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Are farmers motivated to select for heat tolerance? Linking attitudinal factors, perceived climate change impacts, and social trust to farmers' breeding desires

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ABSTRACT

This study provides an understanding of dairy farmers' willingness to include heat tolerance in breeding goals and the modulating effect of sociopsychological factors and farm profile. A survey instrument including a choice experiment was designed to specifically address the trade-off between heat tolerance and milk production level. A total of 122 farmers across cattle, goat, and sheep farms were surveyed face-to-face. The results of the experiment show that most farmers perceive that heat stress and climate change are increasingly important problems, and that farming communities should invest more in generating knowledge and resources on mitigation strategies. However, we found limited initial support for selection for heat tolerance. This attitude changed when farmers were presented with objective information on the benefits and limitations of the different breeding choices, after which most farmers supported selection for heat tolerance, but only if doing so would compromise milk production gains to a small extent. Our results show that farmers' selection choices are driven by the interactions between heat stress risk perception, attitudes toward breeding tools, social trust, the species reared, and farm production level. In general, farmers willing to support selection of heat-tolerant animals are those with positive attitudes toward genetic values and genomic information and a strong perception of climate change and heat stress impacts on farms. On the contrary, negative support for selection for heat tolerance is found among farmers with high milk production levels; high trust in farming magazines, livestock farmers' associations, and veterinarians; and low trust in environmental and animalist groups.

Key words: heat stress, attitudes, selection, breeding tools

INTRODUCTION

Heat stress (**HS**) weakens the productive and reproductive capacity as well as the health status of livestock. The impact on dairy production is more severe due to the higher energy requirements of dairy animals and the metabolic heat production during lactation (Carabaño et al., 2017). The impact of HS on dairy livestock is an increasingly important global challenge due to climate change (Gunn et al., 2019; Hempel et al., 2019; Ranjitkar et al., 2020). In the Mediterranean region, the already high frequency of extreme heat events is expected to intensify in the short and medium term due to climate change (Ali et al., 2022).

Due to the severity of the problem, the dairy industry has been working for decades on technological solutions to manage the farm environment to mitigate the impacts of HS. Today, a wide portfolio of technological solutions and nutritional recommendations exists to improve adaptation of farms to high heat loads (Becker and Stone, 2020; Toledo et al., 2022). Heat stress mitigation options are being rapidly implemented in the more intensive dairy cattle systems and less so in small dairy ruminant systems. For example, fans and sprinklers have proven effective in mitigating the negative impacts of HS on animals and improving their welfare

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(Turner et al., 1992). However, heat-abatement devices require large amounts of energy, water, and financial resources.

Genetic selection for heat-tolerant animals has been proposed as an additional tool to improve farm adaptation to warm and hot conditions (Carabaño et al., 2017). Selection for heat tolerance (**HT**) can be a more environmentally and economically sustainable strategy at the farm level, as it uses less energy, water, and economic resources than the management measures mentioned above. In addition, it can rely (at least in part) on existing information in current selection programs and has the advantage of being cumulative and permanent. Scientists in both the public and private sectors are placing increasing emphasis on research into selection for HT. These recent studies have made very promising advances in enabling selection for HT. Genetic evaluations for HT based on the evaluation of production loss under HS are already available for dairy cattle in Australia (Garner et al., 2016; Nguyen et al., 2016). However, selection for HT is challenging due to the trade-off with high production levels (Carabaño et al., 2014), since highly productive animals tend to be less HT and vice versa. Estimates of genetic correlations between the level of production and the slope of decay for production traits become more negative with increasing mean temperature. The magnitude of the estimated correlations in dairy cattle is very high: −0.8 in Australia (Cheruiyot et al., 2020) and −1 in Spain (Carabaño et al., 2014). These values mean that high-producing cows tend to have a steeper slope of decay (Carabaño et al., 2014). A similar pattern has been observed in sheep, particularly in the Assaf and Manchega breeds, but to a much lesser extent (Carabaño el al., 2019).

The success of selection for HT necessarily relies on the willingness of farmers to include this trait as a breeding goal. Farmers' willingness is highly relevant as it determines the potential outcomes of breeding programs. The importance of farmer participation in the success of breeding programs has been documented in standard breeding programs focusing on traits with clear, direct, and measurable effects on farm economics (Serradilla, 2008; Nielsen et al., 2011, 2014). Studies analyzing farmer interest and participation in breeding programs are scarce and mainly conducted in developing countries (Gizaw et al., 2011; Mueller et al., 2015; Mutenje et al., 2020). Studies have mostly focused on analyzing farmers' preferences for improvement in livestock traits (Martin-Collado et al., 2015; Slagboom et al., 2016; Chawala et al., 2019). To our knowledge, no research has focused on understanding the drivers of such preferences, beyond basic descriptors of farm and farmer profiles (Ahlman et al., 2014; Martin-Collado et al., 2015; Slagboom et al., 2016). In particular, limited information exists on the factors that modulate farmers' willingness to select for HT. This study aims to fill this research gap.

This study has 2 main objectives: to contribute to the understanding of farmers' willingness to make use of breeding tools to improve HT, and to contribute to the understanding of the driving factors that modulate this willingness. Both objectives are defined in support of dairy livestock selection as an effective climate change adaptation strategy at the animal and farm levels. We hypothesize, first, that farmers' willingness to select for HT is negatively influenced by the above-mentioned trade-off between HT and productive traits. Second, we propose that risk perception (Campos et al., 2014) in the context of heat stress and climate change interacts with other sociopsychological factors that usually influence farmers' adaptation to climate change (Iglesias et al., 2021) and their attitudes toward the use of breeding tools (Zoma-Traoré et al., 2021). Third, we investigate whether farmers' trust in stakeholders modulates their willingness to select for HT, as in the case of climate change adaptation choices, through its influence on risk perceptions and beliefs (Arbuckle at al., 2013; Azadi et al., 2019). Finally, we expect to find differences in the willingness to select for HT between the more intensified dairy cattle farmers and the small ruminant (i.e., sheep and goats) dairy farmers.

MATERIALS AND METHODS

Case Studies

We analyzed 3 case studies in southern Spain, each of them focusing on one dairy livestock species (Figure 1): cattle (i.e., Holstein-Friesian breed in northern central Andalusia), sheep (i.e., Manchega breed in La Mancha region) and goats (i.e., Florida breed in the southwestern Andalusia and southern Extremadura regions). All case studies were located in Mediterranean climate regions (cold semi-arid and hot summer Mediterranean climates according to the Köppen climate classification; Figure 1) in Spain with already very high summer temperatures where dairy livestock usually suffer from HS at different times of the year (Ramón et al., 2016; Gómez Cantero et al., 2018). In the coming decades, it is expected that temperatures will increase further, and precipitation is expected to decrease, especially during the summer season (Segnalini et al., 2013).

Before participating in the study, all subjects provided their informed consent, and no personal data was collected. The research protocol, questionnaire content, and methods were conducted in accordance with the guidelines and approved by the Ethics Committee of

