared with NS calves whereas in one of eight herds (12.5%), weights were greater for NS calves compared with AI calves (Table 3.4.). Results of comparison 3 identify the true differences observed between natural service and TAI breeding systems based on replication and applied treatments. When comparing results from comparisons 1 and 2, great variation was present between calving dates and weaning weights, even when no intervention was involved (natural service bred females).

Table 3.3. Effect of breeding system on mean calving date within year (d of calving season)

	Treatment[1]		
Herd	CON	AI	SEM
1	32.1[a]	25.4[b]	2.2
2	32.1	29.4	1.8
3	41.2[a]	35.2[b]	1.8
6	44.9[a]	25.1[b]	2.6
7	34.5[a]	26.8[b]	2.5
8	27.3[a]	21.0[b]	1.5
9	26.8[a]	12.9[b]	3.2
10	32.4	28.4	1.7

[1]Treatment: CON = dams were exposed to natural service breeding, TAI = dams exposed to ovulation synchronization with the 7-d CO-Synch + CIDR protocol and TAI.
[a,b]Means within treatment differ ($P < 0.05$).

Table 3.4. Effect of breeding system on calculated 205-d weaning weight (kg) within year[1]

Herd	Treatment[2]		SEM
	CON	AI	
1	243.8	248.2	3.3
2	233.3	229.8	2.9
3	250.7[b]	266.9[a]	3.3
6	235.5	237.5	4.2
7	225.0	227.7	3.2
8	303.8[b]	315.2[a]	3.7
9	217.6	220.3	5.6
10	271.5[a]	255.0[b]	3.0

[1]Calculated weaning weights represented as kg of body weight
[2]Treatment: CON = dams were exposed to natural service breeding, TAI = dams exposed to ovulation synchronization with the 7-d CO-Synch + CIDR protocol and TAI.
[a,b]Means within treatment differ ($P < 0.05$).

Calving Distribution

At the time of calving, birth date was recorded. The proportion of cows calving in each calving group within year are presented in Table 3.5. Forty percent of cows calving in the first 21-d period of the calving season in year 1 calved in the first 21-d period of the calving season in year 2. Of cows that calved in the third 21-d period of the calving season, 17.1% failed to have a calf the following year.

Table 3.5. Proportion of females calving in 21-d increments in two consecutive calving seasons (%)[1]

Item	Calving group, year 1		
	< 22	22-42	> 42
N	563	609	280
Calving group, year 2			
< 22	40.3 (227/563)	38.4 (234/609)	21.1 (59/280)
22-42	35.9 (202/563)	34.0 (207/609)	33.6 (94/280)
> 42	17.6 (99/563)	21.0 (128/609)	28.2 (79/280)
No Calf	6.2 (35/563)	6.6 (40/609)	17.1 (48/280)

[1]Proportions of cows calving in 21-d interval are represented for two connective calving seasons. Proportions denote the number of females calving in each interval in each year.

Discussion

In the current study, commercial beef herds were exposed to one of two breeding systems, NS and AI, following pervious management only including NS. Data was evaluated within herd and included the following comparisons; the effect of NS for 2 years, NS breeding followed by AI the following year, and comparisons of treatments within the second year. During the planning stages of the current study (comparison 3), great time and consideration was given to the experimental design including replication which was completed with multiple herds, randomization which was done with every herd, and treatments evaluated within a single year. The comparisons evaluated in the current study allowed for alternate methods of evaluating the data to identify the most valid evaluation for increasing producer knowledge and the implementation of change on an operation.

When evaluating data, it is important to understand the method by which the data is analyzed. If data is incorrectly analyzed, incorrect inferences can be made. In an example of feeding behavior, researchers determined that if cyclic variation (i.e. variation in when cattle choose to eat a meal) was not accounted for when evaluating feed intake data, treatment effects can be very misleading (Stroup et al., 1987). In another study, pregnancy rates were evaluated in cows receiving varying types of copper supplementation over a two-year time period (Muehlenbein et al., 2001). Results were varied across years with cows not receiving supplement having greater pregnancy rates in year one whereas cows fed the organically bound mineral had greater pregnancy rates (Muehlenbein et al., 2001). In the current study, if a management choice were to be made from comparison 1 or 2, would the evaluation of the data be correct when evaluated against comparison 3? In both comparisons 1 and 2, variability was observed between calving date and weaning weight within each evaluation. By producers having no additional involvement over a two-year time period (comparison 1), cows calved later in the calving season in year 2 compared with year 1. While no source of variation is known between year for the natural service bred cows, sources of variation on calving date include breed, time of the year, age of the dam, birth and weaning weight of the previous calf, and the interactions of all listed sources (Bourdon and Brinks, 1983). When evaluating comparison 2, variation also occurred between natural service breeding in year 1 and TAI breeding in year 2. Cows calved both earlier and later in the calving season of year 2 compared to year 1 as well as producing calves with both lighter and heavier weaning weights in year 2 compared to year 1. Based on comparison 2 information, the addition of AI may alter, both negatively and positively, the proportion of cows that calve early in the caving season compared to those that calf later in the calving season and the weaning weight of calves.

Calculated calf weaning weights across years demonstrated that regardless of treatment, in 75% of herds, weaning weight increased. While 25% of herds had a decrease in weaning weight, it is important to note that weaning weights for both NS and AI increased together or decreased together based on herd. Based on this information, imputing no additional time or resources led to an increase in weaning weights and potentially the sale price of calves (based on the sale price of calves sold) 75% of the time. While breeding system did not change between years, weaning weight can be affected by many factors, including location, genotype, postpartum environment, cow nutritional status and cow milk production (Spitzer et al., 1995). In a study evaluating the effect of pre-weaning influences on weaning weight, identical and fraternal Hereford heifer twins (n = 88) were evaluated and it was determined that birth weight, milk from d 0 to 240 after parturition, butterfat production, pounds consumed of creep feed, dam weaning weight, and average daily gain from birth to weaning accounted for 78% and 74% of the variation in weaning and gain from birth to weaning, respectively (Christian et al., 1965). Due to the number of factors affecting weaning weight, the direct cause of change in weaning weight between years in the current study cannot be elucidated.

When designing experiments, researchers begin with the formation of a hypothesis, determination of treatment levels, specification of the number of experimental units that will be utilized, randomization for assigning treatments, and determining the statistical analysis that will be performed (Kirk, 1982). Additionally, researchers aim to minimize variation within the experiment by holding variables constant, assigning treatments in a randomized fashion, and including sources of variation as factors in the experiment (Kirk, 1982). The results of the current study and the analysis of the three comparisons prove that variation is a factor and can alter the interpretation of data. Comparisons 1 and 2 evaluate the data across years within a similar cow group whereas comparison 3 evaluates data within a single year with many replicates. In order to correctly evaluate natural service and AI breeding systems, comparison 3, the evaluation within the same year, is the most accurate evaluation.

Implications

Mean calving date and calculated weaning weights were influenced within year and across year when subjected to different breeding systems. Calving date both increased and decreased by year, increasing for NS cows and both increasing and decreasing for AI cows. Calculated weaning weight both increased and decreased across years; however, it was always similar within herd for both treatments. By evaluating mean calving date and weaning weight for eight commercial beef herds, it was elucidated that variation exists both within year and across year. The information evaluated in the current analysis allows for many interpretations of the data with only one comparison being accurate in evaluating the differences between breeding systems. Comparison 3, the designed experiment evaluates the breeding systems against one another in manner in which yields an accurate result.

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CHAPTER 4. EFFECTS OF BREEDING SYSTEM (NATURAL SERVICE OR ARTIFICIAL INSEMINATION), COW HERD APPRASIAL PERFORMANCE SYSTEM, AND FARM BUSINESS MANAGEMENT PROGRAMS ON PRODUCER SELF-EVALUATION AND KNOWLEDGE BASE

Abstract

Objectives were to evaluate the perceptions and attitudes of beef cattle producers in terms of performance, production, and profit and to determine the change in knowledge, understanding, and skill of producers. Production refers to the pregnancy, calving and weaning information relative to applied treatments, performance included the participation in the Cow Herd Appraisal Performance Software program, a record keeping system, and finally, profit included participation in a Farm Business Management (FBM) or financial analysis program. Ten commercial beef cattle producers and nine North Dakota State University county extension agents were selected to participate in an experiment in which producer herds were subject to a comparison of natural service breeding and estrus synchronization and timed-artificial insemination. In addition, producers were also enrolled in a cow herd performance evaluation and farm business management program for two years to evaluate the implications of these respective breeding systems on standard production measures and true economic impact. In order to identify attitudes and thoughts of participating producers, surveys were distributed. Similarly, tests of knowledge were utilized to determine the change in knowledge with regard to project components. A series of meetings, totaling three per producer cohort, over a four-year time period were conducted in which producers were given the same survey instrument and test of knowledge. Producers identified being knowledgeable and understanding in areas related to herd

management and natural service breeding systems at the first meeting, however, understanding increased for every parameter by the second meeting. During the summary/wrap-up meeting, producers identified that participation in the current study increased their knowledge and understanding of project components, skill and ability of performing tasks relative to project components, and their satisfaction relative to the management of their operations. Average test of knowledge scores decreased at the second meeting time compared to scores from the initial date, after which producers were intimately involved in various related programs. For meeting 3, test of knowledge scores increased for questions related to the action of pharmaceuticals related to estrus synchronization but were decreased for questions related to expenses, portion of calf death loss, and principles of sustainability.

Introduction

Decreases in efficiency of a beef production system can be very costly and attributed to poor reproduction and infertility. The decrease in profit of an operation may lead producers to exit the beef industry to pursue more economically viable opportunities. A North Dakota survey administered to beef producers, identified that of those responding, 48.4 percent of producers had plans to exit the beef industry in the next 10 years (Black et al., 2014). Programs and technologies directed at mitigating factors related to poor reproduction and infertility and that increase the sustainability of beef operations are currently available, however often underutilized. Estrus synchronization and artificial insemination (AI) are management techniques available for the advancement of herd genetics by selection of highly proven sires, without the overhead cost of the equivalent of a natural service sire. While time, labor and difficulty have been cited as causes for the lack of implementation of AI (NAHMS, 2009), a North Dakota survey reported that over 51% of producers staying in the beef industry for at least the next 10 years were likely to use AI on their operations (Schook et al., 2014).

When contemplating a change or the inclusion of a new program or technology, producers must first be able to identify the current success of their operation in order measure the success of the change implemented. In terms of herd management, success can be evaluated in a variety of ways. Productiveness of a herd can include the proportion of females that became pregnant in a breeding season, the weight of the calves sold, etcetera. Producers may also evaluate their herd performance, or the evaluation of the herd performance based on collected records and information. Currently, there are third-party systems that maintain beef cattle records for the purpose of evaluating production and performance information. The Cow Herd Appraisal Performance Software (CHAPS) program is a management tool in which information can be collected, stored, and evaluated for benchmarking and herd performance purposes (Ramsay et al., 2016). Lastly, success can be evaluated in terms of profit. Similarly, to the performance record keeping system, programs are available to summarize and analyze returns and costs associated with farming and/or ranching (North Dakota Farm Management Education). Financial data can be used to isolate specific techniques or management decisions that are either lucrative or draining financially.

Increasing the sustainability of an operation includes enhancing agricultural resources by being a steward of land, air, and water, sustaining the economic status of an operation, and increasing the quality of life of producers and their communities (Gold, 2009). Previous approaches to increase sustainability have included extension programming that work to increase the acceptance and implementation of alternative production systems (Hinrichs and Welsh, 2003), however, limited data are currently available that evaluates the use of various extension programming efforts coupled with the inclusion of a new technology or technique on-farm. It is for this reason that we hypothesized that the inclusion of a new breeding program, participation in a record keeping and financial analysis programs may alter the production, performance, profitability of beef cattle operations and potentially affect the proportion of producers likely to stay in the beef industry by increasing the sustainability of their operations. Therefore, the objectives of this study were to determine the change in knowledge, understanding, and skill of producers when using AI as well as record and financial accounting programs.

Materials and Methods

Interviewees

North Dakota State University county extension agents were selected for their involvement and identification of commercial cattle producers in their respective county locations. Agents then selected producers interested in the study who could commit to all phases of the research including maintaining records, participating in project components, and meeting with others to share their story (See Appendix A). Producers recruited had never implemented estrus synchronization or AI into their cow herds as a normal management practice.

Participation in all project components was necessary for producer selection. Producers were required to maintain records including personal animal ID’s, calving dates, weaning dates, animal sales, and feed produced and purchased. Various project phases were also required which included a production phase, a performance phase, and a profit phase. Production was identified as the portion of the study focusing on the comparison of two breeding systems, natural service and artificial insemination. Producers would provide cattle, facilities, and labor to assist with implementing the two breeding systems as well as performing tasks associated with the breeding systems. Performance was identified as the portion of the study focusing on the Cow Herd

Appraisal Performance System (CHAPS), or the benchmarking performance data system. Producers were enrolled in the program and required to provide performance data on their respective herd. Finally, profit was described as the portion focusing on the Farm Business Management (FBM) program, or the financial program used to evaluate expenses, returns, and overall profitability. Producers were required to meet with a FBM instructor to evaluate the financial dynamics of farm and/or ranch profitability. Lastly, producers were required to meet with others. Over the course of the study, meetings were held before, during and post project components and producers were required to attend and participate in various surveys, tests, and discussions.

Instruments

A total of three meetings over a four-year time period were conducted in which 10 producers and nine North Dakota State University county extension agents attended. At the beginning of each meeting, producers were given a survey and a test of knowledge (See Appendix B). Survey questions focused on individual herd management with respect to AI, comfort with the project components, components of sustainability, anticipated results of the study, and concerns about the project. Responses to survey questions were given using the Likert 5-point psychometric response scale including very low, low, moderate, high, or very high, as well as very dissatisfied, dissatisfied, not satisfied or dissatisfied, satisfied, or very satisfied (Jamieson, 2004), depending on the question at hand. Very low/very dissatisfied was given the notation of a 1 while very high/very satisfied was given the notation of 5. The third and final (wrap-up) meeting included a retrospective survey (Appendix B) in which producers were to determine their perception of how their knowledge, skill and ability had changed from the beginning of the experiment to the conclusion of the experiment. Variation in survey was done to identify longitudinal responses versus asking the producers to identify understanding and growth at a single time point. Averages were generated by adding each number corresponding to the Likert scale response and diving by the number of responses. Test of knowledge questions included multiple choice questions focusing on definitions of hormones involved in estrus synchronization protocols, distribution of calving information, labor, and sustainability of agriculture. Responses to test questions were given by selecting the more appropriate response (A-D or check all that apply). Each test question was worth one point for the purpose of determining the number correct for each producer or agent. A perfect score would receive a 10 out of 10.

Data Collection

Within each producer herd, cattle were randomly assigned to one of two breeding systems, natural service breeding (herd bulls only) or estrus synchronization and timed-AI followed by exposure to natural service bulls. In addition, producers were enrolled in a cow herd performance evaluation CHAPS and FBM program for two years to determine the viability of use of these programs for commercial producers and to determine the true economic impact of each breeding system. Data originating from surveys and tests of knowledge were collected during the course of each meeting of which each cohort attended three meetings. At each meeting, participants would begin by completing the survey and test of knowledge. At the initial meeting for each group, project components were discussed next, including the breeding systems, CHAPS program, and the FBM program.

Data Analysis

Survey answers were recorded in an Excel spreadsheet. Means and frequencies of responses were calculated for each question. Tests of knowledge were graded based on previously defined correct answers. Overall scores, means and frequencies were then input into an Excel spreadsheet. No statistical programs were used to evaluate the survey and test data due to small numbers of respondents.

Methodological and Ethical Issues

Within the timeline of the study, issues arose with producer participation. Identification and selection of producers was done by the respective extension agents in their common area. In some cases, identified producers elected not to participate in the study, resulting in agents recruiting different producers.

All survey, focus group, and test questions and methodologies were approved by the North Dakota State University Institutional Review Board (Appendix C). Ethical issues among the researchers, agents, producers, and data collection did not arise.

Results

Meetings were attended by producers, extension agents, support personnel, and researchers. Three meetings were attended over the course of four years, the first just before the start of the breeding system, the second just before to the next breeding season, and the final meeting was held after all data collection occurred for both years. The surveys and tests of knowledge can be found in their entirety in Appendix B. Meeting 1 and 2 will be presented together while meeting 3 will be presented separately, including both before and after data. Data is descriptive in nature and thus should not be used to make statistical inferences.

Surveys

Meetings 1 and 2

The document given to producers was a two-part document, the first being an eight question survey. Producers were asked questions relating to their own herd and experiences with

AI, CHAPS, and FBM. Twenty-one percent of producers had utilized AI on either heifers or cows at some point prior to involvement in the current study. In addition, 43 percent of producers had utilized AI on both heifers and cows. At the second meeting, all producers had utilized AI the previous breeding season.

Questions were developed to evaluate the level of knowledge and understanding of producers with regards to management, NS and AI breeding systems, cow herd analysis, and production economics. Self-reported expectation of knowledge for producers and understanding prior to involvement with the current study ranged from moderate to high with AI breeding systems, cow herd performance analysis, and production economics being the lowest (3.0/5.0) and management of their own operation being the greatest (4.0/5.0). By the second meeting, knowledge and understand for each subject had increased with management of their own operation again being the highest at 4.5 out of 5 (between high and very high). Production economics was the subject in which producer were the least knowledgeable with an average score of 3.2 (between moderate and high). Figure 4.1. illustrates the questions and responses of producers for both meetings 1 and 2.

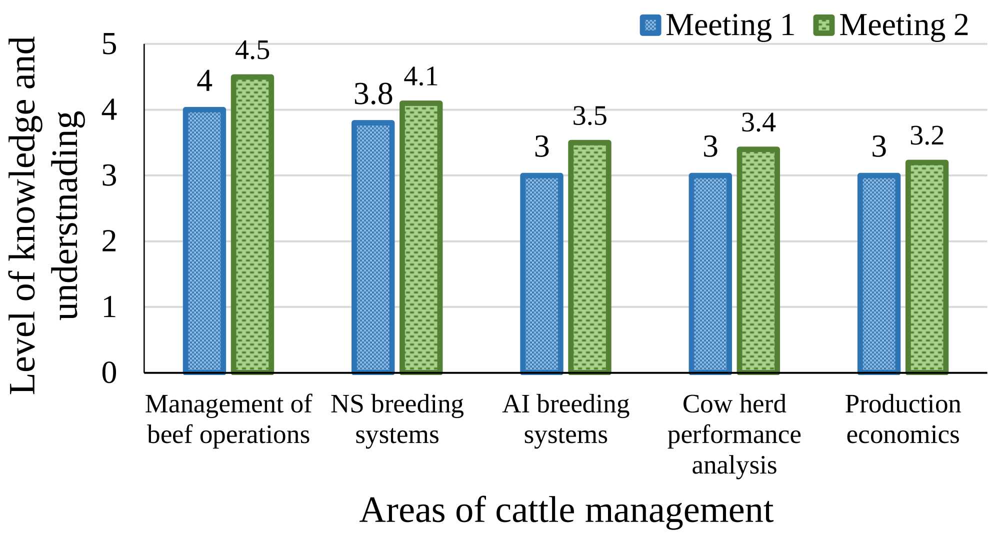

Figure 4.1. Producer perceptions of their knowledge and understanding with regards to various areas of beef cattle management. Meeting 1 = initial meeting (before involvement), Meeting 2 = meeting held after breeding involvement.

