Reprod. Nutr. Dev. 43 (2003) 543–555

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DOI: 10.1051/rnd:2004002

Original article

Insemination factors affecting the conception rate in seasonal calving Holstein-Friesian cows

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(Received 20 June 2003; accepted 24 September 2003)

Abstract — Differences in conception rate to first service between artificial inseminations (AI) carried out by commercial AI operators (CAI) or do-it-yourself operators (DIY), between natural service (NAT) and AI, between different AI sires, and between fresh and frozen-thawed semen, on Irish commercial dairy farms, were studied using logistic regression. The study comprised 12 933 potential first inseminations from 77 spring-calving dairy herds. The data were recorded during 1999 and 2000. Amongst the total, 4 394 cows had repeated records across the two years. Adjustment variables included: herd, year, parity, calving period, calving to service interval, herd size, proportion of North American Holstein-Friesian genes, peak milk yield, semen fresh or frozen-thawed status, AI sire and a cow history variable to account for the correlation structure that may exist between performance records of cows present in both years of the study. Interactions of interest were tested but were non-significant. No significant association was observed between the category of AI operator and the likelihood of conception rate to first service (PREG1). The variation in PREG1 observed within the category of operator (CAI and DIY) was investigated using the Levene test for homogeneity of variance. There was no difference between the level of variation observed within CAI and DIY operators. There were significant differences in the likelihood of PREG1 between different AI sires. Amongst the 40 most commonly used AI sires, 3 sires had a lower likelihood of PREG1 ($P < 0.05$) when compared to the reference AI sire (sire with PREG1 similar to the mean of the group). There was a tendency for a reduced likelihood of PREG1 with the use of fresh semen compared to frozen-thawed semen (OR = 0.80, $P = 0.067$). Amongst the adjustment variables in the model, those significantly associated with the likelihood of PREG1 included the herd, calving period, calving to first service interval and peak milk yield. No significant difference in the likelihood of PREG1 was observed between AI and NAT.

artificial insemination / fertility / DIY AI / natural service

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1. INTRODUCTION

In the majority of Irish dairy herds, artificial insemination (AI) is used for approximately six weeks at the start of the seasonal breeding period to generate replacement females and a natural service (NAT) sire is used thereafter. Artificial insemination may be carried out by operators from commercial AI companies (CAI) or by farmers/farm managers (do-it-yourself (DIY)). Although DIY AI has been practised for over 60 years world-wide and since 1984 in Ireland, very few studies have evaluated the success of DIY operators compared to CAI. Early reports conclude that either there is no difference between the two categories [1–5] or that DIY operators have a wider range and lower overall conception rates [6]. However, in a more recent controlled study, Morton [7] found a 3% higher first service conception rate with professional technicians compared to DIY operators in the same herds. These professional technicians were chosen because of their use of optimal AI practices. O'Farrell and Crilly [8] reported a 6% higher first service calving rate following CAI compared to DIY. It is generally accepted that there is a considerable variation among both DIY [2, 7, 9, 10] and CAI [2, 11–13] operators in their ability to either deposit semen in the uterine body or in conception rates achieved. Whether the degree of variation is greater in one category than the other is unclear. While the design of some of these studies may preclude valid comparisons between CAI and DIY operators, they do indicate a lack of consensus. Recently it has been suggested that increased use of on-farm insemination operators has led to increased variability in insemination skills and contributed to the decline in fertility seen internationally [14].

Given the complexity of the issues that can affect reproductive performance (those relating to the AI operator, sire used and the cow being inseminated), it is difficult to determine if the differences in reproductive performance observed between herds are due to the category of inseminator or are confounded with other factors. Reurink et al. [12] concluded that to provide unbiased estimates of effects such as the AI operator and AI sire, adjustments should be made for factors such as herd, season, age of cow inseminated and month of insemination.

Dairy cattle selected for high milk yield and with a high proportion of Holstein-Friesian genes are more likely to have reduced reproductive performance [15–17]. The calving to service interval has been shown to affect the conception/non-return rate [18, 19]; cows with longer calving to service intervals are more likely to conceive. This has particular importance in Irish spring-calving herds since breeding starts on a fixed calendar date, usually between late April and early May. Once the breeding season has started, it is common for every cow detected in oestrus to be served irrespective of the number of days since calving.