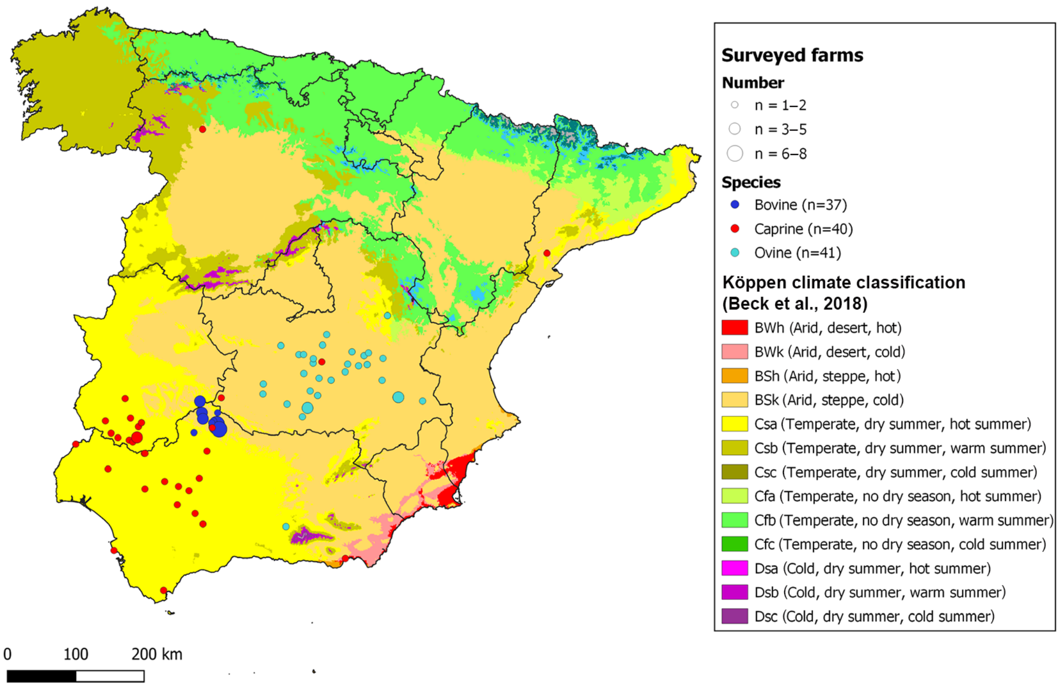

Figure 1. Location of the surveyed farms on a Köppen climate classification map of Spain (Beck et al., 2018).

the Agrifood Research and Technology Centre of Aragon, Spain (no. CEISH_2019_1).

Survey Design and Implementation

A farmer survey was developed to gather information on the willingness of farmers to participate in selection for HT and the drivers of this willingness. A first draft of the survey was designed by the research team and then discussed with technicians from the livestock breed associations (AGRAMA, the Manchega Sheep Breeders Association; and ACRIFLOR, the Florida Goat Breeders Association) and the Livestock Cooperative of the Pedroches Valley (COVAP) involved in the study. The draft survey was then tested on 8 farmers to check the wording and their understanding of the questions, as well as the length of time taken to complete the survey. As a result, the survey was shortened in length and some questions were reformulated to reduce the burden on the respondent.

The final survey consisted of 5 sections. The first section focused on the farming system (i.e., number of adult females and males, number of females per work unit, feed self-sufficiency, average milk production per female, and farm tenure regimen) and the farmer profile (e.g., age, level of education, and family farming tradition).

The second section analyzed farmers' attitudes toward breeding tools using Likert-type questions. It consisted of 8 statements selected from a list developed in a previous study (Martin-Collado et al., 2021). The statements related to attitudes toward different breeding tools, which ranged from selection based on the farmer's eye to the use of genomic and other –omic information and multi-trait indices, take into account not only the farmers' appreciation of the use of genetic evaluations, but also their attitudes toward innovation. The specific questions and full statements are included in Appendix Figure A1.

The third section analyzed farmers' perceptions of climate change and of the impact of HS on the farm. First, they were asked about their belief in climate change and its causes. They were then asked to rate the current seriousness of climate change using the same question and 1 to 10 scale (with 1 = not a serious problem at all and 10 = an extremely serious problem) used in the EU's Eurobarometer polling instrument to monitor the state of Europeans' attitudes toward the environment (European Commission, 2020). For the perception of HS, farmers were asked, by means of Likert-type questions, whether they thought that the HS suffered by their animals had been lower in the past, whether it would increase in the future, and whether the farmers in their case study area should invest more in measures to reduce HS. Finally, they were asked (on a 1–10 scale, where 1 = "no impact" and 10 = "extreme impact") to rate the impact of HS on the farm, both at a general level and on 9 specific aspects of animal and farm performance (milk production, milk quality, reproduction, adult mortality, offspring mortality, animal health, animal welfare, production costs, and farm profitability).

The fourth section was the choice experiment to determine farmers' willingness to select for HT. Before farmers were presented with the choice card (Figure 2), they were asked about their awareness of the possibility of selecting for HT and whether they would be willing to forgo gains in milk production to improve HT. These 2 questions were asked before explaining to the farmer that HT can be controlled through breeding, and therefore the answers would reflect their opinion before participating in the choice experiment.

In the choice experiment, farmers were asked to choose 1 of 4 breeding scenarios: (1) current breeding goals (i.e., status quo scenario, where productive traits are given the highest focus), (2) moderate focus on HT (i.e., moderate scenario), (3) intensive focus on HT (i.e., intensive scenario) and, (4) prioritization of HT (i.e., prioritization scenario). Particular attention was given to presenting realistic scenarios that clearly highlighted the trade-off between selection for HT and milk production. The breeding scenarios were described in detail in terms of the potential improvement in 3 key milk production traits (i.e., fertility, mastitis incidence, and milk composition) due to the selection for HT animals and the associated reduction in genetic gain for annual milk production. The expected gains for each trait under the 4 scenarios were calculated using previously available information on the expected production losses due to HS in these breeds (Carabaño et al., 2014; Ramón et al., 2016; Serradilla et al., 2015) and taking into account the genetic parameters estimated for these breeds (data provided by breeders' associations). The methodology followed Ramón et al. (2021) to estimate genetic responses for production, functional traits, and resilience under different climate change scenarios. The

Selection scenarios	Average annual gain in milk production	DURING HOT SEASON		
		AI fertility	Incidence of subclinical mastitis (>1M Somatic cells)	Milk composition
Current	*4.8 L/ewe*	***Decreases by 12.5%*** *(0.42)*	***Increases to 30-35%***	***Decreases fat by 7.1% and protein by 8.3%*** *(6.5% fat, 5.5%* protein*)*
Moderate focus on heat tolerance	3.0 L/ewe	***Decreases by 8.3%*** (0.44)	***Increases to*** **25-30%**	***Decreases fat by 4.2% and protein by 5%*** *(6.7% fat, 5.7%* protein*)*
Intensive focus on heat tolerance	1.5 L/ewe	***Decreases by 4.3%*** (0.46)	***Increases to*** **20-25%**	***Decreases fat by 2.1% and protein by 2.5%*** *(6.85% fat,5.85%* protein*)*
Prioritization of heat tolerance	No genetic progress in production	**Same as rest of the year** (0.48)	**Same as rest of the year: 15-20%**	**Same as rest of the year** (7% fat, 6% protein)

Figure 2. Example of the choice card showed to Manchega sheep farmers during the choice experiment used to analyze farmer willingness to select for heat tolerance. Values in parentheses refer to the reference values for each trait in each scenario.

scenarios were discussed and agreed with technicians from the Florida goat and Manchega sheep breeders' associations (ACRIFLOR and AGRAMA) and the Livestock Cooperative of the Pedroches Valley (COVAP) involved in the study. This was to ensure that farmers were familiar with the terms, traits, and data used to describe the scenarios to avoid problems of misinterpretation. The 4 scenarios were presented on a choice card (e.g., Manchega sheep scenarios in Figure 2, Florida goat and Holstein-Friesian cattle scenarios in Appendix Figure A2).

Finally, the fifth section analyzed farmers' social trust. Farmers were asked how much they trusted (on a scale of 1 = totally mistrust to 6 = totally trust) the views and advice on farming issues from the following 11 social groups: livestock farmers associations (i.e., breeders' associations and cooperatives), agrarian organizations, individual farmers, livestock farming magazines, veterinarians, farming companies, government agencies, scientists, ecologists, animalists, and the media.

We conducted face-to-face surveys with 122 farmers (38 Holstein-Friesian cattle farmers, 43 Manchega sheep farmers, and 41 Florida goat farmers) between November 2019 and November 2020. Each survey took 20 to 30 min to complete.

Data Analysis

First, a descriptive analysis of the potential drivers of farmers' willingness to participate in selection for HT was carried out and the results compared across case studies (hereafter "species"). Groups of potential drivers were as follows: farm and farmer profiles, farmers' belief in climate change, perceptions on the severity of climate change and the impacts of HS on animal and farm performance, attitudes toward selection tools, and trust in the opinion of social stakeholders on farming issues. Differences between species were analyzed using ANOVA and Tukey's honestly significant difference tests for drivers quantified on a continuous scale. Chi-squared tests were used for drivers measured by categories. All statistical analyses were performed using R software (R Core Team, 2019).

