Factors affecting management changes on farms participating in a Johne's disease control program

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ABSTRACT

Modern Johne's disease programs aim to control *Mycobacterium avium* ssp. *paratuberculosis* (MAP) infection through implementation of management practices that reduce the probability of MAP introduction and within-herd transmission on dairy farms. Success of these programs depends on whether weaknesses in management are corrected through implementation of management improvements. The objectives of this study were, therefore, to (1) assess whether scores in risk-assessment (RA) questions predicted suggestions for management changes for the upcoming year; and (2) determine factors as assessed in an RA that motivated producers to make management improvements and assess whether management improvements were influenced by previously received test results. The RA determining on-farm management related to MAP introduction and transmission were conducted annually by herd veterinarians on 370 dairy farms participating in the Alberta Johne's Disease Initiative. A maximum of 3 management changes that the farmer and the veterinarian agreed upon were recorded in a management plan. The MAP infection status of the herds was assessed through culture of 6 environmental samples. Whereas a management change was proposed for only 4% of questions with scores 1 or 2 (low risk), a change was proposed for 19% of questions with scores >2 [high risk; odds ratio (OR) = 11.4]. Improvement in RA question scores was more likely between the first and second annual RA than between the second and third RA (OR = 1.6). Farms with >3 culture-positive environmental samples collected in the previous year were more likely to improve their management than environmental sample culture-negative farms (OR = 1.3). In conclusion, proposed management changes were oriented toward previously identified weaknesses in management practices, suggesting that the RA was properly used to design targeted management suggestions. Furthermore, improvements in management were

not randomly distributed among farms participating in the control program. Instead, knowledge of MAP infection status of a herd, suggestions for management improvements, and duration of participation all influenced implementation of management improvements.

Key words: paratuberculosis, control, management

INTRODUCTION

Mycobacterium avium ssp. *paratuberculosis* (MAP) is present on dairy farms worldwide (Barkema et al., 2010), causes economic losses to the industry (Wolf et al., 2014b), and is potentially associated with Crohn's disease in humans (Atreya et al., 2014). After in utero or fecal-oral infection, cattle go through an extended incubation period that can ultimately result in development of Johne's disease, a noncurable enteritis (Sweeney, 2011). During incubation, infected cattle frequently remain undetected because antibody production and bacterial shedding occur only intermittently (Mortier et al., 2014a,b), and available tests lack accuracy (Nielsen and Toft, 2008), thereby reducing the effectiveness of testing and culling for successful eradication of MAP on cattle farms (Whitlock and Buerge, 1996; Garry, 2011). As a consequence, most MAP-control programs are not solely based on testing and culling, but encourage implementation of best management practices to prevent MAP introduction and transmission between infectious and susceptible cattle (McKenna et al., 2006). These MAP-control programs can, however, only be effective if farmers make the appropriate management improvements.

The first step toward successful MAP control using best management practices is to identify weaknesses in management and propose changes (Garry, 2011). Weaknesses in management can be identified through the use of a MAP-specific risk assessment, which is completed by farmers and herd veterinarians working in collaboration. Thereafter, identified weaknesses can be addressed by proposed management improvements (USDA, 2003). However, risk assessment as a tool only makes sense if proposed management changes are actually oriented toward deficiencies in management practices.

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The second step, after identifying weaknesses in management, is to improve on-farm management. In 2 US studies, farms generally improved their management during participation in a MAP-control program (Raizman et al., 2006; Wells et al., 2008). Nevertheless, whereas the majority of Ontario dairy farms significantly improved their management, on 20% of the farms, management significantly worsened (Sorge et al., 2011). Decisions regarding management changes are complex and, among others, motivated by expected increases in profit (Edwards-Jones, 2006). Therefore, farmers that know about the presence of a pathogen might be more likely to invest in its control. Furthermore, owners of large herds are regarded as more progressive than owners of small herds (Bergevoet et al., 2004; Sayers et al., 2013), and farms with high risk assessment (RA) scores (bad management) make more management improvements (Sorge et al., 2011). Therefore, the objectives of our study were to (1) assess whether scores in RA questions predicted suggestions for management changes for the upcoming year; and (2) determine factors as assessed in an RA that motivated producers to make management improvements and assess whether management improvements were influenced by previously received test results.

MATERIALS AND METHODS

Data Collection

Participants in this longitudinal study consisted of the 370 dairy farms (63% of dairy farms in Alberta, Canada) that voluntarily participated in the Alberta Johne's Disease Initiative (AJDI), a management-based MAP-control program (Wolf et al., 2014a). Data were collected between November 2010 and April 2014 (farmers could join and leave the program at any given time). Herds were visited annually by their herd veterinarians, who were trained (half-day workshop at the University of Calgary) regarding the importance of MAP control, the link between MAP and Crohn's disease, effective management strategies to control MAP, and the correct way of conducting AJDI procedures. During each visit, veterinarians conducted an RA that identified risk factors for MAP infection on the farm (Appendix, Table A1). The first 4 RA questions dealt with herd characteristics (e.g., herd size and housing), whereas questions 5 to 34 were actual risk factors and management practices as related to MAP introduction and transmission and were based on previous suggestions for RA design (USDA, 2003). Questions had categorical scores (3–5 categories); a higher score was associated with an increased risk. After identifying high-risk areas, veterinarians and farmers decided on

a maximum of 3 proposed management improvements, which were recorded in a management plan (MP). Proposal of <3 management improvements was possible if farmers and veterinarians did not see the need for further management improvements. To assess the herds MAP-infection status, 6 environmental samples (ES) were collected during the herd visit (Wolf et al., 2014a) and processed within 1 wk after collection using a standardized liquid culture protocol with subsequent PCR confirmation conducted on all samples (Forde et al., 2013; Wolf et al., 2014a).

