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Sylvain Quiédeville
Research Institute of Organic Agriculture FiBL, sylvain.quiedeville@fibl.org

Hervé Hoste
INRAE/ENVT, herve.hoste@envt.fr

Yves Le Frileux
Institut de l'Élevage IDELE, yves.lefrileux@idele.fr

Spiridoula Athanasiadou
Scotland's Rural College SRUC, spiridoula.athanasiadou@sruc.ac.uk

Steffen Werne
Research Institute of Organic Agriculture FiBL, steffen.werne@fibl.org

Simon Moakes
Research Institute of Organic Agriculture FiBL, simon.moakes@fibl.org

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Cover Page Footnote

Please address all correspondence to Dr. Sylvain Quiédeville (sylvain.quiedeville@fibl.org).

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Sylvain Quiédeville
Research Institute of Organic Agriculture FiBL

Hervé Hoste
INRAE/ENVT

Yves Le Frileux
Institut de l'Élevage IDELE

Spiridoula Athanasiadou
Scotland's Rural College SRUC

Steffen Werne
Research Institute of Organic Agriculture FiBL

Simon Moakes
Research Institute of Organic Agriculture FiBL

ABSTRACT
This article assesses the costs, benefits, and acceptance of alternative control practices of Gastro-Intestinal Nematodes (GIN) for a typical organic dairy goat farm in France. A participatory Structured-Decision-Making (SDM) framework was used to guide focus group discussions, with an economic farm model and the Rogers and planned behavior theories used within the SDM framework. The study showed that the implementation of alternative GIN control practices can be economically profitable. An increased gross margin of €41 per dairy goat was calculated, which was mainly due to a decrease in the milk withdrawal

cost. The simplicity to use or implement the alternative practices and the experience level of the farmers seem to play a positive role in adoption of the alternative practices consisting of more targeted and strategic treatments. The novel information presented in this article contributes towards facilitating the adoption of suitable alternative approaches for parasite control.

KEYWORDS
Cost-benefit analysis, gastro-intestinal nematodes, organic farming, social acceptance, structured-decision-making.

INTRODUCTION

Gastro-Intestinal Nematode (GIN) infections remain a major health issue for small ruminants (sheep and goats) and can cause considerable production and economic losses at farm level worldwide (Corwin 1997; Taylor, Coop and Wall 2015). A lack of appetite, diarrhea, anemia, poor growth rate, and in extremes cases, death, are possible consequences of GIN infection in small ruminants (Min et al. 2004). GIN control poses an important management issue due to the abundance and impossibility of eradicating the parasitic nematodes, therefore, it is preferable to keep the level of GIN infection within an acceptable range, while minimizing control efforts (Gasbarre, Leighton and Sonstegard 2001). For more than 40 years, the usual mode of control of GIN in ruminants has relied on repeated use of synthetic anthelmintic drugs (Baiak, Lehnen and Da Rocha 2018). Anthelmintics are drugs (medication) that destroy or eliminate parasitic intestinal worms. However, this mode of control of GIN has become ever more challenging given the constant development of resistance to anthelmintic treatments in many parts of the world, especially within sheep and goat enterprises (Paraud et al. 2009; McKenna 2010; Sargison et al. 2010; Sczesny-Moraes et al. 2010). Therefore, alternatives to systematic anthelmintic treatments are needed (Min et al. 2004; Torres-Acosta and Hoste 2008).

As organic small ruminant systems are usually less intensive than conventional ones, it could be assumed that they have a lower risk of GIN infection, with minimum use of anthelmintics (Silva et al. 2014). However, organic livestock systems rely more on grazing and, due to restrictions in the use of anthelmintics, remain considerably exposed to herbage-related parasites (Thamsborg, Roepstorff and Larsen 1999; Takeuchi-Storm et al. 2019).