Second, given the large number of variables and the latent correlation structure between them, principal component analyses were conducted to reduce the number of factors to be included in the subsequent regression analyses, which were performed to determine the magnitude and significance of the reduced set of drivers. The principal component analyses were conducted on the variables related to (1) farmers' attitudes toward breeding tools, (2) farmers' perceptions of the impact of HS, and (3) farmers' social trust. The first 3 principal components (**PC**) of each set of variables were retained as independent variables in subsequent analyses.

Finally, we used probit regression to study how the socioeconomic and attitudinal variables described above (Table 1) were related to farmers' willingness to participate in selection for HT. Before building the probit regression model, we analyzed farmers' willingness to select for HT by describing the results of the choice experiment across species. At this stage, we decided to combine all responses that did not choose the status quo scenario into one category. Therefore, the dependent variable of the probit regression model was dichotomous (i.e., "current breeding goal" vs. "breeding for HT" scenarios). In addition to all the variables described in Table 1, we also included the species as an independent variable in the models. Overall, the analysis to evaluate the factors that determine the willingness of farmers to improve HT by including it as a breeding goal in their breeding program was based on the solution of the following model:

$$\mathrm{y} = \mathrm{g}\left(\mathrm{sp} + \mathrm{PE} + \sum_{i=1}^{3} PC\_BT_i + \sum_{i=1}^{3} PC\_HS_i + \sum_{i=1}^{3} PC\_SC_i\right),$$

where y = binomial variable for willingness to include HT in the breeding scheme (0 = status quo; 1 = inclusion of HT as breeding goal to some extent); sp = species (cattle, sheep, goats); PE = effects included in Table 1 except those accounted for in the PC; $\mathrm{PC\_BT_i}$, $\mathrm{PC\_HS_i}$, $\mathrm{PC\_ST_i}$ = ith principal component for attitude toward breeding tools, perceived heat stress impact, and social trust variables; and g is the probit function.

We used a stepwise procedure to select the variables to be included in the model. Coefficients were estimated by maximum likelihood using the Fisher scoring algorithm. Alternative models were compared using the Akaike information criterion, proportion of variance explained, and χ^2 *P*-value.

RESULTS

Potential Drivers of Willingness to Select for HT: Differences Across Species

Most farmers, regardless of the livestock species, believed that climate change is happening. However, 40% to 60% of them, depending on the species, thought that climate change was due to both natural and human factors (Figure 3). In any case, most farmers (74%, 66%, and 67% of cattle, goat, and sheep farmers, respectively) considered climate change to be a very serious problem (scores 7–10 on the rating scale), and

Table 1. Independent variables included in the probit regression models to assess the effect of groups of factors such as farm, farmer profiles, and farmer sociopsychological factors on farmers' willingness to select for heat-tolerant animals

Group	Variable	Description
Farm profile	Species	Discrete/categorical: Cattle, goats and sheep
	Average female milk production per day	Continuous: Indicator of production level (standardized within species)
	Number of females	Continuous: Indicator of herd/flock size (standardized within species)
	Number of females per work unit	Continuous: Indicator of labor intensification (standardized within species)
Farmer profile	Age	Continuous
	Education level	Ordinal: Basic (1), secondary (2), professional training (3), university (4), postgraduate university (5)
	Dedication	Binary: Full-time or part time
Climate change (CC) severity	Current CC severity perception	Ordinal: Scale from 1 (not a serious problem at all) to 10 (extremely serious problem)
Perceived change in heat stress (HS)	HS was lower in the past HS will increase in the future	Ordinal: Likert scale from 1 (totally disagree) to 6 (totally agree)
Attitude toward breeding tools	Question and full statements presented to respondents are included in the Appendix	Ordinal: Likert scale from 1 (totally disagree) to 6 (totally agree); included in the model as principal components (PC; see Table 2)
Perceived HS impact	Impact on milk quantity Impact on milk quality Impact on reproduction rate Impact on offspring mortality Impact on adult mortality Impact on animal health Impact on animal welfare Impact on production costs Impact on farm profit	Ordinal: Scale from 1 (no impact) to 10 (extreme impact); included in the model as PC (see Table 2)
Social trust	Livestock farmer associations Agrarian organizations Individual farmers Farming magazines Veterinarians Farming companies Governmental agencies Scientists Ecologists Animalists Media	Ordinal: Scale from 1 (totally distrust) to 6 (totally trust); included in the model as PC (see Table 2)

very few of them (3%, 7%, and 7%) thought that it was not a relevant problem (scores 1–2 on the rating scale).

Regarding the perceived changes in the HS suffered by animals (Figure 4), most farmers of all livestock species agreed (i.e., "somewhat agree," "agree," and "strongly agree") that the current HS suffered by animals is higher than a few years ago (92%, 78%, and 88%), that it will be worse in the future (68%, 73%, and 77%), and that they should invest more in measures to reduce HS to prepare for the coming temperature rise (97%, 76%, and 93%). Overall, most farmers perceived that HS had a relevant impact on animal performance and the farm economy (Figure 5). However, we found significant differences between farmers of different species and quite large variability within them, particularly across goat farmers. The impact of HS was perceived as more severe by dairy cattle farmers, followed by sheep and goat farmers. Dairy cattle farmers were particularly concerned about the impact of HS on milk production, reproduction, and welfare, whereas sheep farmers were particularly concerned about lamb mortality.

Farmers' general opinion on the usefulness of genetic and genomic breeding tools was very positive for all species (Figure 6). At the same time, about half of the cattle and goat farmers were also positive about breeding based on appearance (i.e., adult and offspring appearance). This dropped to around one-quarter of the sheep farmers, who were statistically different from the other species (ANOVA $P < 0.05$). However, farmers' initial view of the potential role of genetic selection in improving livestock HT was less positive (Figure 7). Although the goat farmers were statistically more positive (χ^2 $P = 0.024$), in general, only a small proportion of the farmers initially (before being faced with the choice experiment) thought that HS could be managed through breeding (13%, 27%, and 17% of cattle, goat, and sheep farmers, respectively). Most farmers, regardless of the species, thought that breeding for HT was not possible (50%, 20%, and 24%) or were unsure if it

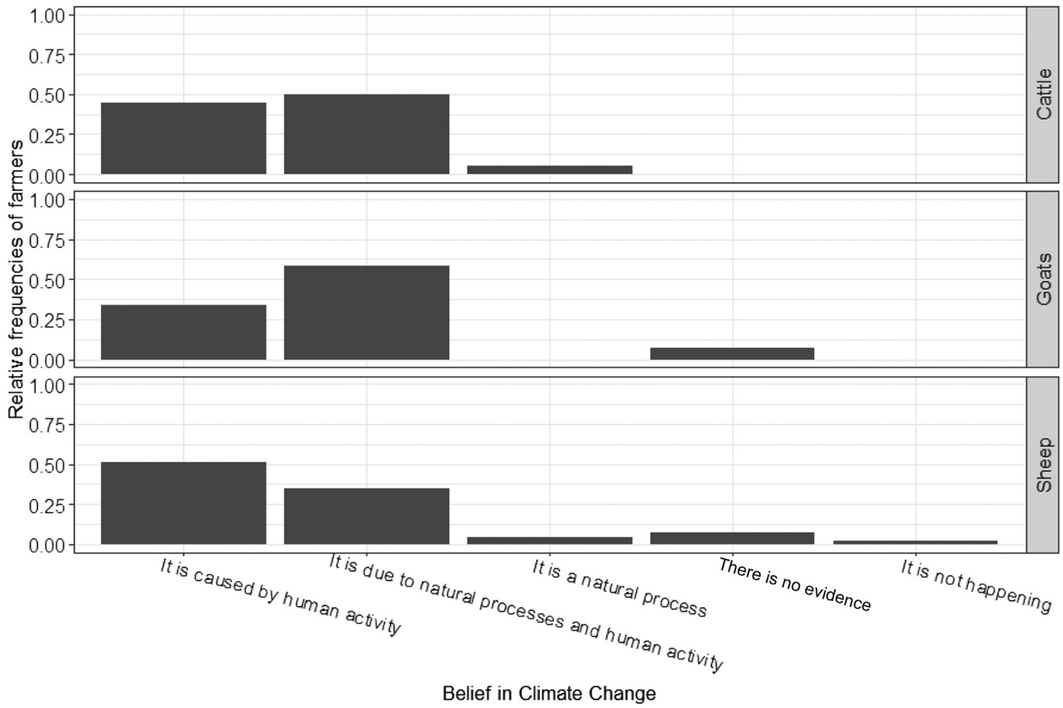

Figure 3. Farmers' belief in climate change and its causes.

