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Dairy cattle farmers' preferences for different breeding tools

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ABSTRACT

Breeding technologies play a significant role in improving dairy cattle production. Scientifically proven tools for improved management and genetic gain in dairy herds, such as sexed semen, beef semen, genomic testing, dairy crossbreeding, and multiple ovulation embryo transfer (**MOET**), are readily available to dairy farmers. However, despite good accessibility, decreasing costs, and continuous development of these tools, their use in Sweden is limited. This study investigated Swedish dairy farmers' preferences for breeding tools through a survey including a discrete choice experiment. The survey was distributed online to 1 521 Swedish farmers and by an open link published through a farming magazine. In total, the study included 204 completed responses. The discrete choice experiment consisted of 10 questions with two alternative combinations, which gave 48 combinations in total. Utility values and part-worth values were computed using a conditional logit model based on the responses in the discrete choice experiment for nine groups of respondents: one group with all respondents, two groups based on respondents using dairy crossbreeding or not within the past 12 months, two based on herd size, two based on respondent age, and two based on whether respondents had used breeding advisory services or not. The strongest preferences in all groups were for using sexed semen and beef semen. Genomic testing was also significantly preferred by all groups of respondents. Except in large herds, MOET on own animals was significantly and relatively strongly disfavoured by all groups. Buying embryos had no significant utility value to any group. Dairy crossbreeding had low and insignificant utility values in the group of all respondents, but it was strongly favoured by the group that had used dairy crossbreeding within the past 12 months, and it was disfavoured by the group that had not. Part-worth values of combined breeding tools showed that combinations of sexed and beef semen, alone or with genomic testing without dairy crossbreeding, were the most preferred tools. Compared with the most common combinations of breeding tools used in the past 12 months, the part-worth values indicated that Swedish dairy farmers may prefer to use breeding tools more than they do today. Statements on the different breeding tools indicated that the respondents agreed with the benefits attributed to the breeding tools, but these benefits may not be worth the cost of genomic testing and the time consumption of MOET. These valuable insights can be used for further development of breeding tools.

Implications

Knowing the dairy farmers' preferences for using different breeding tools provides valuable information for future advisory services, marketing, and research. In general, the dairy farmers in the study were positive about using breeding tools and may want to use them more than they do today. The results give information that can be used to strategise advisory services to increase the use of breeding tools that already have shown economic and genetic benefits and potential environmental benefits. Additionally, the results provide insight into where more research and development on the breeding tools are needed for their benefits to overcome the practical challenges.

Introduction

Breeding technologies have contributed significantly to the development of livestock production (Johnson and Ruttan, 1997). Artificial insemination for dairy cattle saw a breakthrough when

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the first artificial insemination cooperative commercialised it in Denmark in 1936, while half a century later, artificial insemination with sexed semen became available on the market (Lonergan, 2018). Sexed semen increases the chance of conceiving a heifer calf to about 90%, compared with 50% using regular semen (DeJarnette et al., 2009). This allows the farmer to produce replacement heifers from the genetically best cows, thus increasing the herd's genetic level. There is also an economic benefit from combining strategies using sexed semen and beef semen and producing beef × dairy crossbred calves for higher slaughter output (Ettema et al., 2017; Pahmeyer and Britz, 2020). While the use of sexed semen and beef semen is rapidly increasing in other countries (Burnell, 2019), only around 5% of inseminations in Swedish dairy cows in 2019 were with sexed semen (Växa Sverige, 2019) and use of beef semen for dairy cows in that year was around 12% (Växa Sverige, 2020). Clasen et al. (2021) show that more economic gain could be achieved by increasing sexed semen and beef semen use.

Genomic testing became commercially available when genomic breeding evaluation was introduced in 2008 (García-Ruiz et al., 2016). Genomic testing of heifer calves provides genomically enhanced breeding values that allow farmers to select replacement heifers more accurately at a young age (García-Ruiz et al., 2016). Genomic breeding evaluation of females has contributed to faster genetic gain in dairy herds and breeding populations (Bérodier et al., 2019). The frequency of genomic testing heifers in Sweden has increased markedly during recent years, with almost 20% of all heifer calves being genomically tested in 2020 (Lina Baudin, Växa Sverige, personal communication 2021).

According to Touchberry (1992), crossbreeding was probably one of the first genetic experiments performed on dairy cattle, and studies on dairy crossbreeding were performed worldwide in the early 1900s (e.g., Ellinger, 1923). Crossbreeding creates more robust animals, with economic benefits for dairy herds (Clasen et al., 2020; Shonka-Martin et al., 2019). Except for in New Zealand, the frequency of crossbred dairy cattle worldwide is rather low. Systematic dairy crossbreeding, e.g., in a rotational crossbreeding system such as ProCross (www.procross.info), was only practised in a few Swedish herds until recently. In 2019, the proportion of crossbred dairy cows in milk production was almost 10% (Växa Sverige, 2020), but it is unknown how many of those are crossbreds by systematic crossbreeding.

Commercial embryo technology in dairy cattle became available in the 1970s. Multiple ovulation embryo transfer (**MOET**) is today used by breeding organisations across the world (Mapletoft, 2013) and has shown genetic benefits on population level (Pedersen et al., 2012; Sørensen et al., 2011). Compared with other European countries, Sweden ranks relatively low in the number of *in vivo* embryos collected (Quinton, 2019).

Despite breeding tools like sexed semen, beef semen, genomic testing, dairy crossbreeding, and MOET being readily available to farmers, their use in Swedish herds is somewhat limited. Wallin and Källström (2019) interviewed 14 Swedish dairy farmers during 2015 about their perceptions of sexed semen, beef semen, genomic testing, dairy crossbreeding, and MOET. All farmers in the study had an interest in breeding and genetics and had a positive attitude to sexed semen, and most of them used it to select the genetically best cows and heifers as dams. Some of the farmers acknowledged the economic and genetic benefits of genomic selection, while others showed scepticism. In general, MOET was perceived as too expensive and time-consuming relative to its benefits. The main reasons given for using (or not using) modern breeding tools were economic risks and the farmer's interest in breeding and genetics (Wallin and Källström, 2019). Other reasons can be the production system, traditions, and practical conditions (Howley et al., 2012; Khanal and Gillespie, 2013; Verma et al., 2020). The interview study by Wallin and Källström (2019) gave insights into a few Swedish farmers' preferences for the different breeding tools. However, general perceptions need to be investigated on a larger scale, for example, in a survey of many Swedish farmers.

A discrete choice experiment is a standard survey method used for marketing and economic analyses of customer preferences (de Bekker-Grob et al., 2015). It involves letting the respondent choose between combinations of attributes based on random utility theory (Louviere et al., 2010). Within the agricultural sector, discrete choice experiment has been used for practical issues and research, such as assessing farmers' preferences for automatic lameness detection systems (Van De Gucht et al., 2017) and investigating discrimination against agricultural workers (Gerds, 2012). Unlike a simple ranking system, the discrete choice experiment method can be used to estimate the strength and relative importance of respondents' preferences for a given attribute (Hauber et al., 2016).

