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Diversity of breeding practices is linked to the use of collective tools for the genetic management of the Corsican sheep breed

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ABSTRACT

For breeding schemes based on a diversity of production systems, there is a growing challenge in combining standardised tools for the collective genetic improvement of a breed and the selection of a flock able to respond to the specific constraints of the farm and the farmer's objectives. In order to progress on this question, it is necessary to gain better knowledge of how farmers who use one or several of these tools select the future breeding animals of their flocks, and the conditions under which they use these collective tools. We took the example of dairy sheep farming in Corsica (France) and of two collective tools for the Corsican breed's management: the use of milk recording data within and outside of the breeding scheme and the buying of rams from the breeding scheme's cooperative. The tools' use and perception were described by means of interviews with farmers ($n = 40$). Cross-analysis of farms' descriptors and the use of collective tools was performed by statistical analysis using available databases on dairy sheep flocks in Corsica. A diversity of breeding practices was associated to the use of milk recording data and to the purchase of rams sold by the breeding scheme's cooperative. Flock size, milking method and type of land use influenced these breeding practices and the adoption or mistrust of a collective genetic improvement tool. Dissemination of genetic progress through rams from the breeding scheme is possible, provided that a diversity of breeding practices and production environments is represented in the nucleus flocks.

HIGHLIGHTS

- Participating in the breeding scheme of the Corsican breed did not hinder the use of various replacement and culling practices in dairy sheep farms
- Modalities of use of the milk recording tool are multiple and driven by work organisation, perception of the breeding scheme and the farm project
- Rams sold by the breeding scheme's cooperative are present in several commercial farms with varying characteristics

Abbreviations: AI: Artificial Insemination; CORSIA: Cooperative of the breeding scheme of the Corsican sheep breed; OS Brebis Corse: Corsican Breed Sheep Breeders' Association; OMR: Official milk recording; DRAAF: Regional Directorates of Food Agriculture and Forestry; ARSOE Soual: Regional Association of Services for Livestock Organisations; SMR: Simple milk recording; SIEOL: System of Information in dairy sheep farming; EBV: Estimated Breeding Value

Introduction

Official breeding schemes are evolving rapidly. Indeed, tools collectively used by breeders with the final objective of individual standardised performance or genetic potential assessment (milk recording, estimated breeding value (EBV), genomic characterisation)

and diffusion of genetic progress among commercial flocks (artificial insemination (AI), ram sales) are not necessarily readily adopted by farmers and present organisational obstacles (Carta et al., 2009; Labatut et al., 2013; Blasco and Toro 2014; Salaris et al., 2018). In parallel, selection goals applied by breeding

schemes are constantly being reconsidered to respond to the increasing challenges of livestock farming systems, including social, economic and environmental concerns (Olesen et al., 2000; Tixier-Boichard et al., 2015; Phocas et al., 2016). In this context, discussion around the diversification of selection goals in small ruminant populations in the Mediterranean region includes growing concerns for functional traits to cope with harsh environments and limit the workload in farms (Marie-Etancelin et al., 2001; Dwyer and Lawrence 2005; Phocas et al., 2014). The need for breeding schemes to evolve concomitantly on these two aspects (genetic progress on traits included in the breeding goal, diversification of traits to respond contemporary challenges) raises the issue of combining standardised tools for the collective genetic improvement of a breed and the selection of a flock able to respond to the specific constraints of the farm and the farmer's objectives in terms of work and flock performance.

In order to progress on this question, it is necessary to gain better knowledge of how farmers, using one or several tools for the collective genetic improvement of a breed, perform the choice of their future breeding animals. These aspects have scarcely been studied in dairy sheep (Labatut et al., 2008, 2013). This knowledge will enrich the discussion on the conditions where the use of collective tools matches the farmers' requirements, or failing that, discussion on which are the additional modalities of choosing breeding animals that are combined with the use of these tools. It will also contribute to understanding the positioning of farmers towards the adoption/mistrust of collective tools for genetic management. Discussing this question in breeding schemes targeting the management of a breed across a diversity of production environments (milking equipment, level of fodder intensification, workload, etc.) is all the more relevant considering that breeding schemes are often applied in nucleus flocks regardless of the farming conditions in which the whole population is placed.

For this purpose, we take the example of dairy sheep farming in Corsica (France), based on purebred flocks of Corsican sheep breed raised in various production environments (Santucci et al., 2011) and organised around a collective organisation established for years, the breeding scheme of the Corsican sheep breed. Some flocks are registered in the breeding scheme (nucleus flocks) and perform official milk recording (OMR), while flocks not registered in the breeding scheme (commercial flocks) can choose to perform either simple milk recording (SMR) or no milk recording. Additionally, all dairy sheep farmers on Corsica, regardless of their participation in the breeding scheme, can buy rams from the nucleus flocks through the breeding scheme's cooperative called CORSIA (annual sales of rams), thus benefiting from the products of the collective action carried out within the breeding scheme. The use of milk recording within and outside of the breeding scheme, and the use of rams from CORSIA, two collective tools for Corsican breed management, are discussed successively. Their use is described within the range of the breeding practices performed on farms, providing elements on how these tools are perceived by farmers according to the flock production environment and the farmers' objectives. The use of milk recording within the frame of the breeding scheme (OMR, resulting EBV and ewe ranking) is considered separately from the modalities of milk recording in commercial flocks (SMR or no milk recording).

Material and methods

The breeding scheme of the Corsican sheep breed and the use of the milk recording tool among nucleus and commercial flocks

The breeding scheme of the Corsican sheep breed, the implementation of which began in 1985, is nowadays organised and supervised by a breeders' association called OS Brebis Corse. The genetic evaluation of the Corsican breed sheep is focussed on a single objective: milk quantity. The average ewe's milk production was recorded at 154 litres for 197 days of lactation in 2015. Breeding animals in the breeding scheme are also officially (i) genotyped for the PrP gene (rams), (ii) characterised for horn conformation and standard (by a farmers' committee, for rams entering the CORSIA; Figure 1), (iii) scored for udder conformation (on first and second lactation ewes in farms since 2017; not performed at the time of the interviews). The population registered in the breeding scheme of the Corsican sheep breed is around 18% of the total population of dairy ewes, and the number of nucleus flocks in 2015 ($n = 53$) represented around 14% of the total number of farms in the same year ($n = 377$) (Table 1).

