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Profitability of bovine somatotropin administration to increase first insemination conception rate in seasonal dairy herds with heat stress

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ABSTRACT

A dairy farm simulation program was used to estimate the economic value of increased conception rate at first insemination (FCR) as a result of one administration of bovine somatotropin (BST) per lactation. Further, the economically optimal BST administration period in a year was investigated. Typical conditions in Florida were assumed, including reduced milk production and conception rates in the summer and early fall due to heat stress. Administration of a single dose of BST ($6 per dose) per lactation was incorporated into a timed AI protocol for first insemination at 61 days after calving. Increases in FCR of 0, 4, 8, and 12 percentage points (PP) were compared including changes in prices, fertility, and seasonality of cow performance. No direct effect of BST on milk production was assumed. With default inputs and an increase in FCR of 4 PP, the optimal administration period was February through June which resulted in a small gain in profitability of $0.80/slot/year. Typically, one administration of BST per lactation to increase FCR was profitable in the cooler winter and spring, but not the hotter season. The use of BST in the cooler winter and spring resulted in increased seasonality of herd performance and demographics. When no seasonality in milk production was assumed, administration of BST was profitable throughout the year when FCR increased at least 8 PP. In conclusion, increases in FCR were most profitable during the cooler season of the year when basic conception rates were already greater than in the hotter season.

1. Introduction

Dairy cattle fertility is greatly reduced during times of heat stress (Faust et al., 1988; Ray et al., 1992; Thompson et al., 1996; Wolfenson et al., 2000). Conception rates may drop from 40% in cool winter months to 10% in hot summer months (Cavestany et al., 1985). In general, reduced fertility is costly (Plaizier et al., 1997) and many efforts are undertaken to improve fertility during periods with heat stress.

Bovine somatotropin (BST) has been used to increase conception rates at first insemination (FCR) in lactating dairy cows, possibly in combination with a timed AI (estrous synchronization) protocol (TAI). Moreira et al. (2000, 2001) reported that a single dose of BST combined with TAI increased FCR from 22 to 38% in one experiment and 34 to 45% in another experiment. Furthermore, BST administration increases insulin-like growth factor 1 (IGF-1) (McGuire et al., 1992; Jousan and Hansen, 2007) which has additional benefits during the summer due to the thermoprotective actions of IGF-1 on embryo development (Jousan and Hansen, 2004, 2007). In a recent study, administration of BST prior to first insemination in the summer increased FCR numerically from 18 to 24% (Bell et al., 2008). The effect on milk production in that study was not known.

Seasonal differences in milk production and fertility may affect the profitability of increased FCR. An increase in FCR may be more valuable in one season of the year than another season. In one study, increased FCR through implementation of TAI was more profitable during the summer than winter (De La Sota et al., 1998; Risco et al., 1998). However, the value and most profitable BST administration period to increase FCR

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in seasonal herds due to periods of heat stress have not been evaluated. Studies of the effects of improved reproductive performance in seasonal herds are lacking.

The objective of this study was to estimate the profitability of a single dose of BST administration prior to first insemination in lactating dairy cows submitted to a TAI protocol. The second objective was to determine the most profitable season of the year to administer a single dose of BST when milk production and fertility were reduced during the summer as a result of heat stress. Effects of variations in heifer price, milk price, milk yield, fertility, and magnitude of seasonality of reproduction and milk production were studied as well. Administration of BST is a proxy for other methods such as improved insemination technique that may increase FCR. Therefore, the results of this study extend to other methods that increase FCR.

2. Materials and methods

2.1. Approach

The dynamic probabilistic computer simulation program DairyVIP (De Vries, 2006a,b) was used in this study. DairyVIP can be used to evaluate the effects of changes in cow performance, management strategies, such as various insemination policies, and prices on herd statistics such as profit/slot/year. DairyVIP calculates (optimal) voluntary replacement decisions for individual dairy cows with the objective to maximize profitability/slot. A slot is a place for a cow on a dairy farm. The program consists of three modules: 1) a bio-economic module to enter and calculate cow performance data and prices (inputs); 2) an optimization module based on dynamic programming to determine (optimal) future insemination and replacement decisions for individual cows; and 3) a herd performance module based on Markov chains to calculate summary results for subgroups of cows or for the entire herd. The program uses monthly time steps.