The AI-industry has to balance the need of farmers to get cows pregnant and to obtain as many inseminations as possible per ejaculate, particularly in the case of popular sires. Previous studies have shown differences in conception rates between AI sires [19–21]. Preferential mating may bias this effect whereby, for example, herd owners choose to use "fashionable" sires on their "favourite" cows. The vast majority of semen used in Ireland and world-wide is frozen-thawed [22]. In the early days of use, non-return rates following frozen-thawed semen tended to be lower than those following fresh semen [23]. Now, however, similar conception rates can be achieved with frozen-thawed or fresh semen [22, 24–26] despite differences in the in vitro survivability of semen [25] and the sex ratio of calves [27].

Recent statistics show the level of AI usage in Ireland at 37% [28] indicating a high usage of natural service sires (NAT). Mee et al. [29] showed that 70% of Irish dairy farmers surveyed had a stock sire on the farm. While convenience is likely to be the primary reason, there may be those who feel that the conception rates achieved by AI are inferior to those achieved by NAT. Such results have been reported in the past [30–32]. However, with advances in cryopreservation technologies, more recent reports indicate no such difference now exists [25, 33] and one report showed higher calving rates following CAI compared to NAT [8].

The objective of this prospective longitudinal study was to investigate if there is a difference in conception rate between AI carried out by CAI operators and DIY operators on Irish commercial dairy farms. Evidence of differences in conception rate between NAT and AI, between different AI sires, and between fresh and frozen-thawed semen was also investigated.

2. MATERIALS AND METHODS

2.1. Database

The study comprised a potential 12 933 first inseminations from 77 spring-calving dairy herds. The data were recorded during 1999 and 2000. Four thousand three hundred and ninety four cows had repeated records across the two years. The average herd size was 87 cows with a range from 27 to 311. The herds were representative of Irish pasture-based, seasonal calving herds in which recommended practices for health and reproductive management were implemented. The key factors in herd selection were: (1) a high standard of recording, (2) predominantly spring-calving, (3) at least the sire and maternal grand sire were known for the majority of the cows in the herd, and (4) participating in A4 milk recording (once every 4 weeks). Pre-breeding season oestrous detection was practised on 88% of the farms. Ninety-two percent of the farmers observed cows more than twice daily for oestrus during the breeding season, while 99% of the farmers used tail paint and/or a vasectomised bull as an aid to oestrous detection. Concentrate supplementation per cow averaged 745 kg with a range from 335 kg to 1 305 kg for individual farms. All herds were enrolled in the Dairy Management Information System (DairyMIS) run by Moorepark [34]. The DairyMIS is a recorder-based computerised system with monthly collection of details of stock, farm inputs, production and reproduction.

2.2. Conception rate

Insemination dates were recorded through the DairyMIS system for each cow and conception rate (PREG1) was defined as pregnant or not to first service. All cows were determined to be pregnant or not by rectal palpation at least eight weeks after the end of the defined breeding season. PREG1 was therefore described in relation to this and cognisance was not taken of subsequent losses.

2.3. Insemination factors

Data were available for each service indicating whether the cow was served by AI or NAT, and in the case of cows artificially inseminated, whether it was performed by CAI or DIY. Details of whether the semen used was fresh or frozen-thawed and the identity of the AI sire were also available. All services recorded as AI were verified using service records provided by the relevant commercial AI companies. The identity of individual NAT sires was not available. A tele-questionnaire was conducted to obtain details such as age, experience at AI and the level of participation in retraining courses, for each AI (CAI and DIY) operator in the study.

2.4. Adjustment variables

Test-day milk records, parity and drying off dates, for each individual cow, were obtained from the Irish Dairy Recording Co-operative, while calving dates were captured through the DairyMIS system. Each herd was milk-recorded at 4–week intervals. The calving and drying off dates were used to validate the parity and test-day records for a given lactation. Peak milk yield was taken to be the first highest yield recorded during lactation. Peak milk yield data were quartiled. Parity was categorised as parity 1, parity 2, or greater than or equal to parity 3. Calving dates were categorised into 3 calving periods; January and February, March, and April or later. The calving to first service interval, calculated as the number of days between calving and first service, was categorised into four groups: 45 days or less, 46 to 60 days, 61 to 75 days and greater than 75 days.