Nucleus flocks perform OMR (consisting of monthly records for an average of 7.64 records per year per farm in 2015) and artificial insemination (AI) (mandatory on at least 30% of the ewes in the flock) and give the new-born rams from inseminated females with the highest EBV values to the CORSIA for ram testing. At CORSIA, a part of these young rams is selected as
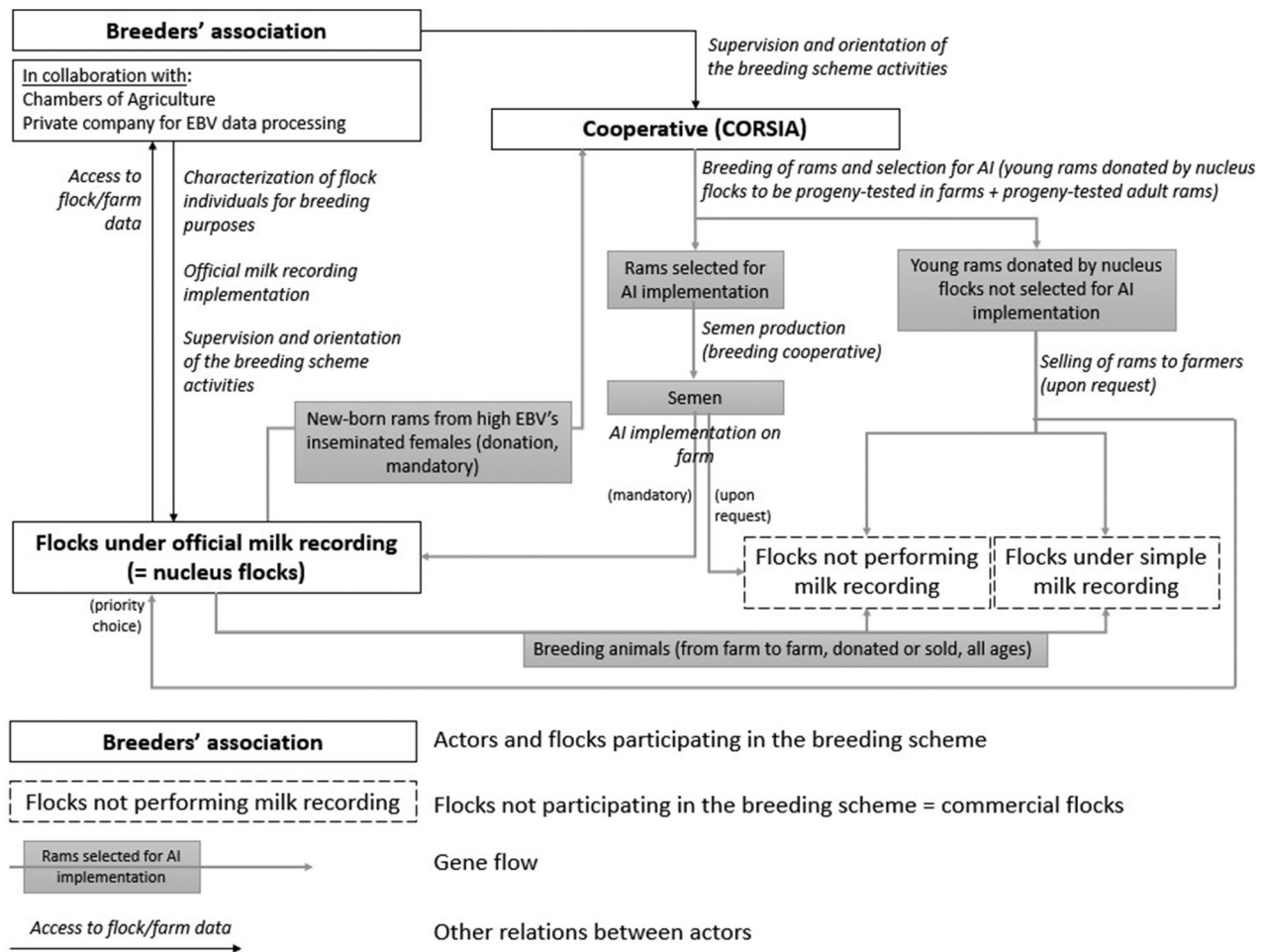
Figure 1. The organisation of the breeding scheme of the Corsican sheep breed and the male gene flow in nucleus and commercial flocks. EBV: estimated breeding value; AI: artificial insemination; CORSIA: Cooperative of the breeding scheme of the Corsican sheep breed.

Table 1. Declared ewe population (rounded figures) and number of flocks according to the use of milk recording in Corsica.

Type of dairy sheep flocks	Population size in 2015 (% of the total population, data DRAAF)	Number of flocks
Nucleus flocks (OMR)	14,700 (18%)	N = 53 (data OS Brebis Corse – SIEOL 2015)
Commercial flocks (SMR)	13,600 (16%)	N = 50 (data OS Brebis Corse – SIEOL 2014)
Commercial flocks (no milk recording)	56,000 (66%)	
Total	84,200 (100%)	N = 377 (data 2015, DRAAF)

DRAAF: Regional Directorates of Food Agriculture and Forestry; OMR: official milk recording; OS Brebis Corse: Corsican Breed Sheep Breeders' Association; SIEOL: system of Information in dairy sheep farming; SMR: simple milk recording.

semen donors (on maternal and paternal EBVs, horn conformation, PrP gene, breed standard and semen production at the time of the study). Semen from these young rams and semen from progeny-tested adult rams kept at CORSIA is produced for AI in nucleus and commercial flocks. Young rams not selected as semen donors are sold to nucleus and commercial flocks through an annual sale. Forty-two percent of the ewes in nucleus flocks were inseminated in 2015, whereas the use of AI was negligible in commercial flocks (500 ewes inseminated in

commercial flocks according to Labatut et al., 2013). Quantitative data on the distribution of rams, in nucleus and commercial flocks, sold by CORSIA are presented in the results. Nucleus flocks have priority choice of the rams sold by CORSIA compared to commercial flocks (two different days of sale).

The SMR consists of a reduced number of recordings per year (four recordings per lactation per milked ewe). It was first developed in Corsica as an intermediary step towards official milk recording, for commercial flocks, before their accession to the breeding scheme

Table 2. Data set presented in the results: description and processing modes.

Data set (sample size if relevant)	Processing modes
Semi-structured interviews with farmers ($n = 40$ farmers)	Thematic analysis based on notes taken during the interview
Replacement/culling rates in nucleus flocks from 2012 to 2015 and number of nucleus flocks through years (provided by the Breeders' Association)	Use of rough data from presented material
Annual declarations of land use ($n = 365$ farms, data 2014) and heads of animals ($n = 377$ farms, data 2015) for agricultural subsidies: individual farm data	Derivation of land use variables in one synthetic discrete variable (type of land use; Table 3)
Official on-farm records of ram IDs for monitored farms (SIEOL database, $n = 206$ farms, milk campaign 2014–2015)	Run tests (in addition to the description of data distribution): Chi-squared test (use of milk recording x type of land use, $n = 365$)[a] Chi-squared test (presence of rams sold by the cooperative of the breeding scheme in the flock x type of land use, $n = 206$)
Use of milk recording in monitored dairy farms (SIEOL database, $n = 206$ farms, data January 2015)	Kruskal–Wallis test Wilcoxon–Mann–Whitney test (distribution of flock sizes according to use of milk recording, $n = 377$)

SIEOL: system of Information in dairy sheep farming.
[a]Changes in milk recording use from 2014 to 2015 were taken into account.