Producers were asked to rate their skill and ability of implementing tasks related to estrus synchronization, the CHAPS program, and the FBM program. Initial results indicated that producers were the least skillful at implementing the CHAPS records program and the most skillful at performing tasks associated with AI (giving shots, inserting CIDRs, handling cattle and AI breeding; 2.8 and 3.6, respectively; Figure 4.2.). For the second meeting, skill and ability increased for each subject, except the ability to perform tasks associated with AI which decreased (3.4/5.0) and activities related to estrus synchronization and AI which did not change.

Producer level of satisfaction with items related to management included overall management of the herd, steps taken to obtain additional knowledge/understanding, steps taken to improve skills and abilities in herd management, and efforts to increase the sustainability of the operation. Responses to this question could range from very dissatisfied to very satisfied. Producers rated their satisfaction with the above mentioned themes as between not satisfied or dissatisfied and satisfied (Figure 4.3.). Satisfaction increased between the first and second meeting with more producers satisfied with the management and the efforts taken to increase the sustainability of their herds.

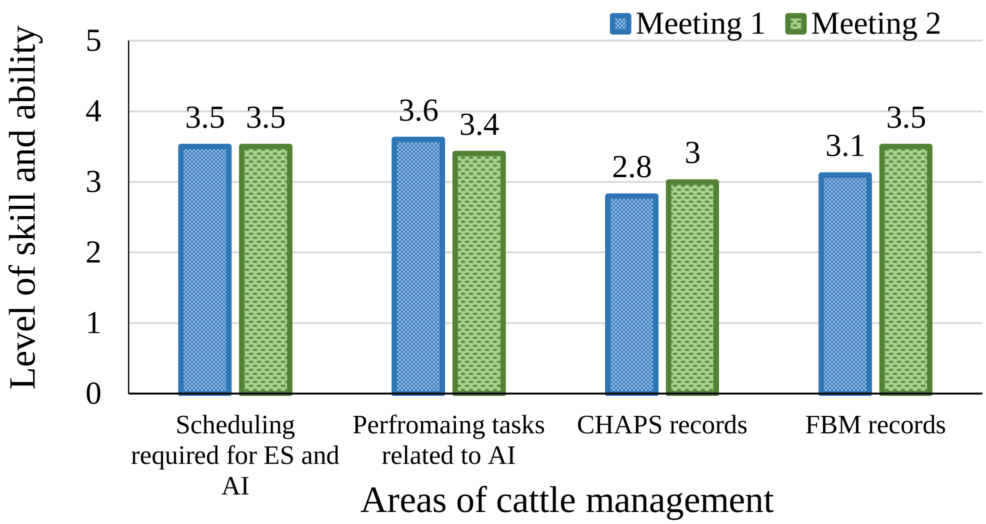

Figure 4.2. Producer perceptions of their skill and ability with regards to various areas of beef cattle management/project components. Meeting 1 = initial meeting (before involvement), Meeting 2 = meeting held after breeding involvement.

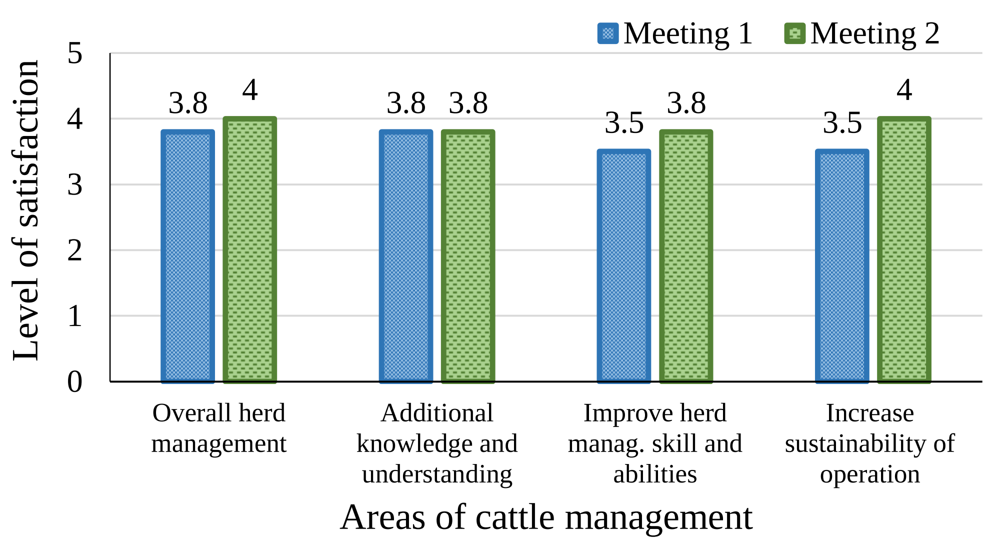

Figure 4.3. Producer perceptions of their level of satisfaction with regards to various areas of beef cattle management. Meeting 1 = initial meeting (before involvement), Meeting 2 = meeting held after breeding involvement.

The next series of questions were related to the anticipated results of implementing AI on producer operations. Questions and proportions of producers answering each question are presented in Figures 4.4. and 4.5. for meetings 1 and 2, respectively.

The final survey question proposed to each producer was open ended in nature. Producers were asked to list the three largest concerns each had about the project and about implementing AI. For the initial meeting, the most commonly listed concerns were time, scheduling, labor, cattle movement, the CHAPS program, conception, profit and bull selection. When polled, labor and time were the most cited reasons for not adopting AI followed by the difficulty of the process (NAHMS, 2009). Odde, (1990) reported that increased management, labor, and time combined with a large percentage of cattle being raised on a range type environments were reasons for decrease value in technology when compared to other breeding systems. Results of the same question in year two had similar findings, with time, scheduling, labor, weather, conception, profit, and facilities being cited as concerns.

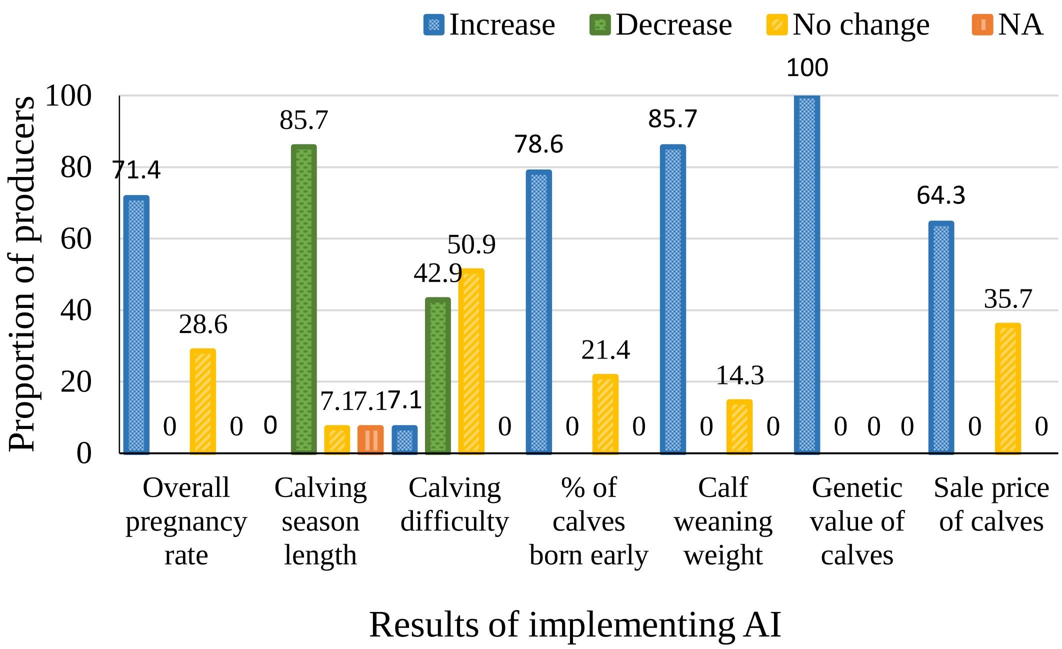

Figure 4.4. Proportion of producers anticipating various results after implementing AI for meeting 1. Response: Increase = producers indicated AI would increase the selected item, Decrease = producers indicated AI would decrease the selected item, No change = producers indicated AI would cause no change to the selected item, NA = producers did not provide a response to the selected item.

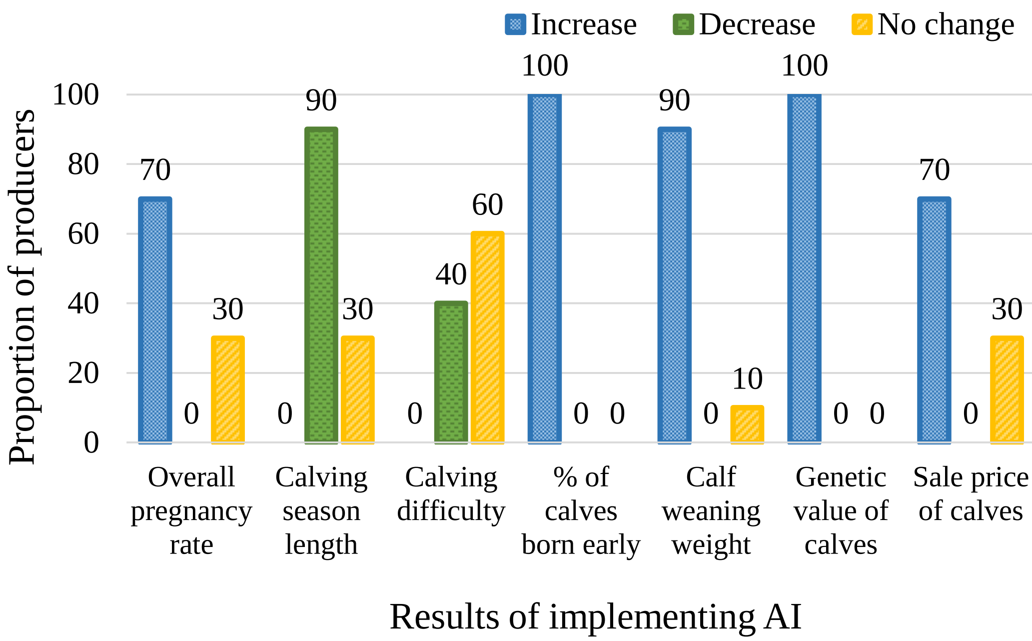

Figure 4.5. Proportion of producers anticipating various results after implementing AI for meeting 2. Response: Increase = producers indicated AI would increase the selected item, Decrease = producers indicated AI would decrease the selected item, No change = producers indicated AI would cause no change to the selected item.

Meeting 3

At the closing of the third meeting, producers were asked to complete a final survey. Questions asked in the final survey were similar to those asked in previous meetings; 1) evaluation of the level of knowledge and understanding of producers with regards to management, NS and AI breeding systems, cow herd analysis, and production economics, 2) the skill and ability of implementing tasks related to estrus synchronization, the CHAPS program, and the FBM program, and 3) producer level of satisfaction with items related to management included overall management of the herd, steps taken to obtain additional knowledge/understanding, steps taken to improve skills and abilities in herd management, and efforts to increase the sustainability of the operation. In contrast to the previous surveys, questions included a before participation and after participation section for each question.

In each identified area of cattle management, on average, producers determined that their knowledge and understanding increased (Figure 4.6.). The AI breeding systems and CHAPS program were the management techniques that producers identified as the areas in which the most growth occurred (2.7/5 to 3.8/5 and 3/5 to 3/5, respectively). In terms of scheduling and performing tasks relative to estrus synchronization and AI as well as the CHAPS and FBM programs, producers identified that participation in the current study increased their skill and ability (Figure 4.7.). Producers began the experiment with a moderate comfort level (from 2.4 to 3) and identified an increase in their abilities relative to AI and the CHAPS and FBM programs from 3.4 to 3.8). Finally, when evaluating producer satisfaction, producers identified that they were neither satisfied nor dissatisfied to satisfied with all levels of cattle management identified before the beginning of the current study (Figure 4.8.). After participation, producers identified that their satisfaction increased to satisfied or highly satisfied with each area of management identified. Producers determined that the ability to increase the sustainability of their operation was the factor that they were most satisfied with based on the averages of the survey answers (4.3/5).

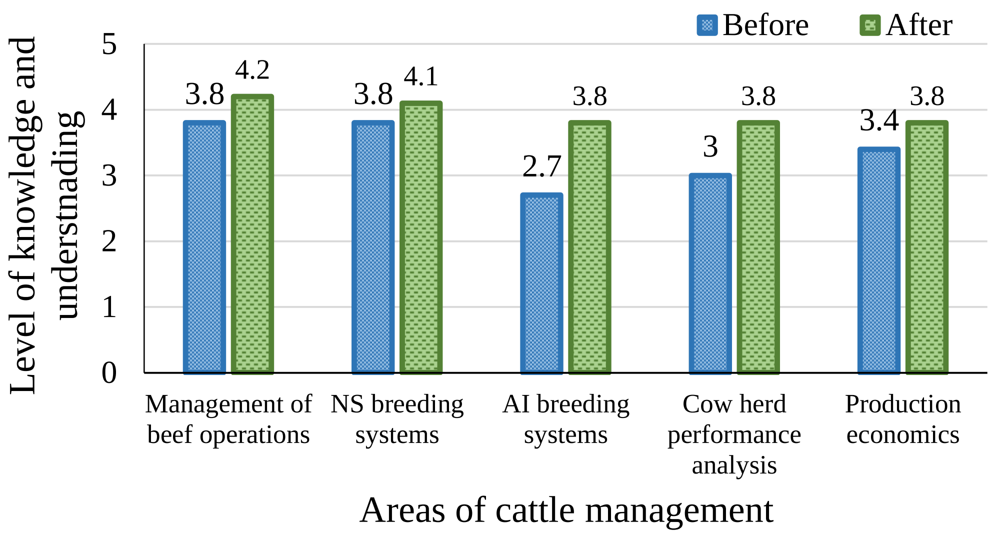

Figure 4.6. Producer perceptions of their knowledge and understanding with regards to various areas of beef cattle management. Before = before participating in the experiment, After = participating in the experiment.

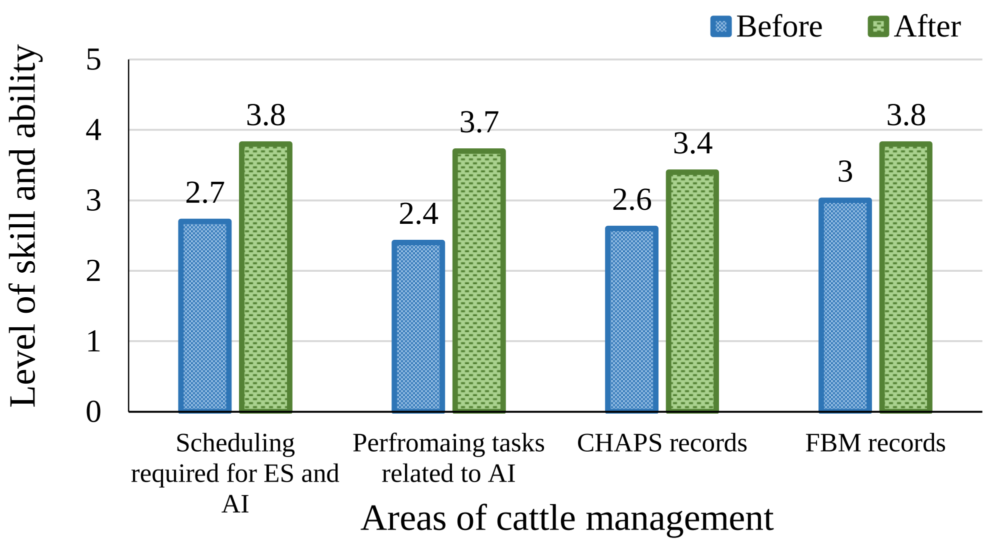

Figure 4.7. Producer perceptions of their skill and ability with regards to various areas of beef cattle management/project components. Before = before participating in the experiment, After = participating in the experiment.

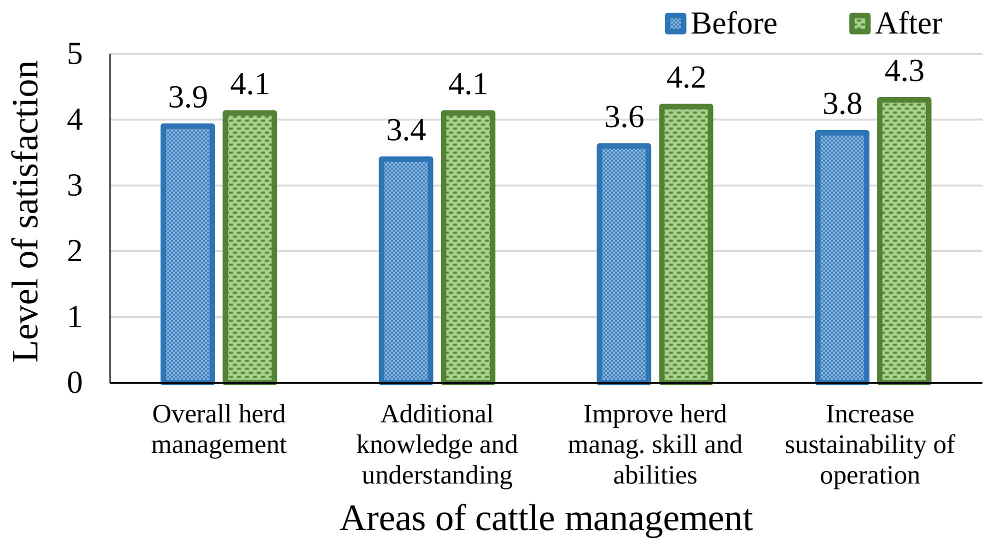

Figure 4.8. Producer perceptions of their level of satisfaction with regards to various areas of beef cattle management. Before = before participating in the experiment, After = participating in the experiment.

The final aspect of the survey was designed for producers to identify the value of various aspects of their cow herd after participation in the current study. Previous research has identified that estrus synchronization and AI offer potential attributes and benefits including shortening the calving season and increasing the number of calves born early in the calving season resulting in older and heavier calves at weaning (Odde, 1990; Rodgers et al., 2012). All participating producers identified that use of AI increased the genetic value of their calves. Additionally, seven out of eight producers identified that the sale price of calves sold increased with the use of AI breeding compared to natural service calves, with a reported average of $496.00/calf. Seven out of eight producers also reported that the use of AI increased the value of heifers retained in the herd by an average of $7,278.00/heifer. While the majority of producers observed a fiscal improvement in calves by way of price per calf and retained heifers, the final meeting reviled that only half of the participating producers identified an increase in weaning weight of calves (increase averaging 34 lb/calf) and overall value of their herds ($8,000.00/herd).

Test of Knowledge

The second section of the survey entailed a 10 question test. Questions included information about natural service mating, the role of estrus synchronization hormones, bull EPDs, calving and death loss, weaning information, expense information, and finally, a question regarding sustainability of agriculture. Mean producer test scores for meeting 1 were 6.64 out of 10. The proportion of producers that answered questions correctly varied between questions, ranging from the lowest score per question of 28.6 percent to the highest score per question being 92.9 percent. Mean correct responses for questions can be found in Table 4.1.