The literature has described potential alternative GIN control practices in small ruminant systems. One of the alternatives is to restrict anthelmintic use either by better defining periods of GIN risk for differing age classes and therefore by treating groups of animals only above a certain level of GIN risk [concept of Targeted Treatment (TT)]; or by identifying individual animals that need to be treated for their own welfare and to prevent the diffusion of GIN to others in the flock or herd [concept of Targeted Selective Treatment (TST)] (Hoste, Le Frileux and Pommaret 2002; Kenyon and Jackson 2012). The GIN risk can be identified on an individual animal basis through diagnostic methods such as fecal egg count tests (with a defined threshold risk), or based on previous observations and epidemiological studies that identified groups of animals as being particularly at risk.

Although there is a vast literature focusing on animal diseases and their economic implications at farm level (Bennett 1992; Dijkhuizen, Huirne and Jalvingh 1995; Dijkhuizen and Morris 1997), there is little evidence on the costs, benefits, and acceptance of alternative GIN control practices in small ruminant systems (Charlier et al. 2014). Kenyon and Jackson (2012) have shown that the use of drugs in a TT approach in UK for sheep flocks reduced anthelmintic applications and related costs by 35 percent and €790[1], respectively. Furthermore, some authors have shown that TT and TST approaches are not necessarily associated with production losses (Charlier et al. 2014). For instance, Kenyon et al. (2013) have shown that lamb growth rates could be maintained while reducing the use of anthelmintics by half in a TST approach. In terms of social acceptance, Cabaret et al. (2009) have found that organic sheep farms were more open to a TST approach compared to conventional.

This article aims to reduce the literature gap by assessing the costs, benefits, and acceptance of selected alternative GIN practices for French organic dairy goat farms in the Occitanie and Auvergne-Rhône-Alpes regions. The alternative GIN control practices studied were as follows: (1) TT & TST, (2) the strategic use of anthelmintic treatments, i.e. the choice of product(s) and application time of the products, (3) the non-access to pastures for kids and young goats (up to one year old) to reduce exposure to parasites, (4) changes in the grazing management [e.g. rotational grazing whereby grazing livestock are regularly moved between portions of the pasture (often called paddocks), allowing the non-used paddocks to rest], and (5) the use of bioactive plants with anti-parasitic effects, e.g. Sainfoin (*Onobrychis viciifolia*), in the ration.

It was hypothesized that alternative GIN control practices are costlier to implement than the traditional mode of treatments and that the effectiveness and ease in use or implementation of alternatives are associated with a higher adoption of these alternatives.

As such problems typically concern a diversity of stakeholders with different needs and views, it was decided to undertake a participatory approach by involving stakeholders in the evaluation process. The advantage of undertaking a participatory approach over others is to consider a broad diversity of stakeholders' views to empower them and enhance responsiveness during the evaluation (Tandon and Fernandez 1984; Greene 1988). Therefore, a participatory approach increases chances that stakeholders will utilize socio-economic results for their own reflection and decision-making on GIN control practices (Weiss 1997; Plottu and Plottu 2009; Young et al. 2013). Decision-making on GIN control practices relates both to the possible undertaking of controlled experiments or simple on-farm testing and to the possible adoption of GIN control practices by farmers. More generally, it can relate to decisions about social exchanges or relations among actors (e.g. between agricultural extension agents and farmers). It may also benefit research programs such as development of essential oils for medication purposes or on breeding to develop resistance of small ruminants against intestinal nematodes.

In the next section, we present the general background, followed by the presentation of the simple economic farm model representing the situation of a typical organic dairy goat farm in the French Occitanie and Auvergne-Rhône-Alpes regions. The approach applied to evaluate the costs, benefits, and acceptance of alternative GIN practices is then defined. Finally, results are presented and the article concludes with lessons learned.

MATERIALS AND METHODS

General Background

The analysis of alternative practices is facilitated when the existing problem is understood well and also when the aims guiding the search of alternatives are well defined (Mingers and Rosenhead 2004). Furthermore, alternatives to current practices have various economic and social implications that need to be considered when analyzing their relevance. Decision science provides methodologies and decision-support tools that can be used to support problem formulation and aims setting as well as to help find relevant alternatives against their effects and implications (Guerrero et al. 2017).