Table 3. Characteristics of the interviewed sample: use of collective tools for genetic management.

	Use of OMR (with EBV and ewe ranking, in breeding scheme)	Use of SMR ($n = 8$)	No milk recording	Total sampled farmers
Buying rams at CORSIA	$N = 8$	$N = 4$	$N = 10$	$N = 22$
Not buying rams at CORSIA	$N = 0$	$N = 4$	$N = 14$	$N = 18$
Total sampled farmers	$N = 8$	$N = 8$	$N = 24$	$N = 40$

CORSIA: Cooperative of the breeding scheme of the Corsican sheep breed; OMR: official milk recording; EBV: estimated breeding values; SMR: simple milk recording.

of the Corsican sheep breed as nucleus flocks. The SMR is nowadays performed in an increasing number of commercial flocks (from 40 flocks in 2011 to 50 flocks in 2014; data from OS Brebis Corse – SIEOL). Records of SMR are not included in the genetic evaluation of breeding animals, and flocks performing SMR do not receive EBV, as the use of SMR is restricted to commercial flocks.

Overview of data collection modes

This work was based on a combination of qualitative and quantitative data that are presented exhaustively in Table 2. All research reported has been conducted in an ethical and responsible manner. No in vivo experiments or clinical trials on humans or animals have been performed. The main mode of data collection consisted of semi-structured interviews (Blanchet and Gotman 1992) with farmers from nucleus and commercial flocks ($n = 40$), performed between May and September 2015. The interviews aimed at specifying the link between the use of collective tools and the on-farm breeding practices. Information on the overall functioning of the farming system was used as illustrative data to discuss this link. The thematic sections of the interview guidelines were i) general information and composition of land, ii) use and perception of collective tools for genetic management, iii) milk production, iv) reproduction, v) animal groups management and feeding practices, vi) replacement and culling practices (rate, temporality, conditions), vii)

motives for choosing replacements and for culling animals. The interview grid is available as Supplemental online material 1. In addition to the data presented in the previous section, information on the culling and replacement rates in nucleus flocks was collected from the Breeders' Association. Finally, regional databases were used to collect information on the flock's size and the land use (data from Regional Directorates of Food, Agriculture and Forestry (DRAAF)), the buying of rams from CORSIA and the use of milk recording (data from farms registered in the SIEOL database[1]). Rams coming from CORSIA were identified on the SIEOL database according to their identification number. The use of regional databases was aimed at specifying the influence of the farming system on the farmers' use of collective tools for genetic management.

Semi-structured interviews with farmers: sampling and data processing

In order to perform semi-structured interviews with Corsican dairy sheep farmers, a purposive sampling was completed with snowball sampling and aimed to cover both the diversity of use of collective tools (OMR, SMR, buying of rams from CORSIA) and the diversity of characteristics of farming systems (Tables 3 and 4). This sampling method did not seek any representativeness of the data obtained, but aimed for a better understanding of the drivers of on-farm genetic management through trends connecting different variables. The use of milk recording could be combined

Table 4. Characteristics of the interviewed sample ($n = 40$): farming systems characteristics.

Variables	Modalities (n)
Flock size	0–100 ($n = 4$)
	101–200 ($n = 12$)
	201–300 ($n = 12$)
	301–400 ($n = 7$)
	401–900 ($n = 5$)
Geographical location	Eastern lowlands ($n = 10$)
	South-western foothills ($n = 9$)
	Northern lowlands ($n = 10$)
	Semi-mountainous and mountainous centre ($n = 11$)
Land use (adapted from Paoli et al. 2013)	Low intensity system on non-tillable rangeland (S1) ($n = 8$)
	Systems with forage crop intensification limited by tillable areas (S2) ($n = 5$)
	Low intensity systems on tillable grassland (S3) ($n = 19$)
	Systems with forage crop intensification on tillable areas with possible sold fodder surplus (S4) ($n = 8$)
Transhumance	No transhumance ($n = 27$)
	Transhumance ($n = 13$)
Milk products	Only milk delivering ($n = 26$)
	Milk delivering and cheese processing ($n = 3$)
	Only cheese processing ($n = 11$)
Milking method	Hand milking ($n = 11$)
	Mechanical milking ($n = 29$)

Table 5. Variables and modalities used in the statistical analysis.

Variables used in the statistical analysis (type)	Modalities
Type of land use (discrete)	S1 (moorlands and rangelands > native grasslands, no cultivated pastures or cultivated pastures < native grasslands)
	S2 (moorlands and rangelands > native grasslands, cultivated pastures > native grasslands)
	S3 (moorlands and rangelands < native grasslands, less than 5% of cultivated pastures or cultivated pastures ≪ native grasslands)
	S4 (moorlands and rangelands < native grasslands, more than 5% of cultivated pastures and cultivated pastures ∼ native pastures)
Presence of rams bought at the CORSIA in the flock (discrete)	Yes
	No
Flock size (continuous)	–
Milk recording (discrete)	OMR
	SMR
	No milk recording

CORSIA: Cooperative of the breeding scheme; OMR: official milk recording; SMR: simple milk recording.

or not with the buying of rams from CORSIA (Table 3). All sampled farmers using OMR (nucleus flocks) were also buying rams from CORSIA.

On-farm breeding practices were described according to the criteria and replacement/culling rates used by farmers to choose the future breeding animals of the flock. Young replacement lambs were mainly chosen by farmers according to the dam's characteristics (either provided through EBV and milk records if available, or subjectively assessed by farmers). In this paper, the dam whose characteristics allows selection of offspring for replacement will be referred as a 'good ewe' for the purpose of simplification, according to the terminology frequently used by farmers during the interviews. In the data processing, we focussed on six main criteria used by farmers to qualify a 'good ewe': the ewe's milk yield and index (EBV), milk persistence, udder traits, behaviour at milking, breed standard and fleece colour. Use of the ewe's ancestry was also considered. These generic terms were used to allow comparison between farms, although each criterion could be expressed by farmers through several words. In particular, milk persistence was used to qualify criteria referring to the length and regularity of lactation through the year ('regular', 'milk persistence', 'constant', 'produces from […] to […]'). The objective of the data analysis was to identify if the qualification of a 'good ewe' could include an extended range of criteria in groups of farmers using the milk recording tool (OMR and SMR).

Regional databases: statistical data processing

Regional databases were processed through statistical analysis using R 3.3. (R Development Core Team 2016). Units considered were the individual farms. Categories of land use were defined as described in Table 5 and allocated to each farm according to the declared composition of land in 2014, in order to get as close as possible to the classification of land use used presented in Table 4.

Chi-squared tests were performed to investigate the link between (i) the presence of rams bought at CORSIA in the flock and the type of land use (level of significance: $p < .001$) and (ii) the use of milk recording and the type of land use (level of significance: $p < .001$). The distribution of individual flock sizes was compared to the use of milk recording. For this purpose, we performed a Kruskal-Wallis test (level of significance $p < .001$) followed by a Wilcoxon-Mann-Whitney test (level of significance $p < .001$) (Table 2).