Statistical Analyses

Data were entered in Microsoft Access (Microsoft Corporation, Redmond, WA, 2007), and management suggestions were linked to associated RA questions. In case of implementation of the suggested change, the scores for these questions were expected to decrease. Data analysis was conducted using STATA 11 (Statacorp, College Station, TX), and statistical significance was defined as $P < 0.05$.

Proposed Management Changes

The number of suggestions in the MP among farms in various years of AJDI participation was compared using a chi-squared test on contingency tables. Proportions of assigned question categories (cattle introductions, visitor access, calf liquid diet, young stock housing, calving pen, lactating and dry cow pens, feeding hygiene and equipment use, and management of likely infected cattle) between veterinarians were also compared using a chi-squared test. Furthermore, proportions of management suggestions made for the different question categories were illustrated in a stacked bar graph, using data from the 9 veterinarians with the highest number of conducted RA. Multilevel logistic regression on question level was used to identify predictors for proposed management changes. The outcome was whether or not (yes = 1, no = 0) an improvement related to a specific question in the RA was proposed in the MP. Predictors were (1) the specific question score in the RA (1, 2, 3, 4, and 5) and (2) the assigned question category ($n = 9$; categories as described above). The analysis was adjusted for clustering in the data set by including veterinarian, farm, and year of participation as random effects, resulting in a 4-level logistic regression model (Dohoo et al., 2003).

Actual Management Changes

Multilevel logistic regression was also used to identify predictors for actual changes in individual management

practices. The outcome was management improvement, defined as score reduction in a specific question did or did not occur between 2 consecutive RA. Predictors were (1) whether or not a question-related management improvement was included in the previous MP; (2) assigned question category (categories as described above); (3) year of participation (management improvements in the second, third and fourth year); (4) mean RA score in the previous year (first, second, third, and fourth quartile of mean RA scores in the data set); (5) herd size (<100, 100–199, >199 cows); and (6) number of positive ES in the previous year (0, 1–3, >3). The analysis was adjusted for the score in the specific question during the previous year (0 = score 1 and 2, 1 = score >2). Veterinarian and farm were included in the model as random effects, resulting in a 3-level logistic regression model.

In both models (proposed and actual change), backward selection procedures were used for variable selection, and coefficient changes >20% were considered as evidence of confounding. The reported odds ratios (OR) were cluster-specific (Dohoo et al., 2009). Population-averaged OR were not reported because preliminary analysis revealed that the cluster-specific OR were very similar to the population-averaged OR (<1% difference). The latent variable approach was used to estimate intraclass correlation coefficients as a measure for the magnitude of clustering by veterinarian, farm, and year of participation (Vigre et al., 2004).

RESULTS

A total of 709 RA and related MP conducted by 55 veterinary practitioners were received. A total of 137 farms submitted 1 RA, 134 submitted 2 RA, 92 submitted 3 RA, and 7 farms submitted 4 RA. Mean herd size was 139 adult cows, ranging from 40 to 680 cows, with 87, 6, and 7% of farms that housed cows in freestalls, loose housing, or tiestalls, respectively. Of the 709 RA, 4 had missing observations for some questions because some age groups were housed off-site. These RA were only included in the analysis for questions with available data.

Proposed Management Changes

Farmers and veterinarians agreed upon a total of 1,598 proposed management changes in the MP (Table 1). Fourteen MP (from 14 farms) did not include any proposed management changes and were excluded from the analysis. The number of proposed management changes decreased with increasing year of a farm's AJDI participation from a mean of 2.38, 2.14, 2.01, and 1.86 suggestions per farm in yr 1, 2, 3, and 4,

respectively ($P < 0.01$). In 8 cases, the proposed management changes could not be identified due to poor handwriting and were excluded from further analysis. The most frequently proposed changes were to increase the number of calving pens ($n = 135$; 8% of all proposed management changes), to separate calves from cows soon after birth ($n = 128$; 8%), and to avoid spreading manure on pastures grazed the same year ($n = 110$; 7%; Table 1). However, the categories of proposed management improvements that veterinary practitioners proposed differed considerably among the practitioners ($P < 0.01$, Figure 1). In total, 8 suggestions were, if implemented, not associated with a decrease in score in any of the RA questions because the RA did not include questions on the particular subject (e.g., not to use milk from test-positive cows to feed calves did not result in a score change for the questions on calf liquid diet because testing of cows was not part of the AJDI program). These suggestions were deleted from further analysis.