In the current study, the effect of a single BST administration prior to first insemination and increases in FCR in a herd using TAI was simulated. Bovine somatotropin was not used after first insemination in the same lactation. Results were calculated for a herd in steady state as determined by the herd performance module.

2.2. Default input values

Input values for the bio-economic module were chosen to represent a typical Holstein dairy herd in Florida such as used in the study of Bell et al. (2008). Typical Holstein dairy herds in Florida are large with hundreds to thousands of cows, use confinement housing with some level of cooling, but are still seasonal in reproductive performance and milk production due to the summer heat stress. Usually total mixed rations are fed. The use of estrus synchronization for first service is common. Inputs in the bio-economic module included body weights, labor needs and feed intake as described by De Vries (2006a). Other inputs are described as follows.

Average daily milk yield for non-pregnant cows was taken from lactation curves estimated from data from Southeast DHI for each calendar month of calving (De Vries, 2004). The lactation curves were adjusted to reflect a slightly greater

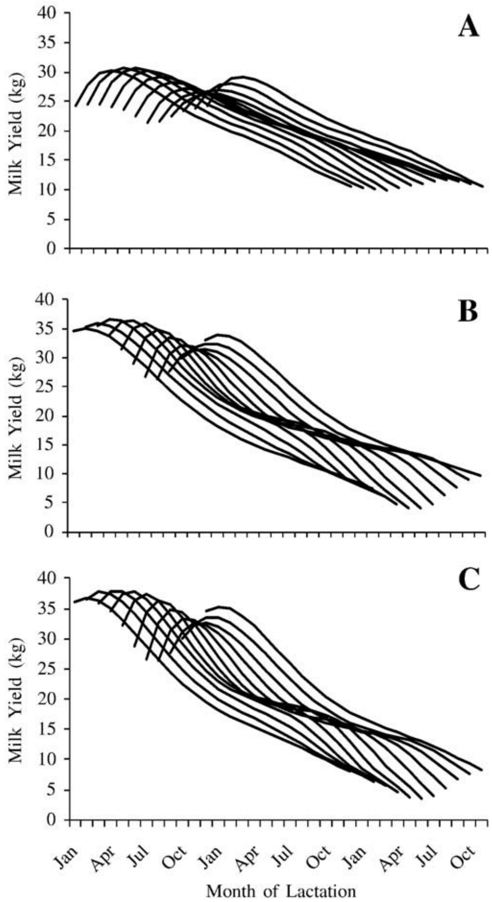

Fig. 1. Default lactation curves for up to 24 months by month of calving: (A) first lactation, (B) second lactation, (C) third and later lactations.

daily milk yield for a representative herd than the original data (Fig. 1). Cows calving in the summer and fall had lower peak milk yields and lower cumulative milk yields than cows calving during the cooler months of the year, and lactation curves were more persistent. For first lactation cows, the lowest daily peak milk yield was 26.3 kg for a heifer calving in September. Milk yield for the first 12 months was at 8702 kg also the lowest for heifers calving in September, provided the cow would remain in the herd for at least 12 months. The highest daily peak milk yield was 30.6 kg for a heifer calving in February (9816 kg in 12 months). For second lactation cows, cows calving in September had the lowest peak at 31.4 kg and the lowest 12-month milk yield at 9349 kg. Cows calving in March had the highest peak at 36.6 kg and the greatest cumulative milk yield in the first 12 months at 10,802 kg. Third lactation cows or later had a minimum daily peak of 32.5 kg when calving occurred in September. Such cows were expected to produce 9535 kg of milk in 12 months. These cows had a maximum daily peak of 37.8 kg when calving occurred in April. Cumulative milk yield in the first 12 months for such cows would be 10,900 kg if the cow remained in the herd. Cows were dry two months before calving. It was assumed that administration of a single dose of BST at first insemination did not affect milk production. This assumption allowed results to be easily extended for other methods that may increase FCR

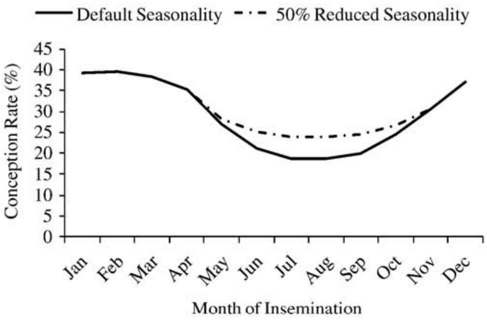

Fig. 2. Conception rate by month of insemination at the default level of seasonality and 50% reduction of seasonality in the hot season.

but not milk production. Examples of such methods are improved AI techniques, greater service sire conception rates, or synchronization programs that would improve FCR.