Therefore, this study investigated Swedish dairy farmers' preferences for using sexed semen, beef semen, genomic testing, dairy crossbreeding, and MOET through a survey including a discrete choice experiment. The aim of the study was to get an insight into farmer preferences for using various breeding tools and provide new knowledge for the development of breeding strategies at farm level in dairy cattle in Sweden and in general.

Material and methods

Survey design

The survey was divided into three parts. The first part consisted of 16 demographic and general questions. Some of these questions were about the farm: geographical location, production system, number of cows within breed group, production level, and breeding management, and about the respondent: gender, age, education, role on the farm, and breeding interest. A question about whether the respondent had used any of the five breeding tools (sexed semen, beef semen, genomic testing, dairy crossbreeding, MOET) within the past 12 months was also included. An English translation of the questions in part 1 is included in Supplementary Material S1.

To limit the length of the survey, we did not ask questions related to the strategy behind the farmers' use of breeding tools or specific reasons for using the breeding tools. Using sexed semen and beef semen referred to insemination with those semen types instead of conventional insemination. Genomic testing (genomic testing) referred to genotyping of females and use of genomically enhanced breeding values to select heifers for breeding and replacement in the herd. Dairy crossbreeding referred to deliberately crossing dairy breeds and utilising the benefits of it, but not necessarily systematic crossbreeding on part of (or the entire) herd. The use of MOET referred to flushing own animals for embryos or buying embryos. We did not ask questions regarding general herd recording. Most Swedish cows are affiliated with the Nordic milk recording scheme, which also includes reproductive information, recordings of veterinarian treatments, status of the animal (alive or dead), slaughter classifications, conformation scores, and pedigree information (Växa Sverige, 2021). The information in the milk recording scheme is used for breeding value estimation provided by the Nordic Cattle Genetic Evaluation (www.nordicebv.info). Additionally, Swedish legislation requires registration of all animals, calvings, and their destiny.

The second part of the survey was a discrete choice experiment with five attributes (the breeding tools sexed semen, beef semen, genomic testing, dairy crossbreeding, and MOET), which had 2, 2, 2, 2, and 3 levels, respectively (Table 1), combined into 48 different sets of breeding tools. The respondent was given 10 tasks with two random sets of combinations, consisting of all five breeding tools.

Table 1
Overview of the attributes included and their levels in the discrete choice experiment survey for dairy cattle farmers.

Attribute	Level
Sexed semen	Yes – in the entire or part of the herd No
Beef semen	Yes – in part of the herd No
Genomic test	Yes – in the entire or part of the herd No
Dairy crossbreeding	Yes – in the entire or part of the herd No
MOET[1]	Buying embryo On own animals No

[1] MOET = multiple ovulation embryo transfer.

Johnson and Orme (2010) recommend at least eight tasks for an analysis to be statistically feasible, while too many tasks may become too time-consuming and tedious for the respondent. Johnson and Orme (2010) also suggest that the discrete choice experiment be designed to ensure that each level within the attributes is shown at least 500 times to the respondents. We limited the discrete choice experiment to 10 tasks, to avoid losing respondents due to the time needed to fill in the survey. Based on this number, we calculated the minimum number of respondents required, using the formula suggested by Johnson and Orme (2010) and rearranged by de Bekker-Grob et al. (2015):

$$\frac{n * t * a}{c} \geq 500 \rightarrow n \geq \frac{500 * c}{t * a}$$

where n = number of respondents, t = number of tasks, a = number of combination sets per task, and c = highest number of levels within attributes. Here, the number of tasks (t) was 10, the number of sets of combinations per task (a) was two, and the highest number of levels within any attribute (c) was three. The minimum sample size, i.e., the minimum number of respondents required for the survey, was thus 75.

We informed the respondents that some combinations might not be a realistic alternative and urged them to choose the combination that they liked the most or disliked the least. We also reminded them to choose based on what they prefer, disregarding whether they can do it today. For example, MOET is not allowed in organic production (European Union, 2018), but we asked the organic farmers to respond as if it were allowed.

The third part of the survey consisted of five seven-point scale matrices consisting of 6–10 statements for each breeding tool. The statements were drawn partly from the interview study by Wallin and Källström (2019) and partly from other statements made by farm advisors. Examples of statements were "genomic testing makes breeding more interesting" and "sexed semen is only profitable if there is a market for dairy heifers". The respondents were asked whether they agreed (1) or disagreed (7) with the statements, with the option to respond "do not know".

All questions in the survey required a response. The respondents were given the option to write a comment at the end of the survey.

The survey was designed and distributed through QuestionPro Survey Software (www.questionpro.com) and was pretested on 20 test subjects (farmers, breeding advisors, researchers). The feedback was used to improve the survey before it was sent out to Swedish farmers.

Respondents

On September 3, 2020, an e-mail invitation containing an internet link to the survey was sent to 1 521 dairy farmers across Sweden, using e-mail addresses obtained from Statistics Sweden (SCB; www.scb.se) for farms registered with dairy farming as the primary activity. A reminder was sent to the same e-mail addresses three weeks later. To improve the response rate during the last week of response collection, we provided a second internet link in the farming magazine "*Husdjur*" (www.vxa.se/husdjur). The magazine published the link in the news feed on its homepage and posted a link on its Facebook page. The survey was closed to responses on October 3, 2020.

By the close of the response period, 184 respondents had completed the survey through the e-mail invitation, a response rate of 184/1 521 = 12%. Another 20 respondents completed the survey through the secondary link. In total, 253 people began to complete the survey and thus the completion rate was (184 + 20)/253 = 81%. It took the respondents an average of 19 (SD 14) minutes to complete the survey. There were no apparent duplicates among the 204 completed responses. Three pairs of respondents were most likely from the same three farms, but the responses were different within pairs, and they were all used in the analysis.

Sixty per cent of the respondents were male and 40% were female. The oldest respondent was an 84-year-old male and the youngest respondent was a 20-year-old female (Fig. 1). The average age of all respondents was 48 (SD 12) years, and the age distribution within male and female respondents was similar (not shown). Most of the respondents had an agricultural diploma or degree as their highest educational background. Most of the respondents reported ownership or co-ownership of the farm.

The respondents expressed a considerable interest in breeding, with a mean score of 3.9 (±0.9) on a scale from 1 (not interested) to 5 (very interested).

Farms

The farms were distributed across all regions in Sweden and corresponded to the national dairy farm distribution. Twenty-four per cent of the farms used an organic production system, which is somewhat higher than the frequency across all dairy farms in Sweden (18%) (Växa Sverige, 2021). The remaining 76% were conventional dairy farms. The average herd size among the respondents was 123 (±132) cows (Fig. 2), which is larger than the average herd size in Sweden (92 cows) (Växa Sverige, 2021). Thirteen per cent of the farms had more than 200 cows, the largest farm had 1 360 cows, and the smallest farm had 14 cows. The average milk yield per cow on the farms ranged between 10 000 and 12 000 kg ECM per year (Fig. 2), which is higher than the average milk yield in Sweden (10 232 kg ECM/yr) (Växa Sverige, 2021). Less than half of the farms had more than 90% of a single breed in their herd, while the majority were categorised as mixed herds. Sixty-one herds had more than 5% dairy crossbreds, but only 10 herds had more than 25% crossbreds.