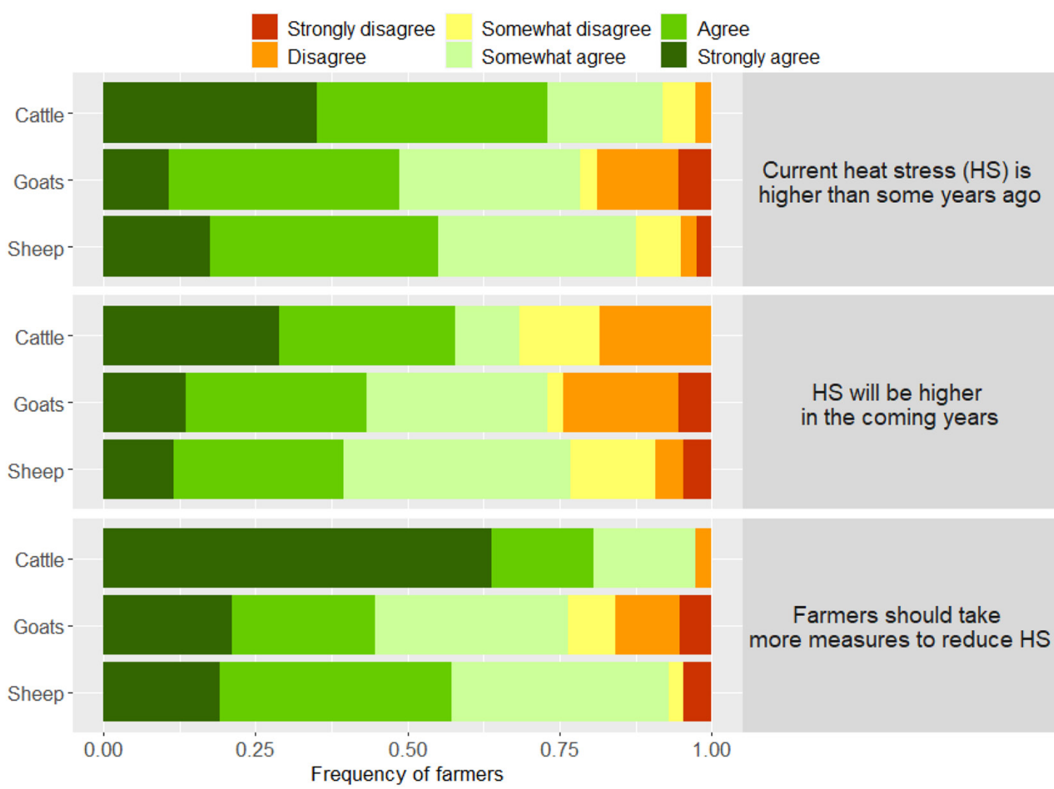

Figure 4. Farmers' perceptions of changes of heat stress and views of measures to be taken.

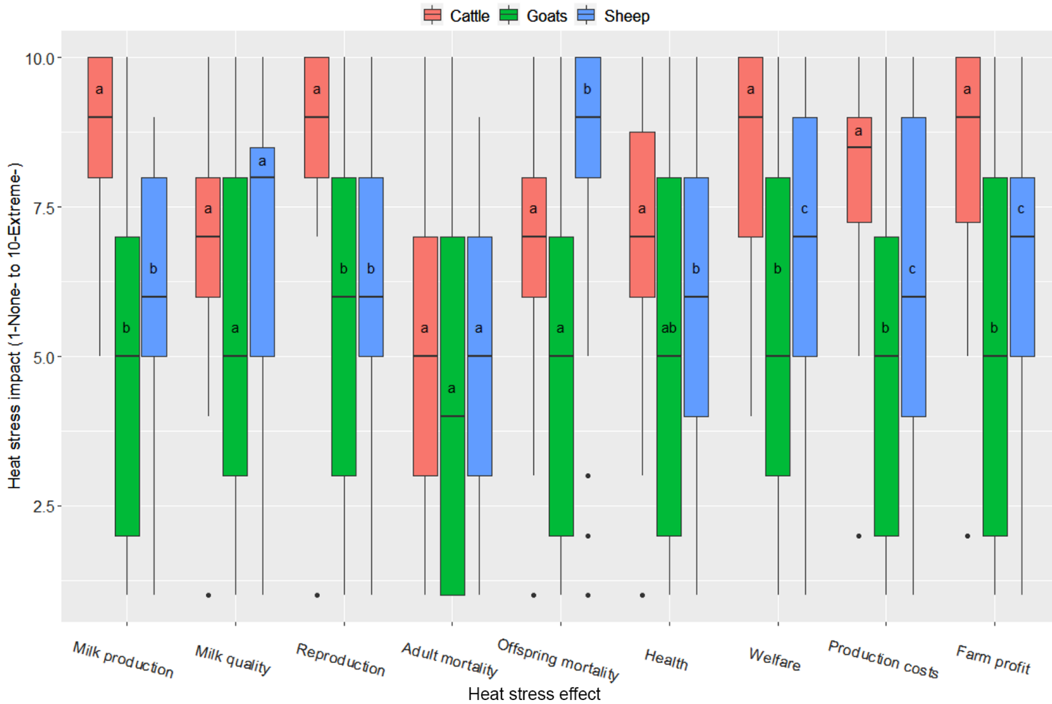

Figure 5. Farmers' perceptions of impacts of heat stress on animal and farm economic performance, on a scale of 1 (no impact) to 10 (extreme impact). Boxplots represent the median (solid lines), first and third quartiles (contained in boxes), dispersion (whiskers), and outliers (dots) of the distribution of perceived impact. Different letters (a–c) indicate differences ($P < 0.01$) in perceived impacts among farmers of different species according to Tukey's honest significant difference test.

was even possible (37%, 54%, and 60%). Furthermore, a high percentage of farmers regardless of the species (42%, 44%, and 40%) were initially unwilling to compromise production gains to improve HT.

Farmers' trust in the opinion and advice of social groups about farming was very similar for all species, except for livestock farmer associations (more trusted by goat farmers) and veterinarians (less trusted by goat farmers; Figure 8). Farmers stated high levels of trust in livestock farmer associations, veterinarians, farming magazines, and science. Trust was still high in farming companies, individual farmers, and agrarian organizations (over 70% of farmers "somewhat trust," "trust," or "completely trust" these social groups). On the contrary, farmers generally mistrust government agencies, the media, and especially ecologists and animalists.

Principal Component Analysis

The first 3 PC explained 68.8%, 82.2%, and 60.1% of the total variance of the variables related to farmers' attitudes toward breeding tools (PC_BT1, PC_BT2, and PC_BT3), farmers' perception of HS impact (PC_HS1, PC_HS2, and PC_HS3), and farmers' social trust (PC_ST1, PC_ST2, and PC_ST3), respectively (Table 2). The first PC of farmers' attitudes toward breeding tools (PC_BT1, Genetic technologies) corresponded to attitudes related to the use of both genetic and genomic breeding values as indicators of animal genetic merit and the use of DNA technology and gene-related tools to assist in animal selection. The second PC (PC_BT2, Traditional phenotypic selection) corresponded to attitudes favoring the appearance of breeding animals (i.e., phenotypic features) as an indicator of animal genetic merit. The third PC (PC_BT3, Genetic values) was mainly explained by attitudes related to the use of genetic values. Regarding the farmers' perception of the impact of HS, the first PC (PC_HS1, Global impact) was related to the overall impact of HS, with all variables contributing more or less equally. The second PC (PC_HS2, Mortality impact) corresponded mainly to the impact on both adult and offspring mortality. The third PC (PC_HS3, Quality impact) corresponded to the impact on milk quality. Finally, the first PC of the social trust variables (PC_ST1, General trust) related to general social trust, with all variables contributing more or less equally. The second PC (PC_ST2, Farmer institutions vs. ecologists) corresponded to trust in livestock farmer associations and farming magazines vs. trust in ecologists and animalists. Finally, the third social trust PC (PC_ST3, Farmers) corresponded mainly to positive trust in individual farmers and farming magazines.