Cows were eligible for insemination starting at 61 days after calving until the end of the 15th month in lactation (day 456), unless the cow was culled earlier. The probability of insemination during the 21-d estrous cycle was 100% for the first insemination and 50% for all later inseminations (representative of a TAI protocol with good compliance of the administration of hormones and insemination). Conception rate peaked in February at 40% and reached its lowest value at 19% in July (Fig. 2) based on De Vries (2004). The average was 29%. Conception rate was not affected by lactation number or days after calving. All eligible cows received a single dose of BST prior to first insemination at 61 days in milk. Therefore, insemination decisions were not optimized. The total risk of abortion after the first month, if the cow was not culled, was 8.2% based on Santos et al. (2004a).

Voluntary replacement decisions were optimized, including the option to delay replacement of culled cows. The risk of involuntary culling per month and lactation was the same as described by De Vries (2006a). Culled cows were immediately replaced by purchased calving heifers. The supply of replacement heifers was assumed to be unlimited.

The default milk price was set to $0.35/kg. The replacement heifer price was set at $1600/heifer. Prices for culled cows were set at $0.90/kg of body weight. Fixed costs such as for real estate depreciation and management overhead were $1.25/slot/day. Other variable costs such as veterinary costs and parlor costs were $1.00/cow/day. Feed cost for dry cows was $0.15/kg dry matter intake and feed cost for lactating cows was $0.20/kg of dry matter. Labor cost was $9/h. Insemination cost was $15/insemination, including the cost of hormones for the TAI protocol. The cost of a dose of BST administration was $6. No additional labor cost as a result of the administration of BST was assumed because in practice administration occurred simultaneously with a scheduled injection of prostaglandin $F_{2\alpha}$ three days prior to insemination in the TAI protocol.

2.3. Experimental design

The analyses consisted of four steps. First, the default scenario was defined as a simulation with all of the default inputs but no BST administration. The results from the other scenarios were compared to the default results.

Second, inputs were changed one at a time and 10 other scenarios were created. The effects of changing inputs on the profit/slot/year were measured. The effect of milk price was evaluated at $0.26 and $0.44/kg. The effect of heifer price was evaluated at $1200 and $2000/heifer. Daily milk yield was increased or decreased by 10% from the default lactation curves. Conception rates during all stages of lactation were increased or decreased by 5 percentage points (PP) from the default conception rate for all eligible cows. A 50% reduction in seasonality of milk yield and fertility in the hot season was simulated by increasing milk yield and conception rates

Table 1
Default herd statistics and effects of changes in inputs without BST administration.

	Default	Heifer price		Milk price		Milk yield		Conception rate		Seasonality	
Herd statistics		$1200	$2000	$0.44/kg	$0.26/kg	Increase 10%	Decrease 10%	Increase 5 PP[a]	Decrease 5 PP	50%[b]	0%[c]
	($/slot/year)	(Δ $/slot/year from default)									
Milk sales	3114	77	−46	844	−832	323	−322	−1	2	30	183
Cow sales	124	58	−24	22	−21	7	−6	−8	13	−3	3
Calf sales	211	18	−7	7	−6	2	−1	5	−5	2	2
Total revenue	3449	154	−77	874	−859	333	−329	−4	10	28	488
Feed cost	1398	9	−5	5	−5	63	−62	−1	2	6	36
Breeding supply cost	41	0	0	0	0	0	0	−4	5	0	1
Heifer purchase cost	501	−2	47	61	−56	18	−17	−18	30	−9	9
Veterinary cost	81	5	−2	2	−2	1	0	2	−1	1	1
Variable labor cost	415	1	0	0	0	0	0	−2	2	−1	0
Variable other cost	365	0	0	0	0	0	0	0	0	0	0
Fixed other cost	456	0	0	−111	0	0	0	0	0	0	0
Total cost	3258	12	39	67	−64	81	−80	−25	37	−4	45
Total profit	192	142	−116	805	−796	251	−250	19	−28	31	142
Milk yield (kg)	8896	222	−130	99	−118	925	−918	−3	6	525	6
Calving interval (months)	13.1	−0.4	0.2	−0.1	0.2	−0.1	0.1	−0.3	0.3	0	0.3
Days to conception (days)	126	−10	5	−4	4	−2	1	−8	9	−1	9
Pregnancy rate (%)	19	1	0	0	0	0	0	4	−3	0	−3
Overall cull rate (%)	31	11	−4	4	−3	1	−1	−1	2	1	2