Half of the respondents reported making breeding decisions in collaboration with a breeding advisor or a semen distributor, 15% made these decisions together with other people on the farm, 8% made them independently, and 27% did not participate in making breeding decisions.

Analysis

Random utility theory expects the respondent to choose the combination that maximises their utility (Hauber et al., 2016). The data from the discrete choice experiment were analysed using a conditional logit model from the "mlogit" package (Croissant,

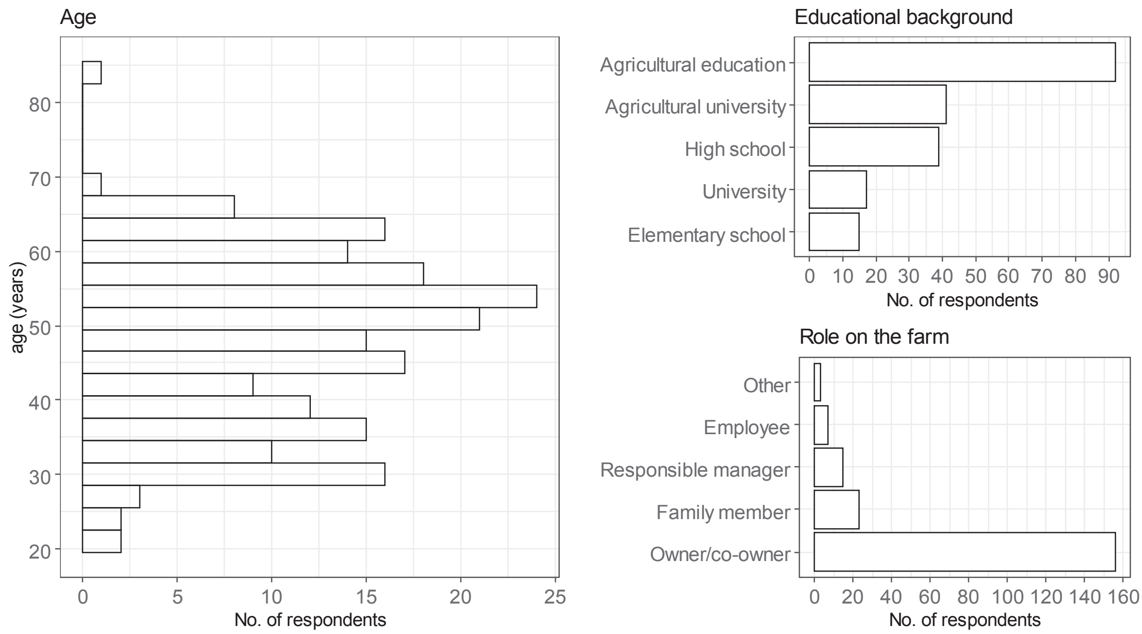

Fig. 1. Distribution of the respondents' age (left), highest educational background (top right), and role on the dairy cattle farm (bottom right).

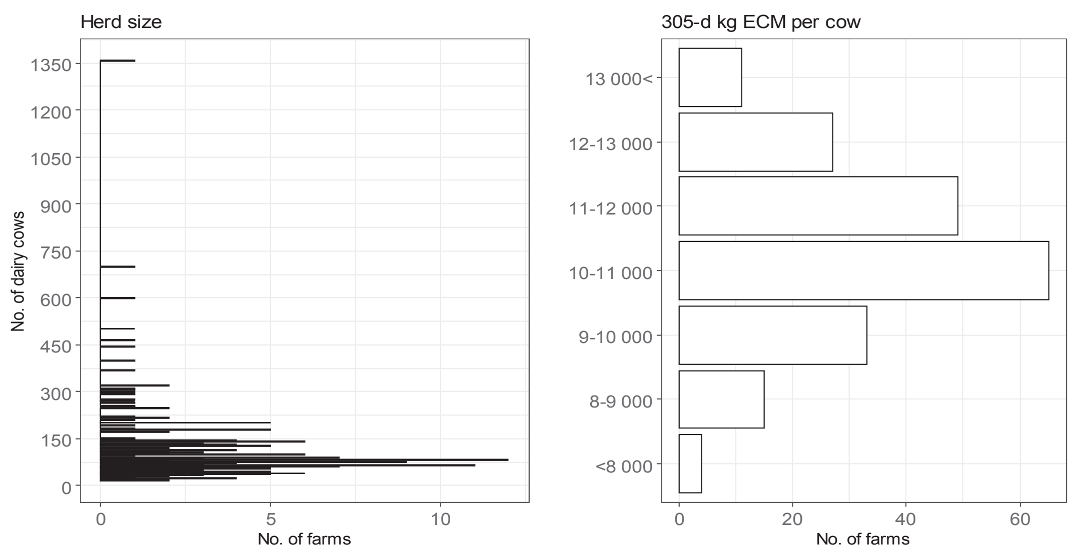

Fig. 2. Frequency of herd size (left) and distribution of groups by 305-day kg ECM yield per cow (right).

2020) in the R-software version 4.0.0 (R Core Team, 2020). The model estimates utility values as regression coefficients of each level within each attribute (breeding tool). A positive utility value means that the respondent favours using the breeding tool at the given level, while a negative value means that they are against using it. The utility values within each breeding tool add up to 0 across the levels. The utility values for the "no" levels (Table 1) are not presented in the results but have the opposite sign of the given utility values for "yes" within each breeding tool. The magnitude of the utility values can be compared relative to each other, to indicate how much one breeding tool is favoured (or disfavoured) relative to another. Each breeding tool's relative importance is calculated by

$$RI_i = \frac{|u_{max,i}|}{\sum_j |u_{max,j}|}$$

where RI_i is the relative importance of breeding tool i (sexed semen, beef semen, genomic testing, dairy crossbreeding, and MOET), $|u_{max,i}|$ is the maximum absolute utility value of levels within breeding tool i, and $\sum_j |u_{max,j}|$ is the sum of all maximum absolute utility values of levels within each breeding tool j (sexed semen, beef semen, genomic testing, dairy crossbreeding, and MOET). The sum of each combination's utility values gives a part-worth value, which is the maximum utility of that combination:

$$pw_c = SS_c + BS_c + GT_c + XB_c + MOET_c$$

where pw_c is the part-worth value of combination c (1...48) and SS_c, BS_c, GT_c, XB, and $MOET_c$ are the utility values for sexed semen, beef semen, genomic testing, dairy crossbreeding and MOET, respectively, at the given level (Table 1) in the combination.

We estimated utility values for the nine different groups of respondents. The first group included all 204 respondents (**ALL**).

The second and third groups included, respectively, respondents who had used dairy crossbreeding as a breeding tool within the past 12 months (**CROSS**; *n* = 80) and respondents who had not used it (**NOCROSS**; *n* = 124). The fourth and fifth groups included, respectively, respondents with more than 100 dairy cows (**LARGER**; *n* = 82) and respondents with 100 or fewer dairy cows in the herd (**SMALLER**; *n* = 122). The sixth and seventh groups included, respectively, respondents older than or 50 years old (**OLDER**; *n* = 103) and respondents younger than 50 years old (**YOUNGER**; *n* = 101). The eighth and ninth groups included, respectively, respondents who make breeding decisions collaborating with a breeding advisor or semen distributor (**ADV**; *n* = 96), and respondents with no breeding advisor or semen distributor (**NOADV**; *n* = 108). Table 2 provides an overview of some of the responses to part 1 for the groups.