The lowest producer score on the test of knowledge came from the question "Which of the following has the LEAST influence on the number of cows a bull can get pregnant?" Possible answers for this question were age of the bull, whether the bull passed a breeding soundness exam, or high libido (sex drive) of the bull compared with moderate libido. The most common answer was A, age of the bull. The highest scored question was found with two questions; 1) "Which of the following products kills a mature Corpus Luteum (CL)?" with answers of GnRH, PGF, or progestins, and 2) "What does the term accuracy mean in relation to bull Expected Progeny Differences (EPDs)?" with answers of degree to which bulls accurately identify cows in estrus, amount of confidence you can place on EPD numbers, or whether numbers were typed accurately in the bull catalogs. For the first of two questions, the most common and correct answer was B, PGF. For the second question, the most common answer was B, amount of confidence you can place on EPD numbers.

At the second meeting, an identical test was distributed. The average for the producer test decreased, with a mean of 6.3 out of 10. The lowest score for a question and the highest scores for questions were similar to those found in the first meeting. Eight of 10 questions received a lower mean score than found in the first meeting. The questions with an increased mean score were questions 7 and 9, “What is the average proportion of calf death loss from calving to weaning?’, and “Which of the following is not considered a direct expense?”, respectively.

The test distributed at the first and second meetings was once more distributed at the third and final meeting. The mean test score decreased from both meeting 1 and 2, averaging 5.67 out of 10. The highest score on a question was similar to that of meeting 1 and 2, “Which of the following products kills a mature Corpus Luteum (CL)?” and 2) “What does the term accuracy mean in relation to bull Expected Progeny Differences (EPDs)?”. The lowest scores on a question was from “Which of the following is not required to calculate pounds weaned per exposed female for this year’s calf crop” with answers of, number of cows turned out this breeding season, number of calves weaned, and weight of calves weaned. The question regarding pounds weaned per exposed females had previously has a correct response rate of at least 60%, whereas, in meeting 3, no producer answered this question correctly. The other low score responses on the test were similar to low score questions from meetings 1 and 2.

Table 4.1. Mean correct test of knowledge response for each question by meeting

Test question	Meeting 1	Meeting 2 Mean score[1]	Meeting 3
1	28.6 (4/14)	0.0 (0/10)	33.3 (2/6)
2	78.6 (11/14)	60.0 (6/10)	83.3 (5/6)
3	92.9 (13/14)	88.9 (9/8)	100.0 (6/6)
4	78.6 (11/14)	70.0 (7/10)	83.3 (5/6)
5	92.9 (13/14)	90.0 (9/10)	100.0 (6/6)
6	57.1 (8/14)	50.0 (5/10)	50.0 (3/6)
7	42.9 (6/14)	50.0 (5/10)	33.3 (2/6)
8	64.3 (9/14)	60.0 (6/10)	0.0 (0/6)
9	64.3 (9/14)	80.0 (8/10)	33.3 (2/6)
10	64.3 (9/14)	60.0 (6/10)	50.0 (3/6)

[1]Mean score = number correct questions divided by total number of question, then multiplied by 100.

Discussion

Surveys

On the Likert scales, initial perception of knowledge and understanding for both producers in terms of herd management and natural service breeding systems were a 4 and 3.8 out of 5, respectively. Perceptions of knowledge and understanding of AI, CHAPS, and production economics were lower with rankings of 3 out of 5. After participating in breeding events, CHAPS, and the FMB program knowledge and understanding of all areas (management, natural service breeding, AI, CHAPS, and FBM) increased. It would seem that after participation in the current study, producers learned or increased the base of knowledge surrounding the project components. A change in knowledge and understanding can be observed from the summary survey in which participating producers identified an increase in their knowledge and understanding in each area of management identified. In a study in which extension agents were given an interview questionnaire, they identified that the learning method of doing and seeing were their preferred methods for learning new information (70 and 18.2 percent respectively; Richardson, 1994). Additionally, when combinations of learning tools could be utilized, agents preferred a combination including doing, seeing, and discussing information (Richardson, 1994). Activities associated with the breeding systems, CHAPS, and FBM were 'learn by doing' techniques with discussion held and presentations given during meeting times. It is unclear which learning techniques was the most appropriate for producers and agents, but knowledge and understanding increased for all components. Future extension efforts may benefit from a program including multiple avenues of learning.

Scheduling and performing tasks relative to estrus synchronization and AI were tasks in which beef producers indicated that they had the most skill and ability, however, this level of comfort stayed the same or decreased after implementation of AI. Initial responses came before participation in the current study. While knowledge and understanding relative to the project components increased, their skill relative to the same factors decreased or remained the same. One factor contributing to this could be an overestimation of skill and ability prior to implementation and a more honest response after implementation. A "response-shift bias" is commonly cited when pre and post surveys are distributed as respondents overestimate behaviors with the pre survey and underestimate behaviors with the post survey (Raidl et al., 2004). Retrospective surveys can be utilized to decrease the "response-shift bias" by asking questions at a single time point as a before and after type question (Raidl et al., 2004). The final summary survey asked questions in this manner in order to minimize "response-shift bias". For scheduling and performing tasks relative to AI, the CHAPS program and the FBM program, producers identified an increase in skill and ability from before participation to after participation in the current study. Differing results allow for the comparison in perception based on survey type.

Participants anticipated that pregnancy rates of cows would increase, the length of the calving season would decrease, calving difficulty would not change, and that more claves would be born in the first 21 d of the calving season with the addition of AI. Furthermore, participants anticipated that weaning weights of calves would increase as well as the sale price received and the perceived genetic value of the calves born from AI. In the current study, producers were correct in identifying calving distributions as a greater proportion of TAI calves were born in the first 21 d of the calving season when compared to natural service calves (Crosswhite et al., 2016). Results observed are similar to those of Rodger et al., (2012) and Steichen (2013) in which greater proportions of females exposed to TAI compared to natural service calve early in the calving season. As previous reports of AI use identify early calving as a potential benefit, producer were correct in their anticipated results. Producers were also incorrect about events including the increase in pregnancy rates and the length of the calving season. Results for the effect of AI on pregnancy rates have been variable with AI both increasing pregnancy rates in *Bos indicus* cattle (Sá Filho et al., 2013), and having no effect on season ending pregnancy rates in *Bos tuarus* cattle (Steichen, 2013). Pregnancy rates for the current study remained the same between treatment groups (Crosswhite et al., 2016). Length of the calving season is often referred to as a potential benefit of estrus synchronization and AI (Larson et al., 2006; Dzuik and Bellows, 2983), however, was not determined for each producer herd in the current study. The length of the calving season is a direct reflection of the length of the producer defined breeding season and not AI use. Producers also anticipated heavier weaning based on previous reports, as heavier weights have been observed for calves born from dams exposed to AI (Steichen, 2013). In the current study, heavier weights were observed for every herd but two (Crosswhite et al., 2016). Due to confidentiality purposes, anticipated and actual results could not be evaluated.

Test of Knowledge

Tests of knowledge were administered to determine if the understanding of various project components relative to AI, performance records, economic records, and sustainability were affected by first hand implementation of such technologies. Mean test scores decreased from the initial date, after which producers were intimately involved in various related programs, to the second meeting and third meetings. Scores from the current study are in contrast to other knowledge tests administered. When tests were administered on the same d, both before and after an educational activity, mean test scores increased (Fishel, 2008). Similarly, when participating in a soil fertility workshop, proportions of question answered correctly during the post-test were greater when compared to the pre-test (La Barge, 2007). In all instances, each group demonstrated some level of baseline understanding or educated guesses, however, in the current study, knowledge level about the various subjects tested decreased. When compared to the other noted studies, there was a significant time difference between testing dates. Fishel (2008) and La Barge (2007) administered tests the same d or just after completion of a workshop. Producers enrolled in the current study completed each test several months after the initial start of the study and several months or years after taking the test the first time. Although test scores decreased between meetings, producers noted great skill and ability at performing tasks associated with project components. It would seem that the mechanisms of action for the tasks associated with estrus synchronization and AI are less important to producers whereas knowing how to complete a task is much more important.

Implications

Commercial beef producers from the state of North Dakota participated in on-farm research in which each herd was bred utilizing a new breeding system, either natural service or AI. Implementation of the different breeding systems included a great deal of on-farm research, participated in by researchers, producers, and extension agents. In addition, each producer was enrolled in a record management program and a financial record keeping program. While overall knowledge and skill with each factor of the current study did increase, average test scores decreased. In addition to survey information and a test of knowledge, focus group discussions determined the use of the technologies included in the study.

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CHAPTER 5. EFFECTS OF BREEDING SYSTEM (NATURAL SERVICE OR ARTIFICIAL INSEMINATION), COW HERD APPRAISAL PERFORMANCE SYSTEM, AND FARM BUSINESS MANAGEMENT PROGRAMS ON PRODUCER PERCEPTIONS

Abstract

Objectives were to evaluate the perceptions and attitudes of beef producers in terms of performance, production, profit, and quality of life and to determine the change in knowledge, understanding, and skill of producers when implementing a new breeding system, record keeping program, and financial analysis program. Production refers to the pregnancy, calving and weaning information relative to applied treatments, performance included the participation in the Cow Herd Appraisal Performance Software program, a record keeping system, and finally, profit included participation in a Farm Business Management (FBM) or financial analysis program. Ten commercial beef cattle producers and nine North Dakota State University county extension agents were selected to participate in an experiment in which producer herds were subject to a comparison of natural service breeding and estrus synchronization and timed-artificial insemination. In addition, producers were also enrolled in a cow herd performance evaluation and farm business management program for two years to determine the viability of use of these programs for commercial producers and to determine the true economic impact of each breeding system. A series of meetings throughout the project period were also attended by producers. A total of three meetings over a four-year time period were conducted in which producers were participants in focus group sessions. Focus group sessions were held to discuss each of the four project components, production, performance, profit, and quality of life. In terms of production,

performance, profit, and quality of life, producers identified genetics, the amount of time and work for each aspect of the study, each producer’s own record keeping system, others involvement, family time, and the ability to participate in on-farm research as important factors. In the final meeting, producers identified aspects of each project component that may attribute to future sustainability of their operation.

Introduction

Decreases in efficiency of a beef production system can be very costly and attributed to poor reproduction and infertility. The decrease in profit of an operation may lead producers to exit the beef industry to pursue more economically viable opportunities. Programs, management techniques, and technologies directed at mitigating factors related to poor reproduction and infertility are currently available, however often underutilized. Estrus synchronization and artificial insemination (AI) are management techniques available for the advancement of herd genetics by selection of highly proven sires, without the overhead cost of the equivalent of a natural service sire. A study was done (Crosswhite et al., unpublished data) to evaluate the effects of breeding system, including TAI, a record keeping program, and a financial analysis program on commercial beef cattle operations in North Dakota as well as the ability for those programs to increase the sustainability of the operation.

While understanding the quantitative data and how it may influence the producer and potential management decisions, a deeper understanding of the material may warrant a more successful adoption to the technology or program. In addition to increases in technology use on livestock operations and producers understanding measures to the success of an operation, the way in which information is obtained by producers is changing. The rate at which people adopt different ideas generally rests on a bell curve; for example, innovators, those who readily adopt new technologies (top two percent of adopters), early and early majority adopters (representing 48 percent of adopters), late adopters (representing 34 percent of the adopters), and finally, the laggards, those whom are the last to adopt a new technology (representing the lower 16 percent of adopters, Rogers 1962).

Extension educators must be aware of the need for a multifaceted approach for handling extension programming including extension bulletins, face to face meetings, internet programs, and newsletters (Dahlen et al., 2014). Previous approaches to increase sustainability have included extension programming that work to increase the acceptance and implementation of alternative production systems (Hinrichs and Welsh, 2003), however, limited data is currently available that evaluates the use of various extension programming efforts coupled with the inclusion of a new technology or technique on-farm. It is for this reason that we hypothesized that the inclusion of a new breeding program, participation in a record keeping and financial analysis programs may alter the production, performance, profitability of beef cattle operations and potentially affect the proportion of producers likely to stay in the beef industry by increasing the sustainability of their operations. Therefore, the objectives of this study were to evaluate to what degree the addition of various producer programs and breeding systems affected the perceptions and attitudes of beef cattle producers in terms of performance, production, and profit.

Materials and Methods

Interviewees

North Dakota State University county extension agents were selected for their involvement and identification of commercial cattle producers in their respective county locations. Agents then selected producers interested in the study who could commit to all phases of the research including maintaining records, participating in project components, and meeting with others to share their story (See Appendix A). Producers recruited had never implemented estrus synchronization or AI into their cow herds as a normal management practice.

Participation in all project components was necessary for producer selection. Producers were required to maintain records including personal animal ID's, calving dates, weaning dates, animal sales, and feed produced and purchased. Various project phases were also required which included a production phase, a performance phase, and a profit phase. Production was identified as the portion of the study focusing on the comparison of two breeding systems, natural service and artificial insemination. Producers would provide cattle, facilities, and labor to assist with implementing the two breeding systems as well as performing tasks associated with the breeding systems. Performance was identified as the portion of the study focusing on the Cow Herd Appraisal Performance System (CHAPS), or the benchmarking performance data system. Producers were enrolled in the program and required to provide performance data on their respective herd. Finally, profit was described as the portion focusing on the Farm Business Management (FBM) program, or the financial program used to evaluate expenses, returns, and overall profitability. Producers were required to meet with a FBM instructor to evaluate the financial dynamics of farm and/or ranch profitability. Lastly, producers were required to meet with others. Over the course of the study, meetings were held before, during and post project components and producers were required to attend and participate in various surveys, tests, and discussions.

Instruments

A total of three meetings throughout the project period were attended by producers. At the beginning of each meeting, producers were given a survey and a test of knowledge (See Chapter 4/Appendix B). After the surveys and tests, focus groups discussions were conducted to evaluate the perceptions of both producers regarding the performance, production, and profit components of the project. Focus group discussions were also used to describe the quality of life changes of producers and their operations. Questions asked during the discussion remained similar throughout the series of meetings, however, were altered slightly from an anticipated result (pre) to during the project (mid). During the final meeting, summary information was discussed and much of the focus group session focused on the concept of sustainability of producer operations with each project component in mind (production, performance, and profit). Interview guides were developed to focus the information discussed with general probes that included possible anticipated results or thoughts (Appendix D).

Data Collection

Each producer herd was randomly assigned to one of two breeding systems, natural service breeding (herd bulls only) or estrus synchronization and timed-AI followed by exposure to natural service bulls. In addition, producers were enrolled in a cow herd performance evaluation (Cow Herd Appraisal Performance Software program; CHAPS) and farm business management (FBM) program for two years to determine the true economic impact of each breeding system. Data originating from surveys and tests of knowledge were collected during the course of each meeting of which each cohort attended three meetings. At the initial meeting for each group, project components were discussed, including the breeding systems, CHAPS program, and the FBM program. Focus group sessions were then held. During the second meeting for each year, surveys and tests of knowledge were addressed first, followed by a project update the focus group sessions.

Data Analysis

Focus group discussions were evaluated by meeting (meetings 1, 2, and 3). Within each meeting, a series of four questions were discussed and each question was evaluated independently. Responses were transcribed and themes were teased out of communications by a color aggregated technique in which similar themes were designated into a specific color by a single individual. Major themes were first evaluated, then moving into more specific discussion topics. Common themes throughout each question subject were then grouped by topic and summarized. The information provided in the following sections outline the progression through question topics and discussion themes. Although not an all-inclusive list, summary themes included in the results were similar across producer participants.

Methodological and Ethical Issues

Within the timeline of the study, issues arose with both producer and extension agent participation. Identification and selection of producers was done by the respective extension agents in their common area. In some cases, identified producers elected not to participate in the study, resulting in agents recruiting different producers.

All survey, focus group, and test questions and methodologies were approved by the North Dakota State University Institutional Review Board (Appendix C). Ethical issues among the researchers, agents, producers, and data collection did not arise.

Results

Meetings were attended by producers, extension agents, support personnel, and researchers. Three meetings were attended over the course of the project timeline, one prior to the breeding system start, before to the next breeding season, and after all data collection for all herds. The focus group questions can be found in their entirety in Appendix D.

Focus group questions were proposed by a moderator and focused around five common topics; production, performance, profitability, quality of life, and sustainability of producer operations. The third meeting included focused questions about the sustainability of producer operations after participation in the experiment. Within each topic, themes emerged and will be individually discussed in the following sections. Due to the timing of each meeting, emergent themes will be discussed individually by meeting.

Meeting 1- Before participation in the research project

Production

The initial question posed to the group was in relation to the expectations anticipated with the inclusion of the estrus synchronization and AI breeding system; "*As you look ahead to your participation in this project over the next two years, what are your expectations in terms of breeding system comparison results*?" with probes including: "*what do you see as the challenges in implementing a new breeding system, how will you go about addressing these challenges, what do you anticipate will change in terms of calves born, calving distribution, and what do you anticipate in terms of the calf crop, calves sold, or heifers retained*?". Two major themes emerged from the discussion, focusing around genetics and time needed to accomplish AI. The most common theme mentioned under the topic of production that appeared throughout the discussion was genetics. Genetics was mentioned as a general statement as well as genetic parameters of the livestock. Participants stated that they hoped for high quality calves with increased weaning weights as well as the ability to retain high quality replacement heifers. Producer perceptions of higher quality calves were based on the ability to use higher quality genetics with AI when compared to the quality of genetics each producer could afford when purchasing a whole herd sire. In addition to the genetic improvement overall, use of high quality semen could increase the growth and weaning weights of calves. Producers have the ability to use expected progeny differences (EPD's) to choose high growth sires that could increase weaning weights and maternal sires capable of producing high quality females. Uniformity was also mentioned in terms of the AI calves in that they would be more uniform in their phenotype. Uniformity was related to the ability to sell larger groups of calves at a single time and increase the appearance or phenotype of potential replacements. Increases in all aspect of genetics was identified as a positive for the ability to retain replacement heifers in the herd, thus enhancing the perception of increased herd quality. As one producer described:

I expect to retain better heifers and improve the quality of my herd.

The second most common theme with regards to production was the time and input required to successfully AI cows. Many of the producers maintain a farming enterprise in addition to their beef herds and scheduling an estrus synchronization protocol and timed-AI session in the summer was thought to be quite a daunting task. The timing of estrus synchronization and AI could affect things like planting crops and haying. Producers asked themselves, "is it worthwhile?". Concerns arose when discussing the topic of AI with the idea of putting effort into something, and hoping to see the results (i.e. heavier weaning weights, earlier calving, higher quality replacement heifers) they were anticipating. One producer described his thoughts on the subject:

As far as time and as far as… is it going to be worth my effort to go through this AI process versus just herding the bulls out the way that I have been doing it.