Results

The first section of 'Results' refers to the results on the use of OMR linked with the ranking of females on EBVs in the frame of the breeding scheme. In the second section of 'Results', the modalities of the use of milk recording in flocks not participating in the breeding scheme (SMR or no milk recording) and the perception of the breeding scheme are considered.

The third section of 'Results' refers to the results on the dissemination of genetic progress through the purchase of rams from CORSIA.

Combination of individual breeding practices and collective tools for genetic management in flocks participating in the breeding scheme ('nucleus flocks', OMR)

Selection of females to produce female and male replacements

In farms participating in the breeding scheme, a list of breeding ewes eligible for AI was proposed by the technician of the farm and discussed with the farmer. Ewes were selected or rejected for AI based on their EBV and other characteristics such as their age and the success or failure of previous AI. Eligible ewes were also ranked according to their EBV. The farmer could choose to add other ewes for insemination because of their specific characteristics (udders, milk persistence during the milk campaign, etc.), with the objective being to keep their offspring for replacement. The decision-making process for choosing such dams, also called 'good ewes' for simplification matters in the text, was however more complex than a decision based on the single EBV. Indeed, among the sampled farms ($n = 8$), a variety of functional or morphological traits were considered by breeders to define a 'good ewe' for internal female replacement, while some farms relied exclusively on the EBV of

the breeding ewe (nuanced by the recorded milk performances during the previous milk campaign(s)) (Figure 2). Non-productive criteria were linked to work organisation (milking ability, behaviour at milking), breed standards and aesthetics, and subject to trade-offs with productive traits.

For example, high-ranked inseminated ewes were not necessarily selected by the farmer to produce replacement animals if he considered their udder characteristics or behaviour as less satisfactory than that of other ewes. Furthermore, some ewes not inseminated because of their age could be chosen to produce replacements. For example, farmers could choose old ewes as dams to produce replacement animals if their previous productive years were considered satisfying. Some farmers used their knowledge of a ewe's ancestry to assess if a young ewe in first lactation could be eligible to produce replacement females. Farmers' assessment of a 'good ewe' was then based on observations at the multi-year scale and a diversity of criteria was observed among farms under the breeding scheme.

The sampled farmers who relied exclusively on EBV (farms G and H, possibly nuanced by milk yield) were located in the eastern lowlands of Corsica and owned flocks of 300 and 420 ewes respectively. Those farmers expressed two types of professional projects: (i) to maximise the milk productivity for a limited land intensification (due to the costs of inputs and the damaged soils, system S3 in Table 4), or (i) to combine
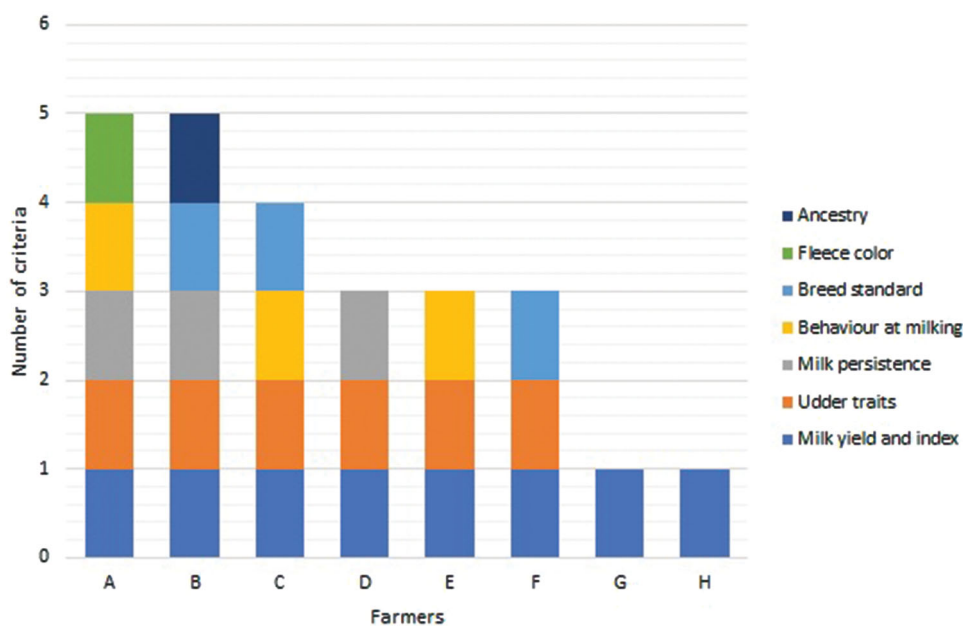
Figure 2. Criteria used by farmers for the qualification of a 'good ewe' for internal female replacement in nucleus flocks (interviewed sample, $n = 8$ farms).

Table 6. Characteristics of nucleus flocks according to the selection criteria considered by farmers (interviewed sample of nucleus flocks, $n = 8$).

	Flock size	Use of waged workforce	Milking method
Consider udder traits when qualifying a good ewe ($n = 6$)	200[a]	No	Mechanical
Exclusively consider productive criteria when qualifying a good ewe ($n = 2$)	420	Yes	Mechanical
	300	No	Mechanical

[a]mean of 6 flock sizes.

several activities (including dairy sheep farming) with little time dedicated to farming and a part of the work delegated to a waged workforce (system S4 in Table 4).

Udder traits were considered for the characterisation of a 'good ewe' in six sampled farms, performing mechanical milking (all farmers in the breeding scheme of the Corsican sheep breed performed mechanical milking). Mentions of udder traits referred to different indicators and objectives, according to the specific conditions in each farm: udder texture under pressure and/or teat positions were assessed for the ease of milking (small flocks milked by the farmer in person; Table 6), and ewes with deep udders were excluded from replacement and could even be culled in order to prevent udder lesions at grazing. Udder depth as a selection criterion was mentioned both by farmers with access to rough, sloppy rangelands and/or transhumant flocks, and by farmers on lowlands with sedentary flocks.

Low representation of milk persistence in OMR farmers could be explained by two categories of farmers' statements: (i) total lactation, as mentioned on the milk recording data, was considered as a sufficient indicator of persistence and (ii) high levels of supplementation were used to maintain high lactation during the winter season.

Tolerance on the breed standard varied among farms and mainly referred to the exclusion of the Sarda breed traits (large ears, white fleece, large size according to farmers' statements). The concern for breed standards depended on the trade-off made by farmers between the wish to preserve the Corsican breed characteristics (morphological and/or diverse functional abilities) and the wish not to hold back genetic progress on productive abilities. Available data on the structural characteristics of the farm (land use, milking methods, etc.) obtained through interviews did not explain the different uses of the breed standard criterion among sampled farms under the breeding scheme. Black colouring as an indicator of hardiness (a common assumption by old shepherds) was mentioned by two farmers, but only considered as a replacement criterion in farm A.