Whereas a management change was proposed for 480 of 13,185 questions (4%) with score 1 and 2 (lowest scores), a change was proposed for 1,711 of 8,807 questions (19%) with scores >2 (highest scores). In the final logistic regression model, questions with score 4 (high risk) had 11.4 times the odds to result in an agreed-upon management change than questions with a score of 1 (low risk; $P < 0.001$; Table 2). The odds for a management change to be included in the MP differed among sections in the RA, with questions regarding calf diet having the highest odds for proposed management changes ($P < 0.001$). The low proportions of variance explained by veterinarians and farmers indicated that the associations described in the model were similar across different farms.

Actual Management Changes

The total (sum) RA score between the first and the last RA improved on 76% (95% CI: 70–81%) of participating farms (Figure 2). Farms most frequently reduced their scores (risk decrease) in questions around calving pen hygiene (Q23; Appendix, Table A1; 25% of risk assessments), purchase rates (Q7; 24%), and use of feeding equipment to remove manure and manure contamination on pasture and crop land (Q19, Q30, Q33; 23–25% dependent on the group of animals; Table 3). Whereas the score of 19% of the questions improved between 2 consecutive RA on farms with 0 MAP-positive ES, on farms with >3 MAP-positive ES the score of 21% of the questions improved between 2 RA (Table 4). In the final logistic regression model, farms with >3 positive ES during the previous year had 1.3 times higher odds for improvement in the score of a question

Table 1. Percentages of farms with high scores (above category 2 of mainly 4 categories; indicates a high risk) in risk-assessment questions during the first year of participation in the Alberta Johne's Disease Initiative, and frequencies of proposed management changes recorded in the accompanying management plans (n = 370 farms)

Risk assessment question	High score ¹ (%)	Proposed management change	No.	% ²
Cattle introductions				
Purchase frequency (Q7)	86	Inquire about seller's Johne's disease control	51	3
		Only buy cattle from herds with known <i>Mycobacterium avium</i> ssp. <i>paratuberculosis</i> status	46	3
Purchase precautions (Q7.1)	85	Test animals before entering herd	1	1
		Keep a closed herd or minimized cattle purchases	21	1
Visitor access				
Visitor access (Q5)	71	Put bull calves outside facility for buyer to pick up	64	4
		Put up biosecurity signs	44	3
		Restrict visitor access to barn	17	1
		Provide visitors with clean boots	16	1
Calf diet				
Colostrum pooling (Q10)	58	Buy a pasteurizer	76	5
Feeding of bulk or pooled milk (Q12)	67			
Colostrum pooling (Q10)		Use colostrum replacement or dam's colostrum	55	3
		Use frozen colostrum labeled with cow identification	62	4
Feeding of nonsaleable milk (Q11)	61	Do not feed mastitis or nonsaleable milk	7	1
Feeding of bulk or pooled milk (Q12)		Do not feed bulk milk	51	3
Cow manure on calf buckets (Q13)	6	Clean or disinfect calf feeders, buckets, nipples, or bottles	10	1
Manure on calf feed and waterers (Q14)	4			
Feeding of nonsaleable or bulk milk (Q11, Q12)		Use milk replacer or pasteurized milk for calves	20	1
Not related to a score improvement in any question		Clip the udder before obtaining colostrum	3	1
Calf and young stock housing				
Proximity to cows or group housing (Q15)	23	Separate calves into individual pens with no contact	28	2
		No direct or indirect cow-calf contact	36	2
Exposure to cow manure or runoff (Q17)	74	No direct or indirect cow-calf contact		
Staff contamination (Q16)	59	Clean boots and coveralls for feeding calves	59	4
Custom heifer rearing (Q9)	3	No related suggestions		
Young stock cleanliness (Q20)	54	Keep stalls as clean as possible or more bedding	4	1
Manure on feed bunks and waterers (Q18)	30	Clean waterers or feed troughs more often	1	1
Calving pen				
Number of cows in calving pen (Q22)	77	Only one cow per calving pen	44	3
Calving pen contamination (Q23)	28	Add clean bedding for every calving	19	1
Animal contamination (Q24)	32			
Nursing of calves (Q27)	51	Removal of calves within 30 min	128	8
Time that calves spend with dam (Q28)	69			
Number of cows in calving pen (Q22)	77	Increase number of calving pens	135	8
Calves born outside calving pen (Q26)	31	Have more cows calve in calving pen	20	1
		Have a calving pen	34	2
Use of calving area for sick cows (Q25)	40	No sick cows in the calving pen	29	2
Lactating and dry cow pens				
Not related to any question		Make a close-up pen for cows ready to calve	17	1
Manure on dry cow feed bunks and waterers (Q29)	22	Clean dry cow drinkers more often	8	1
Dry cow contamination (Q31)	26	More bedding in close-up pen	25	2
		Keep stalls as clean as possible or more bedding		
Lactating cow contamination (Q34)	28	Keep stalls as clean as possible or more bedding		
Manure on dry cow feed bunks and waterers (Q29)	22	Clean waterers or feed troughs more often		
Manure on lactating cow feed and waterers (Q32)	17			
Feeding hygiene and equipment use				
Not related to a score improvement in any question		Disinfect equipment after handling of manure	65	4
Use of feeding equipment to remove manure (Q19)	56	Separate equipment for manure and feeding	85	5
Shared equipment, manure on pasture (Q30)	52			
Shared equipment, manure on pasture (Q33)	53			
Cattle show attendance (Q8)	25	Use trailer for own cattle only	51	3
Equipment use or leftover feed (Q19)	56	Do not feed leftover milking cow ration to heifers	32	2
Manure spread on heifer pasture (Q21)	15	No spreading of manure on land used the same year	110	7
Manure spread on cow pasture (Q30, Q33)				
Not related to a score improvement in any question		Request cleaning of commercial manure haulers	14	1
Management of likely infected cattle				
Not related to any question		On herd health day, check heifers first	10	1
Previous <i>Mycobacterium avium</i> ssp. <i>paratuberculosis</i> test results (Q6)	56	Test for Johne's disease more often	46	3
Not related to any question		Do not feed milk from test-positive cows to calves	4	1
Not related to any question		Cull test-positive cows	41	3
Not related to any question		Cull old cows rather than young ones	1	1