Part-worth values were estimated using the utility values estimated for the ALL group. When calculating the part-worth values, we merged two of the three MOET levels: "MOET on own animals" and "buying embryos". It thereby corresponded to a "yes" alternative and reduced the number of combinations to 32 instead of 48. Thus, we were able to rank them according to the highest part-worth value and compare them against the most common combinations of breeding tools used within the past 12 months.

Results

Many of the respondents reported using sexed semen (77%) and beef semen (75%) within the past 12 months. Almost half of them had used genomic testing (47%), and more than a third had used dairy crossbreeding (39%). Fourteen per cent of the respondents had used MOET within the past 12 months.

Preferences for breeding tools

Sexed semen had significantly positive utility values (Table 3), indicating a preference for using sexed semen as a breeding tool. Comparing the respondent groups, sexed semen had the highest utility values among the groups LARGER (0.711), CROSS (0.662), and YOUNGER (0.644). It was also the relatively most important breeding tool for the respondents within all groups except for SMALLER (Table 4). Note that an "important tool" is a tool that the respondents have strong opinions about, and it can reflect a clear preference for using the tool or a clear preference for not using the tool.

Beef semen had significantly positive utility values among all respondents and is thus a good breeding tool (Table 3). The highest utility value for beef semen was in the LARGER group (0.507). It was the second most important breeding tool within all groups except ADV, for which genomic testing was relatively more important (Table 4).

Genomic testing was favourable across all groups and showed significantly positive utility values (Table 3). The utility values ranged between 0.207 and 0.278 for most groups but were notably different for ADV (0.408) and NOADV (0.115). The relative importance of genomic testing also differed between these two groups: for ADV, it was the second most important breeding tool, while for NOADV, it was the fourth most important breeding tool (Table 4). Among the other groups, genomic testing mostly ranked closely with MOET as the third or fourth most important breeding tool. The only exception was CROSS, where it ranked as the least important breeding tool.

Dairy crossbreeding had only significant utility values for the CROSS group, where it was favourable (0.414), and for the groups NOCROSS and YOUNGER, who were against dairy crossbreeding (−0.271 and −0.110, respectively) (Table 3). The NOCROSS group considered dairy crossbreeding almost as important as genomic testing and MOET (16.1 vs 16.3% and 16.7% (Table 4). For the CROSS group, dairy crossbreeding was almost as important as beef semen (19.9 vs 20.3%), after sexed semen (31.8%). For the remaining groups, dairy crossbreeding was a relatively unimportant breeding tool (0.1–5.5%).

The respondents were clearly against using MOET on their animals. For all groups, the utility values for MOET on own animals were negative, although not significantly negative for the LARGER group (Table 3). The most negative utility values were for the groups SMALLER (−0.356) and ADV (−0.302). Interestingly, the value for SMALLER was slightly significant in favour of buying embryos (0.104). For the other groups, the utility values were not significantly different from zero. Comparing the utility values with the other breeding tools, MOET was relatively important for the respondent groups to avoid (Table 4). In most groups, it was the third most important breeding tool. For the SMALLER group, however, it was the relatively most important breeding tool.

Table 2
Overview of responses to questions about the respondents, the dairy cattle herds, and the use of breeding tools within the past 12 months for different groups of respondents. Frequencies and mean values (with SD).

	Group[1]							
Item	CROSS	NOCROSS	LARGER	SMALLER	OLDER	YOUNGER	ADV	NOADV
N	80	124	82	122	103	101	96	108
Age, years	47 (12)	48 (12)	46 (10)	50 (12)	58 (6)	38 (7)	47 (12)	49 (12)
Female (%)	45	38	49	35	32	49	37	43
Herd size, no. of cows	145 (180)	109 (88)	214 (171)	62 (22)	118 (156)	128 (103)	128 (114)	118 (147)
Breeding interest, 1–5	3.8 (0.8)	4.0 (0.9)	4.0 (0.9)	3.9 (0.9)	3.9 (0.9)	3.9 (0.9)	3.8 (0.8)	4.0 (1.0)
Organic (%)	20	26	22	25	26	21	23	24
>10 000 kg ECM[2] (%)	76	74	87	66	71	78	78	71
Breeding advisor[3] (%)	46	48	53	43	44	51	100	0
Sexed semen (%)	85	73	87	71	71	84	78	77
Beef semen (%)	76	73	87	67	70	80	77	73
Genomic testing (%)	51	44	54	43	44	50	54	41
Dairy crossbreeding (%)	100	0	46	34	37	42	39	40
MOET[4] (%)	13	15	23	8	16	13	13	16

[1] CROSS = respondents who had used dairy crossbreeding as a breeding tool within the past 12 months; NOCROSS = respondents who had not used dairy crossbreeding as a breeding tool within the past 12 months; LARGER = respondents with more than 100 dairy cows in their herd; SMALLER = respondents with 100 or less dairy cows in their herd; OLDER = respondents aged 50 years or older; YOUNGER = respondents younger than 50 years; ADV = respondents who make breeding decisions together with a breeding advisor or semen distributor; NOADV = respondents who make breeding decisions without a breeding advisor.
[2] Energy-corrected milk yield per cow and year.
[3] Making breeding decisions together with a breeding advisor or semen distributor.
[4] MOET = multiple ovulation embryo transfer.

Table 3
Utility values[1] for different groups of respondents[2] on the five breeding tools: sexed semen (sexed semen), beef semen (beef semen), genomic testing (genomic testing), dairy crossbreeding (dairy crossbreeding), and multiple ovulation embryo transfer on own animals (MOET own) or buying embryos (MOET buy). Negative values indicate a preference not to use the breeding tool, while positive values indicate a preference in favour of the breeding tool.

	Group								
Breeding tool	ALL	CROSS	NOCROSS	LARGER	SMALLER	OLDER	YOUNGER	ADV	NOADV
Sexed semen	$0.520_{0.036}$ ***	$0.662_{0.064}$ ***	$0.480_{0.048}$ ***	$0.711_{0.066}$ ***	$0.424_{0.046}$ ***	$0.427_{0.050}$ ***	$0.644_{0.055}$ ***	$0.589_{0.056}$ ***	$0.477_{0.051}$ ***
Beef semen	$0.387_{0.035}$ ***	$0.424_{0.061}$ ***	$0.378_{0.048}$ ***	$0.507_{0.063}$ ***	$0.314_{0.046}$ ***	$0.326_{0.050}$ ***	$0.448_{0.055}$ ***	$0.324_{0.055}$ ***	$0.419_{0.049}$ ***
Genomic testing	$0.244_{0.033}$ ***	$0.213_{0.058}$ ***	$0.274_{0.045}$ ***	$0.259_{0.057}$ ***	$0.229_{0.044}$ ***	$0.278_{0.048}$ ***	$0.207_{0.050}$ ***	$0.408_{0.053}$ ***	$0.115_{0.046}$ **
Dairy crossbreeding	$-0.008_{0.033}$ NS	$0.414_{0.062}$ ***	$-0.271_{0.045}$ ***	$0.001_{0.057}$ NS	$0.037_{0.044}$ NS	$0.051_{0.048}$ NS	$-0.110_{0.051}$ **	$0.029_{0.052}$ NS	$-0.077_{0.048}$ NS
MOET own	$-0.239_{0.046}$ ***	$-0.287_{0.081}$ ***	$-0.251_{0.062}$ ***	$-0.102_{0.079}$ NS	$-0.356_{0.061}$ ***	$-0.259_{0.068}$ ***	$-0.247_{0.069}$ ***	$-0.302_{0.073}$ ***	$-0.230_{0.065}$***
MOET buy	$-0.008_{0.047}$ NS	$0.083_{0.082}$ NS	$-0.031_{0.063}$ NS	$-0.095_{0.080}$ NS	$0.104_{0.062}$ *	$0.039_{0.067}$ NS	$0.014_{0.071}$ NS	$-0.039_{0.072}$ NS	$0.090_{0.066}$ NS