Replacement and culling rates

Individual milk records and EBVs could be used for an easy ranking of the ewes and a stable and high selection pressure on the replacement or culling of females. However, interviews indicated that replacement/culling rates for a stabilised flock size presented some inter-annual variability due to losses, blue tongue disease, and the number of 'good ewes' identified by the farmer every year. This inter-annual variability was confirmed by the evolution of replacement and culling rates at the scale of the total sample of nucleus flocks, between 2012 and 2015 (OS Brebis Corse, 2015). For a given year, differences were also observed among nucleus flocks: in 2015, the replacement rates were 10–15% for 21% of the nucleus flocks, 15–20% for 30% of the nucleus flocks and 20–25% for 34% of the nucleus flocks (OS Brebis Corse, 2015).

According to interview results, replacement and culling rates in the sampled nucleus flocks were also partly influenced by the age of the farmer and the existence of a farm succession. Moreover, breeders mentioned that the lack of commercial channels for culled ewes encouraged low culling rates. The lack of valorisation of adult ewes for meat (up to €8/adult culled ewe) was a general problem at the regional scale and was not specific to farms under the breeding scheme. However, for farms under the breeding scheme, the disposal of culled animals with high production capacity could be eased by giving some of them as breeding animals to other farmers.

Strategies of replacement and the perception of the breeding scheme in flocks not participating in the breeding scheme ('commercial flocks', SMR or no milk recording)

Strategies of replacement: role of milk recording tool (SMR) and replacement criteria (SMR and no milk recording)

Sampled farmers performing SMR ($n = 8$) focussed on one to three replacement criteria, being mainly dairy traits (milk yield and EBV and/or milk persistence) and additionally udder traits or behaviour at milking (Table 7). The 70% ($n = 16$) of farmers not performing

Table 7. Number of criteria taken into account by farmers to qualify a good ewe in SMR (simple milk recording) and no milk recording flocks (interviewed sample of commercial flocks, $n = 32$).

Type of commercial flocks	1 criterion	2 criteria	3 criteria	More than three criteria
SMR flocks ($n = 8$)	$N = 2$	$N = 2$	$N = 4$	$N = 0$
No milk recording flocks ($n = 23$, NA $= 1$)	$N = 1$	$N = 6$	$N = 7$	$N = 9$

Table 8. Characteristics of commercial farms according to the use of milk recording (interviewed sample, $n = 32$).

Use of milk recording	Flock size	Average number of ewes/ person at milking	Use of waged workforce	Cheese processing	Milking method
SMR ($n = 8$)	268[a]	198	Yes ($n = 2$) No ($n = 6$)	Yes ($n = 5$) No ($n = 3$)	Hand ($n = 1$) Mechanical ($n = 7$)
No milk recording with projected SMR use ($n = 2$)	150 300	150	Yes ($n = 1$) No ($n = 1$)	Yes ($n = 1$) No ($n = 1$)	Hand ($n = 1$) Mechanical ($n = 1$)
No milk recording ($n = 22$)	273[a]	187 (N/A $= 2$)	No ($n = 20$) N/A ($n = 2$)	Yes ($n = 8$) No ($n = 14$)	Hand ($n = 10$) Mechanical ($n = 14$)

SMR: simple milk recording.
[a]Mean of flock sizes.

milk recording considered three or more criteria to qualify a 'good ewe' ($n = 23$ respondents). Among those criteria, udder traits and behaviour at milking were frequently mentioned.

The use of milk recording information by sampled farmers performing SMR was heterogeneous and not clearly specified. In particular, it remained unclear whether each farmer took into account monthly records or only total lactation when making their decision. The modalities of this decision-making process were associated with a heterogeneous implication of farm technicians in the on-farm replacement and culling processes: from a simple opinion according to milk recording results, to the full management of both culling and replacement processes. In some cases, the farmer's choice was guided by an indicator of the ewe's performance (colour codes) calculated from milk recording values by the technician: however, the use of this indicator varied among farms.

The low consideration of functional traits in SMR flocks (in comparison with flocks not performing milk recording) had to do with the role of the milk recording tool in achieving the farmers' objectives for their flocks. Two strategies for replacement process and roles played by the milk recording data were identified in sampled SMR flocks. In the first strategy, SMR records were used as a tool to focus the improvement of milk yield, thus keeping a low level of prerequisites on the ewe's functional traits. Farmers adopting this strategy usually remained out of the breeding scheme due to a low confidence in collective action or a perception of AI as a 'risky technique' [see 'Perception of the breeding scheme (SMR and no milk recording)' section]. A second strategy consisted of using milk recording to minimise the risk of misjudgement of animals and maintain a stable level of production in the flock. This strategy was found in farms performing cheese processing and in situations with limited time devoted to observation of the animals (competing tasks, large flock size and/or use of waged workforce, high number of ewes/person at milking and use of mechanical milking) (Table 8).

The difference in flock sizes between SMR farms and farms not performing milk recording was observed at the regional scale ($n = 377$ flocks). Comparison by pairs indicated that median flock size of SMR flocks was higher than that of flocks not performing milk recording ($p < .001$) (Figure 3).

Perception of the breeding scheme (SMR and no milk recording)

Although SMR was first developed in Corsica as an intermediary step towards accessing the breeding scheme, the majority of SMR sampled farmers were not willing to access the breeding scheme. Reasons for not participating in the breeding scheme, for SMR farms, could be diverse but were mainly the use of AI and oestrus synchronisation and the lack of confidence in collective action, often associated with the mention of animals with unsatisfactory productive traits (Figure 4). As a matter of fact, when AI became mandatory in 2010, the number of nucleus flocks dropped from 71 to 58 (data OS Brebis Corse). Conversely, farmers performing SMR with the objective of later performing OMR were generally young farmers wishing to quickly improve the genetic level of their flock.

In farms not performing milk recording, udder traits represented the main limitation of the breeding scheme mentioned by farmers (Figure 4). Different interviewed farmers mentioned different udder traits, including teat positions, udder depth and the

presence of abnormalities in the udder structure. Another limitation of the breeding scheme mentioned by farmers was the existence of crossbred animals resulting from the crossing of the Sarda and the Corsican breeds, which began in Corsica in the mid 1970s. These two limitations mentioned by farmers explain the recent measures taken by the Breeders' Association to score the udders of young ewes (on-farm) and check the rams' breed standard before they are tested as semen donors by CORSIA (see 'Material and methods': the breeding scheme of the Corsican ewe). As for SMR farmers, a reluctance to use AI,