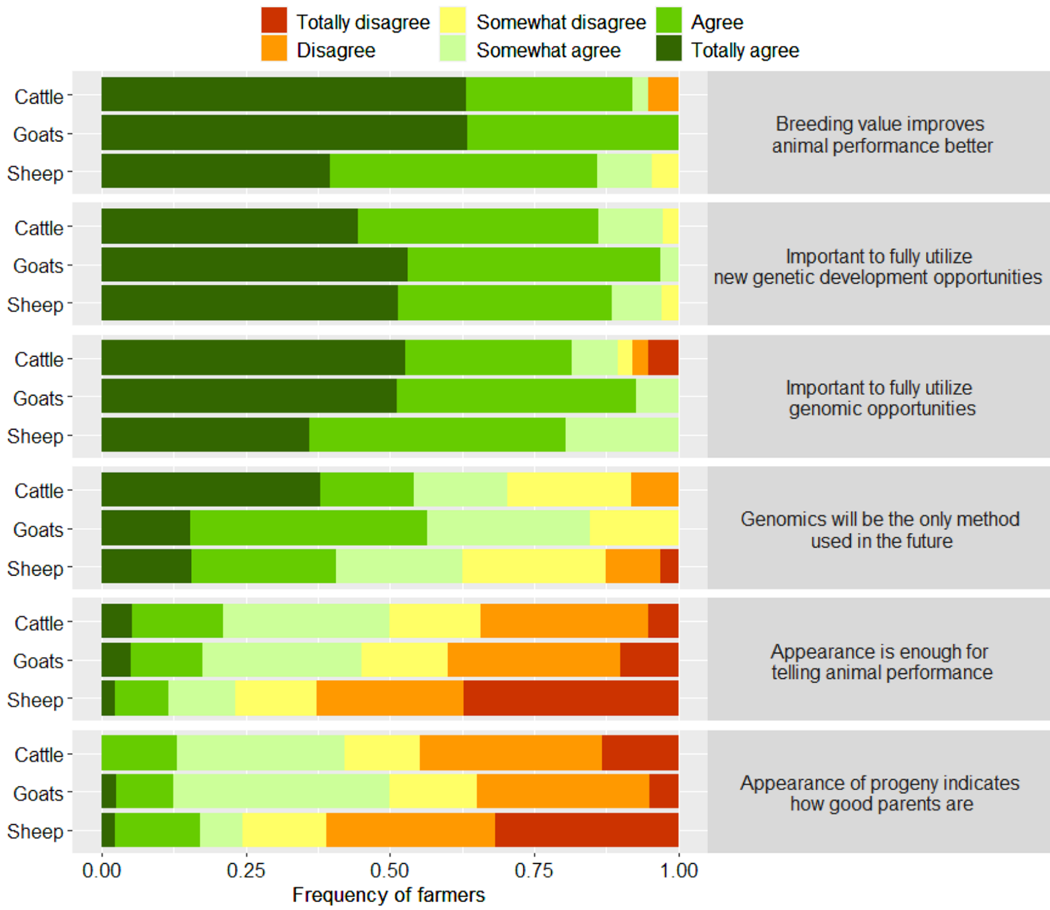

Figure 6. Farmers' attitude toward breeding tools. Full statements are included in Appendix Figure A1.

Probit Regression Models

Regarding the results of the choice experiment across species, cattle farmers were the least positive toward the inclusion of HS as a breeding objective ($P < 0.01$); 42%, 21%, and 19% of cattle, goat, and sheep farmers, respectively, chose the current breeding goal (status quo); therefore they would not be willing to select for HT (Figure 9). The remainder mostly favored a moderate level of breeding emphasis on HT.

Table 3 shows the results of the best regression model using a probit function as the link function. We found that a higher willingness to select for HT was associated with a lower level of milk production, a higher perceived impact of HS on animal and farm performance, and a more positive attitude toward breeding tools. In addition, we found that a higher willingness to select for HT was associated with lower farmer trust in the livestock farmer association and farming magazines versus ecologists and animalists. Finally, the species also modulated the results of the choice experiment; sheep and goat farmers were more likely to select for HT animals than cattle farmers. Farmer profile, farm characteristics (except for production level), perceived severity of climate change, perceived past changes in HS, and expected future changes all did not show significant effects on willingness to select for HT.

DISCUSSION

In this research, we aimed to determine dairy farmers' willingness to select for HT and to understand the role of farm profile, farmer characteristics, and farmer sociopsychological factors in modulating their attitudes toward breeding as an effective tool to reduce the impact of HS. We paid particular attention to farmers' perceptions of climate change, to their perceived impact of HS on animal and farm performance, their attitudes toward breeding tools, and farmers' social trust. This is because all these aspects have been linked to farmers' adoption of innovations in general and climate change adaptation measures in particular (Azadi et al., 2019; Iglesias et al., 2021; Martin-Collado et al., 2021). To the best of our knowledge, our study is the first to ana-

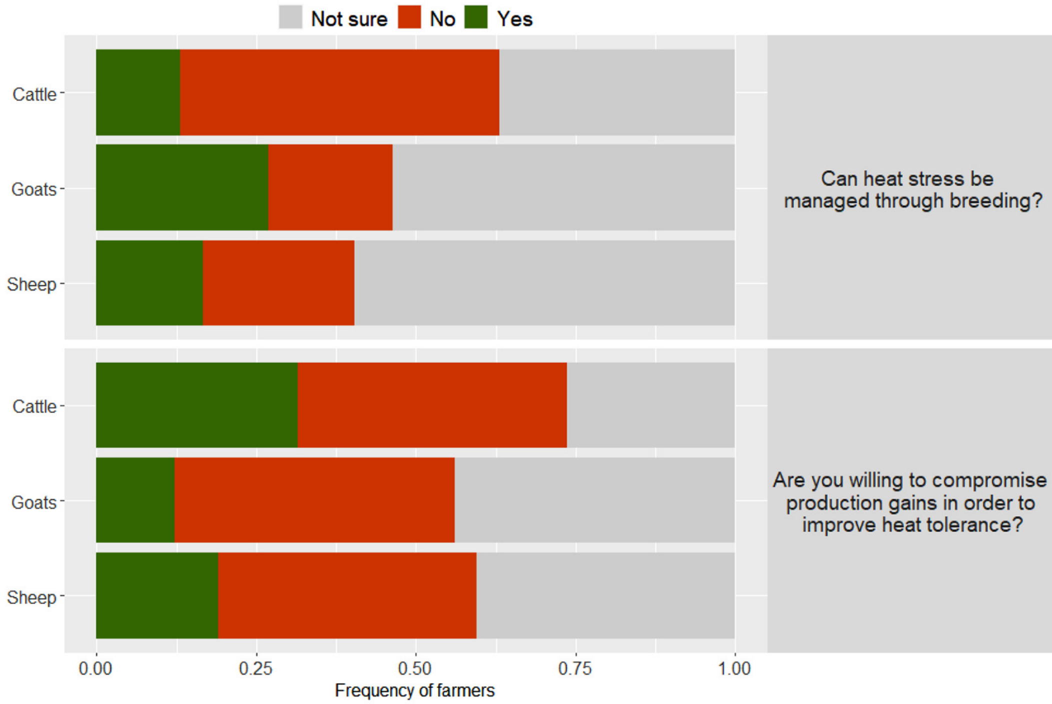

Figure 7. Farmers' initial views about selection of heat-tolerant animals.

lyze the sociopsychological factors influencing farmers' willingness to select for HT as well as their awareness of the impact of HS on their production activity.