Two groups of approaches can be defined, one based on formal decision-making methods, and another group based on less formal methods. Gregory et al. (2012) have shown that most formal decision-making methods such as science-based, consensus-based, and economic or multi-criteria based analyses each have significant limitations such as a lack of social and economic considerations, the omission of important insights, or the absence of a structured process needed to disentangle the system complexity. Less formal approaches comprise the Structured-Decision-Making (SDM) framework (Gregory et al. 2012) and other decision-based methods such as the Multi-Criteria Decision Analysis (MCDA) and Multi-Criteria Analysis (MCA) approaches based on a participatory structured process (Kangas et al. 2001; De Steiguer 2003; Antunes et al. 2011; Lienert et al. 2015). These approaches all rely on a similarly structured process, though the MCDA and MCA approaches are less readily accessible to non-experts. The SDM framework offers more simplicity to stakeholders.

SDM is rooted in decision theory and follows a systematic participatory process that utilizes a range of decision analytical tools and can help stakeholders to co-create, assess, and select between alternative practices (Martin et al. 2009; Gregory et al. 2012; Fatorić and Seekamp 2017). The aims represent what the stakeholders endeavor to attain and form the basis to evaluate alternatives, assuming the success of these alternatives to meet the defined aims is a measure of their appropriateness (Conroy and Moore 2001; Clemen and Reilly 2013).

Due to the complexity of agricultural systems, no consensus has been established on assessing the economic implications of alternative GIN control practices (Lopes et al. 2015). Possible methods range from cost-benefit and decision analysis to more sophisticated econometric models such as regression techniques, Monte Carlo and Markov chains simulations (Harvey et al. 2007; Kudahl et al. 2007). The use of a farm model is one way to perform a cost-benefit analysis (Van Schaik, Nielen and Dijkhuizen 2001). It presents the advantage that control experiments are not necessary to estimate the effects, but the use of assumptions is usually required to specify the model while keeping it simple enough (Schilizzi and Boulier 1997).

In addition, the theory of innovation diffusion by Rogers (1995) and the theory of planned behavior (Terry, Hogg and White 1999; Armitage and Conner 2001; Ajzen 2002; Ajzen 2011) are relevant, complementary, and broadly used approaches to assess the acceptance of innovations, including in agriculture (Kiplang'at and Ocholla 2005; Scott et al. 2008; Rezaei-Moghaddam and Salehi 2010; Talukder 2012). Rogers' theory enlightens the innovation diffusion process, as well as the reasons for adoption (1995). The theory assumes the following five innovation drivers or attributes: (1) relative advantage, (2) compatibility, (3) complexity, (4) “trialability”, and (5) observability. The relative advantage, compatibility, and complexity, represent the perception of how better, how more compatible (in terms of personal beliefs and social values), and how easier the innovation is, compared to the existing practices, respectively. As to the “trialability” and observability, they relate to the extent to which new ideas can be experimented (i.e. ability to trial) and results made available, respectively. The theory of planned behavior stresses that intention is the most important determinant of a person's behavior (Ajzen 2011). It determines a person's intention by three components (Ajzen 1991): (1) the attitude, (2) the subjective norms, and (3) the perceived behavioral control. The attitude is regarded as a person's rational choice based on the subjective utility of the behavior and on the outcomes' likelihood (Ajzen 1991; Kaiser, Hübner and Bogner 2005). The subjective norms refer to the views of individuals in their immediate environment in regard to the behavior in question (Ajzen 1991; Wedayanti and Giantari 2016). Additionally, the perceived behavioral control reflects the apparent ease or difficulty to perform the behavior (Ajzen 1991).

Typical Farm and Baseline System

The French Occitanie and Auvergne-Rhône-Alpes regions were used as case study locations in this investigation, which are two important dairy goat regions in France. To enable an economic assessment of the selected GIN control practices on a typical organic dairy goat farm in the case study, an MS Excel based model was utilized. The calculation model was primarily designed to reflect the gross margin value of a dairy goat system, reflecting the typical milk turnover minus input costs. The model was intentionally simple so that it could be used as a decision support tool in a participatory focus group setting with farmers and advisers, with transparent data input and calculations.