[a] Percentage point.
[b] 50% reduced seasonality of milk yield and 50% reduced seasonality of conception rate in the hot season.
[c] 0% seasonality of milk yield, 100% seasonality of conception rate.

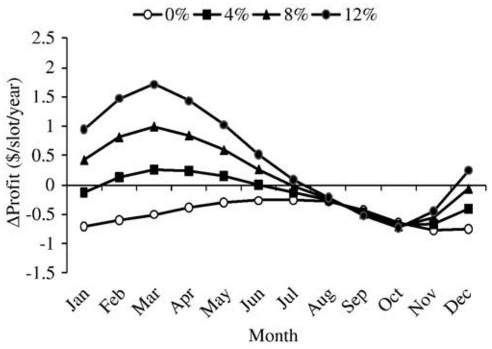

Fig. 3. Change in profit/slot/year by month of BST administration prior to first insemination at 0, 4, 8, and 12 percentage point increases in conception rate at first insemination compared to no BST administration for the default inputs.

during the summer months. Months within each lactation curve that had lower yields than the average had their yields increased by 50% of the difference between that month and the annual average. Similarly, for each month with a conception rate below the annual average, the conception rate was increased by 50% of the difference (Fig. 2). The annual average of the conception rate after the reduction in seasonality was 31%. The effect of seasonality of milk yield alone was evaluated by removing all seasonality from the lactation curves while maintaining the default seasonal pattern of conception rate.

Third, BST was administered during one single calendar month at a time in all scenarios and the effect on profit/slot/year was observed. The FCR was increased by 0, 4, 8, or 12 PP compared to the default FCR to simulate the possible effect of BST administration. The range from 0 to 12 PP was chosen because the effect of BST administration on FCS in clinical trials varied. Months in which there was a gain in profit/slot/year were identified. Collectively, these results would give an initial idea of the period of the year during which BST administration would be profitable.

Fourth, the calendar months in which BST administration was profitable were combined into extended administration periods. For example, if BST administration during the single months of April and May was profitable, BST administration during both months was simulated (a two-month extended administration period). The extended administration period was then changed by adding one month to, or removing one month from, the extended period and evaluating the change in profit/slot/year to ensure that the extended administration period was optimal. This scheme resulted in the combination of months in which BST administration prior to first insemination was profitable.

Finally, the scenario with BST administration and an 8 PP increase in FCR was compared to the default scenario without BST in more detail to gain insight in some underlying factors of changes in profitability. Specifically, factors examined included milk production, reproduction, and herd demographics.

3. Results

3.1. No BST administration

The default dairy farm had a total profit of $192/slot/year (Table 1). Total revenue was $3449 and total cost was $3258/slot/year. Other herd statistics included average milk yield of 8896 kg/slot/year, a calving interval of 13.1 months, 126 days to conception, a 19% pregnancy rate, and an overall annual cull rate of 31%. Culled cows were immediately replaced.

Simulation results of the 10 scenarios are shown in Table 1. In general, as total costs increased by increased heifer price, or total revenue was decreased by lower milk price and milk yield, profit decreased. For example, when heifer price was increased to $2000, there was a loss of $116/slot/day. When milk price was reduced to $0.26/kg, there was a loss of $796/slot/year. Greater conception rates throughout the lactation increased profit. Profitability increased when the degree of seasonality (both conception rate and milk yield) was reduced because cow performance during the summer was improved.

