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Abstract

Even when dairy cattle breeding organizations have no interest to implement environment-specific breeding programs, farmers may benefit from using herd-specific breeding goals instead of the main breeding goal of their breed. To assess this hypothesis, we constructed and compared four different breeding goals under conventional or organic farming system (two per system). The Total Merit Index derived from the simulated breeding goals were used to optimize the mating of 9,143 Montbéliarde females to 54 bulls. Despite strong correlations between the total merit indices (0.98), more than a quarter of the planned matings were different among the breeding goal considered. Results also showed that farmers would economically benefit from using herd-specific breeding goals instead of the main breeding goal of their breed without the need to create a specific breeding program.

Introduction

At breed's level, Mulder *et al.* (2006) showed that from dairy cattle breeding organizations' point of view (breeding elite sires), there is no need to implement environment-specific progeny testing breeding programs when the genetic correlation between two environments is higher than 0.61. More recently, Slagboom *et al.* (2019) reached similar conclusions under genomic selection. But at herd's level when optimizing the matings of their females, even if there is no need to create a specific breeding program, farmers may benefit from using herd-specific breeding goals instead of the main breeding goal of their breed. To test this hypothesis in the case of the Montbéliarde breed, we studied the situation under four distinct breeding goals (organic-based or conventional) for which different total merit indices were derived.

Materials & Methods

Simulated mating plans. To assess the losses/gains related to the optimization of the matings based on a given expected economic score (EES) specific to a farming system (e.g. standard conventional farming system) while the females to be bred (and their future offspring) are raised under a different context (e.g. organic farming system), the average economic results of four mating plans (scenarios) were calculated using the EES values of each of the four farming systems (scales). Therefore, 9,143 genotyped Montbéliarde females from 160 French herds were virtually planned for mating with a set of 54 genotyped bulls, using a linear programming approach. It resulted in 4 mating plans, one per breeding goal tested. Mate allocation optimization was performed based on the EES of each potential mating. This EES accounts for the expected genetic merit of the progeny (expected Total Merit), mates' coancestry, type of semen (sexed or conventional) and risk to conceive an embryo affected by a genetic defect as in Bérodier *et al.* (2020).

Breeding goals definition. To assess the influence of a breeding goal on optimized mating plans, we constructed and compared four different breeding goals, similarly to the work of Slagboom *et al*. (2018): (1) the current breeding goal of the Montbéliarde breed which focuses on standard traits of economic interest but also includes type traits (STD_TYP); (2) an organic breeding goal based on economic optimization at farm level (ORG_ECO scenario); (3) a so-called "ethic" organic breeding goal based on the four main international principles of organic agriculture set up by IFOAM (International Federation of Organic Agriculture Movements), namely Health, Ecology, Fairness and Care (ORG_ETH scenario); (4) a conventional breeding goal based on economic optimization at herd level, consequently, not integrating type traits (STD_ECO scenario). The four main international principles of organic agriculture are not economically orientated. IFOAM asserts that organic farming should sustain and enhance the health of all beings, should be based on living ecological systems and cycles, should ensure fairness with regard to the common environment and life opportunities and should protect the health and well-being of current and future generations and the environment.

Genetic gain and inbreeding depression. The last update of the STD_TYP breeding goal was performed in 2012 based on economic optimization models and including the Montbéliarde breed specific expectations in terms of selection for type. The STD_ECO and ORG_ECO breeding goals were directly derived from economic models specific to the farming system considered (Pinard and Regaldo, 2013), respectively a conventional and an organic farming system. For ORG_ETH system, the challenge was to build a breeding goal that leads to genetic gain on the most important traits according to the four main principles of organic agriculture (and not a purely economic objective). Results from Slagboom *et al.* (2018) were adapted to the traits available for selection in the Montbéliarde breed in France. An in-house software developed by the Institut de l'Elevage was used. Briefly, this software simulates selection in a real population on the animals' estimated breeding values (EBV), provided as an input file with many different weight combinations until a response to selection maximizing economic gain is found. This software also accounts for specific constraints to prevent a negative selection response for a particular trait with no economic value associated (Fuerst-Waltl et al., 2016), for instance traits related to the principles of organic agriculture. The use of data from a real population as an input enables the program to account for observed genetic correlations (positive or negative) between the different traits of the breeding goal. The inputs were: a dataset of 11,400 young Montbéliarde bulls born between 2013 and 2018 with their EBV; economic values of the genetic standard deviation of each trait; if necessary, constraints on responses to selection (e.g., no negative response to selection for dairy production traits). Correlations between the four Total Merit Index EBV (one per breeding goal) were calculated from the EBV of the 54 bulls and 9143 females considered in this study (Table 1).

Table 1. Correlations between Total Merit Index EBV of the four breeding goals.

	STD_ECO	ORG_ECO	ORG_ETH
ORG_ECO	0.98		
ORG_ETH	0.81	0.76	
STD_TYP	0.85	0.88	0.62

Table 2 provides the relative weights per genetic standard deviations unit for the traits included in our four simulated breeding goals. To calculate EES, the economic value associated to one genetic standard deviation of the simulated total merit indices (σ) and to the economic impact of 1% of inbreeding (λ) were calculated as in Bérodier et al. (2020) (Table 2).