[1] SE in subscript; NS = p > 0.1; *p < 0.1; **p < 0.05; ***p < 0.001.
[2] ALL = all respondents; CROSS = respondents who had used dairy crossbreeding as a breeding tool within the past 12 months; NOCROSS = respondents who had not used dairy crossbreeding as a breeding tool within the past 12 months; LARGER = respondents with more than 100 dairy cows in their herd; SMALLER = respondents with 100 or less dairy cows in their herd; OLDER = respondents aged 50 years or older; YOUNGER = respondents younger than 50 years; ADV = respondents who make breeding decisions together with a breeding advisor or semen distributor; NOADV = respondents who make breeding decisions without a breeding advisor.

Table 4
Relative importance (%) within different groups of respondents[1] of the five breeding tools: sexed semen, beef semen, genomic testing, dairy crossbreeding, and multiple ovulation embryo transfer (MOET).

	Group								
Breeding tool	ALL	CROSS	NOCROSS	LARGER	SMALLER	OLDER	YOUNGER	ADV	NOADV
Sexed semen	36.8	31.8	28.5	42.5	28.9	31.0	38.6	34.8	33.9
Beef semen	27.4	20.3	22.4	30.3	21.4	23.6	26.8	19.2	29.7
Genomic testing	17.3	10.2	16.3	15.4	15.6	20.1	12.4	24.1	8.2
Dairy crossbreeding	0.5	19.9	16.1	0.1	2.6	3.7	6.5	1.7	5.5
MOET	18.0	17.8	16.7	11.7	31.5	21.6	15.6	20.1	22.7

[1] ALL = all respondents; CROSS = respondents who had used dairy crossbreeding as a breeding tool within the past 12 months; NOCROSS = respondents who had not used dairy crossbreeding as a breeding tool within the past 12 months; LARGER = respondents with more than 100 dairy cows in their herd; SMALLER = respondents with 100 or less dairy cows in their herd; OLDER = respondents aged 50 years or older; YOUNGER = respondents younger than 50 years; ADV = respondents who make breeding decisions together with a breeding advisor or semen distributor; NOADV = respondents who make breeding decisions without a breeding advisor.

The two most preferred (highest part-worth values) combinations of breeding tools for ALL respondents were sexed semen, beef semen, and genomic testing with or without dairy crossbreeding (Table 5). Those two combinations were the second and third most frequent combination of breeding tools used by the respondents within the past 12 months. The combination of sexed semen and beef semen was the most frequent combination of breeding tool used within the past 12 months and it had the third highest part-worth value. In general, sexed semen was included in all top 10 combinations and beef semen in most top combinations. Genomic testing was generally included in the higher ranks, while MOET was generally included in the lower ranks (Supplementary Table S1). Dairy crossbreeding was distributed equally across the ranking list.

Interestingly, the combination of all breeding tools seemed more preferred than used within the past 12 months. The combination that indicated not using any of the breeding tools had a negative part-worth value (−0.90; Suppl. Table S1), while 16 of the respondents had not used any of the breeding tools within the past 12 months. For 16 respondents, this combination of (not) used tools was the fifth most common combination.

Statements

The whole response scale was used (1 = disagree to 7 = agree) by the respondents in relation to the statements. For most statements, the frequency of "do not know" responses was below 10%. The standard deviation within each statement was between 1.4 and 2.6 (mean 2.1).

The respondents mostly agreed that sexed semen makes breeding more interesting and has benefits, such as increased genetic level in the herd and an excellent strategy to avoid the health risk of buying animals from other herds (Fig. 3). The respondents generally believed that using sexed semen was independent of the

Table 5
Ranking of the 10 most preferred combinations of the five breeding tools: sexed semen, beef semen, genomic testing, dairy crossbreeding, and multiple ovulation embryo transfer (MOET), part-worth values of these combinations, and number of respondents who had used these combinations of breeding tools within the past 12 months.

Rank	Part-worth	Sexed semen	Beef semen	Genomic testing	Dairy crossbreeding	MOET	Current use (n)
1	1.41	X	X	X	–	–	26
2	1.39	X	X	X	X	–	27
3	0.92	X	X	–	–	–	32
4	0.91	X	X	X	–	X	15
5	0.90	X	X	–	X	–	21
5	0.90	X	X	X	X	X	9
7	0.63	X	–	X	–	–	6
8	0.62	X	–	X	X	–	3
9	0.42	X	X	–	–	X	2
10	0.41	X	X	–	X	X	1

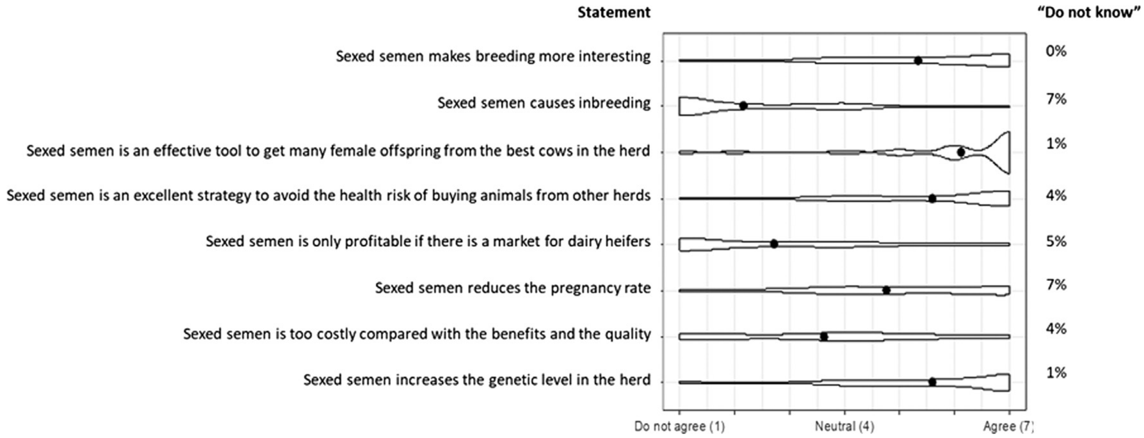

Fig. 3. Responses to statements (left-hand side) about using sexed semen in dairy cattle. Black dots indicate the mean of responses, numbers on the right-hand side indicate the frequency (%) of respondents who answered "do not know" to the statement.

livestock market, i.e., to sell surplus replacement heifers. However, there was a neutral opinion about the cost of sexed semen compared with the benefits and quality.