¹Percentage of farms that had a score ≥ 3 for the specified question in the first risk assessment.²Percentage of management suggestions among all suggestions.

Figure 1. Proportions of proposed management improvements in different management categories suggested by a subset of 9 example veterinarians, each of whom conducted at least 30 Alberta Johne’s Disease Initiative risk assessments and management plans.

compared with ES-negative farms ($P = 0.02$; Table 5). A question with a proposed management change had 1.32 times the odds to actually improve in score than a question where no change was proposed ($P = 0.001$). The odds for improving the score of a question was $1/0.63 = 1.59$ times higher after the first RA than after

Table 2. Final multilevel logistic regression model for proposing a change in management for a specific question in the Alberta Johne’s Disease Initiative risk assessment

Item	Odds ratio	95% CI	<i>P</i> -value	Variance (SEM)	% Variance
Intercept	−3.56 ¹	−3.86 to −3.26	<0.001		
Score in that risk assessment question			<0.001 ²		
1	Reference				
2	2.22	1.83 to 2.71	<0.001		
3	6.50	5.40 to 7.82	<0.001		
4	11.37	9.52 to 13.57	<0.001		
5 ³	16.19	11.75 to 22.30	<0.001		
Risk assessment category			<0.001 ²		
Cattle introductions	Reference				
Visitor access	0.66	0.48 to 0.93	0.016		
Calf diet	1.28	0.99 to 1.66	0.056		
Young stock housing	0.63	0.48 to 0.82	0.001		
Calving pen	0.98	0.76 to 1.25	0.859		
Lactating and dry cow pens	0.51	0.38 to 0.68	<0.001		
Feeding hygiene and equipment use	0.75	0.57 to 0.97	0.030		
Management of likely infected cattle	0.42	0.28 to 0.61	<0.001		
Random effects					
Veterinarian				0.13 (0.04)	3
Herd				0.02 (0.02)	0
Year of participation				0 (0)	0
Observation				—	97

¹Variable describes the log odds for proposed management change in the baseline group.

²Overall Wald *P*-value for the independent variable.

³Only possible in 2 questions (Q7 and Q7.1 in Appendix, Table A1).

Figure 2. Changes in total (sum) risk assessment (RA) scores between the first and the last RA conducted at 233 farms participating at least 2 yr in the Alberta Johne's Disease Initiative (y-axis = total RA score in first RA – total RA score in last RA; x-axis = farm percentiles; 370 = 100%).

the second RA ($P < 0.001$). Improvements in question scores varied between RA categories ($P < 0.001$), with questions regarding cattle introductions least often improving in score.

DISCUSSION

Identification in the RA of management practices linked to a high risk of introduction or transmission of MAP resulted in proposed management improvements, suggesting that the RA was used properly to draw attention to weaknesses in management, as communicated during AJDI veterinarian workshops. Questions linked to a proposed management change were more likely to actually improve in score in the subsequent year. Furthermore, ES-positive farms were more likely to make management improvements. However, the probability for management improvements decreased with increasing years of participation. Clustering within veterinarians and farms was low, suggesting that described associations were similar among participating farms.

As reported in other MAP-control programs, most farms improved their total RA scores during participation (Raizman et al., 2006; Wells et al., 2008; Sorge et al., 2011). The effect of previously received test results

was in agreement with Sorge et al. (2011), who reported more frequent management improvements in herds with MAP ELISA-positive cows compared with herds with MAP ELISA-negative cows (Sorge et al., 2011). A similar relationship was also observed for crop farmers, with those that perceived higher losses caused by a specific pest being more likely to implement a new spraying technique than those that perceived lower losses (Mueller and Jansen, 1988). Positive test results made farmers aware of the presence of MAP in their herd and the associated economic losses. These test-positive farms can expect a higher net benefit from implementation of new management practices than test-negative farms, as higher production through increased health outweighs the costs for management changes (Wolf et al., 2014b). However, motivation for management improvements may be decreased in test-negative, and perhaps false-negative, herds, which could result in increased probabilities for MAP introduction into uninfected herds and increased within-herd transmission in false-negative herds.

Rates of management improvements differed among categories of questions in the RA, similar to Sorge et al. (2011). However, a much stronger driver for proposal of management improvements was the RA score for

the particular question. This suggests that the RA was properly used to draw attention to observed weaknesses in management on that particular farm.