For the focus group conducted in the case study, a typical goat farm was defined based on input from local experts. This typical farm comprised 65 hectares of permanent grassland (i.e. grassland remaining unploughed for many years) and grazed woodland (i.e. combining grazing with tree production). Table 1 summarizes the characteristics of this typical farm that was used as the baseline system.

Table 1: Characteristics of the French Typical Organic Goat Farm

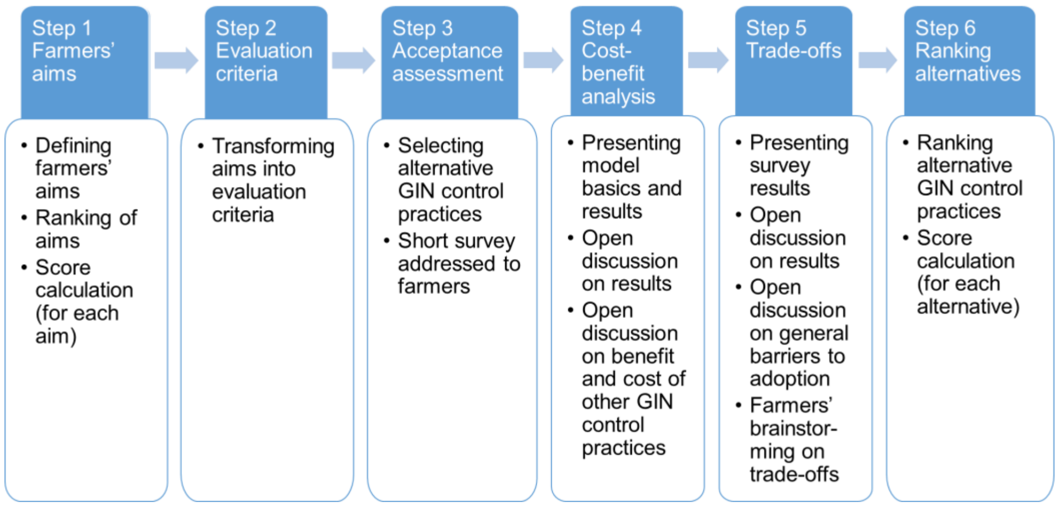
Characteristics	Annual records
Surface (ha)	65
Land occupation	Permanent grassland and grazed woodland
Family labor (AWU)	2
Adult dairy goats (#)	102
Goats at first lactation (#)	18
Productive goats during the year (#)	120
Billy goats (#)	1
Young goats of 7 to 12 months (#)	7
Kids of 3 to 7 months (#)	29
Milk production of adult goats (l/goat/year)	447 (471*95% efficiency)
Milk production of goats up to 12 months (l/goat/year)	380 (400*95% efficiency)
Lactation period (days/year)	305
Concentrates (g/goat/day)	600
Concentrates composition	Barley; maize; faba bean; alfalfa
Drenching with Fenbendazole for adult goats, goats at first lactation and billy goats (doses/year)	3
Drenching with Fenbendazole for kids and young goats of 3 to 12 months (doses/year)	1

Note: Annual work unit (AWU) is the annual full-time equivalent employment.

Participatory Step-wise Approach

The participatory method used to evaluate the costs, benefits, and acceptance of alternative GIN practices originates from the comprehensive SDM approach. Focus groups were organized in 2018, one in Occitanie and another in the Auvergne-Rhône-Alpes French regions. Four different organic and low input conventional farmers along with two local technical advisers attended each focus group (eight farmers across focus groups). Furthermore, one moderator and one assistant were involved in each focus group. Farmers were invited by the two local technical advisers and selected upon their interest in the topic of parasites, their system diversity, and their location. The focus group method was iterative and comprised of 6 steps (c.f. figure 1).