Many of the respondents shared the same opinions about beef semen (Fig. 4), e.g., that beef × dairy crossbreds increase the income from slaughter animals and that the knowledge about beef × dairy crossbreeding is sufficient in Sweden to make it safe to choose. The respondents mostly disagreed with the statement that the use of beef semen causes calving difficulties. Many (29%) answered "do not know" about methane emissions from raising beef × dairy crossbred calves compared with dairy bull calves, and the rest were generally neutral to it. Most respondents disagreed that it is challenging to sell beef × dairy crossbred heifers on the market, but 12% did not know.

The responses to genomic testing statements were generally neutral (Fig. 5) compared with the responses to sexed semen and beef semen statements, and more respondents answered "do not know" to these statements. The most apparent response was that most respondents disagreed with the statement that genomic testing causes inbreeding problems. Although the averages were closer to neutral, the responses were towards agreement about the benefits of genomic testing, which is an easy tool to use and makes breeding more interesting. On the economic side, however, the respondents seemed split on the statements that genomic testing is too costly compared with the benefits and that the motivation for using it is dependent on a stable milk price.

The respondents were neutral to, or had split opinions about, dairy crossbreeding (Fig. 6). The respondents generally disagreed that dairy crossbreeding takes too long for the full effect and is dependent on a stable milk price. They tended to agree that dairy crossbreeding makes robust animals. There was also slight agreement with the statements that dairy crossbreeding threatens purebreds and that it is insecure to use without breeding values for dairy crossbreeding animals. The respondents were split on the statement that it is challenging to sell crossbred dairy heifers on the market, but 30% of them did not know.

Between 10 and 21% of the respondents answered "do not know" to the statements about MOET (Fig. 7). There was agreement with statements about the benefits of MOET among those who had an opinion. However, the respondents also agreed that MOET is too complicated and time-consuming compared with the benefits.

Discussion

The number of responses in this study (204) was relatively low compared to the number of invited farmers (1 521). The farms tended to be, on average, larger than the average Swedish herd and with a higher yearly milk production. The respondents were, on average, very interested in breeding. Furthermore, the respondents had used or at least tried the various breeding tools to a large extent, suggesting that they are more interested in breeding than the average Swedish farmer. When inviting the farmers to the survey, we emphasised our desire for responses regardless of breeding interest. However, people may be more likely to respond to surveys on topics that they are interested in, which probably causes a systematic bias in the survey results (Little and Rubin, 2019; Lohr, 2019). Therefore, the results from this study may not perfectly rep-

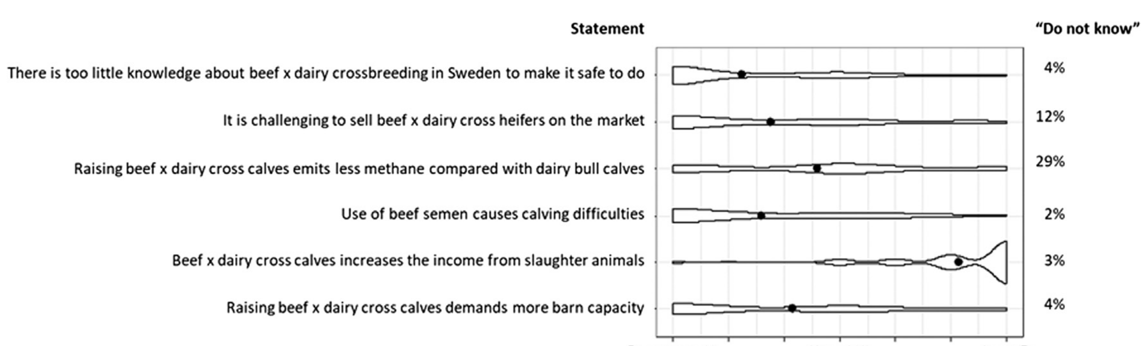

Fig. 4. Responses to statements (left-hand side) about using beef semen in dairy cattle. Black dots indicate the mean of responses, numbers on the right-hand side indicate the frequency (%) of respondents who answered "do not know" to the statement.

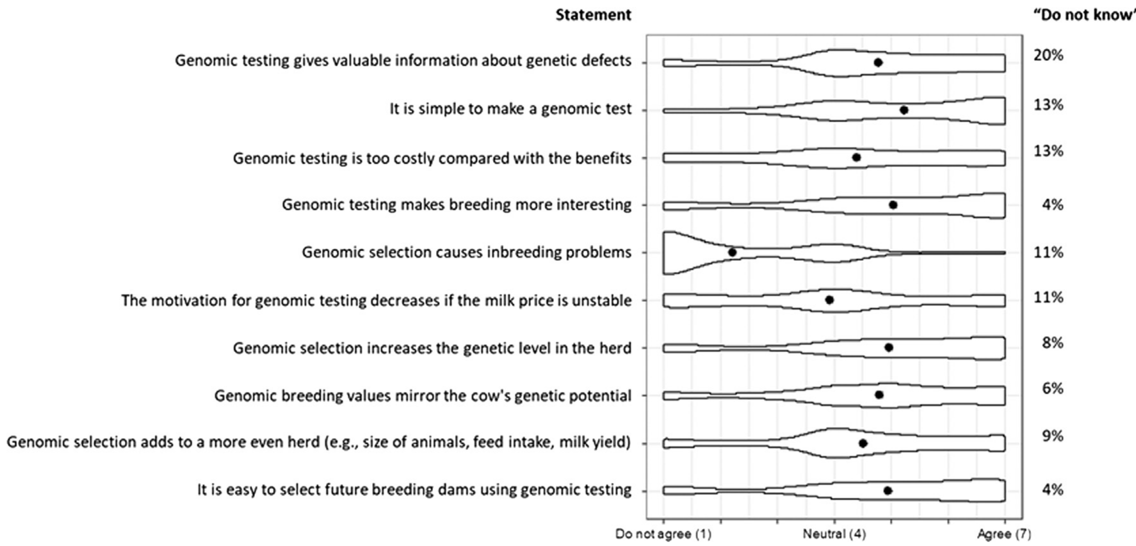

Fig. 5. Responses to statements (left-hand side) about using genomic testing in dairy cattle. Black dots indicate the mean of responses, numbers on the right-hand side indicate the frequency (%) of respondents who answered "do not know" to the statement.