Farmers' Perception of Climate Change and HS

One of the critical underlying drivers of farmers' uptake of problem-solving innovations is their perception of the risk of such a problem to the farm, which we found to be related to perceptions of climate change in the case of HS. Contrary to previous studies showing that many farming communities are usually skeptical about climate change (Kuehne, 2014; Doll et al., 2017; Davidson et al., 2019), we found that most farmers believe that climate change is happening and that it is a very serious problem. However, in line with other studies, around half of the farmers believed that climate change was a consequence of both human activities and natural processes, despite strong scientific evidence that climate change is a human-induced process (IPCC, 2022).

According to our results, scientists are highly trusted by farmers. Paradoxically, the perceived impact of climate change by farmers in Spain and EU countries is below the social average, whereas their skepticism toward the scientific explanation the anthropogenic causes of climate change is higher than in the general civil society (European Commission 2018, 2020). One explanation for this apparent paradox may lie in farmers' social trust. On the one hand, trust in public authorities, institutional actors, and environmental organizations has been found to be associated with farmers' belief in climate change and in their predisposition to taking adaptation measures on their farm. On the other hand, trust in actors with large agricultural interests works in the opposite direction (Arbuckle at al., 2013; Azadi et al., 2019). In this sense, the farmers' skepticism about the anthropogenic causes of climate change may be a reaction to their general lack of trust in governmental agencies, the media, ecologists, and animalists (who are the main spokespersons on climate change impacts and adaptation strategies), and may also be related to political ideologies (Running et al., 2017).

Regardless of farmers' views on the causes of climate change, our results show that most of them see HS as an increasingly important issue. This awareness is paving the way for new approaches and innovative solutions, such as breeding. Farmers perceive HS as having a negative impact on animal performance and farm profits, more so for cattle than sheep and goats. These differences in farmers' perceptions on the impact of HS across species are consistent with differences in HT at the biological level, with cattle and goats being the least and most HT species, respectively (Silanikove, 2000). The metabolic rate of cattle is higher, and their ability to retain water to maintain body temperature is

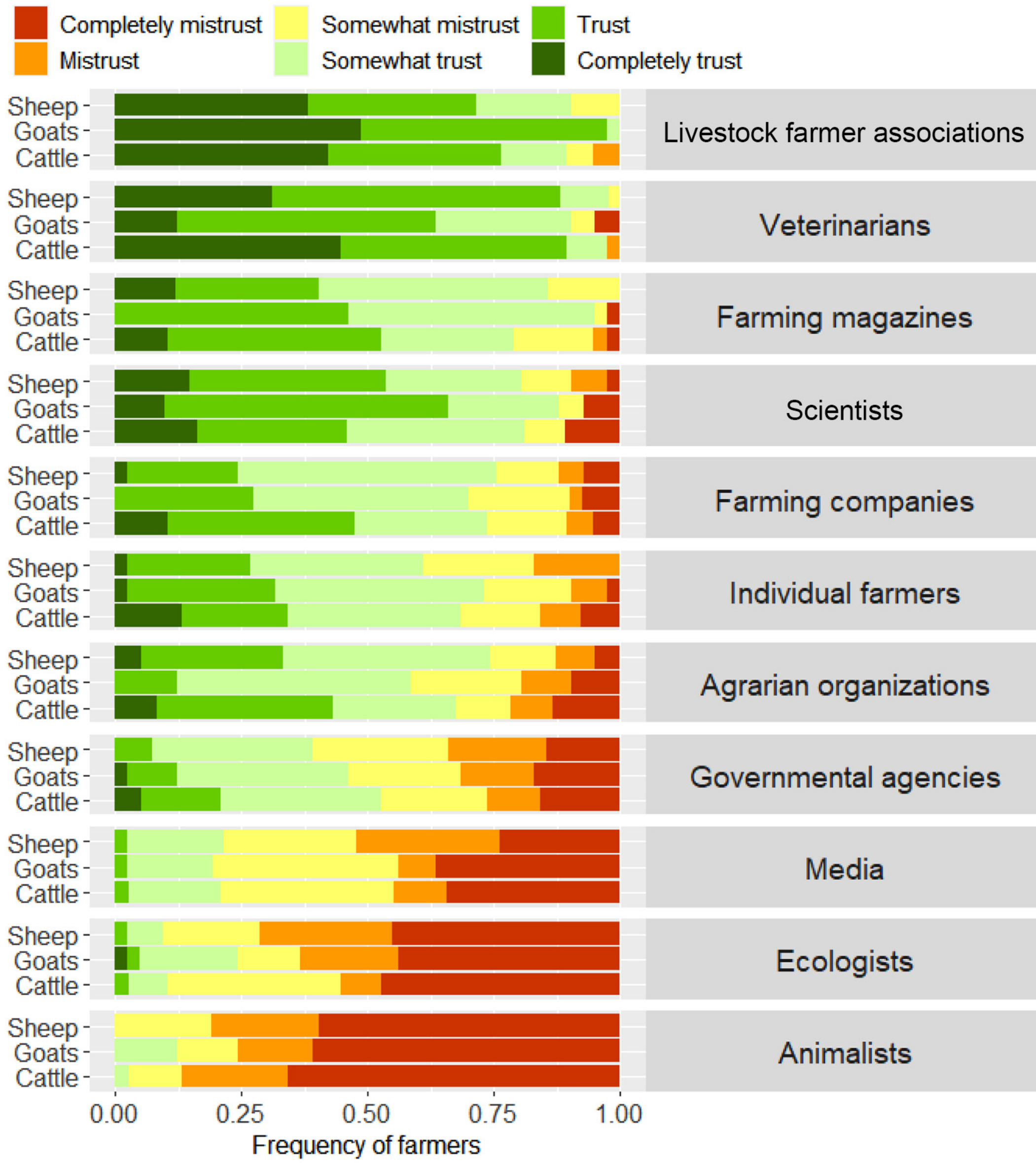

Figure 8. Farmers' social trust of opinions and advice about farming.

poorer than in other ruminant species, which rapidly affects feed intake. Therefore, physiologically, cattle (and especially dairy cattle) are the least prepared to cope with HS (Silanikove, 2000).

Farmers' Initial Views of Breeding for HT

Despite the farmers' awareness of climate change and the impact of HS on the farm, our results show that only a small proportion of them were aware that breeding could be used to manage HS, regardless of the species. This result is to be expected, as HT is a novel breeding trait not included in the breeding programs of the case studies. As hypothesized, most farmers initially stated that they would not be willing to compromise production gains to improve animal HT. However, after receiving detailed information about the potential advantages (i.e., reduction of HS impact on fertility, mastitis incidence, and milk quality) and disadvantages (i.e., reduction of milk production gains) of selecting for HT, most farmers indicated that they would be willing to select for it. However, the antagonism between HT and productive traits still drove farmers' choice toward a moderate focus on HT.

To the best of our knowledge, HT is included in breeding programs in only a few countries worldwide,

Table 2. Eigenvectors, eigenvalues, and percentage of variance explained for the first 3 principal components (PC) for farmers' social trust, perceived impact of heat stress on animal and farm performance, and attitudes toward breeding tools

Attitude toward breeding tools (BT)				Perceived heat stress (HS) impact on animal and farm performance				Social trust (ST)			
Variable[1]	PC_BT1: Genetic technologies	PC_BT2: Traditional phenotypic selection	PC_BT3: Genetic values	Variable	PC_HS1: Global impact	PC_HS2: Mortality impact	PC_HS3: Quality impact	Variable	PC_ST1: General trust	PC_ST2: Farmer institutions vs. ecologists	PC_ST3: Farmers
Genetic value	0.60	−0.09	0.69	Milk quantity	0.84	−0.38	0.13	Livestock farmer associations	0.50	0.50	−0.08
Breeding index	0.70	−0.17	0.17	Milk quality	0.63	0.32	0.69	Agrarian organizations	0.75	−0.11	−0.29
Adult appearance	0.18	0.88	0.17	Reproduction	0.85	−0.19	0.05	Individual farmers	0.62	−0.05	0.49
Genomic	0.66	−0.07	−0.26	Offspring mortality	0.70	0.47	−0.33	Farming magazines	0.53	0.54	0.45
Opportunity	0.85	−0.08	0.05	Adult mortality	0.78	0.41	−0.03	Veterinarians	0.59	0.38	−0.36
Genomic future	0.71	0.07	−0.29	Welfare	0.87	−0.08	−0.05	Farming companies	0.64	−0.10	−0.09
Offspring appearance	0.19	0.87	−0.09	Diseases	0.85	0.08	−0.21	Governmental agencies	0.68	−0.06	−0.29
New tools	0.72	−0.10	−0.31	Production costs	0.88	−0.17	−0.11	Scientists	0.62	0.35	0.13
				Profitability	0.87	−0.24	−0.03	Ecologists	0.64	−0.51	0.18
								Animalists	0.68	−0.46	0.27
								Media	0.56	−0.21	−0.35
Eigenvalue	3.11	1.6	0.8		5.93	0.77	0.66		4.28	1.36	1.01
Variance explained	38.9	19.9	10.0		65.9	8.9	7.4		38.5	12.4	9.2
Cumulative variance explained	38.9	58.8	68.8		65.9	74.8	82.2		38.5	50.9	60.1

[1]Full statements presented to respondents are included in Appendix Figure A1.