Table 2. Traits' relative weights per genetic standard deviation and economic values associated to each breeding goal (= scenario).

	Trait[1] (%)														Value[2] (€)	
Scenario	FY	PY	FR	PR	CS	MS	CF	HF	CI	LO	CE	CM	MS	TT	σ	λ
STD_ECO	12	36			17	1	13	4		17					295	26.1
ORG_ECO	15	39			12	9	9	2		14					295	34.5
ORG_ETH	7	17			13	19	15	4		19	3	3			251	34.5
STD_TYP	1	9.8	4.8	29.4	8.7	5.8	9	4.5	4.5	5			5	12.5	246	26.1

[1] Traits included each breeding goal: Fat yield (FY), Protein yield (PY), Fat rate (FR), Protein rate (PR), Cells (CS), Mastitis (MS), Cow fertility (CF), Heifer fertility (HF), Calving to first insemination interval (CI), Longevity (LO), Calving Ease (CE), Calf Mortality (CM), Milking speed (MS), Type traits (TT)
[2] Economic values associated to one genetic standard deviation (σ) and to 1% of inbreeding (λ)

Economic gain. The 16 economic results obtained from the simulated mating plan were expressed as a deviation from a random mating plan (i.e., where cows were mated at random to one of the 54 bulls available - Bérodier *et al.* (2020)). For instance, the expected average economic gain when optimizing the mate allocation based on STD_TYP information while the herd is under an ORG_ECO farming system, compared to a random mating situation, was calculated as:

$$\frac{\sum_{i=1}^{nb\_couples} score_{i,ORG_{ECO}}(STD\_TYP) - \sum_{j=1}^{nb\_couples} score_{j,ORG_{ECO}}(RAND)}{nb\_couples}$$

With $score_{i,ORG\_ECO}$(STD_TYP) the ORG_ECO EES of couple i which was planned using linear programming mate allocation optimization base on STD_TYP information; $score_{j,ORG\_ECO}$(RAND) the ORG_ECO EES of couple j which was planned using random mate allocation; nb_couples the number of couples to plan (9,143, the number of females to mate).

Results

Mate allocation value.

Table 3 can be interpreted as follows: if breeders' breeding goal (scale) is ORG_ETH and their breeding plan are based on the STD_TYP information (scenario), they will earn on average 78€ more per mating over the productive life of an offspring by optimizing their matings using the STD_TYP total merit index whereas they could have earned on average 107,5€ more per offspring by optimizing their matings with the ORG_ETH total merit index.

Table 3. Average economic score deviation (in euros) from random matings.

	Scale[1]			
Scenarios[2]	STD_ECO	ORG_ECO	ORG_ETH	STD_TYP
STD_ECO	84	90.6	94	63.5
ORG_ECO	80.6	93.6	89.7	66.3
ORG_ETH	74.4	81.6	107.5	57.9
STD_TYP	69	81	78	73.9

[1] Farming system of the herd and farmer's breeding goal
[2] Type of EES used to optimize the matings

As expected, for each economic score scale (i.e. for each farming system), the best average economic score is obtained with the scenario (i.e. with the mating plan) using the same information (Table 3). For instance, farmers in ORG_ETH farming systems can expect to increase on average its benefit from 29.5€ (= 107.5 - 98) per per female offspring over its carrier when using ORG_ETH instead of STD_TYP breeding goal to optimize matings. In table 4, the percentage of identical matings between two scenarios indicates that despite strong correlations between the total merit indices (e.g., 0.98 between the STD_ECO and ORG_ECO scenarios), more than a quarter of the planned matings are different. Similarly, the lower the correlations between the total merit indices of the different breeding goals, the lower the correlations between the bulls' contributions (i.e., their number of planned matings).

Table 4. Percentage of identical matings between two mate allocation scenarios (lower triangular matrix) and correlations between sires contributions (i.e. number of planned matings) across scenarios (upper triangular matrix).

	STD_ECO	ORG_ECO	ORG_ETH	STD_TYP
STD_ECO	-	91%	78%	65%
ORG_ECO	74%	-	70%	71%
ORG_ETH	58%	52%	-	55%
STD_TYP	53%	57%	45%	-

Discussion

These results confirm our hypothesis that farmers can benefit from using herd-specific breeding goals instead of the main breeding goal of their breed even when there is no need to create a specific breeding program adapted to their within-herd breeding goal. For the four breeding goals simulated, the correlations between the total merit indices are not low enough to justify the creation of new, separate selection schemes, according to Mulder *et al*. (2006) and Slagboom *et al*. (2018). Nevertheless, we have shown that the less farmers' breeding goal is correlated to the one of the breed (due to the specificities of their farming system and/or their own expectations), the more they could improve their within-herd breeding choices by using information specific to their farming system and their breeding goal. Indeed, access to EBV specific to their breeding goal and farming system would allow them to better select sires and make better matings plan choices in order to maximize the genetic and the economic gains for their own breeding goal. We recommend farmers to use the breeding goal that matches their production system.

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