oestrus synchronisation and mistrust of collective action for the genetic improvement of the breed were identified in farms not performing milk recording. Finally, the encouragement for fodder intensification was considered as a limitation of the breeding scheme for farmers not performing milk recording (Figure 4). Several interviewed farmers who had performed OMR in the past decreased the use of cultivated pastures after leaving the breeding scheme (Table 9). At the regional scale, positive correlations were found between fodder intensification and nucleus flocks on one side and between extensive land use
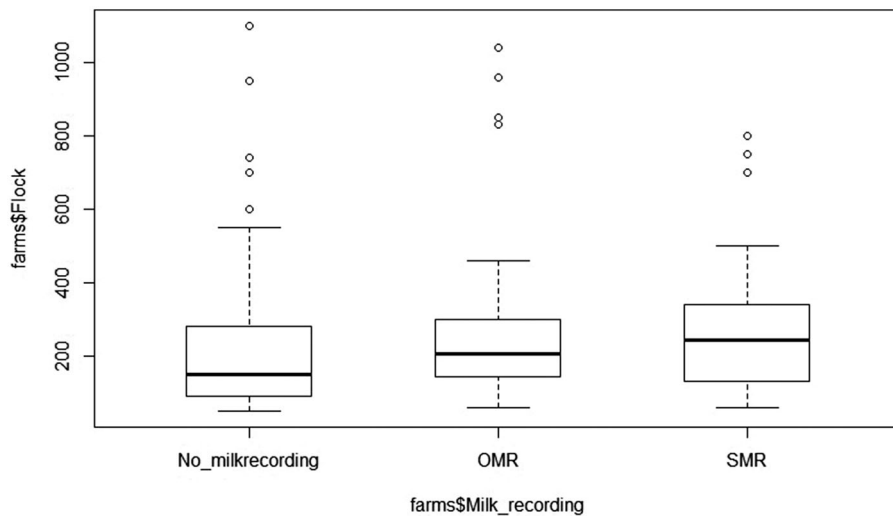

Figure 3. Flock sizes in farms performing official milk recording (OMR), simple milk recording (SMR) and farms not performing milk recording in Corsica (regional database).
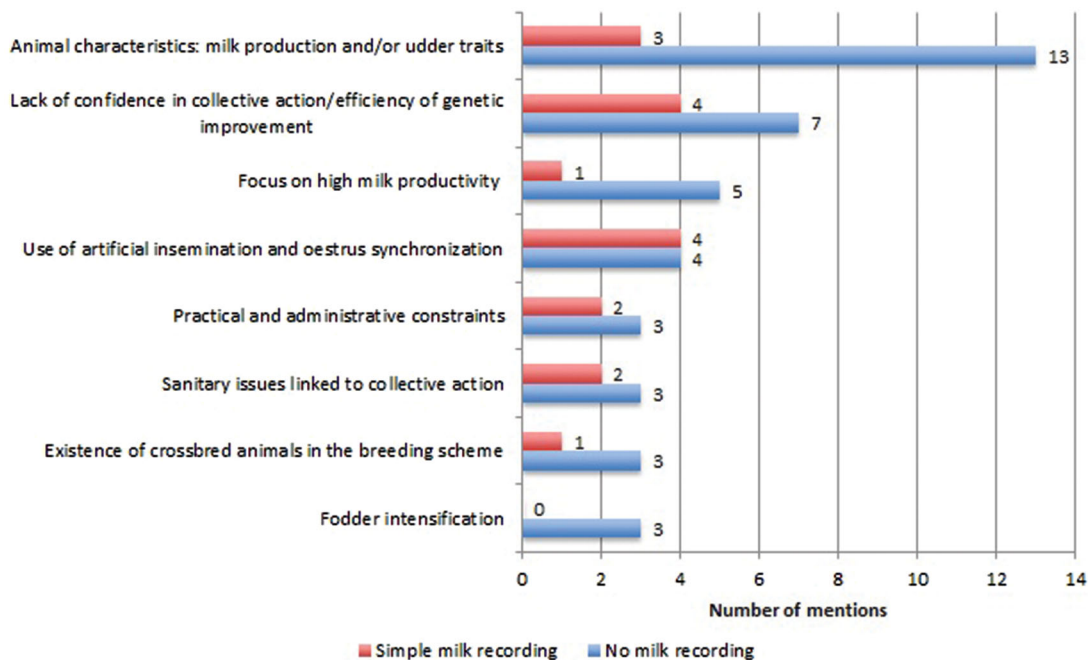

Figure 4. Limitations of the breeding scheme as perceived by interviewed farmers in sampled commercial flocks (simple milk recording, $n = 8$ farms, or no milk recording, $n = 24$ farms).

Table 9. Land use in commercial farms (interviewed sample, $n = 32$).

History of participation in the breeding scheme	Current type of land use[a]	Evolution of land use before and after the abandonment of the breeding scheme
Never participated in the breeding scheme ($n = 26$)	S1 ($n = 7$) S2 ($n = 4$) S3 ($n = 12$) S4 ($n = 3$)	–
Participated in the breeding scheme then stopped ($n = 6$)	S3 ($n = 4$) S4 ($n = 2$)	Decrease of cultivated pastures ($n = 5$) Remains the same (S4, $n = 1$)

[a]S1: Low intensity system on non-tillable rangeland; S2: Systems with forage crop intensification limited by tillable areas; S3: Low intensity systems on tillable grassland; S4: Systems with forage crop intensification on tillable areas with possible sold fodder surplus

Table 10. Destination of rams sold by the CORSIA: study of 206 flocks (SIEOL database).

	Distribution of rams bought at CORSIA	Total number of rams in SIEOL database	Number of flocks that include rams bought at CORSIA	Total number of flocks in SIEOL database
OMR	276	835	47	53
SMR	165	661	29	48
No milk recording (farms in SIEOL database[a])	266	1409	53	105
Total	$N = 707$ rams	$N = 2905$	$N = 129$	$N = 206$

CORSIA: Cooperative of the breeding scheme of the Corsican sheep breed; SIEOL: system of Information in dairy sheep farming; OMR: official milk recording; SMR: simple milk recording.
[a]The number of rams sold by CORSIA to non-monitored farms not included in the SIEOL database was negligible to null.

(rangelands) and absence of milk recording on the other side ($p < .001$).

Dissemination of genetic progress through the selling of rams by the breeding scheme's cooperative (CORSIA)

The perception of the farmers (commercial flocks) on the breeding scheme indicated that their primary concern was the unsatisfactory characteristics of the animals coming from the breeding scheme (Figure 3).

However, around a half of these sampled commercial farmers were buying rams occasionally or systematically from CORSIA ($n = 14$). At the regional scale, the dissemination of genetic progress, through the selling of rams by CORSIA to commercial flocks, was also noticeable (Table 10). Indeed, interviews indicated that farmers considered the use of rams from CORSIA as: (i) a real tool to improve flock genetics, (ii) a simple way to avoid inbreeding and (iii) a solution to the lack of other reliable options or even a strategy of risk diversification. They often associated this channel with other modes of ram replacement, such as own internal replacement or supply from other farmers, which was the traditional way to avoid inbreeding in the absence of controlled mating (farms not performing AI). The buying of rams from CORSIA was mainly based on ancestry EBV, but the order of choice was decided according to a random ranking of farmers, which limited the possibilities of choice of rams for low-ranked farmers. The origin of the ram was rarely requested by the farmers.