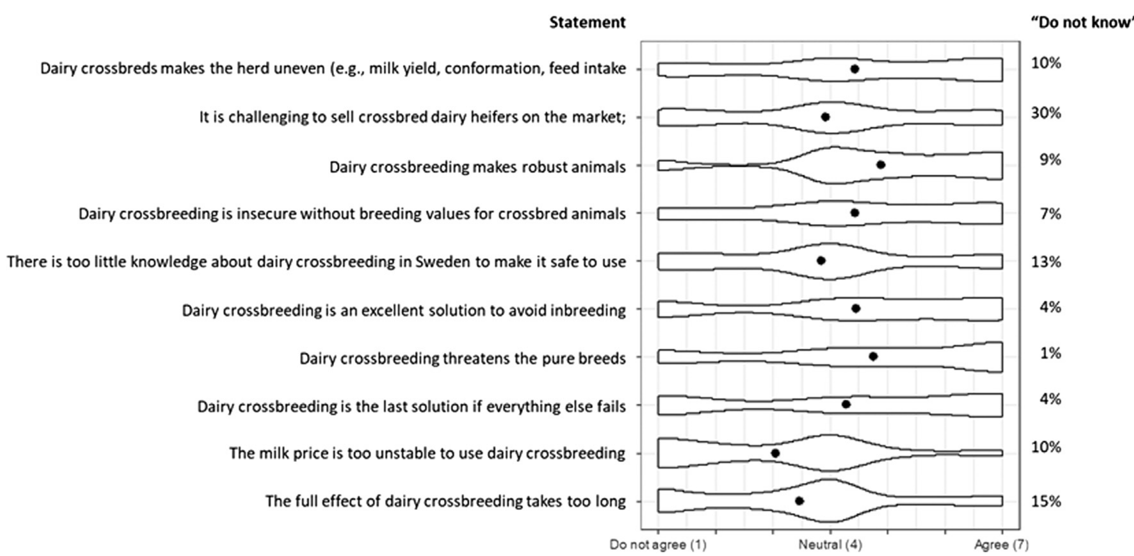

Fig. 6. Responses to statements (left-hand side) about using crossbreeding in dairy cattle. Black dots indicate the mean of responses, numbers on the right-hand side indicate the frequency (%) of respondents who answered "do not know" to the statement.

resent the views of the current average Swedish farmer, but rather the average future farmer, with higher yields and larger herds. Also, these farmers were clearly interested in breeding. Thus, their values and practices may form future trends in breeding at farm level, and their large interest in breeding makes them important stakeholders for universities and breeding organisations.

The interview study by Wallin and Källström (2019) investigated farmers' perceptions of sexed semen, beef semen, genomic testing, dairy crossbreeding, and MOET on a small scale (n = 14), and their findings can be used to help understand the results in this study.

Use and preference of breeding tools

Reported use of the breeding tools within the past 12 months gave the impression of much more extensive use of these tools than current Swedish statistics suggest. For example, 77% of the respondents reported using sexed semen in their herd within the past 12 months, but the latest statistics (from 2019) indicate that just 5% of inseminations in Sweden are with sexed semen (Växa Sverige, 2019). Of course, the two values are not directly comparable, because some respondents may have tried the tool only once or twice, but the discrepancy suggests that the respondents in this study use breeding tools more frequently than the typical Swedish farmer. However, based on how the question was formulated, we cannot say whether the farmers had used the breeding tool systematically or just tested it occasionally.

The respondents indicated the highest preference for sexed semen and beef semen, and these were also the two most used breeding tools. Combinations including both sexed semen and beef semen generally ranked high on the preferred and current use rankings. Compared with the three other breeding tools (genomic testing, dairy crossbreeding, and MOET), the sexed semen and beef semen concepts have been on the market for longer and therefore the farmers may be more confident in choosing them (or not choosing them). Furthermore, there is no immediate practical dif-

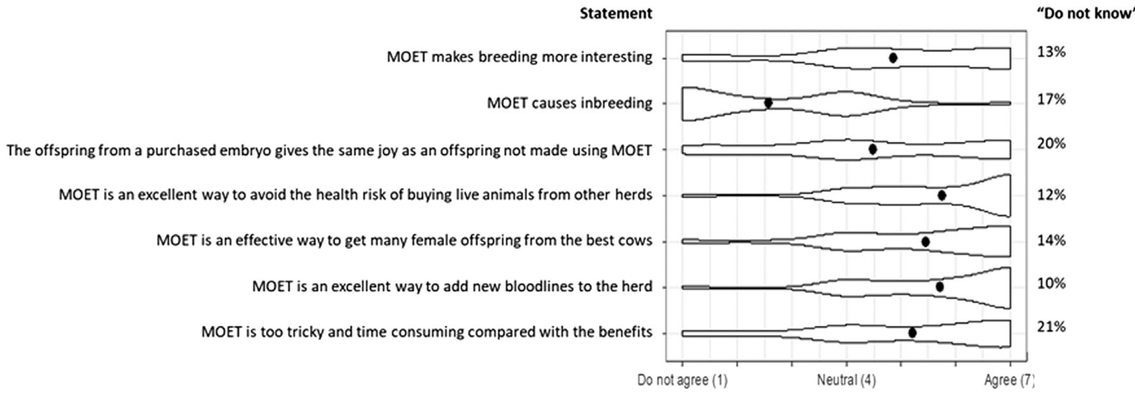

Fig. 7. Responses to statements (left-hand side) about using multiple ovulation embryo transfer (MOET) in dairy cattle. Black dots indicate the mean of responses, numbers on the right-hand side indicate the frequency (%) of respondents who answered "do not know" to the statement.

ference between insemination using sexed semen, beef semen, or regular semen. On the other hand, starting genomic testing or applying MOET involves additional practical tasks that increase the workload for the farmer.

The respondents somewhat agreed that the pregnancy rate is reduced with sexed semen and were on average neutral to the statement that sexed semen is too costly compared with the benefits. These two statements may be connected, since in the interview study by Wallin and Källström (2019), one farmer pointed out that sexed semen is too costly and reduces pregnancy rates if the artificial insemination technician is inexperienced. In Sweden, 75% of all inseminations are carried out by the farmers themselves, instead of specialist technicians (Växa Sverige, 2020). The pregnancy rate with sexed semen is 70–90% of that with conventional semen (Borchersen and Peacock, 2009; Healy et al., 2013; Maicas et al., 2020) but to our knowledge, there is no scientific evidence to support or indicate that pregnancy rate is reduced when farmers carry out inseminations.

In general, the respondents were in favour of genomic testing. In addition, the part-worth value ranking of combinations compared with the combination of breeding tools used within the past 12 months suggests that the respondents want to use genomic testing more than they do now. The answers to the statements about genomic testing indicate that the respondents are aware of the genetic benefits of genomic testing. However, they seemed split on the economic statements, i.e., that genomic testing is too expensive compared with the benefits and that the motivation for using it depends on the milk price. Between 2015 and 2020, the cost of a genomic test in Sweden almost halved, from €50 to €22.5. According to Hjortø et al. (2015), the breakeven price of genomic testing lies between €21 and €37, depending on the reproductive level in the herd and the strategic use of sexed semen. Genomic testing was the least important breeding tool in the CROSS group, probably because genomically enhanced breeding values are not yet available for crossbred animals in Sweden.

According to the discrete choice experiment analysis, dairy crossbreeding was insignificant to the farmers when studied as a whole (the ALL group). However, the results for the groups CROSS and NOCROSS indicated two types of farmers: those in favour of dairy crossbreeding and those against it. During recent decades, a concept of three-breed rotational crossbreeding, with Holstein, Swedish Red, and French Montbéliarde (ProCross; www.procross.info), has gained popularity in Sweden. The benefits attributed to this crossbreeding strategy are based on a 10-year research trial in Minnesota, USA (Hazel et al., 2017), about which some of the respondents in this study showed scepticism in their additional comments. These farmers were explicitly concerned about implementing an "American" breeding strategy, and one respondent wanted to see other crossbreeding strategies on the market.