3.2. Single month BST administration

Fig. 3 shows the effects on profit/slot/year when FCR was increased one month at a time for the default inputs. When FCR did not change, BST administration decreased profitability in each month it was used due to the $6 cost per dose. The loss was the least in July because fewer cows were eligible for a first service than in other months.

Increased FCR of 4 PP resulted in gains when administered in Feburary through June. When FCR was increased by 12 PP, profit increased when administered in the months of January through July. The most profitable month to administer BST was March, but profit/slot/year was less than $2.00, even at a 12 PP increase in FCR. In general, greater increases in FCR

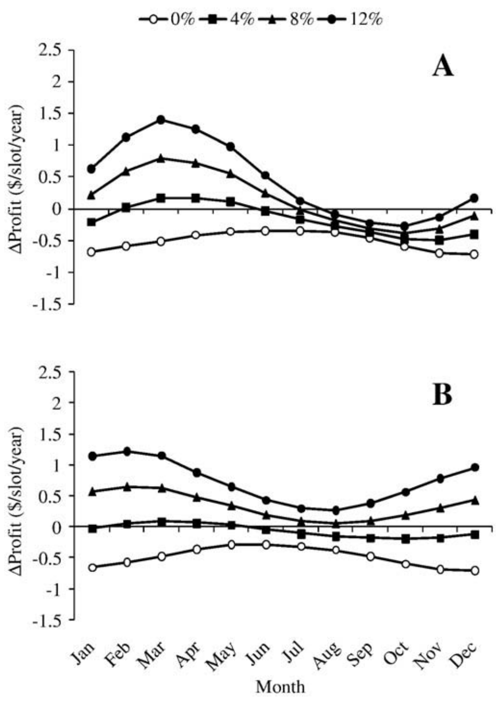

Fig. 4. Change in profit/slot/year by month of BST administration prior to first insemination at 0, 4, 8, and 12 percentage point increases in conception rate at first insemination compared to no BST administration and (A) 50% reduction in seasonality of milk yield and conception rate during the hot season, or (B) no seasonality of milk yield and default seasonality of conception rate.

resulted in longer periods when BST administration was profitable and greater gains in profitability.

When seasonality of milk yield and fertility were both reduced by 50% in the hot season, a 4 PP increase in FCR resulted in maximum gains when administered in the months of February through May (Fig. 4A). When FCR increased, profit increased and the number of profitable administration months increased. When seasonality of milk yield was eliminated, the effect of increased FCR was reduced (Fig. 4B). These results show the dramatic effect of seasonality in milk yield/cow/day on the profitability of an increase in FCR in seasonal herds that experience heat stress in the summer.

In general, the most profitable months of BST administration at first insemination were in the cooler winter and spring. Further, the months that resulted in a gain in profitability were sequential. Variations in heifer price, milk price, overall conception rate, milk yield, and reduced seasonality did not affect the way in which profit changed as a result of BST administration and increased FCR. Collectively, the profit gained or lost by BST administration during one month of the year changed only between −$1.50 (no increase in FCR) and $2.50/slot/year (12 PP increase in FCR) in all scenarios (not shown).

3.3. Optimal BST administration period

Single months in which BST administration was profitable were joined to create extended administration periods. When FCR increased by 4 PP with default inputs, the optimal administration period was February through June which resulted in a small gain in profit of $0.80/slot/year (Table 2). When FCR increased by 8 and 12 PP, the optimal extended administration period covered more months and overall profit was increased. Table 2 also shows the sensitivity of the profitability of the extended administration periods to variation in the inputs for each increase in FCR.

In all but two scenarios the optimal extended administration period consisted of the same months as the single months that resulted in a gain in profitability. However, in the scenario where heifer price was $1200 and the increase in FCR was 12 PP, the single months with a gain were January through July but the optimal extended administration period was February through July. Not administering BST in January increased profit/slot/year by $0.03. In the second scenario, when heifer price was $2000 and FCR increased by 8 PP, an advantage of $0.83 was gained through the addition of July to the single months of December through June that showed a gain in profit.

3.4. Further analysis of the effects of BST administration

Herd statistics from the default scenario with no BST administration were compared to the default scenario with BST administered from January through June and an 8 PP increase in FCR. In this scenario, BST administration increased profit/slot/year by $4.13. Annual changes in revenues, costs

Table 3
Changes in herd statistics as a result of BST administration at first service in January through June (default inputs with an 8 percentage point increase in conception rate at first service).