The proportion of North American Holstein-Friesian (NAHF) genes for individual cows was calculated as described by Evans et al. [35]. NAHF varied from 0 to 75%. Four categories of NAHF were created: cows with less than 50%, 50%, 51% to 74% and 75% NAHF genes.

Herd size was defined as the number of first services for a particular herd-year. Herd size was categorised as less than 75, 75 to 149 and 150 or more.

A cow history variable was created to represent previous performance. That is to account for the correlation structure that may exist between performance records of cows present in both years of the study (4 394 cows). In year one, all cows received a history variable value of 2 (representing null information). In year two, cows with no record in year one also received a value of 2. Those with a successful PREG1 in year one received a value of 1, while those with an unsuccessful PREG1 in year one received a value of 0.

2.5. Statistical analysis

The statistical procedure implemented was logistic regression [36] using the PROC LOGISTIC procedure in SAS [37]. As indicated previously, each independent variable of interest was quartiled or categorised into up to 4 groups. One of these groups was designated as the reference category for odds ratio (OR = 1). An OR of > 1 implies increased likelihood and an OR < 1 implies an inverse association. In this analysis, the reproductive outcome for each category of independent variable was compared to the reproductive outcome of the reference group for that variable. Adjustment variables were selected on the basis of biological plausibility. Statistical significance is defined as $P < 0.05$.

To investigate if differences in conception rate existed between the CAI and DIY, and, whether there was an effect of AI sire or the use of fresh or frozen-thawed semen on conception rate, a logistic regression model was constructed with PREG1 as the dependant variable. The independent variables of interest were category of AI operator (CAI or DIY), AI sire, and fresh or frozen-thawed semen status, with herd, year, parity, calving period, calving to service interval, herd size, proportion of NAHF genes, peak milk yield and the history variable included in the model as adjustment variables. Interactions of interest were included but were non-significant so were removed from the final model. While it might have been appropriate to include genetic merit (predicted difference) for milk yield as an adjustment variable, it would have resulted in a substantial reduction (47%) in cow numbers due to missing values. It was therefore considered reasonable to include peak milk yield as a measure of genetic potential for milk production. It may in fact be considered more appropriate, since phenotypic performance is probably more likely to influence the farmer's decisions, such as voluntary waiting period and AI sire used. Data were restricted to first services from AI sires with 50 or more first services ($n = 40$). Due to missing values within the data set, the final number of first services per AI sire in the analysis ranged from 48 to

927, or a mean of 203 first inseminations with a standard deviation of 201. The reference AI sire had a PREG1 similar to the mean for the 40 sires (49% PREG1 from 91 first inseminations). Insemination records by DIY operators with less than 10 first inseminations per year were also excluded. The resultant data set had 8 431 first AI records.

An analysis was carried out to investigate if there was a difference in variability in conception rates (PREG1) among operators within CAI and DIY. This was carried out using the Levene test for homogeneity of variance [38]. For this analysis data were restricted to first service AI records carried out by the operators (both CAI and DIY) who had 50 or more first service inseminations in the data set ($n = 17$ and 52 for CAI and DIY operators, respectively).

To investigate if the conception rates following NAT were different from those following AI, a logistic regression model was constructed with PREG1 as the dependent variable and independent variables including service type (AI vs. NAT), herd, year, parity, calving period, calving to service interval, herd size, proportion of NAHF genes, peak milk yield and the history variable.

Interactions of interest were also tested but were non-significant and so were removed from the final models. Multicollinearity among independent variables in each model was investigated [39] but was not detected. A coefficient of determination (adjusted r^2) was used to estimate the proportion of variation explained by each model [40]. The fit of estimated models was assessed using the Hosmer-Lemeshow goodness of fit test (C_{HL}) [41].

3. RESULTS

The mean conception rate to first service in year one and year two was 49% and 48%, respectively. However, there was a large variation among herds, with the actual herd averages ranging from 26% to 89% and 28% to 70% in years one and two, respectively. The mean calving to first service interval was 72 and 70 days for year one and year two, respectively, with herd averages ranging from 52 to 91 days and 58 to 91 days, respectively.