Performance

The second question posed to the group centered around expectations relative to enrollment in the Cow Herd Appraisal Performance Software (CHAPS) program; "*As you look* *ahead to your participation in this project over the next two years, what are your expectations in terms of involvement with the Cow Herd Appraisal Performance System (CHAPS)?*" with probes including: *what do you see as a challenge for participating in the Cow Herd Appraisal Performance System (CHAPS), benefits, and how will you go about addressing this challenge?".* The CHAPS program is a beef production record keeping system aimed at providing beef producers with important information regarding individual herds and improving managerial decisions and herd performance. During the initial meeting, producers had been informed that participation was necessary as a part of the current study, however, not all had participated at the time of the initial meeting. Anticipated results, thoughts and attitudes towards the CHAPS program were of interest. Throughout the discussion, four main themes emerged including, the producers own system, time necessary to take records, intensiveness of the records/use of information, and the involvement of others.

Throughout the discussion, the topic of one's own record keeping style was an emergent theme. All producers in attendance stated that some form of record keeping was done at each location. The majority of participating producers routinely collect calving date and sex for each calf born. Data that can be collected for the CHAPS program may or may not be more intensive than is recorded on farm, including calf birth weight, calving ease, sire, and weaning weight. Concerns arose with the idea of collecting birth weights and recording calving ease, as many producers thought the task was not worth the time or effort needed to take the weights. Producers also included that collection of more intensive records may not be necessary and voiced concerns regarding taking such records. One producer had this to say about the program:

I am keeping track; I just have not done it through the CHAPS.

In addition, participants questioned the amount of useful data that could be collected on the herd that could not be determined by the producers themselves. Producers were concerned that additional time would be required to collect additional data (i.e. calf birth weights, individual weaning weights, etc.) without the addition of useful reports that may aid in making management decisions. Some mentioned that increased time with cattle regardless of CHAPS program participation will lead to increased knowledge about their herd. The idea was discussed by a producer:

> *I can judge whether I got a poor cow or a poor calf in there and I can go out and do the same thing as what you're doing in the CHAPS program and go out and sell it.*

The next emergent theme discussed was the amount of time the program would take. Producers were concerned about time spent in front of a computer entering data as well as the amount of time taken away from completing other tasks. Although negative comments were made regarding the time taken, one individual who already participated in the CHAPS program stated that they "*would be lost without it*" and even though it takes time, for him it is worth the hassle. Due to concerns regarding time spent entering data, it was discussed that the CHAPS program does not require producers to enter data by hand, but calving books may be mailed to the CHAPS office and support staff may enter the necessary information. The ability for producers to be able to send in data as opposed to entering it themselves may be a benefit to utilizing the program. Although this information was discussed, increased time required to take part in the obligatory activities was still of anticipated concern for the involved producers. As one producer said:

> *Oh I absolutely hate sitting at the desk, I hate it with a passion. I got to really force myself to do it not just for the record keeping of the calves but the farming too. I'd much rather be out there doing stuff.*

The third theme that appeared throughout out the interviews was the idea of the information obtained by the program was more intensive than it needed to be. Producers considered their current personal records to be substantial without the need for more intensive records. It was included that if extra data is to be collected, action was required; producers must actively make a change as suggested by the data. One producer stated:

> *Just another stack of paper, but the information's good coming off of it, as long as you follow through with it. Information is one thing. If you don't load them in the trailer, then it doesn't matter.*

As discussed previously, there was not a consensus with regard to the CHAPS program as some believed they could identify positive and negative attributes about individual cows without the involvement of the CHAPS program and some believed the program was worthwhile.

The final emergent theme that appeared in the interview with regard to the CHAPS program was the inclusion of others in the data collection process. Many producers have included family members including a spouse, children, and nieces/nephews into the operation by way of additional help with record keeping. While anticipated results were increased time in front of a computer, allowing someone else to help was seen as a benefit of the program. As one producer said:

> *I get my kids involved and my wife involved more in the record keeping and I don't have to sit there and look at the computer*.

The topic of generational differences in producers was also discussed. Those producers with children or the involvement of a younger demographic included that the idea of the CHAPS program may be more appealing to those with smartphones, computers, and tablets.

Profit

The third question posed to the producer group dealt with information regarding the Farm Business Management (FBM) program; "*As you look ahead to your participation in this project over the next two years, what are your expectations in terms of the Farm Business Management program*?" with probes including: *what do you see as a challenge to participating in the Farm Business Management (FBN) for two years, how will you go about addressing this challenge, and what do you anticipate regarding changes in variable input costs or net income*?". The FBM program is an adult education program geared at those in the agriculture industry aimed at assisting with financial record keeping and goal setting. At the time of the initial meeting, producers knew of the FBM program, however, not all producers had not yet entered into the program. At the time of the initial meeting, producers knew of the program Questions were asked in hope that producers would identify concerns and detail their perception of the program as well as anticipated results. Several producers had previous experience with the FBM program, whether they were currently enrolled or had been enrolled in previous years. The experience allowed for increased discussion about perceptions from those with firsthand knowledge about the program. Throughout the focus group discussion, three main themes emerged, the people in the program, the program details, and the ability to generate profit or increase profitability.

Within the FBM program, there are 17 instructors located in various extension centers, colleges, and schools throughout the state. Producers were tasked with contacting their closest instructor and meeting with them to discuss factors related to producer profitability. Quality of instructor was one of the most commonly discussed topics. Producers previously involved in the program found the instructors to be very friendly and intelligent. The idea of friendly people increased the interest of the group. One producer involved in the program for a number of years had this to say:

> *I really enjoyed working with the people in the farm management program they're really sharp, intelligent people and uh they just can analyze your records then and give you a little better understanding of where you're at*

The next emergent theme revolved around the FBM program as a whole and the information that could be generated. Producers discussed the individualization of the information for different aspects of an operation, whether that be the farming sector, the cow calf sector, or retained ownership of calves through the feeding period. Producers not already involved in the program anticipated an increased knowledge about their spending, cost saving, and whole operation financials. It was also discussed that the program allows for comparisons in order to make more informed financial decisions. It was also mentioned that the CHAPS program and the FBM programs are similar in that they both require record keeping:

> *It forces you to keep better records and that type of thing.*

Lastly, the theme of profit generation was discussed. Producers anticipated the ability to evaluate their financial outputs for cost cutting ideas as well as inspection of areas in which more money could potentially be spent. As cattle ranching and farming are the sole income of many of the included producers, profit generation is of great importance. Ideas in which lead to an increase in profits are very attractive and the anticipation of producers was that this program could increase their knowledge about their finances. One producer described his interest in utilizing the FBM program as a program:

> *Where I can cut costs to where I can put a little more money in than I need to or I can afford to put more money where it makes sense.*

Quality of Life

Quality of life was the last topic discussed in the focus group discussion. Producers were asked what factors affected their quality of life; "*What factors come to mind when you think about having a good "Quality of Life*?" with probes including: *outside of work what areas of life do you prioritize and make time for, what do you wish you had more time for, and how do you think and of these items could change by implementing a different breeding system in your herds*?". This line of inquiry was used to determine the factors that might affect one's quality of life as well as to evaluate the addition of a new breeding system on their production system. Three main themes were brought up from the discussion including spending time with family and friends, high quality genetics, and time.

Spending time with family and friends was the most commonly shared contributing factor of quality of life for the group of producers. Each producer mentioned interest in working cattle with family and friends as well as spending time with family and friends doing recreational activities outside of cattle work. The act of teaching both family and friends the way of life on a cattle operation was very pleasing to each producer. One producer had this to say:

> *There's my family. Every time we work the cattle, my kids come. We do everything together. That's very good, I think.*

Another emergent theme found throughout the discussion was the idea of genetics. In previous sections genetics was mentioned as an anticipated result of AI breeding. Genetics was again mentioned with regards to quality of life and the idea that positive improvements to the genetic base and phenotype of the herd would increase the quality of life of producers. Producers detailed the interest in higher quality herd genetics and overall happiness in the quality of the cows. This is observed by a producer stating "

Just the quality of the new genetics that you can bring in without having to go buy the extremely high dollar bulls.

Another producer described the idea of wanting to look out over his herd to say:

I like my cows.

Participation in a breeding program that includes the use of high quality genetics could have potential benefits for the phenotype of calves generated and could therefore increase the quality of life of producers by increasing genetics of cattle.

The third theme discussed throughout the focus group discussion was the idea of time. While producers did not think that the addition of the AI breeding system would affect their quality of life, they did feel that it would decrease the time they had for completing other tasks. The addition of the AI breeding system requires three d of working cows in a 10-d period. This amount of time and work may take away from other tasks needing to be completed, such as farming or other family commitments. Decreased time for completing certain tasks can also lead to increased stress. One producer had this to say:

For the week that you're doing it, actually for the three d that you're doing it, you have to take time out of your other schedule and put on the back burner things you could be doing, things you're supposed to be doing to do this, I guess. It'd be a stressful thing at the least.

In addition to the time factor, weather was also mentioned as a negative attribute of the new breeding system. The estrus synchronization protocol used in the current study included a time sensitive breeding time. Due to the timing of many synchronization protocols, weather and time can be confounding issues. If weather is poor on the d of breeding, the cows must still be bred.

Meeting 2- After implementing breeding systems but before calves were born

Production

The second of three meetings included another focus group session, similar to the previously discussed session. In terms of questions, producers now had knowledge regarding AI breeding system, having experienced it with their own herds or with each respective producer. At each location, cows were randomly distributed into one of two breeding groups and at the time of the second meeting, were awaiting the birth of the calves conceived to that breeding. The production component included two question topics; one relating to the expectations met in terms of production ("*after participating in the first year of the project, were your expectations met in terms of production*" with probes including: "*how did the perceived work of implementing a new breeding system change/not change from previous expectations and have the production steps taken up to this point made you more aware of how the different breeding systems implemented could contribute to sustainability on your ranch*") and the other focusing on potential expectations for the upcoming calving and breeding seasons ("*what are your expectations for year two in terms of production*" with probes including: "*do you anticipate easier calving or better use of available resources due to possible concentration of the calving season. do you anticipate better phenotype in calves or heavier weaning weights of calves from the AI system, and if the process could be changed for the better, what are some ways in which this could be facilitated*"). This line of inquiry was followed to evaluate the effectiveness of the breeding program and to determine what producers may expect for the coming year. The first question, related to meeting expectations included three main themes; work and time, awareness of cows, and family involvement. The second question, related to expectations for the coming year included two main themes; genetics and the calving season.

The most commonly discussed theme related to meeting expectations was work and time. Producers agreed that there are a necessary number of people required to perform the tasks associated with estrus synchronization and AI and although more work was needed to complete the tasks, the process went smoothly. One producer described the experience as:

> *Yea I thought it all went pretty good I guess. It wasn't much to it. It was a pretty simple deal.*

Producers noted that the amount of work was increased when compared to the natural service breeding system, however, if the necessary number of people are available, the work load can be manageable. One producer described the experience:

> *…it's a lot of work. I anticipated a lot more work than it was I guess you know just trying to get all of the cows in.*

In addition, the topic of scheduling tasks was discussed with regard to time. Estrus synchronization and timed-AI with the protocol utilized require three working d, on which timing of tasks is very important to the success of the breeding. Scheduling is more intensive with AI when considering not only scheduling time but also labor and other farming tasks.

Family involvement was also an emergent theme throughout the discussion. Producers detailed the ability for their families to be involved in the working d and increasing the number of times the cows needed to be handled increased the number of times the family could handle cattle together. A producer described this idea:

> *We like working cattle together and when you get everybody there its usually good food and comradery and even if it's just our family.*

Producers also found that the AI breeding system may be generational within a family. Children and teenagers expressed great interest in the cattle work and parents described a potential shift in breeding systems by children planning to take over the family herd.

The final theme discussed when questioning producers about their expectations relative to the addition of the AI breeding system was the awareness of producers to their cows. Producers had previous concerns about cattle movement and flow when being worked several times in a 10-d period. Producers detailed that cattle movement was not as strenuous as previously thought and one producer had this to say:

> *My biggest concern was bringing the cattle in that many times, back to back to back. I thought by the third time they wouldn't even look at that alley way or chute. And they actually they went, they funneled through better than I thought they would.*

In addition, disposition of cattle was of concern, however, no problems with poor dispositioned cattle were mentioned in the discussion.

Within the first question topic, the subject of sustainability was discussed with relation to production. When asked if they had become more aware of breeding systems contributing to the sustainability of their herds, producers detailed factors including family and cattle as positive attributes of AI. Producers described the additional work required to implement AI but also included that it allowed for more family bonding time by way of working cattle together. Producers also included that the benefit anticipated with increased genetics, more uniform phenotype, earlier calving, and high quality replacement heifers would contribute to the sustainability of their operations when utilizing AI. A Producer stated that:

> *I don't think we've seen the benefit of it yet until the calves are on the ground on next fall when we get the production out of it.*

When discussing the expectations of participants for the upcoming year, genetics was a major emergent theme. As in the initial or pre-meeting, also focusing on expectations, producers anticipated a uniform set of calves that could sold as larger groups based on an increase in appearance or phenotype of potential replacements. Calves born from TAI exposed females were also expected to be heavier at weaning. Use of AI has the potential to increase weaning weights of calves with the use of high quality bulls as well as increase the number of cows that calve early in the calving season. Performance could include this increase in weight or potential performance further down the line. One producer described his expectations as:

> *I'm excited to see the results, the calves, come weaning time when it's time to start weighing and shipping and just see what they kind of did; I'm just expecting bigger, heavier calves.*

In addition, participants were anticipating the ability for producers to retain high quality replacement heifers with the improved genetics obtained from using high quality AI sires.

Calving was also an emergent theme as producers would begin calving very shortly after the meeting took place. A shorter calving season was anticipated with more cows calving early in the calving season when compared to the natural service sired cows. This was said in response to anticipated results:

> *A pretty busy calving season. They are all going to come pretty quick.*

Performance

At the time of the second meeting, producer involvement in the CHAPS program was continued by those previously involved as well as not being started by others. The line of questioning was included to evaluate whether any preconceived thoughts about the CHAPS program were true after participation in the program. The main question asked from the focus group guide was "*after participating in the first year of the project, were your expectations met in terms of performance*" with probes including: "*what are some of the benefits you have seen with the Cow Heard Appraisal Performance System (CHAPS) program, what are some of the challenges you have seen with the CHAPS program, and has the CHAPS program made you more aware of how the different breeding systems implemented could contribute to sustainability on your ranch*". Within the scope of CHAPS, five emergent themes were described including the overall program, cattle performance, data retrieved, generational differences and extension efforts.

The first of the themes discussed was the overall program. Producers detailed the use of the CHAPS program, describing it as a benefit. The program was described as:

> *It will just be a nicer system, a more accurate system, a way more accurate system then what I've done in the past.*

In addition, producers discussed the ability to set goals and make decisions with the supplemented information, something they found useful. Producers felt that multiple years of data may be needed in order to obtain accurate information. One producer described their experience as being able to:

> *Track your weaning weights, compare yourself to other producers and see how you're doing and some of those other areas too.*

Negative attributes were also mentioned, like the time necessary to enter all of the information and receiving back more information than one could or would use. Many producers felt that the time spent was unnecessary based on the information returned that may or not be useful for making management decisions.

Cow quality and performance were the next items to be discussed in the focus group session. Producers detailed the interest in a program that may help in the selection of replacements, visualization of both cow and calf performance, and clear evidence for culling females. Prior to any involvement, producers were not unified in the acceptance of the program. A producer described their thoughts on the CHAPS program:

> *…it's going to give really good idea of how this cow, how she's performing, how the calf is performing. And you can always compare that just year after year. It's going to help you make a lot better decision on what to do with those cows and those calves.*

Generational difference among those producers actively in the beef industry when compared to the next generation was the next topic to be discussed. Many of those involved have children or other family members interested in a more technological approach. A multigenerational difference was also observed in the first focus group discussion. It was described that the program could work very well in the hands of the younger generation, one more suited for computer programs. Additional discussion included the movement of the CHAPS program toward a smartphone or tablet app version. Producers currently using a smartphone or tablet for everyday use discussed the ease of CHAPS implementation that could be possible with an app version of the program. The producers with smartphones were interested in the potential for a more handheld option. A producer described his thoughts on the subject:

> *Those kids are so far ahead of people like myself. They get more shit on the smart phone than I could even find, I mean their computer orientated. Everything about them and when the next generation takes over, the CHAPS program is going to be a breeze.*

Profit

Questions related to profit for the second meeting focused on the ability of the FBM program to meet expectations of producers. At this time, producers were to be involved with the program. The purpose of this line of questioning was to evaluate the previously defined expectations and the current attitudes after implementation. The main question posed from the focus group guide was "*after participating in the first year of the project, were your expectations met in terms of profit*" with probes including: "*has the Farm Business Management (FBM) program been beneficial/challenging, how have you are you going to go about addressing the challenges, and has the FBM program made you more aware of how the different breeding systems implemented could contribute to sustainability on your ranch?*" Throughout the discussion, three themes emerged including, the overall program, the data collected, and the people involved with the program.

The overall program was again a major theme that emerged from the focus group discussion. Producers described FBM as a beneficial and informational program. In addition, there was discussion that focused around the necessary information needing to be entered into the program. Producers added that information gathering was difficult and things needed to be entered by hand, however, once completed, the program was easy to use. A producer had this o say about the program:

> *…trying to get everything entered from the past year was kind of difficult but I think now that we are caught up, I think it's going to be a lot easier to keep up with things.*

There was further discussion about the similarity between FBM and other programs available, as one producer couple are involved with a different financial program.

In addition to the overall program, the data collected was another reviewed topic. After some involvement with the program, producers discussed the ease at which tax time would be with the help of the FBM personnel. All financial information is carefully categorized and cost breakdowns are available, allowing for tax filing to be an easy task to be completed. One producer described their experience by saying:

> *For us it's nice because everything is categorized so if I want to go in and see how much money did I spent on protein tubs this year, I can just go up and say oh, that's how much.*

This type of information gives producers the opportunity to analyze spending and keep better track of inputs and outputs.

The final emergent theme is again a previously discussed topic, the FBM program instructors. It was reiterated that the people are very easy to work with as well as being very intelligent. A pair of producers discussed one instructor individually, describing that he has the intellectual capability of offering a "*safe, unbiased opinion on financial decisions*". Another producer described himself as being "*overextended*" and the FBM program has the ability to help distribute responsibilities.

Quality of Life

As with the previously discussed questions for the second meeting, producer quality of life was evaluated to determine if the program had any effect. At the time of the second meeting, producers had participated in one year of AI breeding and should have entered into the CHAPS and FBM programs. Producers were asked "how the change in breeding systems affected their quality of life". Three major themes emerged when producers were asked if the change in breeding system affected their quality of life; family, increased interest in AI, and increased workload.

For producers, similarly to the pre-program meeting, family was a major influence of quality of life. Producers identified having more family time in addition to more overall bonding time in response to the breeding system affecting their quality of life. Increases in family bonding was noted due to increased cattle working d, adding to increased need for labor and support, a role taken by family members. In response to the effect of the breeding system on producer quality of life, one producer described the effect as:

> *I think probably family, working together…but something like this you've got the whole family there.*

The addition of the AI breeding system created the opportunity for learning and experimentation with an unfamiliar breeding technique. The second major theme to be discussed was the interest in pursuing an AI system after completion with the current study. Many producers discussed potential future plans including AI and experimentation with different estrus synchronization protocols. Heat detection was discussed to alleviate some of the time constraints with a more structured timed-AI protocol. A producer had this to say about future endeavors:

> *It's going to be a good thing. We're going to look to do more heat detecting instead of the timed deal.*

The final emergent theme relative to producer quality of life centered around work. As previously anticipated, the addition of the AI breeding system included increases in work and the amount of time necessary to complete tasks relative to cattle management. The breeding system was discussed as being more involved and causing more time away from other farm related activities. While increasing time with family, quality of life during the stressful time of breeding also decreased. Researcher involvement decreased the amount of work necessary for producers to complete as a part of the ongoing study. This was mentioned by a producer who stated:

I'm not going to say it's no work, because it was very involved, and without your assistance it's going to be way, way more involved.