Herd statistics	No BST (profit/slot/year)	BST in January through June (Δ profit/slot/year)
Milk sales	3113.67	1.77
Cow sales	124.38	−1.43
Calf sales	211.41	2.48
Total revenue	3449.45	2.82
Feed cost	1398.40	−0.58
Breeding supply cost	41.17	1.38
Heifer purchase price	501.00	−2.27
Veterinary cost	81.15	0.78
Variable labor cost	415.02	−0.62
Fixed other cost	456.00	0.00
Variable other cost	364.80	0.00
Total costs	3257.53	−1.31
Total profit	191.92	4.13
Pregnancy rate (%)	19%	1%
Overall cull rate (%)	31%	31%
Days to conception	126	−5

Table 2
Increase in profit compared to the default scenario for extended BST administration periods.

Scenario	4 PP [a]		8 PP		12 PP	
	All positive [b] Months	Δ profit ($/slot/year)	All positive Months	Δ profit ($/slot/year)	All positive Months	Δ profit ($/slot/year)
Default	Feb–Jun	0.80	Jan–Jun	4.13	Dec–Jul	7.96
Heifer price $1200	Mar–May	0.37	Jan–Jun	2.99	Jan–Jul [c]	6.18
Heifer price $2000	Feb–Jun	0.96	Dec–Jul [d]	4.64	Dec–Jul	8.86
Milk price $0.44/kg	Feb–Jun	0.95	Jan–Jun	4.89	Jan–Jul	8.23
Milk price $0.26/kg	Feb–May	0.54	Dec–Jul	3.72	Dec–Jul	7.42
Milk yield increase 10%	Feb–Jun	0.86	Jan–Jun	4.26	Dec–Jul	8.05
Milk yield decrease 10%	Feb–May	0.72	Jan–Jun	3.09	Dec–Jul	7.84
Conception rate increase 5 PP	Mar–May	0.45	Jan–Jun	3.25	Jan–Jul	6.41
Conception rate decrease 5 PP	Jan–Jun	1.38	Dec–Jul	3.34	Dec–Jul	10.57
50% Seasonality [e]	Feb–May	0.48	Jan–Jun	3.35	Dec–Jul	6.80
0% Seasonality in milk yield [f]	Feb–May	0.19	Jan–Dec	4.16	Jan–Dec	9.29

[a] Percentage point.
[b] Months in which BST administration at first service increased profit/slot/year.
[c] Profit increased by $0.03 compared to BST administration in the single months of February through July.
[d] Profit increased by $0.83 compared to BST administration in the single months of December through June.
[e] 50% reduced seasonality of milk yield and 50% reduced seasonality of conception rate in the hot season.
[f] 0% seasonality of milk yield, 100% seasonality of conception rate.

and selected other herd statistics are shown in Table 3. The increases in FCR increased the pregnancy rate only by 1% although FCR increased by 8 PP. This is due to the limited number of cows that received BST in any given month (≈10%). Overall cull rate decreased by less than 1%. Total revenues increased by $2.48/slot/year, mostly due to an increase in calf sales. Milk sales also increased when BST was administered, but this difference was only due to a change in herd demographics because no direct effect of BST on milk production was assumed. Total cost reduced by $1.31/slot/year. The increase in average breeding supply costs, which included BST costs, was only $1.38/slot/year because of fewer inseminations.

Pregnancy rates (Fig. 5A) peaked in January and were lowest in July for both scenarios. The scenario without BST had lower pregnancy rates from January to June with the greatest difference in January. Pregnancy rate is a direct reflection of the differences in FCR between both scenarios because there was no difference in the probability of insemination per estrous cycle.