Implementation of management improvements and number of suggestions made decreased with duration of participation in the AJDI, confirming results of a study reporting similar differences in total RA scores between yr 1 and 2 and yr 1 and 4 (Wells et al., 2008). It is unlikely that 2 or 3 yr of AJDI participation resulted in perfect management. Therefore, farmers and veterinarians likely exhausted cheap and easy to implement options for management improvements. Making changes in RA design over the years, either through focusing on different areas on a farm or adding an additional disease to the program, may increase the motivation to make additional management improvement.

The total RA score was previously identified as a predictor for a reduction in RA scores (Sorge et al., 2011). This is in contrast to results of our study, where the question score in the previous year was identified as a predictor for management improvements and the total RA score did not affect management improvements. This suggests that herds with bad management in general were not more likely to implement management improvements.

In regards to proposed management improvements, results of the present study were similar to results of another study because changes in calf-feeding regimen and calving pen management were frequently proposed in both studies (Pieper et al., 2015). However, whereas purchase of pasteurizers was frequently proposed in the present study, reducing cattle purchase was a focus

Table 3. Question-specific changes in risk assessment (RA) scores on 233 farms participating in the Alberta Johne's Disease Initiative for at least 2 yr

Question	Change in score between 2 RA (%)		
	Worse	Equal	Better
Cattle introductions			
Purchase frequency (Q7)	9	68	24
Risk at purchase (Q7.1)	7	73	19
Visitor access			
Visitor access (Q5)	7	72	20
Calf diet			
Colostrum pooling (Q10)	12	67	21
Feeding of nonsaleable milk (Q11)	8	75	17
Feeding of bulk or pooled milk (Q12)	9	69	22
Cow manure on calf buckets (Q13)	10	79	11
Manure on calf feed and waterers (Q14)	9	85	6
Calf and young stock housing			
Custom heifer rearing (Q9)	2	98	0
Proximity to cows or group housing (Q15)	15	70	15
Staff contamination (Q16)	13	64	23
Exposure to cow manure or runoff (Q17)	15	67	17
Manure on feed bunks and waterers (Q18)	16	66	18
Animal contamination (Q20)	19	58	22
Calving pen			
Number of cows in calving pen (Q22)	8	76	16
Calving pen contamination (Q23)	16	58	25
Animal contamination (Q24)	19	63	19
Use of calving area for sick cows (Q25)	19	57	24
Calves born outside calving pen (Q26)	17	60	23
Calves nurse the cow (Q27)	11	66	23
Time that calves spend with dam (Q28)	15	60	24
Lactating and dry cow pens			
Manure on feed bunks and waterers (Q29)	22	61	17
Animal contamination (close-up cows) (Q31)	20	63	17
Manure on feed bunks and waterers (Q32)	17	68	15
Animal contamination (Q34)	16	64	20
Feeding hygiene and equipment use			
Show attendance (Q8)	5	82	13
Use of feeding equipment to remove manure (Q19)	13	63	25
Manure spread on heifer forage or pasture (Q21)	10	73	17
Shared equipment, manure on pasture grass (Q30)	11	66	23
Shared equipment, manure on pasture grass (Q33)	12	65	23
Management of likely <i>Mycobacterium avium</i> ssp. <i>paratuberculosis</i> -infected cattle			
<i>Mycobacterium avium</i> ssp. <i>paratuberculosis</i> testing history (Q6)	11	69	20

in Pieper et al. (2015). These differences could be explained by differences in farm management between the study locations, but might also be due to differences in RA designs and veterinarian trainings, making veterinarians focus on certain management areas on a farm.

Proposed management improvements in various categories differed among veterinarians, suggesting that veterinarians may have had preferences for specific management practices, which confirms findings of another study (Pieper et al., 2015). However, interobserver variability was only approximated within the present study because management suggestions were not compared between veterinarians conducting MP on the same farms.

A still unaddressed question is whether the implementation of management practices resulted in a reduction of MAP-positive ES and, therefore, a reduction of MAP within-herd prevalence. We refrained from addressing this question because it was assumed that ES were too imprecise to approximate MAP within-herd prevalence, and the study duration of 2 to 4 yr was too short to achieve a detectable within-herd prevalence re-

duction, considering that suggested management practices mainly addressed cow-to-calf transmission and ES collection was only done in cow pens. Furthermore, the ES culture protocol improved over the years, resulting in a higher number of positive samples in 2013 than in 2010, which would have biased study results (Wolf et al., 2014a). However, knowledge on effectiveness of various management practices for control of MAP is a major knowledge gap which needs to be addressed in future studies.

A limitation of our study was the method of risk factor and management assessment, with some risk factors and management practices assessed by veterinarians (e.g., animal contamination), and others assessed by producers (e.g., number of cows that calve outside the calving pen). Self-reported management can differ from true management, mainly because of misunderstanding the subject, suggesting potential for bias due to producer-assessed management (Sayers et al., 2013). This might especially be important in Alberta, where many dairy farmers are recent immigrants, which makes knowledge of the language a likely constraint.