Sampled farmers that did not buy rams from CORSIA usually claimed the importance of milking ease and breed standard. Milking ease referred in this case to udder texture under pressure and milk flow at milking. This objective was strongly present in farms performing hand-milking or having previously performed it, but not exclusively. Indeed, ease of milking was a criterion associated with farmers' know-how and legitimacy, used to claim a professional identity. For that reason, elderly farmers, farmers who inherited their parents' flock and those located in historical areas of sheep farming were particularly critical of the udder traits observed on the offspring of CORSIA rams. Breed standard referred to both aesthetical standards and to the will to build a flock reflecting its owner's work and identity. It also referred to hardiness, a complex notion that farmers associated either to low susceptibility to disease or to climatic variations, the degree of the rangelands' exploitation in relation to milk production, and the walking ability and longevity of ewes. In the farmers' rationale, the small size of the ewe and its active behaviour on pastures – signs of hardiness – were linked to some populations of the Corsican sheep breed originating from the mountainous centre of the island, by opposition to lowlands animals, often associated with crossbreeding with the Sarda sheep breed. As the nucleus flocks were spread all over Corsica and represented a diversity of farming practices, rejecting rams sold by CORSIA was then a way to prioritise animal populations resulting from ancient pastoral practices and mountainous areas, that is to say hardy animals. These

Table 11. Land use in farms purchasing rams at the CORSIA (from SIEOL and regional databases).

Regional bases	Flocks including rams from CORSIA	Flocks without rams from CORSIA
Type of land use[a]	S1 ($n = 32$)	S1 ($n = 25$)
	S2 ($n = 19$)	S2 ($n = 6$)
	S3 ($n = 61$)	S3 ($n = 36$)
	S4 ($n = 11$)	S4 ($n = 8$)
	N/A ($n = 6$)	N/A ($n = 2$)

CORSIA: Cooperative of the breeding scheme of the Corsican sheep breed; SIEOL: system of Information in dairy sheep farming.
[a]See Table 5 for description of S1, S2, S3 and S4.

farmers used the same criteria of location and farming practices to choose the providers of their rams from among the Corsican farmers. Some of them considered that selection of the hardiest ewes occurs *de facto* in transhumance systems, as a result of a history of selection and losses on pastures that regularly excluded those ewes least able to follow the flock. Four farmers did not purchase rams at CORSIA but bought rams directly from nucleus flocks to improve the productive level of their flock. They justify their choice by a lack of confidence in the characteristics of the offspring of the rams sold by CORSIA (udder traits, genetic value) and/or by a lack of confidence in the collective registering of filiations. In this case, the farmer's decision was mostly based on his/her knowledge and trust of the provider, whose practices ensure the quality of the animal. Finally, social isolation played a role in the farmer's choices: inaccurate data on ram prices or on their conditions of availability at CORSIA were sometimes mentioned by farmers.

We previously indicated that location and type of farming system could influence the choice of ram providers among the sampled farmers, dissuading the purchase of rams produced by the collective action of the flocks participating in the breeding scheme. Yet, for the 206 flocks with available data (covering all the flocks where rams from the cooperative were sold), there was no set pattern between purchasing rams at CORSIA and land use (Chi-squared test residuals, $n = 206$, $p > .001$) (Table 11). This finding supports the hypothesis of a complex decision-making process and confirms the multifactorial modalities of supply in external rams identified from interviews results.

Discussion

The results of this study generate three discussion points. The first point questions the tools used for the dissemination of genetic progress, particularly the interest in and status of the selling of rams produced in nucleus flocks to the whole ewe population through CORSIA. The second point is the opportunity to combine collective action based on standardised selection goals for the breed, and ensure the availability of breeding animals adapted to the diversity of production environments in which the breed is raised. The third point is methodological and questions the variables and data to be considered in studies on farmers' preferences for animal traits and their breeding practices.

Dissemination of genetic progress

The dissemination of the genetic progress within nucleus flocks depends on the engagement of breeders in the use of collective tools such as AI and on accurate phenotype and pedigree recording. The decrease of the nucleus population of the Corsican breed sheep following the decision on obligatory AI, and the limitations expressed by Corsican farmers towards the functioning of the breeding scheme (including AI and other practical and administrative constraints; Figure 3), echo trends observed in several breeding schemes in the Mediterranean area, with the exception of the well-established breeding scheme of the Lacaune breed (Barillet, 2007). Indeed, due to varying public financial support for the collective management of breeds, to the multifactorial causes of success or failure in AI and to the specific economic and organisational constraints linked to AI implementation in sheep, AI and performance recording can suffer from a low adoption rate in flocks (Kukovics et al., 2011; Labatut et al., 2013). In the breeding scheme of the Sarda breed, for example, a decrease in the number of recorded ewes and flocks has been observed since 2006, alongside a decrease in the percentage of ewes with a known sire and the number of scored udders for ram indexing (Salaris et al., 2018). In Greek sheep breeds such as the Karagouniko and the Chios, natural mating remains the main tool for genetic progress dissemination within nucleus flocks, and discontinuities in public funding for local breed management also compromise the efficient implementation of phenotype and pedigree recording in farms (Valergakis et al., 2010; Perucho et al., 2018b). In the case of the Karagouniko breed, one consequence has

been the 79% decrease in the population registered in the breeding scheme between 1990 and 2014 (Perucho 2018a).

The weak interest for AI also brings into discussion the dissemination of genetic progress in commercial flocks. In Corsica, 61% of the rams bought from CORSIA were directed to commercial flocks. This number is even higher when farm-to-farm flow such as the sale of new-born male lambs or ram flow for one mating season only, are added in. This additional gene flow is not easily assessable due to traceability failures. Even in the absence of exhaustive data, it can be concluded that the male gene flow from the nucleus flocks towards commercial flocks is quite high if compared with the same gene flow through AI. Moreover, it would be interesting to quantify female gene flow originating from nucleus flocks, as qualitative interview data suggests a flow of culling ewes from nucleus to commercial flocks. If dissemination of genetic progress seems to be noticeably supported by the breeding scheme's cooperative selling rams in Corsica, this is not the case for all breeding schemes. In particular, in the breeding schemes of French Western Pyrenees sheep breeds, the breeding centre encounters difficulties in selling rams, although farmers claim a shortage of breeding rams at the local level (Labatut et al., 2013). Farmers justify their mistrust of such rams by the unsatisfactory traits of the animals, particularly related to breed standard and hardiness (Labatut et al., 2013). The findings of this study can provide several hypotheses to explain the relative success of rams sold by the cooperative of the Corsican sheep breeding scheme: (i) the risk of integrating undesirable characteristics in the flock is mitigated through the diversification of rams and/or the selection on non-productive traits for male and female internal replacement, (ii) the existence of a diversity of production systems and selection criteria among nucleus flocks ensure the adaptive capacities of the rams sold by the cooperative and (iii) the exclusion of rams sensitive to scrapie from the breeding scheme encourages farmers to supply their flock through this channel. This leads us to discuss the possibilities of combining collective actions based on standardised selection goals for a breed, and ensuring the availability of breeding animals adapted to the diversity of production environments.