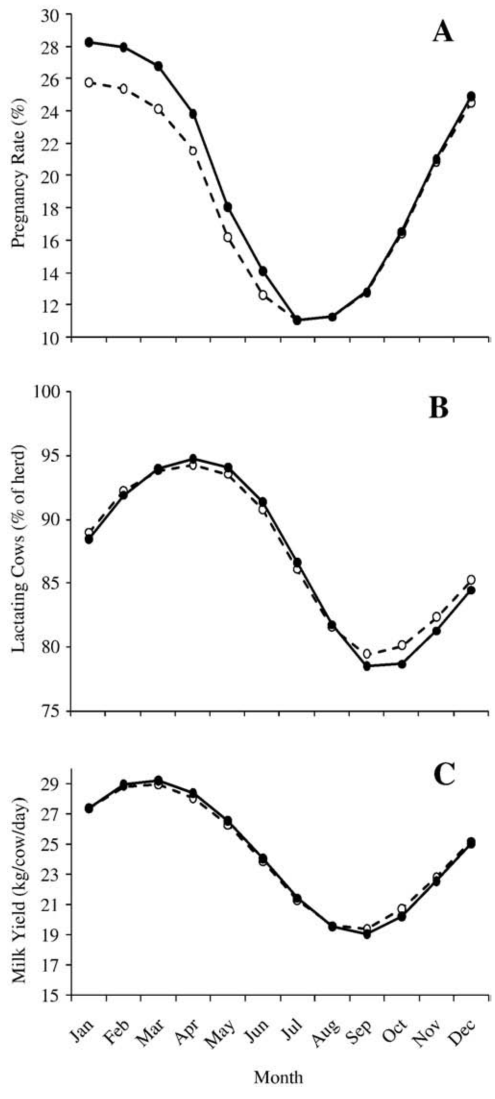

Fig. 5. Comparison of (A) pregnancy rate, (B) fraction lactating cows, and (C) milk yield between default inputs without BST (--○--) and with BST (–●–) administration at to first insemination applied in January through June and a first service conception rate increase of 8 percentage points.

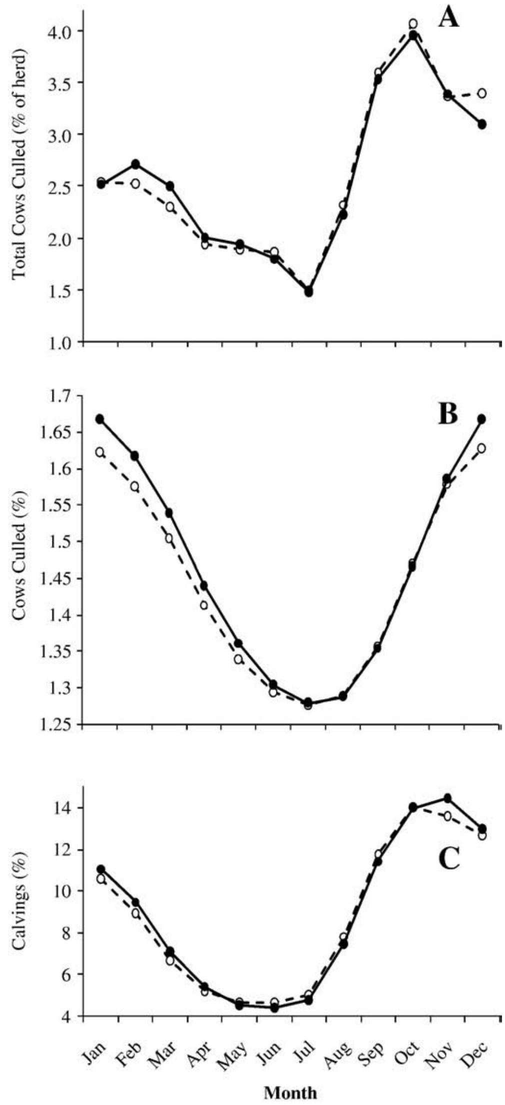

Fig. 6. Comparison of (A) total cows culled, (B) cows culled involuntarily, and (C) calvings between default inputs without BST (--○--) and with BST (–●–) administration prior to first insemination applied in January through June and a first service conception rate increase of 8 percentage points.

The percent lactating cows was greatest in April for both scenarios and lowest in September (Fig. 5B). The greatest variation between both scenarios was from September through December with the scenario with BST maintaining a greater proportion of lactating cows during this time. Milk yield per slot peaked in March and reached a low in September in both scenarios (Fig. 5C).