Table 4. Changes in risk assessment (RA) question scores for individual questions assessed on 233 farms participating in the Alberta Johne's Disease Initiative for at least 2 yr

Item	Change in score between 2 RA [n (%)]		
	Worse	Equal	Better
Number of <i>Mycobacterium avium</i> ssp. <i>paratuberculosis</i> -positive environmental samples			
0	804 (12)	4,591 (69)	1,244 (19)
1–3	306 (13)	1,619 (70)	404 (17)
4–6	220 (16)	855 (63)	291 (21)
Proposed management change			
No	1,263 (13)	6,559 (69)	1,617 (17)
Yes	77 (7)	656 (61)	348 (32)
RA section			
Cattle introductions	54 (8)	480 (71)	146 (21)
Visitor access	25 (7)	247 (72)	69 (20)
Calf diet	134 (10)	985 (73)	239 (18)
Calf and young stock housing	252 (12)	1,497 (74)	286 (14)
Calving pen	358 (15)	1,493 (63)	523 (22)
Lactating and dry cow pens	306 (18)	1,093 (64)	296 (17)
Feeding hygiene and equipment use	175 (10)	1,186 (70)	337 (20)
Management of likely infected cattle	36 (11)	234 (69)	69 (20)
Year			
2nd RA	938 (13)	4,769 (66)	1,523 (21)
3rd RA	369 (12)	2,290 (75)	414 (13)
4th RA	33 (15)	156 (72)	28 (13)
Mean question score in previous RA			
1st quartile (low risk)	425 (15)	1,958 (69)	440 (16)
2nd quartile	344 (13)	1,838 (70)	428 (16)
3rd quartile	291 (12)	1,717 (68)	503 (20)
4th quartile (high risk)	280 (11)	1,702 (66)	594 (23)
Herd size			
<100 cows	355 (11)	2,183 (70)	594 (19)
100–199 cows	750 (13)	3,852 (68)	1,047 (19)
>199 cows	235 (14)	1,180 (68)	324 (19)
Question score in the previous year			
Low risk (<3)	1,152 (18)	4,633 (73)	539 (9)
High risk (>2)	188 (4)	2,582 (62)	1,426 (34)

However, the scores for all questions were recorded by veterinarians who could clarify questions for producers, which likely reduced potential for bias through misunderstanding. Another related concern might be that producers falsely stated that they implemented management practices to achieve progress. This was mitigated by data being collected by herd veterinarians, who are trusted advisors on the farm. Furthermore, producers received a written statement stating that results were treated anonymously by researchers, and no financial rewards were given for improvements in management. In addition, because management improvements were assessed through comparisons between subsequent RA scores instead of through asking whether changes were made, improvement rates were unlikely to have been overestimated.

Because herd size and MAP prevalence did not differ between study participants and nonparticipants (Ritter et al., 2014), the study population was likely representative of the target population. Study results can be generalized to other dairy farm populations because herd sizes and management strategies in freestall herds

are likely similar in other Canadian provinces, Europe, and most states in the United States. Adoption rates of best management practices are likely higher in control programs for diseases that more frequently manifest as clinical disease, such as digital dermatitis or mastitis, because associated disease losses are more visible to farmers, and therefore more obvious than losses through MAP. Therefore, results of the current study can be generalized to control programs on dairy farms targeting infectious pathogens with primarily subclinical occurrence.

CONCLUSIONS

Participation in a management-based MAP-control program resulted in management improvements on most farms. These management improvements were targeted toward weaknesses identified in current management. Farms that were ES MAP-positive were more likely to implement new best management practices than ES-negative farms, which suggests that knowledge of the infection status of a herd is important for management

Table 5. Final multilevel logistic regression model for improvement in the score of a question between 2 consecutive annual Johne's disease risk assessments

Item	Odds ratio	95% CI	P-value	Variance (SEM)	% Variance
Intercept	-2.70 ¹	-2.93 to -2.46	<0.001		
Number <i>Mycobacterium avium</i> ssp. <i>paratuberculosis</i> -positive environmental samples			0.029 ²		
0	Reference				
1-3	0.93	0.77 to 1.14	0.502		
4-6	1.32	1.03 to 1.68	0.026		
Proposed management change			<0.001 ²		
No	Reference				
Yes	1.37	1.64 to 1.61	<0.001		
RA section			<0.001 ²		
Cattle introductions	Reference				
Visitor access	1.28	0.90 to 1.82	0.167		
Calf diet	1.49	1.16 to 1.93	0.002		
Young stock housing	1.48	1.16 to 1.89	0.002		
Calving pen	2.22	1.76 to 2.78	<0.001		
Lactating and dry-cow pens	2.94	2.28 to 3.79	<0.001		
Feeding hygiene and equipment use	2.16	1.69 to 2.76	<0.001		
Management of likely infected cattle	1.66	1.17 to 2.37	0.005		
Year			<0.001 ²		
2nd RA	Reference				
3rd RA	0.63	0.54 to 0.73	<0.001		
4th RA	0.55	0.39 to 0.93	0.025		
Mean question score in previous RA	Not significant		(0.473) ²		
Herd size (no. of cows)	Not significant		(0.149) ²		
Score in that question in the previous year			<0.001 ²		
Low risk (<3)	Reference				
High risk (>2)	7.21	6.33 to 8.20	<0.001		
Random effects					
Veterinarian				0.12 (0.06)	4
Herd				0.29 (0.05)	8
Observation				—	88

¹Variable describes the log odds for management improvement in the baseline group.