Thirty-three percent of first services were recorded as CAI (22 operators), 63% were recorded as DIY (55 operators) and 4% as NAT. Ninety-two percent of all first AI services were recorded as frozen-thawed semen. The mean calving date across the two years was February 28 with 58%, 27% and 15% of cows calving in calving periods 1, 2 and 3, respectively. The mean peak daily milk yield was 30.7 kg with a standard deviation of 5.9 kg. Individual values ranged from 7.6 kg to 55.0 kg.

No significant association was observed between the category of AI operator and likelihood of PREG1 having adjusted for herd, year, calving period, calving to service interval, parity, proportion of Holstein-Friesian genes, peak milk yield, herd size, the history variable, semen fresh or frozen-thawed status and AI sire (Tab. I). However, there were significant differences in the likelihood of PREG1 between different AI sires. Amongst the 40 most commonly used AI sires (each with greater than 47 first inseminations), three had a lower likelihood of PREG1 compared to the reference AI sire. These sires had 210, 83 and 61 first inseminations represented in the analysis, respectively. The mean OR for these three sires (0.43) corresponds to a 20-percentage unit lower likelihood of PREG1 for these sires compared to the reference sire. Changing the reference AI sire to the AI sire with the highest conception rate for the group (57% PREG1 from 99 first inseminations) resulted in nine sires with a lower likelihood of PREG1 compared to this reference sire (Tab. II). These sires had between 61 and 927 first inseminations represented in the analysis. The mean OR

Table I. The association between the category of AI operator (CAI vs. DIY), fresh or frozen-thawed semen status, year, calving period, calving to service interval, parity, proportion of North American Holstein-Friesian genes, peak milk yield, herd size, and history variable with likelihood of PREG1[1] (n = 8 122 observations).

	OR	95% CI	P-value
Category of AI operator			
Commercial	1		
Do-it- yourself	0.67	0.36–1.23	NS
Semen status			
Frozen-thawed	1		
Fresh	0.80	0.63–1.02	0.067
Year			
1999	1		
2000	0.98	0.83–1.17	NS
Calving period			
January and February	1		
March	0.82	0.71–0.95	< 0.01
April and later	0.64	0.51–0.80	< 0.001
Parity			
1	1		
2	1.11	0.94–1.32	NS
3 and greater	1.08	0.90–1.29	NS
Calving to 1st service interval (days)			
> 75	1		
61 to 75	0.82	0.73–0.93	0.001
46 to 60	0.73	0.61–0.86	< 0.001
< 46	0.62	0.49–0.77	< 0.001
Holstein %			
< 50	1		
50	0.98	0.85–1.12	NS
51 to 74	0.99	0.87–1.13	NS
75	0.91	0.77–1.07	NS
Peak daily milk yield (kg·day^{-1})			
< 26	1		
26 to 29	0.94	0.81–1.09	NS
30 to 33	0.84	0.71–0.99	< 0.05
> 33	0.81	0.68–0.97	< 0.05
Herd size			
< 75	1		
75 to 149	1.11	0.86–1.43	NS
> 149	1.28	0.76–2.16	NS
History variable			
Unsuccessful Preg1 in year 1	1		
Successful Preg1 in year 1	1.18	1.00–1.40	0.052
Null information	1.09	0.88–1.35	NS

[1] PREG1 = conception to first service, OR = Odds ratio, CI = confidence interval, NS = $P > 0.050$.

Table II. Association between AI sire and likelihood of PREG1[1] (n = 8 122 observations).