Meeting 3- After all phases of the project had been completed

Focus group questions for the third meeting centered around three of the primary question topics, production, performance, and profit. At this meeting, summary data was discussed and overall conclusions about project components were of primary concern. Discussion about each question topic and their experience with the breeding systems, CHAPS and FBM programs reached saturation after the second meeting. Information included in the following section focused around the concept of sustainability of their production systems, herd performance, and profit.

Production

The final meeting included another focus group session, similar to the previously discussed session. In terms of questions, producers had been involved with the program for three to four years and had potentially continued with the technologies involved after researcher participation had ended. The production component included two question topics; one relating to the expectations met in terms of production ("*what were your experiences with the production component of the project*" with probes including: "*what were your experiences during the calving season, did you notice any difference in claves from a phenotype/visual appearance standpoint, and did the breeding systems impact the sustainability of your operation*") and the other focusing on future plans in the area of production with probes including: "*did you use estrus synchronization and AI after our involvement and do you foresee any future AI/NS breeding system use*"). Producers each discussed their experiences relative to AI use with themes including calving, proportion of females becoming pregnant to AI, genetics, and ways in which they believed AI would or did improve their herd or may improve the sustainability of their operation.

In terms of production, producers were pleased with the number of claves born in the first few weeks of calving as it seemed to "tighten up the calving window", however, one producer was disappointed with the number of females that became pregnant to AI after using the technology in the next years. He stated that weather may have been a driving factor for poor conception based on the rain and mud associated with the days of breeding. Overall, producers mentioned that the quality of genetics of their cows was improving with the use of AI due to the ability to select for high quality bulls. Producers were able to retain heifers and even bull stock for future breeding years as well as having the ability to sell high quality heifers from off of their operation. One producer said this about his experience:

> *We ended up with 14 half-brothers off of what we AI'ed. I'm breeding the whole cow herd to that... that alone saved me 50, 60 thousand bucks in the program…It's working out very well. I'm very happy with the genetics that we got off of that.*

When discussing the topic of production with regards to sustainability, producers were split as to their feelings about which breeding system was more sustainable, natural service or AI breeding. One producer determined that the ability to participate in the study allowed him to answer a previously unknown question, as to whether AI was a feasible practice for his operation:

> *I always knew that doing it with the heifers was good but I always wondered what it would do in the cows. I only did it one year so I can't really say but I don't think it really paid. I'm not doing it again, not at this point in time.*

Natural service was the breeding system that would be more sustainable for his operation compared with the additional labor and calving distributions observed with the use of AI. Other producers identified that AI was a sustainable practice on their operations and described how genetics would factor into his future sustainability:

> *This spring I'm planning to AI the daughters off those AI calves to the next set of genetics and do the same thing. We are planning on keeping another 10, 12, 15 bulls and just do groups every two, three years. I'm not buying bulls, I plan on selling half of these three yr old bulls that I kept that were half-brothers and cash them out that ways.*

While AI breeding was likely to be continued in the future for those operations that determined it may be a sustainable option for their operation, it was discussed that resources, time, and the size of breeding groups of females at any given time may determine the use each year. One producer had this to say:

> *I think that it depends on what you're doing and what you have the ability to do. Like for us, not that we have that corral unit, I think that it would be feasible and sustainable for us to AI.*

Performance

At the time of the third and final meeting, producers had previously been involved with the CHAPS program and two of the producers in attendance were still using the program. The main question asked from the focus group guide was "*what were your experiences with the performance component of the project*" with probes including: "*what are some of the benefits you observed with CHAPS, has taking better records made any differences to the cow herd, has the CHAPS program aided in making management decisions, and has the CHAPS program aided with the use of other/different breeding programs*". When discussing the CHAPS program, several emergent themes were brought up including what to do with the CHAPS book at the end of each year, the use of the program, and the sustainability of the program in their operations.

In terms of performance, views on the usefulness of the CHAPS program were mixed among the group. Two of the producers in attendance previously used the CHAPS program before participating in the current study. Each of the producers continued to use the program after the conclusion of the current study. One discussed his appreciation of the simple program in which information could just be entered into the computer. When asked what information was used from the final book that is sent to each CHAPS participant, this is what the producer had to include:

> *…the cows that have had the most calves, the best weights, and that's what I kind of look at for doing the heifers.*

Another producer described how much about his cows he knew just by taking the time to enter the information into the CHAPS program. The program offered this producer the opportunity to keep records on cows for a number of years which allowed him to evaluate generational lines of cattle and to evaluate their productiveness. In contrast, other producers described how each had not used any of the information that came out of the CHAPS program to date.

An additional question was asked to the producers based on the CHAPS program to evaluated whether the idea of record keeping was worthwhile on their operation. The majority of producers determined that some kind of record keeping was worthwhile. One, however, determined that records were not necessary.

> *So as far as knowing everything about a cow in detailed records, I think its BS. There are always things that you can learn from data, but it depends on who you are and what you value your time at.*

Performance, or the use of the CHAPS system was discussed in terms of overall herd sustainability. Responses for whether a record keeping system would increase the sustainability of an operation were similar to those observed for production, mixed. While it was discussed that a record keeping system involves more time in an office/computer type setting, producers determined that it may increase the sustainability of an operation by forcing the operator to evaluate collected records. One producer discussed his thoughts on the CHAPS program:

Yea I would never quit at this point. No way.

It was also discussed that a record keeping program was not necessary and led to more time away from the cow herd.

I hate sitting in the office, it's my least favorite pace to be.

Profit

The final meeting included questions relative to profit or the FBM program. At this time, producers were to be involved with the program. The purpose of this line of questioning was to evaluate the previously defined expectations and the current attitudes after implementation. The main question posed to the focus group guide was "*what were your experiences with the profit component of the project and what are your future plans in the profit area*" with probes including: "*did the FBM program allow you to see any differences between money saved/lost within the breeding system, what are some of the benefits you saw with the FBM program, did the FBM program allow you to make more/less changes within the herd (culling, purchasing, etc., has the FBM program allowed you to see the financial strengths or weaknesses within your operation, and will you continue keeping track of spending /purchasing to the extent that FBM recommends or will you revert to previous year's financials?*" Throughout the discussion, the most common theme revolved around the helpfulness of a financial management program and the ability of a financial program to increase the sustainability of an operation.

There was little discussion about the effect of the FBM or a financial program on the sustainability of a beef cattle operation. All producers were in agreement that a financial program was essential to the sustainability of an operation. One producer said this in regard to increasing the sustainability of his operation:

Oh, mine it does absolutely.

Much of the discussion revolved around participating in a financial program and the ease of transitioning the program material to an accountant around tax season. Producers were grateful for the ability to file their taxes easily. Of programs and technologies introduced in the current study, producers identified a financial program to be the most useful tool to aid in the sustainability of their operation.

Discussion

Focus Groups

Commercial beef cattle producer perceptions and attitudes were evaluated both before and after participation in a new breeding system, production record system, and a financial record system. Focus group findings were presented by meeting and by project topic.

Production

In terms of production, there were several main themes discussed over the course of two meetings. Increases in genetics was by far the most common and thoroughly discussed. Participants anticipated higher quality calves that would not only weigh more than their natural service sired counterparts, but that would be more uniform in their phenotype. Estrus synchronization and artificial insemination have been reported to create the opportunity for potential benefits including concentrating the calving season and increasing calf uniformity through increasing calf age and genetic potential (Lamb et al., 2006; Larson et al., 2006; Busch et al., 2007). The use of artificial insemination also allows producers the ability to incorporate superior genetics into their herds without having to purchase a bull of similar or equal quality (Lamb et al., 2009). In addition, participants were very interested in the ability to keep back better replacement heifers, that could then propagate their increased genetics. Artificial insemination allows producers the opportunity to select for traits available in proven sires. Artificial insemination also decreased the mean d to conception compared to females bred via natural service (Steichen et al., 2012). Concentration of the calving season, possible with use of ES and AI, may allow for more calves to be born earlier in the calving season (Rodgers et al., 2012). In addition, heifers that conceive during a synchronized period wean calves that are older and heavier at weaning time, compared with heifers that do not conceive during the synchronized period (Steichen et al., 2014).

In the current study, producer perceptions and anticipated results were similar to findings of the breeding program. Calves born from dams exposed to TAI were older with a greater proportion of calves being born in the first 21-d period of the calving season compared with calves born from dams exposed to natural service. Artificial insemination calves were also heavier at weaning compared with natural service calves. Based on previous research, results observed in the current study are similar for those observed on commercial herds, potentially making estrus synchronization and TAI beneficial for commercial cattlemen.

Project participants both anticipated and reported increased time and work associated implementing AI. This is in agreement with the National Animal Health Monitoring System (NAHMS) study stating that time and labor in addition to cost were the major reasons in which producer implementation of AI was low (NAHMS, 2009). Although work involved with AI was determined to be increased compared to natural service, producers were not deterred and stated that the process went well. The estrus synchronization protocol utilized in the current study required cattle to work three times in a 10-d period; to insert the CIDR device and give GnRH, to remove the CIDR device and give $PGF_{2\alpha}$, and finally to time-breed females and give GnRH. With increased management, labor, and time associated with implementing AI and ES combined with a large percentage of cattle being raised on a range type environment, producers may not see the economic value in such technology (Odde, 1990).

Performance

The most discussed topic among participants in terms of performance was the idea of producers each having their own system for record keeping or not keeping many records at all. Current record systems were described as hand-written books as well as computer programs such as Excel and CHAPS. A national survey reported that hand-written records were present on nearly 80 percent of operations while on-farm computer programs were present on roughly 15-20 percent of operations (APHIS, 2011). While nearly all producers collect some form of data, the same national survey reported that only 66.1 percent of operation, representing 79.1 percent of cows, have individual cow identification of some kind (APHIS, 2011). While all producers enrolled in the study had individual identification for each female, record keeping style and the information collected varied among operations. The CHAPS program, utilized in the current study, is a management tool in which information can be collected, stored, and evaluated for benchmarking and herd performance purposes (Ramsay et al., 2016). While not all data collected on each operation while using the program would be identical, a similar format could be used.

Research participants described the program as time consuming and intensive. Ramsay et al. (2016) reports that pregnancy rate, pregnancy loss, calving percentage, death loss, weaning rate, calving distribution, and an assortment of other markers are all evaluated with the CHAPS program. While more intensive and therefore more time consuming than the common records collected on-farm, if the information is utilized by producers, production decisions could be made. In the current study, the producer uses of the final CHAPS book, a product that evaluates each herd, was minimal or nonexistent.

Producers discussed the ability of the CHAPS program to increase the involvement of others in their ranch operations. While many producers have children or family members interested in becoming more involved or one d taking over the operation, the idea of a more computer based program was of interest to many. The younger generation has long been thought of as the computer generation, however, older adults are a growing internet group (Chung et al., 2010). The baby boomers are now browsing the internet for health information, to make online purchases, and to obtain religious information (Chung et al., 2010). Producer perceptions of the CHAPS program were more positive with the second meeting, while still citing that the program is time consuming, now understanding the use of such a program. Increased use of programs on the computer by those other than the younger generations may help to elucidate the increased acceptance of a computerized record keeping system. It is important to note that with the CHAPS program, a computerized program is not the only use but producers can also send in records or data for cows and calves without sitting in front of a computer at all. While the idea of computers is growing on the older generations, the younger generations are still very likely to use such programs as they can aid in decision making and community development (Valaitis, 2005). A North Dakota survey reported that 90.6 percent of producers use cell phones, 63.3 percent use email, 43.6 percent use email or the internet via a cell phone, and only 25.1 percent of producers use any form of social media (Dahlen et al., 2014).

Profit

When evaluating the management of an enterprise, financial management was an area of great importance with a higher ranking correlated to the more acreage farmed (Dobbins and Robbins, 1983). The profit component of the current study included themes such as the quality of the overall program and the quality of the instructors involved. Although the program was time consuming with regard to entering data and information, the producers felt that they were able to understand their financials by individualizing information and setting personal goals. The ability for producers to actively make changes to their financial record keeping is similar to results observed in a financial educational program, where participants sought financial advice after training (Osteen et al., 2007). During the final meeting, producers determined that the financial management program was of great importance to them.

Quality of Life

The term quality of life refers to the life conditions, social surroundings, physical conditions, and resources of an individual (Cella and Nowinski, 2002). Bogousskavsky et al., (1998) describes quality of life as social assimilation, economic self-sufficiency, physical independence and mobility, and the occupation of social time. Evaluation of the quality of life of producers was done to determine if participation in the current study would have any influence. During the first meeting, the focus group were asked to identify factors that influenced their quality of life. Table 5.1. includes some of the factors mentioned by the participating producers in the current study. For the purpose of the current study, producers determined that time spent with family was the most important factor when evaluating their quality of life. In addition, producers identified a sense of pride they received when looking out into their cow herd. While time was mentioned in terms of increased time with family and friends working cattle, with the addition of the AI breeding system, time for recreational activities (i.e. boating) would be negatively affected.

Table 5.1. Factors affecting beef cattle producer quality of life[1]

The amount of time spent with family
The amount of time spent with friends
The amount of time spent on recreation
Lifestyle, control over how you time is scheduled
Lifestyle, ability to be your own boss
Financial stability

[1] Items determined to be important by producers during the first meeting.

When evaluating the factors that affect producer quality of life, there is not a clear path from breeding system of origin to quality of life, however, there are a series of connections (Figure 5.1.). It is unknown whether or not something in each producer's life led them to be a part of the current study, yet each participated in both natural service and AI breeding systems. After participating in the breeding systems, producers mentioned an increase in time, income, and herd quality. While not directly related to factors stated to affect quality of life, increases in income would allow for more free time, recreational vacations, and their preferred lifestyles. In addition, the increased cattle work, while taking time away from other tasks, led to more time spent with family and friends. Lastly, with increases in genetic value of calves with the use of AI sire semen, producers will have the ability to be prideful in their herd.

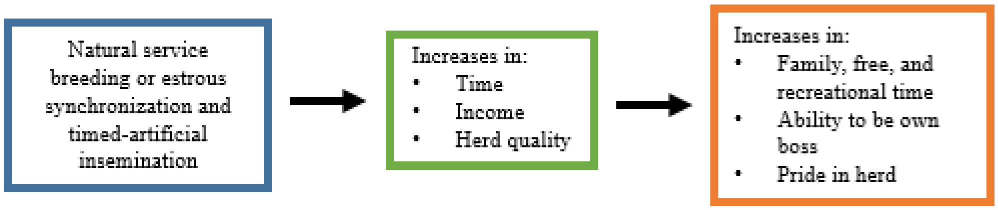

Figure 5.1. Diagram depicting the path of influence and the factors that affect quality of life relative to natural service and AI breeding systems.

Implications

Commercial beef producers from the state of North Dakota participated in on-farm research in which each herd was bred utilizing a new breeding system, either natural service or AI. Implementation of the different breeding systems included a great deal of on-farm research, participated in by researchers, producers, and extension agents. In addition, each producer was enrolled in a record management program and a financial record keeping program.

Producers

Overall, producers seemed to enjoy participating in the current study. Each seemed to learn something about their herds as well as more about the techniques and technologies being applied. Even in times of certainty with regards to the management of their herds, producers were still able to increase the knowledge and understanding about the factors that affect their production, performance, and profitability.

Future Research

Although animal science researchers are constantly striving to answer questions with an overall goal of increasing efficiency, profitability, and performance of various species, implementation of applied research is not always readily accepted by those in production agriculture. This has been the case with estrus synchronization and AI. With the use of on-farm research, those in production agriculture are able to implement various technologies or advancements first hand with someone there to aid in the process.

During the current study, participants included more than just the producer, extension agent, and the researchers. Family, friends, and neighbors also came to participate and learn. With this in mind, the ideas learned during the course of the study were further disseminated by those involved to reach a wider audience. The notion of disseminating information and allowing those influenced by others to make informed decisions is known as the cascade effect. Producers, family, friends, and neighbors participating in the breeding, record keeping, or financial programs of the current study have the ability to disseminate information based on their experiences and directly influence others to then decide on a particular action, implementation or no implementation.

On-farm research can be a powerful tool in terms of dissemination of results and ideas. Not only are those completing the research growing their social and career network, but allowing for real world application of ideas can lead to increased or decreased implementation based on results.

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CHAPTER 6. EFFECTS OF PRE-BREEDING ADMINISTRATION OF INJECTABLE TRACE MINERAL SUPPLEMENTS ON SUBSEQUENT REPRODUCTIVE PERFORMANCE IN BEEF HERDS

Abstract

Objectives of this study were to evaluate the effects of an injectable trace mineral supplement administered prior to breeding on reproductive parameters including pregnancy rates, calving distribution, and calf weaning weights. One thousand three hundred eleven commercial beef cows originating from four herds in North Dakota were stratified within herd by DPP, then randomly assigned to receive one of two treatments: 1) Cows received no additional treatments prior to bull turnout (**CON**; n = 638) or 2) Cows were administered an injectable trace mineral supplement (60, 10 and 15 milligrams per milliliter (mg/mL) of zinc, manganese and copper as disodium EDTA chelates, and 5 mg/mL of selenium as sodium selenite) subcutaneously 30 d before bull turnout (**ITM**; n = 673). On the d of mineral administration, blood samples were collected from a random sample of females (n = 37; 8 to 10 females per herd) immediately prior to mineral injection via jugular venipuncture in 10-mL Vacutainer tubes (BD Worldwide, Franklin Lakes, N.J.) and were analyzed for baseline mineral status. Total mixed rations were collected for the animals still in confinement prior to pasture/bull turnout and water samples were collected from all available water sources for each herd. Herd bulls were turned out to a common pasture and remained there for the duration of the producer-defined breeding season. The presence of a viable fetus was determined at least 45 d after the conclusion of the breeding season. At parturition, birth date was recorded. A similar ($P = 0.36$) proportion of cows became pregnant by the end of the breeding season for cows in the CON (92.9%) and ITM (92.0%) treatments. Weaning weights of calves on the side of cows receiving treatments also

were similar (P = 0.90). At calving, mean calving date was not different (P = 0.99) for those calves born from ITM cows or control cows. When evaluating the distribution of calves born in the calving season by 21-d increments, the proportion of calves born in the first 21, 22 to 42, or more than 42 d of the calving season were similar (P = 0.40) between groups. When an injectable trace mineral supplement was administered to commercial beef cows 30 d prior to breeding, no influence on pregnancy, weaning weight, or calf distribution was observed.

Introduction

Reproductive performance and superior overall herd health are vital to a successful and profitable cow herd. Deficiencies of trace minerals can lead to anemia, immune suppression, reduced ovulation, irregular estrous cycles, fetal malformations, and abortions, as trace minerals are vital to fetal development and nutrient transfer (Hostetler et al., 2003). Increased reproductive failure and herd death loss could result in decreased profitability for cattle producers.