²Overall Wald P-value for the independent variable.

decisions. Furthermore, management improvements decreased over years of participation, suggesting that it became increasingly difficult to make management improvements, based on the knowledge gained by conducting the same RA over several years.

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APPENDIX

Table A1. Prevalence of risk factors on farms participating in the Alberta Johnes's Disease (JD) Initiative, stratified by the year of participation

Item	Year of participation			
	1	2	3	4
General section				
Q5. What access do farm visitors have?				
No restrictions	234	115	41	0
Restrictions to mature cattle	28	22	9	0
Restrictions to preweaned cattle	26	28	13	1
Restricted access or required to wear special clothing	82	67	36	6
Q6. JD history?				
Yes, JD has been observed in the herd	109	71	31	0
Do not know	99	34	27	2
JD never observed; no testing done	97	42	10	1
JD never observed; testing in past 5 yr with negative results	65	86	31	4
Q7. Did you purchase any animals, including bulls, in last 5 yr?				
Yes, from multiple herds at public auctions	180	96	30	2
Yes, from auctions with known contributors	90	53	38	4
Yes, but only 1 or 2 animals from a single herd	1	9	5	0
Yes, from JD Herd Status Program ¹ farms	52	38	12	0
No purchases				
Q7.1. What precautions were taken?				
No precautions	272	143	50	5
Seller indicated no JD in the herd, but had never tested	31	25	16	0
Purchased animals were tested before delivery	13	9	8	0
Purchased animals came from low-risk herds (JD Herd Status Program)	5	19	13	2
No purchases	49	37	12	0
Q8. Show attendance; equipment sharing				
Yes, herd members attend shows or hauled in shared vehicles	60	27	9	1
Yes, pens are cleaned by custom manure removal operations	33	20	9	1
Yes, shows are only attended with herds with lower risk for <i>Mycobacterium avium</i> ssp. <i>paratuberculosis</i>	9	3	2	0
No show attendance, no shared equipment	268	183	79	5
Preweaned heifers				
Q9. Are any calves raised on custom heifer-rearing operations?				
Yes, the rearing operation raises heifers from multiple herds	11	4	5	1
Yes, but the rearing operation raises only heifers from my herd	2	4	2	0
No, all heifers are raised on farm	357	225	92	6
Q10. What is the source of colostrum?				
Pooled colostrum from >1 cow	37	13	4	0
Some calves get colostrum from a cow other than their dam	176	95	45	2
Calves are only given their dam's colostrum	124	92	36	4
Calves are only given pasteurized colostrum or colostrum replacer	33	33	14	1
Q11. How often is nonsaleable milk fed to calves?				
Nonsaleable milk is always (weekly) fed	178	94	27	1
Nonsaleable milk is often (once or twice a month) fed	47	28	15	0
Nonsaleable milk is rarely (once or twice a year) fed	24	12	11	0
Nonsaleable milk is never fed	121	99	46	6
Q12. What are the sources of liquid diet fed to calves?				
Bulk or pooled milk	208	103	35	2
Milk from individual cows	41	32	12	0
Pasteurized milk or milk replacer for <2 yr	34	33	12	2
Pasteurized milk or milk replacer for >2 yr	87	65	40	3
Q13. Is there any cow manure on milk feeding utensils?				
Extensive manure contamination	2	1	0	0
Some manure contamination	20	5	4	1
Traces of manure, but utensils washed at least weekly	108	69	25	2
No manure, utensils washed daily	240	158	70	4
Q14. Is there any cow manure in water buckets and feed bunks?				
Extensive manure contamination	3	0	0	0
Manure is clearly visible in calf feeders or water buckets	12	3	4	1
A scant amount of manure is visible	83	44	20	1
All calf feed and water containers are clean	272	186	75	5
Q15. How are calves housed?				
Close proximity to cows	14	9	1	0
Group pens until weaning	72	38	20	3
Individual pens with contact through partitions	107	61	24	1
Individual pens without contact	177	125	54	3

Continued

Table A1 (Continued). Prevalence of risk factors on farms participating in the Alberta Johne's Disease (JD) Initiative, stratified by the year of participation