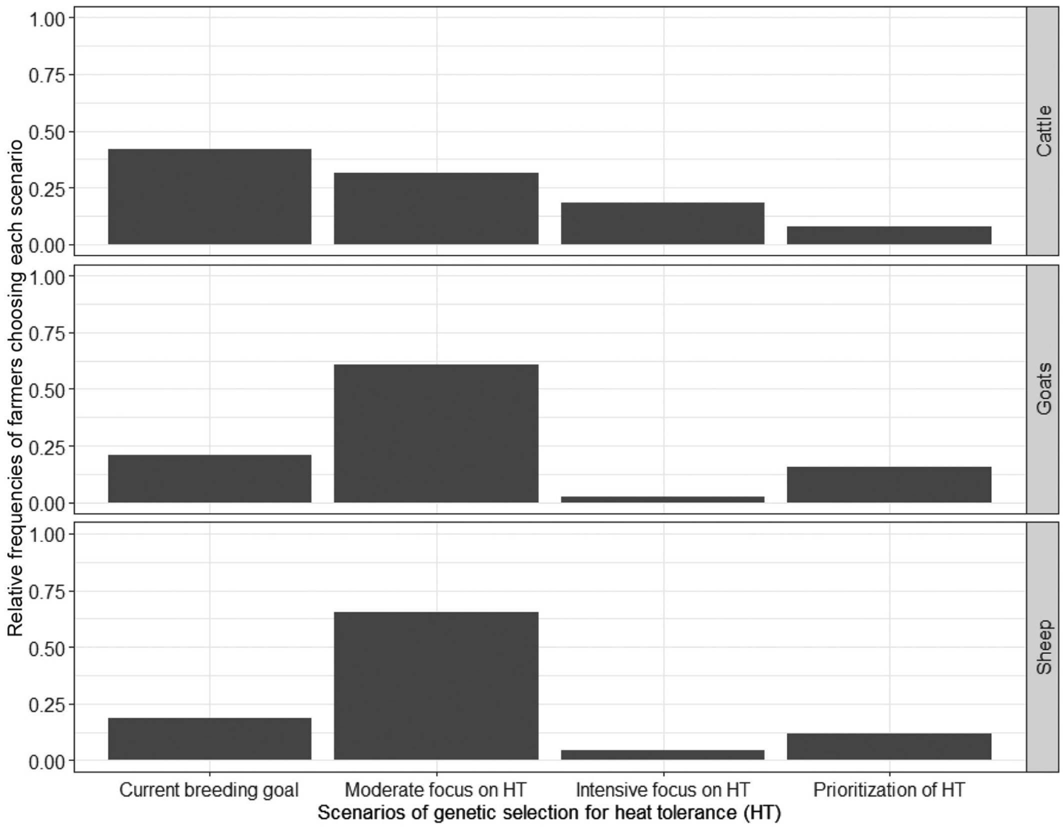

Figure 9. Farmers' choice of alternative genetic breeding scenarios giving increasing emphasis to heat tolerance.

such as dairy cattle in Australia (Pryce and Haile-Mariam, 2020). In this country, dairy farmers have been routinely receiving HT breeding values since 2017. In a recent article, Cheruiyot et al. (2022) report a positive acceptance of HT breeding values by Australian farmers and a slight change in the undesirable negative trend in HT previously observed in this population. The same undesirable trend in HT has been observed

Table 3. Results of the logistic regression models for the association of farm profile and sociopsychological factors with farmers' willingness to select for heat tolerance; results are shown for the class "Willing to select for heat tolerance" in relation to the class "Prefer the current breeding goal" (no selection for heat tolerance)

	Model 2. Probit linking function			
Coefficient[1]	Estimate	SE	Z-value	P-value
Intercept	−0.004	0.253	−0.016	0.99
Species (reference: cattle)				
Sheep	1.081*	0.435	2.483	<0.05
Goats	1.083**	0.368	2.941	<0.01
Milk production (standardized)	−0.311*	0.153	−2.033	<0.05
Social trust PC2_ST1, Farmer institutions vs. ecologists	−0.228***	0.135	−1.685	0.092
Attitude toward breeding PC1_BT1, Breeding tools	0.171*	0.086	1.989	<0.05
Attitude toward breeding PC3_BT3, Genetic values	0.448**	0.157	2.857	<0.01
Perceived heat stress impact PC1_HS1, Global impact	0.155*	0.073	2.117	<0.05
Null deviance	134.68 on 112 df			
Residual deviance	106.65 on 105 df			
Proportion of variance explained	0.2085			
χ^2 P-value	0.000217			
AIC	122.65			

[1]PC = principal component; ST = social trust; BT = breeding tools; HS = heat stress; AIC = Akaike information criterion.

*$P < 0.05$; **$P < 0.01$; ***$P < 0.1$.

in other dairy cattle (Santana et al., 2015; Carabaño et al., 2021) and dairy sheep populations (Carabaño et al., 2021) subject to selection to improve milk production. Moreover, under scenarios related to climate change, Ramón et al. (2021) reported that under future climate scenarios of +1 and +2°C increase in annual temperature, a set of weights of 35%, 17.5%, 17.5%, 10%, and 20% for milk yield, fat yield, protein yield, fertility, and weather resilience, respectively, resulted in higher benefits compared with current indices that do not account for HT. Overall, there is a clear need for an intensive dissemination program to inform farmers about the potential of breeding tools to control animal susceptibility to HS, to increase the willingness to include HT in the breeding goals.

Drivers of Farmers' Willingness to Select for HT

Our study confirms our hypothesis that farmers' willingness to select for HT is modulated by several interrelated factors ranging from HS risk perception, attitude toward breeding tools, social trust, the species reared, and farm milk production level. Both innovation uptake and general climate change adaptation behaviors are associated with farmers' willingness to select for HT. The literature has also established that (in addition to farm productivity factors) attitudes toward innovation and trust in different sources of information are drivers of overall innovation adoption (Meijer et al., 2015; Roussy et al., 2017; Toma et al., 2018). Furthermore, risk perceptions and social trust are usually highlighted as key drivers of farmers' climate change perceptions and adaptation behaviors (Mase et al., 2017; Azadi et al., 2019). Our results also suggest that farmers' attitudes, rather than data-based technical facts, may be more relevant for modulating their willingness to select for HT. This is illustrated by the fact that goat farmers showed the highest willingness to select for HT even though they perceived themselves to be less affected by HS than cattle and sheep farmers.

Attitude Toward Breeding Tools. Positive attitudes toward the use of genetic values and genomic information to select breeding animals positively influenced farmers' willingness to select for HT. This was an expected result, as it is well known that intrinsic factors such as farmers' knowledge, perceptions, and attitudes toward the innovations play a key role in their adoption (Meijer at al., 2015; Kuehne et al., 2017), and that attitudes are shaped by people's experiences with a particular object or activity (Albarracín et al., 2014). Our results seem to indicate that farmers who have positive experiences with the use of genetic values and genomic information are more likely to use them to select for novel traits, such as HT. Finally, the fact that variation in response to the statements used to measure attitudes toward breeding tools was related to farmers' willingness to select for HT confirms the appropriateness of the attitudinal scale developed by Martin-Collado et al. (2021).