Combining collective tools and individual selection

When a breed is raised in a diversity of production environments, it is important to ensure that the animals selected remain adapted to their specific production environment in order to fully express their genetic potential. This can be managed by ensuring that nucleus flocks disseminating genetic progress (through AI) are raised in a diversity of production environments. This option, commonly adopted, also allows to select a range of animals displaying adaptive capacities towards their respective production environments. An alternative way to preserve a breed adaptive capacity is the diversification of breeding goals according to the different types of production environment identified in nucleus flocks (Macciotta et al., 2005). This second option is increasingly being studied along with the development of genomic selection (possibility of customised indexes, Phocas et al., 2016). Our results indicate that the nucleus flocks of the breeding scheme of the Corsican sheep breed are raised in a diversity of production systems in terms of land use but with a high proportion of systems with fodder intensification with respect to the total flocks of Corsica. Likewise, nucleus flocks are found in a diversity of geographical locations, associated to a range of agroecological conditions. The use of the milk persistence criterion to define a 'good ewe' probably supports the indirect selection of an adaptation to feed restriction and to thermal stress (Ramón et al. 2016). Still, the range of feeding constraints applied to the different nucleus flocks should be further investigated to quantify the constraints applied on the breed. Indeed, a trend towards a decreased use of rangelands and an increase in feeding inputs has been described in various regions of the north side of the Mediterranean area from the nineties (Caja 1990; Jouven et al. 2010; Hadjigeorgiou 2011). Results obtained suggest that the current functioning of the breeding scheme of the Corsican ewe is managing to continue the indexing of milk quantity and to maintain a breed adapted to the range of agroecological and farming conditions. The diversity of selection criteria considered in nucleus and commercial flocks, the work performed by the breeding scheme on functional traits of interest to farmers (standards, horns, udder) and some constraining agroecological environments represented in nucleus flocks (transhumance, mountainous areas) partly explain this successful combination. In dairy and meat goat herds in southern France, for example, Delaney (2018) has indicated that the integration of intensively raised breeding stock with high genetic potential in flocks submitted to a range of agroecological constraints (mountainous foraging) are successful if the external animals are integrated in the herd at a young age. Also, the internal

replacement of female lambs is an important tool for the improvement of the flock performance in dairy sheep farms (Phocas et al. 2014) and can help in off-setting the introduction of undesirable traits by means of long-term selection.

Breeding practices in nucleus and commercial flocks also suggest that some functional traits such as udder morphology could be appropriately included in the calculations of EBV values in the future. Udder morphology is indeed mentioned by several farms of the sample, regardless of their belonging to the breeding scheme or their milking method. These results are explained by the impact of udder morphology on two functional traits: milking ease (hand milking and machine milking), which is a major challenge for labour alleviation in farms, and udder health and production (Marie-Etancelin et al. 2001; Carta et al. 2009). Breed standard is also mentioned both as a limitation of the breeding scheme and as a selection criterion for nucleus and commercial farms. These two traits are also important traits in other countries of the Mediterranean area, either already included in esti-mated breeding values, studied for future integration in estimated breeding values, or sources of disagreements among breeders. The breed standard is a characteristic of varying importance for several dairy sheep farmers of the French Western Pyrenees, inducing different breeding strategies among farmers involved in the collective management of local sheep breeds (Labatut et al. 2008) and a shift towards the revaluation of aesthetic criteria in the breeding routine of the local Black-Face Manech breed (Labatut et al. 2007). As for Corsican farmers, udder morphology is also a concern in several Mediterranean breeds. It is included as a current selection goal in the breeding schemes of the Sarda, Latxa and Lacaune breeds (Carta et al. 2009; Granado-Tajada and Ugarte 2018; Salaris et al. 2018) or simply scored in other breeds such as the Chura breed (Gutierrez-Gil et al. 2008). Hardiness, a challenging trait to phenotype (Friggens et al. 2017), is targeted by Corsican farmers through breed standard and refers to various abilities including feeding efficiency on rangelands and longevity. Likewise, according to interviews with 38 French ruminant farmers spread all over France (Phocas et al. 2015), hardiness refers to an overall capacity to produce efficiently and ranks among the main agroecological priorities for selection goals, together with efficiency and production, closely followed by reproduction and health traits (Phocas et al. 2016). The ability to produce efficiently on rangelands and under low feeding supply could be a relevant trait to consider for customised indexes in Corsica. The small size of the Corsican breed population though challenges the possibilities of genomic selection required for such customised indexes.

The focus on a set of important criteria describing a 'good ewe' has shown that a diversity of replacement criteria could be used regardless of the use of collective tools. In addition, farmers' objectives and constraints towards working aspects (flock size, waged workforce, milking method) influenced these replacement criteria, although not all breeding practices or replacement criteria could be clearly linked to specific farm descriptors. It would be interesting to identify the whole set of criteria considered in farmers' decision-making processes for replacement and culling, and the weighting of farming constraints in this final decision. Such analysis raises questions of (i) the amount and type of information available on the animals when the farmer makes their decision, and (ii) the farmer's possibilities according to the range of constraints faced in the farm context, as suggested by the inter-annual variability of replacement and culling rates in nucleus flocks. A follow-up of the farm including more detailed data collection of the farmer's discourse, *in situ* observation of practices and possibly on-farm measurement of the products of decision-making (breeding animals) could allow the specification of modalities and opportunities of the genetic management being performed (Landais et al. 1988).

Conclusions

Individual farmers' choices for the modalities of replacement and culling were not hindered by farmers' participation in the breeding scheme. Factors influencing farmers' perception and use of collective tools, including the modalities of use of milk recording within or outside of the breeding scheme, were linked to (i) the time devoted to animal observation and the work management (flock size, milking method, waged workforce) and (ii) the feeding resources and the potential of land use to reach the production goal. The importance of diversifying the selection criteria by including morphological and functional traits such as udder traits or breed standard also appeared in the limitations associated with entering the breeding scheme. However, considering the noticeable level of use of rams from the breeding scheme's cooperative, the use of genetics from the breeding scheme (buying of rams from CORSIA) was compatible with the individual objectives for flock genetic management in a diversity of commercial flocks.

This comprehensive approach to the breeding practices applied in Corsican dairy sheep farming suggests that on-farm breeding practices cannot be restricted to the use of collective tools. The case of dairy sheep farming in Corsica illustrates that it is possible to use standardised performance recording tools and tools to disseminate genetic progress in a diversity of farms, provided that the adverse effects of collective action are offset by the use of additional selection criteria suited to the farmers' objectives and the constraints of the production environment.

Note

1. For Corsica, the System of Information in dairy sheep farming (SIEOL) is managed by the Regional Association of Services for Livestock Organizations (ARSOE Soual) and includes the monitored dairy sheep farms of Corsica (all nucleus flocks and a part of commercial flocks): farms under OMR, farms under SMR, farms under single technical support, farms under single scrapie genotyping.

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