Item	Year of participation			
	1	2	3	4
Q16. Staff hygiene routine when entering calf barn				
Staff never clean boots or change coveralls	107	35	9	0
Staff sometimes clean boots and change coveralls	110	68	28	2
Staff always clean boots and sometimes change coveralls	132	107	48	4
Staff always clean boots and change coveralls	21	23	14	1
Weaned heifers				
Q17. Exposure to cow manure or runoff				
Heifers share pens or pastures with cows	123	70	29	1
Heifers are housed near cows, exposure to runoff	150	103	47	1
Heifers housed near cows, no exposure to runoff	48	22	11	0
Heifers never housed near cows, no exposure to runoff	49	38	12	2
Q18. Manure contamination of feed bunks and water troughs				
Manure build-up in housing, contaminated feed bunks and water troughs	14	2	0	0
Manure clearly visible in feed bunks and water troughs	97	49	17	2
Traces of manure visible, feed bunks and water troughs cleaned more than once a month	164	113	51	2
No manure visible, feed bunks and water troughs cleaned more often than once a month	94	69	31	3
Q19. Is feed equipment used for manure, or left over feed given to heifers?				
Feeding equipment is used to remove manure	157	75	21	3
Feeding equipment not used for manure, but cow left over feed fed to heifers <1 yr of age	49	24	9	0
Feeding equipment not used for manure, but cow left over feed fed to heifers >1 yr of age	54	42	18	2
Feeding equipment is not used for manure, left over feed is never fed to heifers	109	92	51	2
Q20. To what degree is manure contamination evident on heifers?				
Manure is present above hocks or knees and on flanks	40	12	5	0
Manure is present on hocks or knees or on flanks	161	90	47	6
Manure is present up to dewclaws	135	104	40	1
No visible manure on animals	33	27	7	0
Q21. Manure spread on heifer forage or pasture used the same year				
Manure is spread on pastures where heifers graze	36	12	4	0
Manure is spread on land next to heifer pastures	21	9	2	0
Manure is spread on forage land used to feed heifers	131	74	33	1
Manure is never spread on land used for heifers	181	138	60	6
Calving pen				
Q22. How many cows are in a calving pen at a time?				
>1 cow >50% of the time	245	150	64	4
>1 cow 25-50% of the time	41	25	13	0
>1 cow <25% of the time	54	35	13	2
Never >1 cow	30	23	9	1
Q23. How contaminated with manure is the calving pen?				
Visible manure covering >66% of the bedding	26	3	3	0
Visible manure covering 50% of the bedding	76	29	9	1
Visible manure covering 10% of the bedding	196	151	66	4
No visible manure	72	50	21	2
Q24. To what degree is manure contamination evident on cows?				
Manure present above hocks and on teats or udders	17	3	3	0
Manure present up to hocks or on teats or udders	100	56	23	5
Manure present above dewclaws, but not on teats or udders	209	145	65	2
No visible manure, udder hair is clipped and teats are washed	44	29	8	0
Q25. Use of calving area for sick cows				
Frequent use of calving area by noncalving cows or known <i>Mycobacterium avium</i> ssp. <i>paratuberculosis</i> -positive cows	80	46	12	0
Occasional use of calving area by noncalving cows	68	44	19	0
Rare use of calving area by noncalving cows	106	62	32	3
Calving area is never used by noncalving cows	116	81	36	4
Q26. Calves born outside the calving area in the past year				
>10%	80	40	16	0
6-10%	33	25	9	0
1-5%	173	108	48	4
Never	84	60	26	3
Q27. What percentage of calves nurse their dam?				
>50% nurse their dam, are left >4 h	93	36	12	0
10-50% nurse their dam	96	63	24	0
<10% nurse their dam	155	112	57	6
None	26	22	6	1

Continued

Table A1 (Continued). Prevalence of risk factors on farms participating in the Alberta Johne's Disease (JD) Initiative, stratified by the year of participation

Item	Year of participation			
	1	2	3	4
Q28. How long do calves stay with their dam?				
<10% of calves are removed <30 min	176	88	36	1
10-50% are removed <30 min	77	62	25	2
50-90% are removed <30 min	77	54	22	0
>90% are removed <30 min	39	29	16	4
Dry cows				
Q29. Manure contamination of feed bunks and water troughs				
Extensive manure contamination	5	0	0	0
Manure clearly visible	75	43	19	1
Trace amounts of manure visible	189	129	53	3
No manure contamination	101	61	27	3
Q30. Manure contamination in dry-cow forage or on pasture used the same year				
Feeding equipment is used to scrape manure	156	72	22	3
Feeding equipment not used to scrape manure, but manure spread on pasture or crop land	38	18	4	0
Feeding equipment not used to scrape manure, manure not spread on pasture but on crop land	54	45	18	0
Feeding equipment not used to scrape manure, and manure not spread on pasture or crop land	122	98	55	4
Q31. Manure contamination on close-up cows				
Manure above knees or hocks and on flanks	25	10	4	1
Manure above knees or hocks but not on flanks	73	35	20	2
Manure not above knees or hocks	194	134	56	3
Cows are clean above fetlocks	78	54	19	1
Lactating cows				
Q32. Manure contamination of feed bunks and water troughs				
Extensive manure contamination	10	3	0	0
Manure clearly visible	53	20	6	0
Trace amounts of manure visible	199	134	59	4
No manure contamination	107	76	34	3
Q33. Manure contamination in lactating cows forage or on pasture used in the same year				
Feeding equipment is used to scrape manure	156	76	20	3
Feeding equipment not used to scrape manure, but manure spread on pasture or crop land	38	12	4	0
Feeding equipment not used to scrape manure, manure not spread on pasture but on crop land	52	38	20	0
Feeding equipment not used to scrape manure, and manure not spread on pasture or crop land	123	107	55	4
Q34. Manure contamination on lactating cows				
Manure above knees or hocks and on flanks	36	10	3	1
Manure above knees or hocks but not on flanks	69	37	20	1
Manure not above knees or hocks	214	138	59	2
Cows are clean above fetlocks	50	48	17	3

¹JD Herd Status Program: This is a voluntary program in which participating farms can be certified as farms with a low risk for *Mycobacterium avium* ssp. *paratuberculosis* infection through repeated testing.