The foundation of grazing beef cattle diets consists of roughly 85% forage, however not all nutrients can be obtained from forage alone (Greene, 2000). The National Research Council (NRC) has established requirements for successful animal production, based on ongoing research, for most minerals thought to be essential in beef cattle diets. If not found in feedstuffs, minerals should be supplemented to influence immunity, reproduction, and weight gain (Lalman and McMurphy, 2004). Mineral composition of forages, types of supplementation and individual animal intake of mineral supplementation are highly variable. Additionally, palatability, individual requirements, mineral content of available water sources, and season of year are all factors that must be considered when evaluating the consumption of mineral supplements as each is a factor affecting intake of minerals (McDowell, 1996).

Injectable trace mineral products are currently available and may be used for a more targeted supplement delivery. Injectable mineral products are, however, not blanket nutrients or broad spectrum, but contain only a few trace minerals: copper, manganese, selenium, and zinc. The label of injectable trace mineral products explicitly states that they are NOT a mineral replacement product and that other sources of mineral should be available to cattle. Injectable mineral supplements currently available are labeled as a source of zinc, manganese, selenium, and copper to be administered four weeks before calving **and** four weeks before breeding in beef cows (Multimin 90, USA). Particular minerals involved in reproductive performance and growth include but are not limited to copper, manganese, selenium and zinc (Hostetler et al., 2003). Copper is required for red blood cell formation and regulation, manganese for fetal bone formation, and selenium and zinc are required for protection from free radicals and involved in muscle generation (Hostetler et al., 2003).

Injectable supplementation advantages include the targeted delivery of known trace mineral elements. When growing heifers were administered half of the manufacturers recommended dose of trace mineral supplement, at three different time points, no differences were observed in age at puberty or attainment of pregnancy (Arthington et al., 2014). In contrast, when trace mineral injections were administered 30 d before calving and 30 d before breeding with the addition of an artificial insemination (AI) breeding system, a greater proportion of those females receiving the injectable supplement became pregnant to AI compared with cows not receiving injectable supplement (60.2 percent and 51.2 percent, respectively; Mundell et al., 2012).

To date, few studies have evaluated the use of injectable mineral supplements administered before breeding while utilizing a natural service breeding system on commercial beef operations. Data currently available regarding injectable trace mineral supplements are conflicting with regards to their effect on pregnancy attainment, weaning weights and calving distribution. Therefore, the objective of this study was to evaluate blood mineral levels before treatment administration on a subset of cows as well as evaluate the effects of injectable trace mineral supplements administered 30 d before the start of the breeding season on pregnancy rates, calf weaning weights, and calving distributions.

Materials and Methods

All cattle were managed according to the Federation of Animal Science Guide for the Care and Use of Agricultural Animals in Agriculture Research and Teaching (FASS, 1999). All procedures were reviewed and approved by the Institutional Animal Care and Use Committee of North Dakota State University.

Treatments and Sampling

Four North Dakota State University extension agents from varying geographical locations throughout the state of North Dakota were recruited to identify a commercial beef producer in their area for participation in this experiment. Selection of producers was based on a history of good record keeping and commitment to all phases of the proposed research. Expectations of cooperating producers included assisting with data collection and record keeping for their operation. Each herd (1-4) was managed individually and management decisions were made by each producer.

One thousand, three hundred and eleven postpartum beef cows (Herd 1: n = 146; Herd 2: n = 501; Herd 3: n = 460, and Herd 4: n = 204) were stratified within herd by d postpartum, then randomly assigned to receive one of two treatments: 1) Cows received no additional treatments prior to bull turn out (**CON**; n = 638); or 2) Cows were administered 6 mL of an injectable trace mineral supplement (60, 10, and 15 mg/mL of zinc, manganese, and copper, as disodium EDTA chelates, and 5 mg/mL of selenium as sodium selenite) subcutaneously on d -30 relative to bull turn out (**ITM**; n = 673).

On d -30 relative to bull turnout, blood samples were collected from a subset of eight to 10 cows within each herd. Blood was collected via jugular venipuncture in 10-mL Vacutainer tubes (BD Worldwide, Franklin Lakes, NJ) for analysis of baseline mineral status. Blood samples were immediately placed on ice and allowed to clot for a minimum of 12 hrs. Blood samples were then centrifuged 1,200 x g for 20 min with plasma collected and stored at -20°C in a commercial freezer. Blood samples were analyzed for concentrations of cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), Molybdenum (Mo), selenium (Se), and zinc (Zn; Table 6.1.) via inductively coupled plasma-mass spectrometry (ICP-MS) by Michigan State University Diagnostic Center for Population and Animal Health (MSU-DCPAH; East Lancing, MI). Plasma samples were diluted 20-fold with a 0.05% EDTA and Triton X-100, 1% ammonium hydroxide, 2% propanol and 20 ppb of scandium, rhodium, indium and bismuth solution (Wahlen et al., 2005). Concentrations of minerals were calibrated using a 4-point linear curve from the analyte-internal standard response ratio. The lowest identifiable concentrations for each mineral was 0.1 ug/mL for copper and zinc, 0.5 ng/mL for manganese, and 0.1 ng/mL for cobalt, molybdenum, and selenium. Plasma concentrations of iron were analyzed using an Olympus iron kit, utilizing TPTZ [2,4,6-Tri-(2-pyridyl)-5-triazine] as the chromogen.

Samples of total mixed rations were collected and placed in bags for herds 3 and 4 while supplemented hay samples were collected for herd 1, representing the animals still in confinement prior to pasture/bull turn out. Feed samples were collected and dried overnight in a 100 degree °C oven, and samples were sent to MSU-DCPAH for analysis via ICP-MS. The control diet utilized was the NIST[3] Typical Diet. Feed sample results are listed in Table 6.1. Water samples were also collected from any and all available water sources for each herd, chilled, and also sent to the MSU-DCPAH for analysis via ICP-MS. Water sample results are illustrated in Table 6.2.

Table 6.1. Mineral composition of feed samples[1]

Mineral	Mineral Requirements[2]	Rec. Maximum Levels[3]	Herd[4] 1	Herd[4] 3	Herd[4] 4
Aluminum	-	-	51.5	681.8	824.4
Antimony	-	-	< 5.0	< 5.0	< 5.0
Arsenic	-	-	< 2.5	< 2.5	< 2.5
Barium	-	-	32.4	35.2	42.2
Boron	-	-	5.7	14.5	9.5
Cadmium	-	-	< 0.3	< 0.3	< 0.3
Calcium	-	-	3436	14.5	3794
Chromium	-	1,000.00	< 1.0	4.9	1.4
Cobalt	0.15	25.00	< 0.50	0.53	< 0.50
Copper	10.00	40.00	4.2	20.5	6.1
Iron	50.00	500.00	225	965	917
Lead	-	-	< 2.5	< 2.5	< 2.5
Magnesium	1,200-2,000	4,000	1583	3167	2276
Manganese	40.00	1,000.00	63.1	134.9	71.5
Mercury	-	-	< 10.0	< 10.0	< 10.0
Molybdenum	-	5.0	3	< 1.0	1
Phosphorus	-	-	1928	2747	1685
Potassium	600-700	20,000	22714	12684	16051
Selenium[5]	0.10	5.00	< 10.0	< 10.0	< 10.0
Sodium	600-1,000	-	< 50	787	463
Sulfur	1,500	3,000-5,000	1095	2210	1568
Thallium	-	-	< 12.5	< 12.5	< 12.5
Zinc	30.00	500.00	10.5	53.2	20.7

[1]Mineral results are reported as ppm
[2, 3]Adapted from National Research Council (NRC). Nutrient requirements of beef cattle. 8th (revised) edition. Washington, DC. National Academy Press. 2016. p. 110.
[4]Herds 1, 3, and 4 are represented. Herd 2 cattle were on grass pasture at least 1 month prior to treatment administration.
[5]Labrotory sensitivity not adequate to detect differences in feed samples

Table 6.2. Mineral composition of water samples[1]

		Herd			
Mineral	Rec. Maximum Levels[2]	1a	2a	3	4
Aluminum	< 5.0	< 0.05	0.31	0.53	< 0.25
Antimony	-	< 0.006	< 0.25	< 0.25	< 0.25
Arsenic	< 0.05-0.2	< 0.10	< 0.25	< 0.25	< 0.25
Barium	< 1.0	< 2.0	0.098	0.356	< 0.025
Boron	< 5.0-3.0	.	0.33	0.06	0.36
Cadmium	< 0.05	< 0.005	< 0.025	< 0.025	< 0.025
Calcium	< 1,000	.	73.34	131.08	68.49
Chromium	< 0.1	< 0.10	< 0.05	< 0.05	< 0.05
Cobalt	< 0.1	.	< 0.025	< 0.025	< 0.025
Copper	< 0.5	< 1.3	< 0.025	0.031	< 0.025
Iron	< 0.4	< 0.30	0.425	1.404	3.429
Lead	< 0.05-0.1	< 0.015	< 0.10	< 0.10	< 0.10
Magnesium	< 90-250	.	49.072	36.457	30.109
Manganese	< 0.05	< 0.068	0.142	0.716	0.051
Mercury	< 0.003-0.01	< 0.002	< 0.50	< 0.50	< 0.50
Molybdenum	< 0.06	.	< 0.10	< 0.10	< 0.10
Phosphorus	< 0.7	< 10.0	< 0.64	< 0.50	< 0.50
Potassium	< 20	.	17.2	4.8	8.7
Selenium[3]	< 0.01-0.05	< 0.050	< 0.50	< 0.50	< 0.50
Sodium	< 150-800	58.32	470.1	16.0	628.8
Sulfur	< 500	< 250.0	253.0	78.4	271.2
Thallium	0.002	< 0.002	< 0.50	< 0.50	< 0.50
Zinc	< 5.0-25	< 5.0	0.086	0.29	0.091

[1]Mineral results are reported as mg/kg.
[2]Recommended maximum levels based on water quality- MSU-DCPAH.
[3]Labrotory sensitivity not adequate to detect differences in water samples.

Within herd, cows from each respective treatment were comingled on pasture. Natural service bulls were turned out to all cows 30 d after treatment administration and remained with cows for the duration of the producer defined breeding season. Transrectal ultrasonography or rectal palpation was used to determine the presence of a viable fetus at least 30 d after the end of the breeding season by a herd veterinarian. Calf weaning weights were collected at the time of weaning for the year of administration [year 1; weaning weights of suckling calves (WWS)] to determine if any effects of injectable trace mineral supplementation administered to the cow pre-breeding affected the weight of the calf at her side.

From the time of pregnancy determination and weaning to calving, females were comingled and managed together on common pastures throughout the grazing season and throughout the wintering period. At the time of calving, birth date and calf sex were recorded. In the current study, the start of the calving season was defined as the date that the third calf was born for each producer operation to remove any early born outliers in the calving season. Calves were then categorized into one of three 21-d interval calving groups based their respective date of birth: born in the first 21 d of the calving season (≤ 21), born from d 22 to 42 (22-42), and born after d 42 of the calving season (≥ 42). If a female was determined to be pregnant at the end of the breeding season but failed to calve the calving group was referred to as “no calf”. The following fall season, weaning weights of calves conceived the year of administration were collected for each herd. These weights allow for the evaluation of whether pre-breeding administration of ITM had effects on calf performance that began pre-breeding, continued through gestation, and were detectable at weaning.

Herd Descriptions

Herd 1 was located in Stark county, ND and was comprised of 140 Angus and Simmental based crossbred cows. The average BCS for the herd was 4.6 with an average DPP of 71 d. At the time of treatment administration, cows were housed in a dry lot fed ad libitum grass hay. Bulls were turned into common pastures on June 18th, 2015. The first calf was born on March 22nd, 2016, and the last calf was born on May 19th, 2016.

Herd 2 was located in Mountrail county, ND and was comprised of 474 Angus based crossbred cows. The average BCS for the herd was 4.5 with an average DPP of 71 d. At the time of treatment administration, cows were housed in varying grazing pastures (6 in total) within a radius of 50 square miles. Bulls were turned into common pastures on June 10th, 2015. The first calf was born on February 21st, 2016, and the last calf was born on June 12th, 2016.

Herd 3 was located in Lisbon county, ND and was comprised of 434 Angus based crossbred cows. The average BCS for the herd was 4.8 with an average DPP of 64 d. At the time of treatment administration, cows were housed in a dry lot fed a TMR consisting of silage, corn, grass hay, and a vitamin and mineral premix. Bulls were turned into common pastures on June 14th, 2015. The first calf was born on March 15nd, 2016, and the last calf was born on June 19th, 2016.

Herd 4 was located in McKenzie county, ND and was comprised of 204 Angus based crossbred cows. The average BCS for the herd was 4.4 with an average DPP of 78 d. At the time of treatment administration, cows were housed in a dry lot fed TMR consisting of corn, grass hay, dried distillers grains and a vitamin and mineral premix. Bulls were turned into common pastures on June 20th, 2015. Calving information was only obtained on a portion of the herd. Due to the incomplete calving data, herd 4 will not be included in the following analysis, however, the first calf birth date of those recorded was March 14th, 2016, and the last calf was born on May 5th, 2016.

Statistical Analysis

The MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) was used to analyze all continuous data (blood serum mineral concentrations, calf birth date and calf weaning weights) and the GENMOD procedure was used to analyze binomial data (pregnancy rate and calving distribution). In order to evaluate blood serum mineral concentrations, models included: 1) the effect of treatment among herds for each mineral, and 2) the effect of treatment within individual herd. Multiple models were used to analyze pregnancy data including: 1) the effect of treatment and herd and the interaction between treatment and herd, and 2) the effects of BCS, DPP, and categorical BCS and DPP. Data for days postpartum (DPP) and body condition scores (BCS) were categorized to determine differences in groups of data. For DPP, cows were ≤ 60, 61-70, 71-80 or > 80 based on the interval from calving to the bull turnout date. For BCS, categories used were < 4, 4, 5, or > 5 based on their cow condition at the time of treatment administration. For weaning weights, the model included herd and treatment and the interaction between herd and treatment. Lastly, models for mean calving date, and the proportions of cows calving in defined caving periods (≤ 21), 22-42, and ≥ 42) included herd, treatment, and the interaction. Means were separated using the LSMeans procedure of SAS and significance was declared at $P < 0.05$).

Results and Discussion

The current study was conducted to evaluate the effects of a single pre-breeding administration of an injectable trace mineral supplement on pregnancy rate and weaning weights in commercial beef herds. The injectable trace mineral supplement is labeled for 2 administrations; one at four weeks before calving and one at four weeks before breeding for beef cows. The treatment in the current experiment was administered at only one of the 2 recommended time points, 30 d before breeding. Prior to treatment administration, free-choice mineral was available for all cows or was included in a total mixed ration (TMR).

Blood Mineral Concentrations

At the time of treatment administration, blood samples were collected on a subset of females. No differences ($P = 0.128$) were observed in the blood mineral levels between females for Co, Cu, Fe, Mn, Mo, Se, or Zn. Cows in herd 3 had greater ($P = 0.01$) copper concentrations compared with all other herds. Mineral concentrations were similar for all other tested minerals within herd 3.

Variation of blood mineral levels did exist among herds for cobalt, copper, molybdenum, selenium, and zinc, whereas no herd differences were observed for iron and manganese (Table 6.4.). Concentrations of cobalt were greatest ($P < 0.01$) in herd 3, whereas both herds 3 and 4 had the lowest molybdenum concentrations. While copper levels were all within normal ranges for each herd, greater ($P < 0.01$) concentrations of copper were observed in herds 1 and 3 which also had the decreased molybdenum levels. Sulfur, copper, and molybdenum interactions have been established in many species. Sulfides have the ability to bind to copper to form insoluble copper sulfide (Suttle, 1991) as well as the ability to interact with molybdenum and form thiomolybdates, or insoluble complexes decreasing absorption (NRC, 2005). Increased molybdenum and sulfur in the diet of a ruminant can decrease the availability of copper and cause a deficiency (Suttle, 1991). High selenium concentrations were observed in each herd, however, in a national geochemical survey done by the U.S. Department of the Interior (2012), soil selenium levels in North Dakota ranged from 0.20 to 0.73 ppm. More specific to various areas of the Northern Great Plains (North Dakota region), a study was completed evaluating selenium concentrations in available forage that represented high, low, moderate, and unknown selenium levels (Pierre, SD, Fargo, ND, Jamestown, ND, and Miles City, MT, respectively; Lawler et al., 2000). Researchers observed a wide variation of available selenium in forage levels (Pierre: 4.07. Fargo: 1.20, Jamestown: 0.50, and Miles City, MT). Furthermore, researchers also evaluated available selenium based on time of year, dates corresponding with early spring growth (June) and high production (July). In Jamestown and Miles City, concentrations of available selenium in forage was less in June than in July (Lawler et al., 2000). While all reported serum levels in the current study are higher than the adequate range (determined by Michigan State University Diagnostic Center for Population and Animal Health) variation does in exist within the state of North Dakota. Lastly, zinc concentrations were all within normal limits for each herd, however herd 1 had the lowest ($P < 0.01$) concentrations. Although differences were not observed between treatments, as was anticipated relative to the timing of the sample collection, increased herd variation was observed. Herds were located in 4 different counties and all supplemented with varying feed, hay, and mineral supplements.

Table 6.3. Mean blood serum levels for each herd

Mineral	Normal Range[1]	Herd 1	Herd 2	Herd 3	Herd 4	SEM	P-value
Cobalt, ng/mL	> 0.1	0.19[a]	0.21[a]	0.79[b]	0.47[a]	0.06	0.04
Copper, ug/mL	0.6-0.8	0.61[a]	0.51[b]	0.67[a]	0.57[b]	0.04	0.03
Iron, ug/dL	110-180	124.50[a]	148.88[ab]	158.22[ab]	162.10[b]	13.22	0.05
Manganese, ng/mL	1.5-2.5	5.05	2.89	6.17	0.67	1.77	0.08
Molybdenum, ng/mL	4-100	23.32[b]	31.59[c]	6.52[a]	12.44[a]	2.13	0.05
Selenium, ng/mL	70-100	101.50[a]	127.00[b]	107.56[a]	125.00[b]	3.49	< 0.01
Zinc, ug/mL	0.9-2.0	0.73[a]	0.94[b]	0.93[b]	0.86[b]	0.04	0.03

[1]Normal ranges are based on MSU-DCPA. Levels are determined to be adequate if within listed ranges.

[2]Mineral levels represented for each herd are averaged values for each herd.

[a,b,c]Means differ within herd ($P < 0.05$).