AI sire	No. first services	OR	95% CI	*P*-value
*Sire 1	99	1		
Sire 2	193	0.71	0.41–1.21	NS
Sire 3	108	0.71	0.39–1.30	NS
Sire 4	210	0.46	0.27–0.79	< 0.01
Sire 5	103	0.56	0.30–1.04	NS
Sire 6	49	0.76	0.36–1.61	NS
Sire 7	145	0.51	0.29–0.91	< 0.05
Sire 8	85	0.56	0.28–1.15	NS
Sire 9	121	0.51	0.28–0.91	< 0.05
Sire 10	48	0.88	0.40–1.90	NS
Sire 11	412	0.78	0.48–1.28	NS
Sire 12	61	0.75	0.37–1.52	NS
Sire 13	784	0.58	0.37–0.92	< 0.05
Sire 14	50	0.66	0.31–1.39	NS
Sire 15	83	0.72	0.37–1.43	NS
Sire 16	289	0.75	0.45–1.25	NS
Sire 17	73	0.56	0.28–1.15	NS
Sire 18	103	0.81	0.42–1.54	NS
Sire 19	231	0.71	0.42–1.21	NS
Sire 20	335	0.79	0.46–1.35	NS
Sire 21	407	0.59	0.36–0.95	< 0.05
Sire 22	83	0.34	0.18–0.64	0.001
Sire 23	927	0.60	0.38–0.96	< 0.05
Sire 24	91	0.83	0.43–1.61	NS
Sire 25	100	0.74	0.40–1.37	NS
Sire 26	272	0.81	0.47–1.40	NS
Sire 27	697	0.74	0.47–1.17	NS
Sire 28	111	0.68	0.36–1.26	NS
Sire 29	61	0.22	0.09–0.58	< 0.01
Sire 30	236	0.74	0.42–1.30	NS
Sire 31	315	0.64	0.39–1.06	NS
Sire 32	128	0.68	0.38–1.22	NS
Sire 33	53	0.54	0.25–1.17	NS
Sire 34	74	0.78	0.40–1.56	NS
Sire 35	118	0.55	0.30–0.99	< 0.05
Sire 36	188	0.70	0.41–1.21	NS
Sire 37	124	0.86	0.48–1.55	NS
Sire 38	57	0.68	0.33–1.38	NS
Sire 39	292	0.78	0.45–1.35	NS
Sire 40	206	0.90	0.52–1.57	NS

[1] PREG1 = conception to first service, OR = Odds ratio, CI = confidence interval, NS = $P > 0.050$.
*AI sire with highest PREG1.

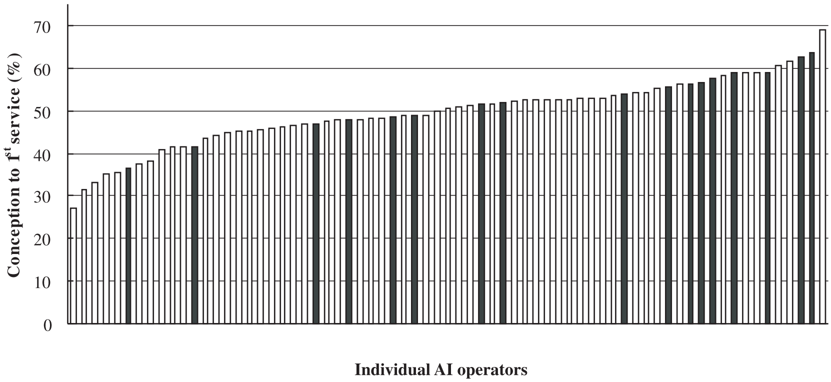

Figure 1. Variation in conception rate to first service within the category of AI operator; CAI, ■; DIY, □.

(OR = 0.48) for these sires equates to an 18-percentage unit lower likelihood of PREG1 compared to the best sire (Sire 1), or conception rate differences of between 12 (Sire 23) and 32 (Sire 29) percentage units for individual sires when compared to this reference sire. There was a tendency for a reduced likelihood of PREG1 with the use of fresh semen compared to frozen-thawed semen (OR = 0.80, $P = 0.067$) (Tab. I).

Amongst the adjustment variables in the model, those significantly associated with the likelihood of PREG1 included herd, calving period, calving to first service interval and peak milk yield. Cows calving in March, or April and later had a lower likelihood of PREG1 when compared to those calving in January or February (OR = 0.82, $P < 0.01$ and OR = 0.64, $P < 0.001$, respectively). Cows with shorter calving to service intervals were less likely to become pregnant to first service compared to the reference category (> 75 days calved). Cows calving 45 days or less, 46 to 60 days and 61 to 75 days had odds ratios of 0.62 ($P < 0.001$), 0.73 ($P < 0.001$) and 0.82 ($P = 0.001$), respectively. These odds ratios correspond to a reduction in the likelihood of PREG1 of approximately 12, 8 and 5-percentage units when compared to the reference category. Cows with peak milk yields greater than 29 kg had a reduced likelihood of PREG1 (OR = 0.84, 0.81, $P < 0.05$). The adjusted r^2 for the model was 0.08. According to the C_{HL} the model fitted well to the data (C_{HL} = 6.998; df = 8; $P = 0.537$).