Perceived Heat Stress Impact. The relationship between farmers' perceptions of the general impacts of HS on animal and farm performance and their willingness to select for HT is consistent with the well-established relationship between the severity of perceived impacts of a problem and farmers' implementation of solutions (Vignola et al., 2010; Keshavarz and Karami 2016) and, in particular, with the perceived impacts of climate change on farms and farmers' adaptation measures (Arbuckle at al., 2013; Azadi et al., 2019).

Social Trust. Our results support previous findings that farmers' trust in different social actors influences the extent to which they adopt innovation (Kroma 2006; N. Rust, S. Iversen, M. Reed, R. Neumann [Newcastle University, Newcastle, UK], E. Ptak, C. Kjeldsen, T. Dalgaard [Aarhus University, Tjele, Denmark], J. de Vries [Strategic Communication Group, Wageningen University, Wageningen, the Netherlands], J. Ingram, J. Mills [University of Gloucestershire, Cheltenham, UK], M. Muro [Milieu Consulting, Brussels, Belgium], unpublished data, https://doi.org/10.1108/EOR-10-2023-0002) and adapt their behavior to climate change (Arbuckle at al., 2013; Azadi et al., 2019). We found that farmers with high trust in farming magazines, livestock farmers associations, and veterinarians, as well as mistrust in ecologists and animalists, were less willing to select for HT. Mistrust in ecologists and animalists may be related to perceptions of climate change and its relationship to HS risk perceptions, as discussed above. Alternatively, the fact that trust in key farming stakeholders reduces farmers' willingness to select for HS may indicate a lack of awareness among these stakeholders of the potential of breeding tools to improve HT. This indicates a need to raise awareness among farmers and other key stakeholders on the potential use of breeding as a tool to mitigate the impact of HS.

Species. Our results show that the species reared has a strong influence on farmers' willingness to select for HT. Unexpectedly, this influence does not seem to be related to species HT at the biological level. If this were the case, we would have expected to find a higher willingness to select for HT in the species such as dairy cattle that suffer more from HS. However, dairy cattle farmers were the least willing to select for HT. The biological differences in HT between species could be partly or fully masked by other differences between farmer communities rearing different species. In particular, farmers' positive experiences with technological solutions to reduce HS are likely to negatively affect their views on the need for breeding to solve the problem. This explanation is supported by the fact that technological solutions to HS are widespread in the dairy cattle case studies and very limited in the sheep and goat case studies. We must acknowledge that we cannot completely rule out some interviewer bias, as the interviewers were different for each species. However, as we used a close-ended, structured questionnaire (Hughes et al., 2021) and all interviewers were trained before administering the questionnaire, interviewer bias, if present, is very likely to be limited.

Milk Production. Finally, our study shows that a high level of milk production reduces the willingness of farmers to select for HT. Farmers with high milk production are very likely to make greater use of agricultural technologies to mitigate HS and may prioritize technological solutions to HS over the use of breeding tools, as discussed above. In order for these farmers to find a balance between production and functional traits when pursuing the latter, they need to become aware on the impact of HS on production and other traits. In addition, a high production level could be an indicator of a productivist attitude of the farmer. Productivist farmers have farm production as a primary goal and consequently prioritize selection for production traits over functional traits (Martin-Collado et al., 2015). Nevertheless, it has been observed that productivist farmers will engage in activities that reverse the previous emphasis on farm production where these do not conflict with their primary production objective (Walford, 2003). Breeding for HT does not appear to be an exception.

CONCLUSIONS

Most dairy farmers see climate change and HS as increasingly important issues. However, they are generally unaware that breeding can be used to manage HS. Farmers' reluctance to sacrifice any production gains to improve animal HT can be overcome by providing detailed information on the potential advantages and disadvantages of selecting for HT. Even in this case, farmers would select for HT if it meant only a moderate reduction in genetic gain for milk production. Their willingness to select for HT is modulated by several interrelated factors, ranging from HS risk perception and attitudes toward breeding tools and social trust, to the species reared and the production level of the farm. There is a need to raise awareness among farmers and other key stakeholders of the potential use of breeding as a tool to mitigate the impact of HS.

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Appendix

Below are some statements about the breeding of bulls/rams/bucks and the reproduction of cows/sheep/goats. Please indicate how much you agree/disagree with each one.

- Using breeding values to select reproductive animals improves the performance of cattle better and faster than other ways of selecting.

Totally disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Totally agree	I do not know
☐	☐	☐	☐	☐	☐	☐

- Combining information from several traits into breeding indexes is the best way to summarize genetic merit information.

Totally disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Totally agree	I do not know
☐	☐	☐	☐	☐	☐	☐

- The appearance of a bull/cow is sufficient for telling its performance.

Totally disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Totally agree	I do not know
☐	☐	☐	☐	☐	☐	☐

- The use of genomic information to select reproductive animals will improve the performance of beef cattle better and faster than any other method.

Totally disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Totally agree	I do not know
☐	☐	☐	☐	☐	☐	☐

- It is important to fully utilize opportunities for the breeding of beef cattle with genomic and gene information.

Totally disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Totally agree	I do not know
☐	☐	☐	☐	☐	☐	☐

- Genomic information will be the only information used to select bulls/cows in the future.

Totally disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Totally agree	I do not know
☐	☐	☐	☐	☐	☐	☐

- The appearance of progeny fully indicates how good the bull/cow is.

Totally disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Totally agree	I do not know
☐	☐	☐	☐	☐	☐	☐

- It is important to fully utilize opportunities for the breeding of beef cattle with new genetic developments (transcriptomics, epigenetics, gene regulation networks, and metagenomics).

Totally disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Totally agree	I do not know
☐	☐	☐	☐	☐	☐	☐

Figure A1. Survey questions on farmers' attitudes toward breeding tools.

A

Selection scenarios	Average annual gain in milk production	DURING HOT SEASON		
		AI fertility	Incidence of subclinical mastitis (>1M Somatic cells)	Milk composition (kg of fat + kg of protein per milk liter)
Current	*4.5 L/goat*	***Decreases by 5%*** *(50%)*	***Increases by 12%*** (33%)	***Decreases by 15%*** *(0.16 kg)*
Moderate focus on heat tolerance	3.1 L/goat	***Decreases by 3%*** (51%)	***Increases by 8%*** (32%)	***Decreases by 10%*** *(0.17 kg)*
Intensive focus on heat tolerance	1.8 L/goat	***Decreases by 2%*** (52%)	***Increases by 5%*** (31%)	***Decreases by 6%*** *(0.18 kg)*
Prioritization of heat tolerance	No genetic progress in production	**Same as rest of the year** (53%)	**Same as rest of the year** (29%)	**Same as rest of the year** (0.19 kg)

B

Selection scenarios	Average annual gain in milk production	DURING HOT SEASON		
		AI fertility	Incidence of subclinical mastitis (>260,000 somatic cells)	Milk composition
Current selection	*75 L/cow*	***Decreases by 15-20%*** *(30%)*	***Increases to 15-20%***	***Fat decreases by 9%*** *(3.32%)* ***Protein decreases by 7%*** *(3.02%)*
Moderate focus on heat tolerance	50 L/cow	***Decreases by 12-15%*** (32%)	***Increases to*** **12-15%**	***Fat decreases by 6%*** *(3.43%)* ***Protein decreases by 4.5%*** *(3.10%)*
Intensive focus on heat tolerance	25 L/cow	***Decreases by 10-12%*** (33%)	***Increases to*** **10-12%**	***Fat decreases by 3%*** *(3.55%)* ***Protein decreases by 2%*** *(3.18%)*
Prioritization of heat tolerance	No genetic progress in production	**Same as rest of the year** (34.5%)	**Same as rest of the year: 5-7%**	**Same as rest of the year** Fat 3.65% and protein 3.25%

Figure A2. Examples of the choice cards showed to (A) Florida goat and (B) Holstein-Frisian cattle farmers during the choice experiment, used to analyze farmer willingness to select for heat tolerance.