Pregnancy

Treatment had no effect (*P* = 0.36) on the proportion of cows became pregnant by the end of the producer-defined breeding season (92.9% and 92.0 for control and ITM, respectively). There was also no treatment effect observed within herd in the proportion of cows that became pregnant within herd (*P* = 0.27; Figure 6.1.). Currently, published data on the effects of mineral supplementation on pregnancy rates is highly variable. Pregnancy rates observed in the current study are in agreement with other published studies (Vanegas et al., 2004; Mundell et al., 2012, Arthington et al., 2014), however, are in contrast to others (Mundell et al., 2012; Brasche et al., 2015). When evaluating the effects of mineral supplementation on pregnancy rates to AI, a greater proportion of those females receiving the injectable mineral supplement before calving and before breeding became pregnant to AI (60.2%), compared with to those not receiving injectable supplement (51.2%; Mundell et al., 2012). In contrast, proportions of females pregnant to AI were similar to those administered an injectable trace mineral supplement compared with control females (Vanegas et al., 2004; Brasche, 2015). When evaluating the effects of injectable trace mineral supplementation on season ending pregnancy rates, heifers receiving the injectable trace mineral supplement 30 d prior to breeding had greater season ending pregnancy rates compared to untreated controls, (season ending: 92.7% and 83.3%, respectively; Brasche et al., 2015). This is in contrast to Mundell et al., (2012) in which season ending pregnancy rates were similar for ITM and control treated females. When natural service breeding was the only breeding system used, similar proportions of heifers of reproductive age became pregnant for those administered an injectable trace mineral supplementation 30-d before breeding and control heifers (Arthington et al., 2014). Based on published results, it is important to note the differences in each studies observed results with regard to the time point and breeding system utilized. When natural service breeding was used on commercial beef cattle operations in the current experiment, no advantage was observed for cows injected with a trace mineral injectable supplement.

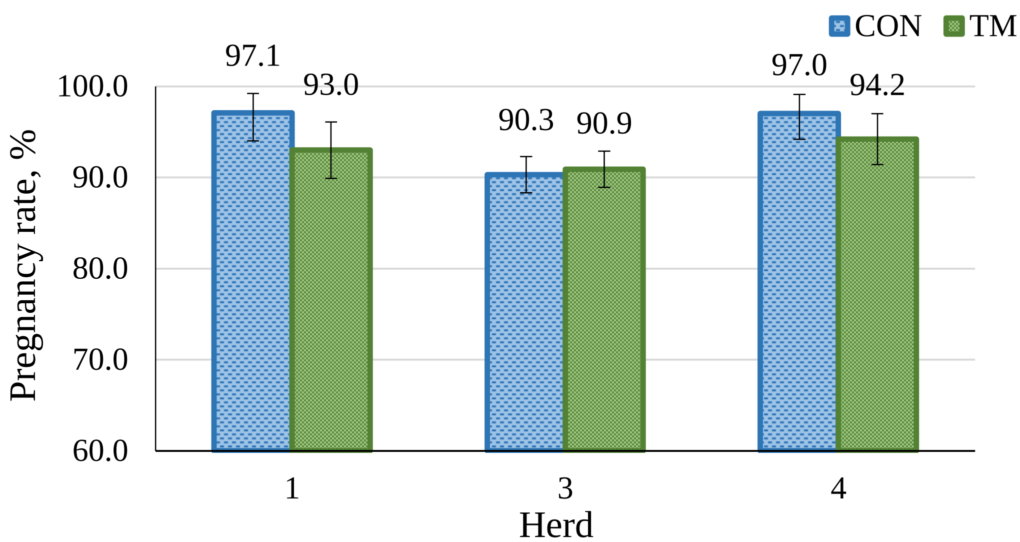

Figure 6.1. The proportion of cows that became pregnant during the producer defined breeding season. Treatments: CON = control, ITM = injectable trace mineral supplementation. Means differ within herd by treatment (P < 0.05).

Variable effect on pregnancy attainment among studies may be explained by the mineral need of each animal or herd. Each of the above mentioned studies was done using an injectable trace mineral supplement containing copper, manganese, selenium, and zinc. In a study involving free-choice mineral supplementation, Muehlenbein et al. (2001) reported that cows (n = 30 in each group) not supplemented with any type of free-choice copper had greater pregnancy rates in the first 30 d of the breeding season compared to those that were supplemented with free-choice inorganic mineral (86% and 57%, respectively) with organically supplemented cows being an intermediate (75 percent). The following year, a replicate study was completed with the same cow groups and treatments. After year two of the study, cows that were supplemented with organically bound copper had greater pregnancy rates in the first 30 d of the breeding season, when compared to those not supplemented with organically bound copper (85% and 61%, respectively), with inorganic mineral supplemented cows being an intermediate (80%; Muehlenbein et al., 2001). Differences in years were thought to be caused by copper status at the beginning of the treatment period, as year 2 liver concentrations of copper were reduced compared with year 1. Researchers hypothesized that the supplementation in the second year was more beneficial, potentially due to levels in year 1 being much lower (40 mg/kg and 58 mg/kg, respectively).

There was an effect ($P = 0.05$) of DPP on the attainment of pregnancy, which followed a predictable trend; a greater proportion of females with greater than 80 DPP became pregnant compared with females with fewer than 60 DPP (99% and 88%, respectively; Figure 6.2.). Females with greater than 60 DPP to 80 DPP were similar ($P = 0.10$) between treatments (61 to 70, 71 to 80). Cows calving earlier in the calving season have a longer postpartum interval time compared with cows calving later in the calving season. Earlier calving females have more time for uterine involution and the resumption of estrous cycles before a breeding event will occur, factors that affect postpartum infertility (Short et al., 1990). When BCS was included as a covariate as well as when it was included in categorical form, the proportion of cows that became pregnant in the breeding season was similar ($P = 0.46$).

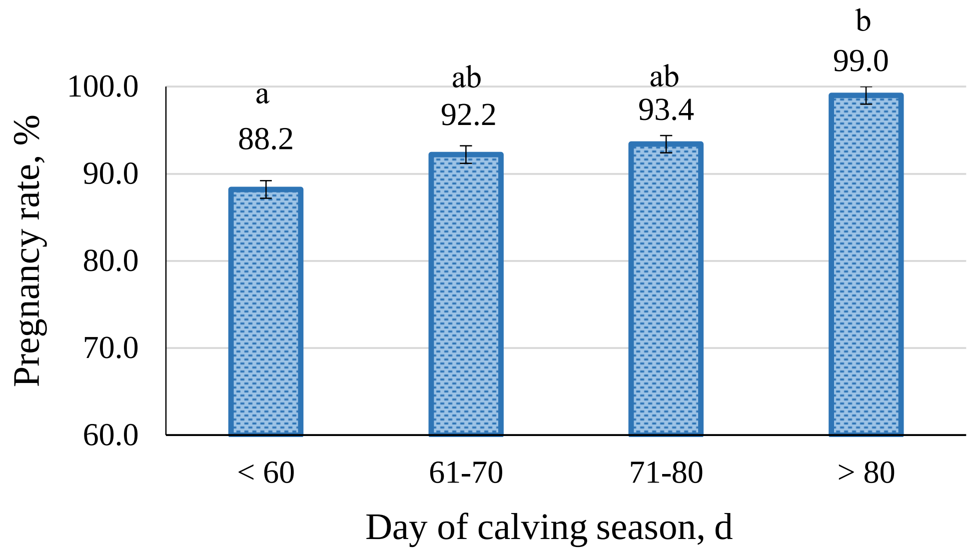

Figure 6.2. The proportion of cows that became pregnant when DPP was categorized.
[a,b]Means differ when bars lack a common superscript ($P < 0.05$).

Weaning Weights

Weaning weights of suckling calves were recorded to determine if the injectable trace mineral supplement may have had an effect on nutrition of the dam and, therefore, the weight of the calf at her side. Weights of calves from ITM dams were not different ($P = 0.90$) than of calves born from CON dams (283.1 ± 2.0 kg and 287.0 ± 2.1 kg, respectively). Calf were also not different within herd between the CON and ITM treatments ($P = 0.32$). The nutritional status and therefore body condition of a cow both at calving and postcalving are associated with milk production (Roche et al., 2009). Optimal BCS or the ability of a females to be in a positive energy balance may positively affect the milk produced and therefore the weight of the nursing calf (Roche et al., 2009). In contrast to the current study in which calf weights were collected, Mundell et al. (2012) observed no effect of trace mineral supplement on cow body weight and body condition 30 d before calving until weaning. In contrast, supplementing cows with high levels of inorganic mineral resulted in greater BW loss from March 13th to May 13th (the time after calving to before breeding) compared with supplementing high levels of organic mineral or low levels of inorganic minerals (Stanton, et al., 2000). It is important to understand the differences in supplementation of ITM at a single time period versus a fed mineral supplemented for roughly two months.

Calving Distribution

At parturition, calf birth date and sex were recorded. Mean calving date was not different ($P = 0.99$) for calves born from dams administered the injectable trace mineral supplementation, compared with calves born from CON dams (25.7 ± 0.75 d and 24.6 ± 0.72 d, respectively). In addition, no difference ($P > 0.40$) was observed in the distribution of calving when the calving season was divided into 21-d increments (Figure 6.3.). The same is true within individual herds, as no differences ($P = 0.28$) were observed between treatments for mean calving d or the proportion of cows calving in 21-d intervals. When overall calving date was observed between herds, two herds had similar ($P = 0.75$) calving date, while all others were not similar ($P < 0.01$; Figure 6.4.). In contrast to the current study, the proportion of calves born in the first 20 d of the calving season was greater for cows supplemented with an injectable trace mineral supplement 30 d before calving and 30 d before breeding compared with control or unsupplemented cows (60.2% and 51.2%, respectively; Mundell et al., 2012). In the current study, natural service breeding was used whereas in Mundell et al., (2012), artificial insemination was utilized. A benefit of breeding with artificial insemination is an increase in the proportion of cows calving early in the calving season (Rodgers et al., 2012; Steichen et al., 2013; Crosswhite et al., 2016). It is unclear if the trace mineral injectable supplement in the study by Mundell et al., (2012) caused an increase in the proportion of calves born earlier in the breeding season when compared to controls. When evaluating differences in results, it is important to recall that natural service breeding was using in the current study as well as only administering one of the recommended doses of ITM.

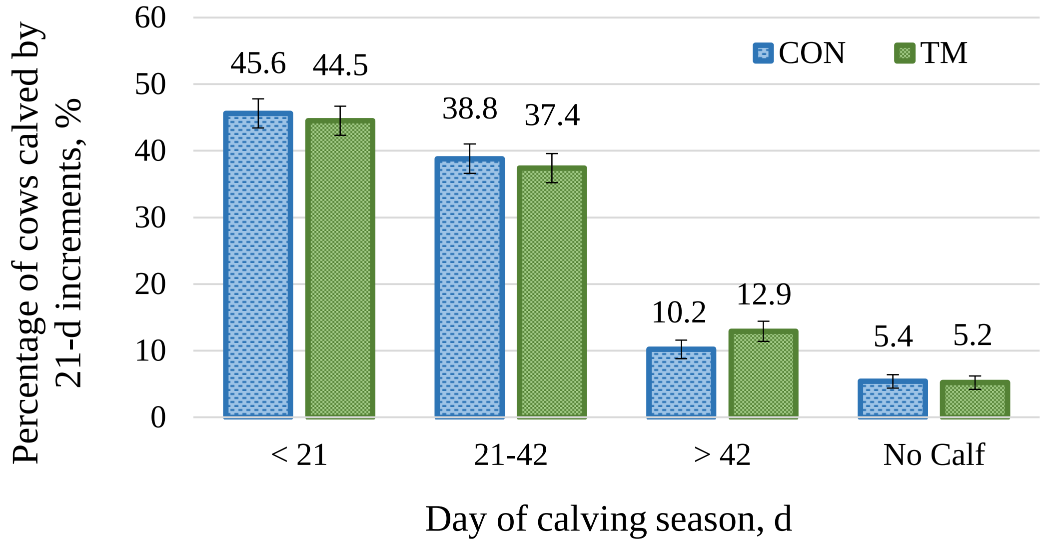

Figure 6.3. The proportion of cows calved by 21-d increments of the calving season between trace mineral treatments. Treatments: CON = control, ITM = injectable trace mineral supplementation.

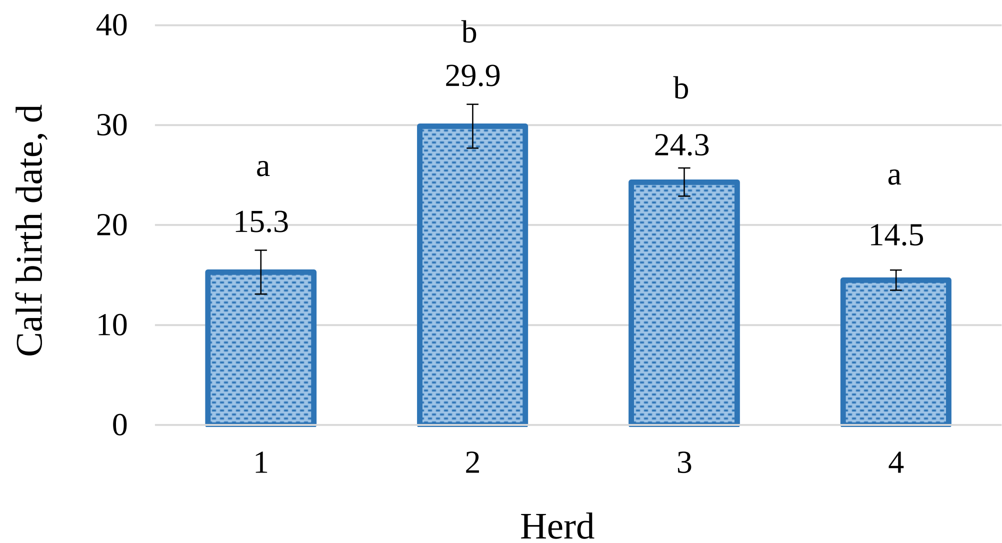

Figure 6.4. The mean calf birth date among herds. [a,b]Means differ ($P < 0.05$).

Implications

The incorporation of an injectable trace mineral supplement administered 30 d before bull turnout did not affect the proportion of cows that became pregnant in the breeding season on commercial operations, as well as calf weaning weights and the distribution of calving. It is important to note that only a single pre-breeding injection of the trace mineral product was administered compared with the label recommendation or two doses; one pre-calving and one pre-breeding. On many beef operations, producers only want to work cattle when it is absolutely necessary (i.e. vaccinations, breeding, weaning, and culling) as to decrease the stress of the animal. The use of a product labeled for 30 d before breeding could coincide with various management techniques currently being employed on producer operations like vaccinating, grass turnout, calf branding, or the use of reproductive technologies. The effect of the mineral supplement, however, was not evaluated when used before calving and the additional supplement may have additive effects that carry over to the time of breeding and result in greater pregnancy rates and attainment of pregnancy earlier in the breeding season.

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CHAPTER 7. OVERALL CONCLUSIONS

Reproductive performance and efficiency are vital components of any profitable cow-calf production system. Producers may be able to enhance profitability with the use of selected management strategies including the use of estrus synchronization and AI, record keeping and performance programs, and the inclusion of injectable trace mineral supplements. Selection of management strategies that fit individual operations will be key in terms of increasing profitability as well as decreasing stress of producers.

The use of estrus synchronization and AI create the opportunity to increase the mean age of calves by greater proportions of cows calving earlier in the calving season. At the time of weaning, calves are heavier when compared to calves born later in the calving season. When evaluating the use of estrus synchronization and AI on commercial beef operations in North Dakota, increases in profitability were observed when bull numbers were reduced. When utilizing AI, one must assume that some proportion of females will become pregnant, generally 40-70 percent in published studies, if all protocols are followed correctly. If this is fact the case, the number of bulls needed to breed an entire herd will not be necessary, therefore, allowing for a decrease in natural service clean-up herd sires.

In addition to a change in breeding systems, use of record keeping and whole farm financial management programs could increase the awareness of producers and the pleasure one finds in raising cattle. Although additional programs were thought to increase work load, overall perceptions of both programs turned from negative to positive after participation. It may be worthwhile for producers to be involved with programs that allow one to take a step back to evaluate whole operation records and financials.

Lastly, previous research has evaluated the use if injectable trace mineral supplements and their effect on reproduction of beef cattle. Benefits have been observed, from increasing to pregnancy rates to increasing the mineral concentrations found in liver tissue. Although the study included in this body of work does not show a benefit to using this type of product, it is important to note that administration was not given according to label recommendations. When evaluating the use of injectable trace mineral supplements on commercial operations in the state of North Dakota, it is not a management decision that readily increases the reproductive rates of cattle and therefore profitability.

APPENDIX A. EXPECTATIONS OF COOPERATING PRODUCERS

Expectations of Cooperating Producers for the 2012 NCR-SARE Research and Education Grant Proposal: Submitted by North Dakota State University

Evaluating the Sustainability of Beef Cattle Breeding Systems

1) Maintain Records:

Producers will collect, maintain, and provide project personnel with records of animal ID numbers, calving dates, weaning dates, animal sales, and feed produced and purchased. These records will be vital for the success of the project.

2) Commit to All Phases of Project for 2 Years:

Phase 1-*Production*: Cows at each location will be used to evaluate 2 breeding systems. Producers will provide facilities, cattle and labor assistance to accomplish the proposed research.

Phase 2- *Performance*: Producers will be enrolled in the Cow Herd Appraisal Performance System (CHAPS) for 2 years to evaluate and benchmark herd performance data. Reports from CHAPS and meetings with project staff detailing herd performance will give producers objective tools to aid in the optimization of herd management.

Phase 3- *Profit*: Producers will be enrolled in the Farm Business Management (FBM) program for 2 years. The FBM program will allow producers to evaluate the financial dynamics of their operations. Tracking income and expenses and sharing returns and overall profitability will allow other producers to weight the merits of each respective breeding system.

Year 1- Cattle will be bred in each of 2 breeding systems and calf weaning data will be collected. Year 1 allows producers to become comfortable with project personnel, collection of herd performance and financial data, and will serve as a baseline for comparing year 2 data.

Year 2- Calves from each breeding system will be born and weaned. *Production*, *Performance*, and *Profit* records obtained in year 2 will reflect 2 different breeding systems being in place on each operation.

3) Meet with Others and Share Your Story:

Meeting Attendance: Over the course of the project 4 meetings will be held for participating producers (Introductory, Mid-Point, Data Summary and Wrap-Up). Meetings will begin with surveys about attitudes toward and expectations of each breeding system. In addition, a test of knowledge regarding breeding systems will occur at each meeting.