No significant difference was observed between NAT and AI for PREG1 (OR = 1.18, $P = 0.120$) having adjusted for herd, year, calving period, calving to service interval, parity, proportion of Holstein-Friesian genes, peak milk yield, herd size and the history variable (not shown). The adjusted r^2 for the model was 0.071 and the C_{HL} indicated a good model fit (C_{HL} = 5.845; df = 8; $P = 0.665$).

The results show a similar level of variability in conception rates within CAI and DIY with standard deviations of 7.2 and 8.0 within CAI and DIY operators, respectively ($P = 0.829$). The analysis conducted (the Levene test for homoscedasticity) tests for differences between the variances of different groups. The AI operator (CAI and DIY) conception rates to first service are illustrated in Figure 1. While the mean (and range) conception rates for CAI and DIY operators within this analysis were 53% (37–63%) and 49% (27–69%), respectively, this analysis did not account for any of the adjustment variables used in the logistic modelling. There was wide variation in the level of experience and age of operator within both the CAI and DIY categories. Commercial AI and DIY operators in the current study had, on average, 29 and 8 years experience practising AI, respectively. This ranged from 1–37 (SD = 10.3) and 1–19 (SD = 4.1) years for CAI and DIY, respectively. The mean age of the operator within both CAI and DIY was 52 and 41 years, ranging from 27–67 (SD = 11.1) and 24–62 (SD = 9.1), respectively. Official retraining was not commonly practised among DIY operators in the current study. Thirty-two percent of the DIY operators attended between 1 (73%) and 4 refresher courses since the initial training course. These were generally carried out in the first few years after the initial course. In contrast, CAI operators received refresher courses each year and extra tuition was provided if individual non-return rates warranted it.

4. DISCUSSION

The results of the present study showed no difference in the likelihood of PREG1 between CAI and DIY operators. This was in agreement with the majority of published reports [3–5], but in contrast to the findings of Morton [7] and O'Farrell and Crilly [8]. This apparent difference may reflect differences in study design. Morton [7] compared both CAI and DIY operators within the same herds and found slightly higher conception rates with the former, adjusted for eleven factors likely to affect conception rate. However, the CAI operators in that study were a selected group, deemed to be using optimum AI techniques. In the present study, the CAI operators were not a selected group. O'Farrell and Crilly [8] indicated that higher calving rates were achieved by CAI compared to both DIY and NAT in medium and large herd sizes (> 65 cows). In that study, the category of operator records were adjusted for year and the interaction between the category of operator and year only. In the current study, adjustments were made for herd, year, parity, calving period, calving to service interval, herd size, proportion of Holstein-Friesian genes, peak milk yield, the use of fresh or frozen-thawed, AI sire and accounted for repeated lactations. No interaction between herd size and the category of AI operator was found. A recent study by Mackey et al. [42], similar in design to that carried out by Morton [7], showed a 1.7 percentage unit numerical advantage in non-return rate to CAI operators compared to DIY operators across six commercial dairy herds. However, similar to the present study, a large variation was evident across herds.

One might expect CAI operators to have better conception rates when compared to DIY operators who often have minimal training or re-training, no supervision and less practice. However, commercial companies in general only provide a once-a-day AI service. This may result in DIY operators benefiting slightly from better timing of AI, particularly with cows observed in oestrus a.m. [43]. In addition, those DIY operators represented in the present study may represent successful DIY operators who have achieved good results over years and therefore have continued to use DIY AI. Those monitored, had on average, 8 years AI experience.

The results of this study showed a similar level of variability in conception rates within CAI and DIY. This is in agreement with the findings from previous reports [2, 7]. Although there are no recent publications on the reasons for inter-operator variability in conception rates, Shannon [44] attributed 78% of this to the commercial technician themselves, 9% to the herds, 1% to the cows within these herds and the remainder to sampling variance. More recently, Visser et al. [45] attributed 19% of the explained variation in conception rate to the individual AI operator, second only to the herd in importance. De Kruif [46] and Barth et al. [33] cited personal qualities or personal problems as possible reasons for differences in performance between individuals, or differences over time. The wide variation in conception rates found within both CAI and DIY operators in the present study is a cause for concern and suggests that annual auditing of performance should be carried out within both categories of operator and action taken where results are poor.