It was clear that the respondents disliked MOET. Even though the average response to the statements indicated that they agreed on its benefits, MOET was considered relatively essential to avoid among the groups analysed in the discrete choice experiment. There are probably several reasons for this. In the responses to statements, most agreed that MOET is too complicated and time-consuming given the benefits. The fact that 24% of the respondents practised organic farming may be a second reason, but the group of respondents from organic farms was too small (n = 48) for a separate discrete choice experiment analysis to be statistically sound. However, the strong significance against MOET in the ALL group and in most other groups analysed suggests that the result was not only affected by organic farmers' opinion. In other words, conventional farmers were also against MOET. A third reason may be that only 14% of all the respondents had used MOET, so few had experience of using it, and there was a relatively high frequency of "do not know" answers to the statements about MOET. A fourth reason may be the joy of succeeding as a breeder. The respondents were split on the statement about whether offspring resulting from MOET gives as much joy as offspring obtained (as a breeder) through generations of breeding. This statement was based on a response given by one of the farmers interviewed by Wallin and Källström (2019). The joy of breeding to that farmer was in the underlying planning, and not in creating a faster genetic gain.

Comparison of part-worth values of the combinations of breeding tools versus the frequency of use of the breeding tools within the past 12 months gave two indications, that: (1) the farmers are already using some of the tools they prefer, and (2) they may want to use more breeding tools than they are already using. The respondents had the highest preference for the same three combinations of breeding tools as they had used during the past 12 months, although not entirely in the same order. Using none of the breeding tools was among the least preferred combinations, although it was among the most common options currently used by the farmers.

Factors affecting willingness to adopt breeding tools

In this study, we did not investigate explicit reasons for the preferences indicated by the responding farmers. However, we compared discrete choice experiment analyses between groups depending on herd size and respondents' age, which may be influential factors.

Comparing the regression coefficients from discrete choice experiment analyses on herd size (LARGER versus SMALLER) indicated that respondents with large herds had a stronger preference for using some breeding tools. For example, the regression coefficient on sexed semen was almost 70% larger for the group with large herds than the group with small herds (Table 4). Furthermore, MOET was insignificant for respondents with large herds, but those with smaller herds were significantly against MOET on their animals but neutral to buying embryos. This was probably related to a more frequent use of MOET the past 12 months (23%) in the LARGER group than in the SMALLER group (8%). Based on data from 1814 US dairy farms, Khanal and Gillespie (2013) investigated the type of dairy producers most likely to adopt advanced breeding tools (MOET, sexed semen, artificial insemination) and examined the factors influencing adoption. They found that larger farms (≥100 cows) were more likely to adopt MOET and sexed semen (and artificial insemination), because these farms were more profitable and could thus afford to invest in more advanced breeding tools. Herd size also played a significant role in willingness to pay for sexed semen in a study by Verma et al. (2020) on 89 commercial dairy farmers in India. In the current study, a higher frequency of respondents from the LARGER group had used the breeding tools the past 12 months than respondents from the SMALLER group. Howley et al. (2012) investigated factors affecting willingness to adopt artificial insemination on Irish dairy, beef, and sheep farms, using comprehensive data from a national farm survey answered by approximately 1 100 farmers yearly between 1995 and 2009. They found that increased herd size had a (small) negative effect on dairy farmers' likelihood to adopt artificial insemination, whereas stocking rate had a positive effect. Howley et al. (2012) therefore concluded that the negative effect of herd size was associated with extensive production systems.

When comparing the two age groups in the present study (YOUNGER versus OLDER), the differences were minor. Interestingly, sexed semen and beef semen preferences were stronger among the young respondents, while the preference for genomic testing was slightly weaker and the preference against MOET on own animals was nearly the same. Respondents from the YOUNGER group also tended to have used more of the breeding tools in the past 12 months, than respondents from the OLDER group. In the studies by Khanal and Gillespie (2013) and Howley et al. (2012), younger respondents were more likely to adopt breeding tools. Both studies concluded that this is because younger farmers have more than 10 years of farming to come, and therefore, it is more relevant for them to make long-term decisions. Howley et al. (2012) suggested that younger farmers might also have a higher level of education and better knowledge about breeding tools. Unfortunately, we could not make a discrete choice experiment analysis based on education level, as there were too few respondents with a university education (n = 58).

In the study by Howley et al. (2012), making breeding decisions with an advisor was associated with a higher likelihood of adopting breeding tools. In the present study, the most noticeable difference between ADV and NOADV was for genomic testing. The preference for genomic testing was positive for both groups, but genomic testing was 3.5 times more important to those who made decisions with a breeding advisor (ADV). This suggests that the breeding advisors had a positive effect on the farmers' preference for genomic testing. However, several respondents added critical comments about breeding companies and advisory services in Sweden. They claimed that the breeding advice they received was too much in one direction and left little opportunity for the farmer to individualise their breeding goals. Eight out of the 14 farmers interviewed by Wallin and Källström (2019) had the same perception of advisory services. On the other hand, those in that study who used breeding advisors were very satisfied with their inputs.

Discrete choice experiment

Unlike a simple conjoint analysis, the discrete choice experiment approach allows for selection of preferred combinations of levels between attributes rather than single attributes (Louviere et al., 2010). Thus, we analysed the respondents' preferences for combinations of breeding tools, rather than merely ranking the breeding tools individually.

The optimal number of combined concepts and tasks given to respondents is a balance between the number of respondents required for the observations to be statistically sound and a fair cognitive challenge. Increasing the number of tasks (10 in our study) might have reduced the response rate, given that 19% of the respondents who began the survey did not complete it and that the rest spent on average 19 minutes on it. Thus, the choice tasks may have become too heavy a burden for some respondents. In other discrete choice experiment studies, Bech et al. (2011) did not experience a lower response rate on presenting 16 compared with four tasks to the 1 053 respondents, while Hensher et al. (2001) found a negligible impact on response rates (about 165 respondents) on increasing the number of tasks. Both studies concluded that more tasks add no additional variation between the estimated utility values in each experiment. Given the recommendations by Johnson and Orme (2010), reducing the number of tasks from 10 to eight (the minimum number of tasks recommended) would require at least 94 respondents if each level within the attribute were to be shown at least 500 times.

Conclusions

The Swedish dairy farmers who participated in this survey reported a clear preference for using sexed semen and beef semen in their herds, probably because most had already used it previously and there is no practical barrier between regular insemination and sexed semen or beef semen. The farmers were also positive towards using genomic testing, but the cost of genomic testing compared with its benefits might still be an issue for some farmers. There was a clear aversion to using MOET on own animals, but buying embryos was not significant to the farmers. For many of the respondents, dairy crossbreeding was not an important tool, but in groups of farmers who had used dairy crossbreeding or not used it, there was a pattern of two extreme groups favouring and against it. These valuable insights into farmers' preferences for breeding tools can be used by e.g., breeding advisors and companies to strategise their services, and by researchers to guide further development of breeding tools.

Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.animal.2021.100409.

Ethics approval

Not applicable.

Data and model availability statement

None of the data were deposited in an official repository. Data can be provided upon request to the corresponding author.

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Declaration of interest

None.

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