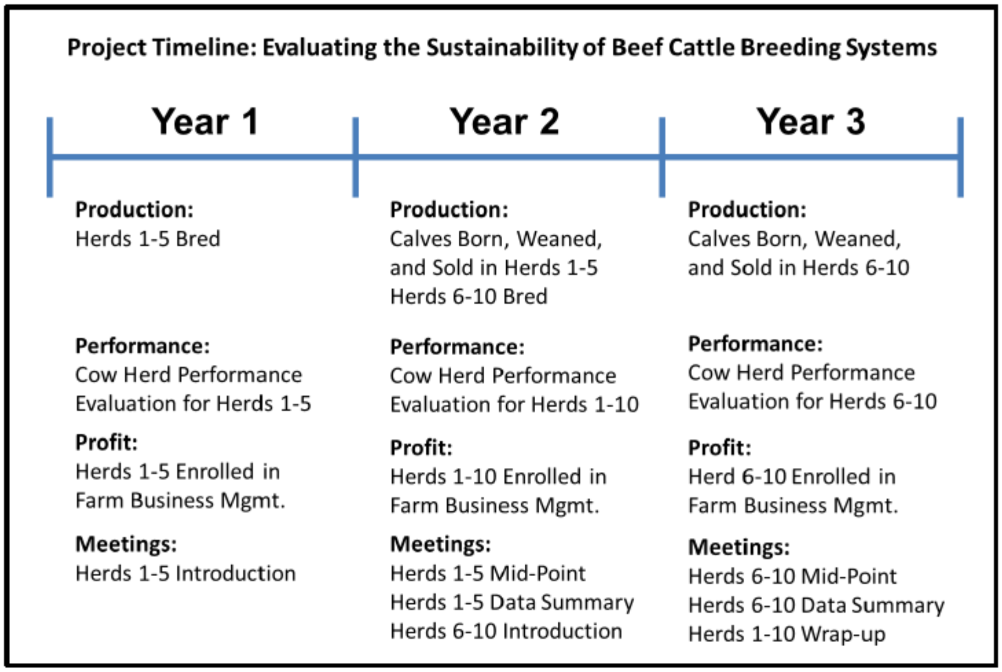
Sharing Your Story: Producers will have the opportunity to share their story by participating in a panel discussion held at the NDSU Beef College. In addition, producers will be invited to speak with other producers at meetings held by cooperating county Extension Agents.

Our goal in developing this project, evaluating the *Production*, *Performance*, and *Profit* of each breeding system, and sharing data and experiences with other producers is to evaluate the true ***sustainability*** of each breeding system!!

Expectations of Cooperating Producers for the 2012 NCR-SARE Research and Education Grant Proposal:
Submitted by North Dakota State University

Evaluating the Sustainability of Beef Cattle Breeding Systems

The following figure depicts the timeline of activity and the nature of producer involvement during each year of the proposed project:



APPENDIX B. SURVEY AND TEST OF KNOWLEDGE

<u>Meeting 1 and 2:</u> Pre-Meeting Survey for Cooperating Producers

Identifier: _______________

(Identifier = last 4 digits of childhood phone number)

1) Had you ever used artificial insemination (AI) on your operation before participating in this project?
   If yes, please describe the use (check all that apply):

   Heifers Only ☐ Cows Only ☐ Both ☐

2) Have you used artificial insemination (AI) on your operation since participating in this project?
   If yes, please describe the use (check all that apply):

   Heifers Only ☐ Cows Only ☐ Both ☐

3) Do you plan to use AI in the future?
   If yes, please describe the use (check all that apply):

   Heifers Only ☐ Cows Only ☐ Both ☐

4) Please rate your level of ***Knowledge and Understanding*** in each of the following areas:

	Very Low	Low	Moderate	High	Very High
	1	2	3	4	5
Management of your operation	☐	☐	☐	☐	☐
Natural service breeding systems	☐	☐	☐	☐	☐
Artificial insemination breeding systems	☐	☐	☐	☐	☐
Cow herd performance analysis	☐	☐	☐	☐	☐
Production economics	☐	☐	☐	☐	☐

5) Please rate your ***Skill and Ability*** to implement each of the following in your cow herd:

	Very Low	Low	Moderate	High	Very High

	1	2	3	4	5
Scheduling activities required for estrous synchronization and artificial insemination	☐	☐	☐	☐	☐
Performing tasks associated with AI (giving shots, inserting CIDRs, handling cattle, AI breeding)	☐	☐	☐	☐	☐
Cow Herd Appraisal Performance Software (CHAPS) performance records	☐	☐	☐	☐	☐
Farm Business Management financial records	☐	☐	☐	☐	☐

6) Please rate your ***level of satisfaction*** with each of the following:

	Very Dissatisfied 1	Dissatisfied 2	Not Satisfied or Dissatisfied 3	Satisfied 4	Very Satisfied 5
Overall management of your herd	☐	☐	☐	☐	☐
Steps taken to obtain additional knowledge/understanding	☐	☐	☐	☐	☐
Steps taken to improve skills and abilities in herd management	☐	☐	☐	☐	☐
Efforts to increase the sustainability of your operation	☐	☐	☐	☐	☐

7) What do you anticipate happened as a result of implementing artificial insemination on your operation? Indicate whether you think each item decreased, increased, or stayed the same (no change).

	Decrease	No Change	Increase
Overall pregnancy rate of your herd	☐	☐	☐
Length of your calving season	☐	☐	☐
Incidence of calving difficulty	☐	☐	☐
Proportion of calves born early in the calving season	☐	☐	☐
Weaning weight of calves weaned	☐	☐	☐
Genetic value of calves	☐	☐	☐
Sale price of calves sold	☐	☐	☐

8) What are your 3 largest concerns about the project and about implementing artificial insemination in your cow herd?

-

-

-

Multiple Choice Questions:

9) Which of the following has the ***<u>LEAST</u>*** influence on the number of cows a bull can get pregnant?
   - ☐ Age of the bull
   - ☐ Whether the bull passed a breeding soundness exam
   - ☐ High libido (sex drive) of the bull compared with moderate libido

10) Which of the following products causes ovulation (release of the egg from the follicle)?
   - ☐ GnRH (gonadotropin-releasing hormone; Cystorellin, Fertagyl, etc)
   - ☐ PGF (prostaglandin $F_{2\alpha}$; Lutalyse, Estrumate, etc)
   - ☐ Progestins (CIDR, MGA)

11) Which of the following products kills a mature Corpus Luteum (CL)?
   - ☐ GnRH (gonadotropin-releasing hormone; Cystorellin, Fertagyl, etc)

- ☐ PGF (prostaglandin $F_{2\alpha}$; Lutalyse, Estrumate, etc)
- ☐ Progestins (CIDR, MGA)

12) Which of the following products stops cattle from coming in to heat and can initiate estrous cycles in non-cyclic females?
    - ☐ GnRH (gonadotropin-releasing hormone; Cystorellin, Fertagyl, etc)
    - ☐ PGF (prostaglandin $F_{2\alpha}$; Lutalyse, Estrumate, etc)
    - ☐ Progestins (CIDR, MGA)

13) What does the term ***accuracy*** mean in relation to bull Expected Progeny Differences (EPDs)?
    - ☐ Degree to which bulls accurately identify cows in estrus
    - ☐ Amount of confidence you can place on EPD numbers
    - ☐ Whether numbers were typed accurately in the bull catalogs

14) Which of the following is closest to the average proportion of calves born in the first 21 days of the calving season?
    - ☐ 50%
    - ☐ 65%
    - ☐ 80%

15) What is the average proportion of calf death loss from calving to weaning?
    - ☐ 3%
    - ☐ 6%
    - ☐ 9%

16) Which of the following is ***not required*** to calculate pounds weaned per exposed female for this year's calf crop?
    - ☐ Number of cows turned out this breeding season
    - ☐ Number of calves weaned
    - ☐ Weight of calves weaned

17) Which of the following ***is not*** considered a direct expense?
    - ☐ Purchased protein supplements
    - ☐ Fuel and oil
    - ☐ Repairs
    - ☐ Hired labor

18) Which of the following are principles of sustainable agriculture?
    - ☐ Long-term profit

- Stewardship of land, air, and water
- Quality of life

THANK YOU FOR YOUR TIME!!!!!!

Meeting 3:

1. For each class of females please indicate past/future plans for AI use in your operation (Check all that apply):	**Heifers Only**	**Cows Only**	**Both**
Did you use AI before participating in this project	☐	☐	☐
Have you used AI since participating in this project	☐	☐	☐
Do you plan to use AI in the future	☐	☐	☐

2. Please rate your level of ***Knowledge and Understanding*** in each of the following areas:		Very Low	Low	Moderat e	High	Very High
Management of your operation	*Before participation*	☐	☐	☐	☐	☐
	Now, after participation	☐	☐	☐	☐	☐
Natural service breeding systems	*Before participation*	☐	☐	☐	☐	☐
	Now, after participation	☐	☐	☐	☐	☐
Artificial insemination breeding systems	*Before participation*	☐	☐	☐	☐	☐
	Now, after participation	☐	☐	☐	☐	☐
Cow herd performance analysis	*Before participation*	☐	☐	☐	☐	☐
	Now, after participation	☐	☐	☐	☐	☐
Production economics (Farm Business Management)	*Before participation*	☐	☐	☐	☐	☐
	Now, after participation	☐	☐	☐	☐	☐

3. Please rate your ***Skill and Ability*** to implement each of the following in your cow herd:		Very Low	Low	Moderate	High	Very High
Scheduling synchronization/AI activities	*Before Participation*	☐	☐	☐	☐	☐
	After Participation	☐	☐	☐	☐	☐
Performing synchronization/AI tasks (inserting CIDRs, AI breeding, etc.)	*Before Participation*	☐	☐	☐	☐	☐
	After Participation	☐	☐	☐	☐	☐
Cow Herd Appraisal Performance Software (CHAPS) performance records	*Before Participation*	☐	☐	☐	☐	☐
	After Participation	☐	☐	☐	☐	☐
Farm Business Management financial records	*Before Participation*	☐	☐	☐	☐	☐
	After Participation	☐	☐	☐	☐	☐

4. Please rate your ***level of satisfaction*** with each of the following:		Very Dissatisfied	Dissatisfied	Not Satisfied or Dissatisfied	Satisfied	Very Satisfied
Overall management of your herd	*Before Participation*	☐	☐	☐	☐	☐
	After Participation	☐	☐	☐	☐	☐
Steps taken to obtain additional knowledge/understanding	*Before Participation*	☐	☐	☐	☐	☐
	After Participation	☐	☐	☐	☐	☐
Steps taken to improve skills and abilities in herd management	*Before Participation*	☐	☐	☐	☐	☐
	After Participation	☐	☐	☐	☐	☐
Efforts to increase the sustainability of your operation	*Before Participation*	☐	☐	☐	☐	☐
	After Participation	☐	☐	☐	☐	☐

5. Please indicate whether you feel incorporating AI changed the value in each category below. Also, please provide an **estimated monetary ($$) value** for the contribution to your herd.	Decrease	No Change	Increase	Estimate
Genetic value of calves	☐	☐	☐	---
Sale price of calves sold, $ per calf	☐	☐	☐	$/calf
Value of heifer calves retained, $ per calf	☐	☐	☐	$/calf
Weaning weight of calves, lbs	☐	☐	☐	lbs.
Overall value of herd, whole herd $	☐	☐	☐	Total $ value

Please provide examples of areas in which the project changed the value of your herd.

____

____

____

6. After participating in the breeding project, did you share information or experiences from the project with others?	Yes ☐	No ☐

Please provide examples of what information was shared and who it was shared with.

____

____

____

7. Will you continue to participate in the Farm Business Management program?	Yes ☐	No ☐
Did you make any changes based on the information learned in the Farm Business Management program?	Yes ☐	No ☐

Please provide examples of changes made based on the FBM program.

____

____

8. Will you continue to participate in the CHAPS program?	Yes ☐	No ☐
Did you make any changes based on the information learned in the CHAPS program?	Yes ☐	No ☐

Please provide examples of changes made based on the CHAPS program.

____

____

9. Have you made changes to your operation that did not include breeding techniques or breeding management as a result of learning during the course of the project?	Yes ☐	No ☐

Please provide examples of areas in which you made changes to your operation (i.e. financial, farming, record keeping, time, etc).

____

____

____

10. Please provide a statement regarding your experience with the project and/or overall value of the program to your herd that you would be comfortable sharing with other producers.

____

____

____

____

APPENDIX C. INSTITUTIONAL REVIEW BOARD APPROVAL

NDSU NORTH DAKOTA STATE UNIVERSITY

Institutional Review Board
Office of the Vice President for Research, Creative Activities and Technology Transfer
NDSU Dept. 4000
1735 NDSU Research Park Drive
Research 1, P.O. Box 6050
Fargo, ND 58108-6050

701.231.8995
Fax 701.231.8098
Federalwide Assurance #FWA00002439
Expires April 24, 2011

Wednesday, March 06, 2013

Carl Dahlen
Animal Science

Re: IRB Certification of Exempt Human Subjects Research:
Protocol **#AG13171 , "Evaluating the Sustainability of Beef Cattle Breeding Systems"**

Co-investigator(s) and research team: **Gary Goreham, Mellissa Schook**

Certification Date: 3/6/2013 Expiration Date: 3/5/2016
Study site(s): **Minot, Bismarck, and Carrington**
Funding: **NCR-SARE, USDA NIFA**

The above referenced human subjects research project has been certified as exempt (category # 1) in accordance with federal regulations (Code of Federal Regulations, Title 45, Part 46, *Protection of Human Subjects*). This determination is based on IRB Materials (received 3/4/2013).

Please also note the following:

- If you wish to continue the research after the expiration, submit a request for recertification several weeks prior to the expiration.
- Conduct the study as described in the approved protocol. If you wish to make changes, obtain approval from the IRB prior to initiating, unless the changes are necessary to eliminate an immediate hazard to subjects.
- Notify the IRB promptly of any adverse events, complaints, or unanticipated problems involving risks to subjects or others related to this project.
- Report any significant new findings that may affect the risks and benefits to the participants and the IRB.
- Research records may be subject to a random or directed audit at any time to verify compliance with IRB standard operating procedures.

Thank you for your cooperation with NDSU IRB procedures. Best wishes for a successful study.

Sincerely,

Kristy Shirley

Kristy Shirley, CIP, Research Compliance Administrator

APPENDIX D. FOCUS GROUP QUESTION GUIDES

Meeting 1

"Evaluating the Sustainability of Beef Cattle Breeding Systems"
Producer Focus Groups- Meeting 1

1. As you look ahead to your participation in this project over the next two years, what are your expectations in terms of breeding system comparison results?

   Probes:

   a. What do you see as the challenges in implementing a new breeding system? How will you go about addressing these challenges?
   b. What do you anticipate will change in terms of calves born? Calving distribution?
   c. What do you anticipate in terms of the calf crop? Calves sold? Heifers retained?

2. As you look ahead to your participation in this project over the next two years, what are your expectations in terms of involvement with the Cow Herd Appraisal Performance System (CHAPS)?

   Probes:

   a. What do you see as a challenge for participating in the Cow Herd Appraisal Performance System (CHAPS)? Benefits?
   b. How will you go about addressing this challenge?

3. As you look ahead to your participation in this project over the next two years, what are your expectations in terms of the Farm Business Management program?

   Probes:

   a. What do you see as a challenge to participating in the Farm Business Management (FBN) for two years?
   b. How will you go about addressing this challenge?
   c. What do you anticipate regarding changes in variable input costs? Net income?

4. What factors come to mind when you think about having a good "Quality of Life?"

   Probes:

   a. Outside of work what areas of life do you prioritize and make time for?
   b. What do you wish you had more time for?
   c. How do you think and of these items could change by implementing a different breeding system in your herds?

Meeting 2

"Evaluating the Sustainability of Beef Cattle Breeding Systems"
Producer Focus Groups- Meeting 2

1) After participating in the first year of the project, were your expectations met in terms of PRODUCTION?

    <u>Probes:</u>

    a. How did the perceived work of implementing a new breeding system change/not change from previous expectations?
    b. Have the production steps taken up to this point made you more aware of how the different breeding systems implemented could contribute to sustainability on your ranch?

2) What are your expectations for YEAR TWO in terms of PRODUCTION?

    <u>Probes:</u>

    a. Do you anticipate easier calving or better use of available resources due to possible concentration of the calving season?
    b. Do you anticipate better phenotype in calves or heavier weaning weights of calves from the AI system?
    c. If the process could be changed for the better, what are some ways in which this could be facilitated?

3) After participating in the first year of the project, were your expectations met in terms of PERFORMANCE?

    <u>Probes:</u>

    a. What are some of the benefits you have seen with the Cow Heard Appraisal Performance System (CHAPS) program?
    b. What are some of the challenges you have seen with the CHAPS program?
    c. Has the CHAPS program made you more aware of how the different breeding systems implemented could contribute to sustainability on your ranch?

4) What are your expectations for YEAR TWO in terms of PERFORMANCE?

Probes:

a. Do you think multiple years of CHAPS data will help you better manage your herd? Are there any other benefits or challenges you anticipate?
b. How have you gone about addressing previous challenges? Future challenges?

5) After participating in the first year of the project, were your expectations met in terms of PROFIT?

Probes:

a. Has the Farm Business Management (FBM) program been beneficial/challenging?
b. How have you are you going to go about addressing the challenges?
c. Has the FBM program made you more aware of how the different breeding systems implemented could contribute to sustainability on your ranch?

6) What are your expectations for YEAR TWO in terms of PROFIT?

Probes:

a. Do you think multiple years of FBM data will help you gain perspective into the financial strengths and weaknesses of your operation? Are there any other benefits or challenges you anticipate?
b. What do you see as a challenge to participating in the FBM program for another year?

7) How has the change in breeding systems affected your QUALITY OF LIFE?

Meeting 3

"Evaluating the Sustainability of Beef Cattle Breeding Systems"
Producer Focus Groups- Meeting 3

1) What were your experiences with the PRODUCTION component of the project?

   <u>Probes:</u>

   a. What were your experiences during the calving season?
      1. Was the volume of calves born within a short window of time overwhelming?
      2. Was calving any different (more difficult, less difficult) than in previous years?
      3. Was the calving season condensed at all?

   b. Did you notice any differences in calves from a phenotype/visual appearance standpoint?
      1. Weaning weights of calves?
      2. Did you retain any heifers?
      3. What was the phenotypic and genetic perceived value?
      4. Did you sell your calves any differently (from a marketing standpoint)?

   c. Did the breeding systems impact the sustainability of your operation?
      1. In which ways has the breeding system impacted the sustainability of your operation?

2) What are your future plans in the PRODUCTION area?

   <u>Probes:</u>

   a. Did you use estrus synchronization or AI in the second year?
   b. Do you foresee any future AI/NS breeding system use?
      a. Cows? Heifers? Both?
      b. Timed-AI? Heat detection? A combination?

3) What were your experiences with the PERFORMANCE component of the project?

   <u>Probes:</u>

   a. What are some of the benefits that you have seen with the CHAPS program?

b. Has taking new/better (if applicable) records made any differences to the cow herd?
c. Has the CHAPS program aided in making management decisions?
    1. Breeding/culling?
    2. Targeted nutrition?
    3. Did you utilize the CHAPS data after receiving it (the year following project participation)?
        a. If so, how was it used?
d. Has the CHAPS program aided with use of other/different breeding programs?

4) What are your future plans in the PERFORMANCE area?

<u>Probes:</u>

a. Will you continue taking records to the extent that CHAPS recommends or will you revert to previous year's record taking?
    1. Birth weights, weaning weights, etc.

5) What were your experiences with the PROFIT component of the project?

<u>Probes:</u>

a. Did the FBM program allow you to see any differences between money saved/lost within the breeding systems?
b. What are some of the benefits you saw with the FBM program?
c. Did the FBM program allow you to make more/less changes within the herd (culling, purchasing, ect)?
d. Has the FBM program allowed you to see financial strengths or weaknesses within your operation?

6) What are your future plans in the PROFIT area?

<u>Probes:</u>

a. Will you continue keeping track of spending/purchasing to the extent that FBM recommends or will you revert to previous year's financials?
b. Have you continued to use the FBM program or a similar program since participating in the project?

7) Do you feel the project changed the SUSTAINABILITY of your herd for future years?

Probes:

a. Which aspects had the biggest impact?