Both the duration of initial training [47] and participation in retraining [48, 49], have been shown to have significant effects on the accuracy of semen deposition and conception rate. It is generally accepted that the AI technique, in particular the site of semen deposition, is the primary factor associated with the variability between operators [50]. Conversely, Macmillan et al. [11] suggested that factors outside the control of the operator such as the accuracy of oestrous detection, timing of AI, herd fertility and management are more important. As indicated previously, the herds present in this study were representative of herds in which recommended practices for health and reproductive management were implemented. One might assume that the experience of the operator was a critical factor in AI success; White [4] showed a 5-percentage unit difference in conception rate between DIY operators with 1 compared to 3 years experience. Everett et al. [51] stated that CAI operators with higher conception rates had better skills and tended to inseminate more cows. Roche et al. [21] attributed very low conception rates to part-time or new CAI operators who inseminated fewer cows. However, Wholohan et al. [52] stated that experienced commercial operators were as likely to err as newly trained operators. Furthermore, Cembrowics [53] showed that the age of operator (23–52 years), years of experience (4–18) or number of inseminations did not significantly affect the conception rate.

AI sire had a significant effect on the likelihood of PREG1. Previous studies have also highlighted that differences in non-return rates between AI sires do exist [10, 19–21, 33]. This may be a particular problem with sires whose semen does not survive freezing and thawing well [54]. However, techniques are available which can compensate for deficiencies in semen freezability such as increased sperm numbers per dose [24, 25]. It is of concern that such large differences in adjusted conception rates were evident within the current data set. Previous studies report non-return rate differences of 15 to 16 percentage units between the best and worst sires [9, 10]. In the current study differences as large as 32 percentage units were evident. A possible contributor to the more extreme differences in conception rates observed in the current study may be the relatively low number of inseminations present for some sires. Smaller sample sizes will, due to chance, result in greater variability among sires. However, for the most part the number of inseminations per sire should have been sufficient to provide a good indicator of the performance of individual sires. Closer attention by AI companies must be paid to individual sire non-return rates. Differentiation between maiden heifer and lactating cow inseminations, for example, would likely remove some bias in estimated non-return rates. Pregnancy rates in this study were estimated to be as low as 25% for individual sires. This is not satisfactory in practice.

In the past, conception rates with frozen-thawed semen were lower than those achieved with fresh semen [31]. However, both cryopreservation and semen diluent processing technologies have improved since then. Frozen-thawed semen requires higher sperm dose rates (10–25 million vs. 2.5–5 million per insemination) and has higher processing and storage costs than fresh semen, but it can be stored long term allowing a greater flexibility of use. The results of the present study indicate that with current semen processing techniques, conception rates following the use of frozen-thawed semen are at least comparable to those following fresh semen.

Although the results of this study provide no evidence that PREG1 achieved by NAT was higher than that achieved from AI, it must be recognised that the number of first services available for NAT was small as compared to that for AI. However, the results concur with studies carried out by O'Farrell [55] and Williamson et al. [56], which found no significant difference between NAT and AI. In the latter study, however, it was concluded that greater variation in conception rates was evident from NAT when compared to AI. Due to the limited number of NAT services per herd it was considered inappropriate to look at this relationship in the current study.

Examining the relative importance of each of the main effects in the logistic regression model, those variables having the greatest affect on PREG1 were herd, calving period and calving to first service interval ($P < 0.001$). The overall significance of variables such as AI sire, semen status and peak milk yield, were lower with overall P-values ranging between 0.05 and 0.10. However, the analysis does indicate that, for example, the choice of AI sire (when compared to a reference sire) can have important practical relevance.

ACKNOWLEDGEMENTS

The authors acknowledge the financial support of AIB Bank, Holstein UK and Ireland, the National AI Co-ops and Dairy Levy funding. The technical assistance of D. Cliffe, T. Condon, K. O'Malley, J. Kenneally and the many UCD summer students is also acknowledged. This study would not have been possible without the support of 77 commercial dairy farmers. The authors acknowledge their co-operation in relation to access to their dairy herds and farm records.

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