Total culling (voluntary and involuntary) was slightly different between the two scenarios (Fig. 6A). The greatest differences were observed in December, February, and March. In December, the scenario without BST had a greater total cull rate. In February and March, the scenario with BST resulted in increased total culling. Both scenarios showed a peak of involuntary culling in December and a minimum in July (Fig. 6B). The greatest differences in involuntary culling occurred from December through April. During this time the scenario with BST administration resulted in a greater proportion of cows culled.

The proportion of calvings was at a minimum for both scenarios in June while the peak was October for the scenario without BST and shifted to November for the scenario with BST administration (Fig. 6C).

4. Discussion

The default scenario resulted in plausible statistics for well-managed herds in Florida (De Vries et al., 2008). Culled cows were immediately replaced, which is in agreement with De Vries (2004) who found that delayed replacement of cows culled in the summer was optimal only in herds with extreme differences in cow performance between the cool and hot season.

The results of this study suggest that the profitability of increased FCR is greater in the cooler winter and spring than in the summer and fall when cows in Florida experience heat stress. Risco et al. (1998) found that it was more profitable to increase pregnancy rates in the summer than in the winter. In their study, increases in pregnancy rates in the summer were assumed to be greater than in the winter. In addition, the seasonality of milk production was not clear in the study by Risco et al. (1998). In the current study, absolute increases in FCR were the same in every month, regardless of the baseline conception rate. The seasonality of milk production needs to be considered when the profitability of increases in FCR is evaluated. Cows conceiving in the summer and early fall have lower peak milk production than cows conceiving in the cooler months.

In the current study, BST was administered to every cow to increase FCR at 61 days after calving to mimic the field study by Bell et al. (2008). Effects on profit/slot/year were minimal. De Vries (2006a) showed that the value of a new pregnancy is lower early in lactation and increases when non-pregnant cows approach mid to late lactation. In addition, high producing cows might be candidates for delayed first breeding to maximize profitability (Le Blanc, 2007). Morales-Roura et al. (2001) showed that BST increased the conception rate of cows remaining open after five or more inseminations. Instead of applying BST early in lactation as in the current study, BST administration later in lactation could result in greater profitability when both the value of a new pregnancy is greater and the effect of BST on conception rate is expected to be greater. Similarly, the use of embryo transfer to increases pregnancy rates in the summer (Hansen and Arechiga, 1999) may be more valuable when applied to cows later in lactation.

Cycling status prior to treatment has been identified as an indicator of success in field trials where BST was evaluated as a treatment to increase conception rate (Moreira et al., 2000; Moreira et al., 2001). Thus, in addition of stage of lactation, knowledge of the cycling status could allow for a targeted application of BST administration to increase conception rates.

In this study it was assumed that all cows had a first insemination as part of a TAI protocol. Administration of a single dose of BST increased FCR at comparable levels (4 to 12 PP) when estrus detection was employed (Santos et al., 2004b).

The direct effect of BST on milk production was omitted in this study to make results directly applicable to other methods that aim to increase FCR but not milk production. In practice, a single dose of BST may be expected to increase milk production, but this effect was not quantified in the study by Bell et al. (2008). An additional increase in milk production would make the application of a single dose of BST more profitable. Eliminating the use of BST as a lactogen and only applying it for its reproductive effects may not be best use of the technology. It is not uncommon for dairy producers to completely discontinue BST use because of personal preference or at the request of their milk processors as has recently been the case in Florida.

The use of BST, or any other method, to increase conception rate in the winter, will result in a herd with a more seasonal calving pattern. This many not be desired by all herds. For instance, increased seasonality may cause problems when resources are constrained, such as parlor capacity and barn capacity, and may put a strain on cash flow when milk sales decline during the summer and fall because less milk is produced. Such seasonal herd constraints could shift the optimal BST administration period to the warmer season. The optimal allocation of BST or other technologies that enhance cow performance in seasonal herds under herd constraints deserves further attention.

5. Conclusions

An increase in FCR as a result of a single dose of BST administration increased profitability in the cooler season but not in the warmer season in dairy herds that had reduced milk production and conception rates in the summer due to heat stress. Increases <4 PP in FCR could be profitable if administered in the cooler season only. Increased FCR in the cooler season would make herds more seasonal, which may be undesirable. Economic evaluations of changes in reproductive efficiency in seasonal herds should include seasonal effects on milk production.

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