Figure 1: Step-wise Approach



Step 1: Farmers' aims. The general aims of the farmers were identified by asking what they wished to achieve in relation to their farms. They were asked to think individually about their own aims, before briefly explaining them to the focus group stakeholders. This information was collated and after the moderator had eliminated duplicates, farmers were asked to rank them according to their importance. The ranking was based on choice-based approaches (Merino-Castello 2003). A score of importance was calculated for each aim by only taking the primary choice of each farmer into account. The importance score equals the number of times an aim was ranked first by the number of times it could be ranked first i.e. by the number of farmers. The second and third choice were also requested as supporting information.

Step 2: Evaluation criteria. Farmers were asked to define criteria or indicators that are able to measure the fulfilment of their own aims defined in the previous step.

Step 3: Acceptance assessment. All attributes of the Rogers' theory were considered to analyze the acceptance of alternative GIN control practices and for the theory of planned behavior, but only the attitude and subjective norm components were used. The subjective norm component was considered through questioning the influence of the surrounding social context on adoption (farm neighbors, social pressure, and views of others), while the attitude factor was reflected via the perceived usefulness on the alternative practices. The perceived behavior control component was excluded due to its closeness to the complexity attribute defined in the Rogers' theory. The complexity attribute indirectly reflects the role of previous experiences and barriers (Ajzen 1991); nevertheless,

Table 2: Acceptance Assessment Survey

Components	N°	Questions	Type of answer
Relative advantage and social context	1	Do you think that these alternative practices are more effective than your current practices or past practices (if the practice has already been adopted)?	Likert scale
	2	Please also specify whether you adopted or not these different practices	Yes / No
	3	If you already adopted these practices, would you say that your decision was influenced by the surrounding social context (farm neighbors, social pressure and views of others)?	Likert scale
Compatibility	4	When thinking about these different practices, would you say that they are in line with your personal beliefs and social values (e.g. animal welfare, importance of common good)?	Likert scale
Complexity	5	When thinking about these different practices, would you say that: (a) They are easy to use/to implement?	Likert scale
	6	(b) They are easy to understand?	Likert scale
"Trialability" and adaptability	7	When thinking about these different practices, would you say that: (a) They can be tested without requiring an extensive involvement (e.g. capital, labor, and training)?	Likert scale
	8	(b) They can be adapted/modified to suit your own needs?	Likert scale
Observability	9	When thinking about the "observability" of these different practices, would you say that evidence on their potential benefits is available (to ensure a fair judgment of them)?	Likert scale
Usefulness and experience	10	When thinking again about these different practices, would you say that: (a) They are/would be useful in your case?	Likert scale
	11	(b) You already have many experiences on similar practices?	Likert scale

the experience factor was integrated per se in the approach to study its specific effect on innovation uptake. Five alternative GIN control practices were selected by the two local technical advisers. These were then presented to the farmers to assess the acceptance of innovation, undertaken using a short survey. Table 2 shows the questions addressed to farmers.

Step 4: Cost-benefit analysis. The farm model computed the benefits and costs of the alternative GIN practices. To represent a theoretically optimum adoption of the alternative approaches, a scenario that adopted all novel interventions was modelled. However, the change in grazing management was not modelled as effects may vary considerably depending on the specifics. Results of the modelled alternatives could be challenged by farmers in the focus group and the model could be instantly revised. In addition, farmers were offered the possibility to provide insights on the effects of alternative GIN practices that were not considered in the model.

The different economic components, calculated at a herd level, are as follows:

- Milk turnover: The milk turnover equals the milk production (in liter) multiplied by the milk selling price (€1.00/l). The effect of the GIN control practice consisting of keeping young goats indoors can influence the growth rate and thus the first lactation production level and milk turnover (Alberti et al. 2012).
  The assumed entry weight of the kids (3 to 7 months), goats of 7 to 12 months, and adult goats is, respectively, 4, 20, and 36kg; while their end weight is, respectively, 20, 36, and 55kg. This corresponds to a daily weight gain of 0.12, 0.13, and 0.18kg, respectively. A decreased growth rate, due to an increased parasite level (exposure to GIN), can be modelled by applying a percentage change to the daily weight gain value. The milk yield per goat is assumed to be proportional to the end weight value, all other factors being equal.
  The direct effect of GIN on milk production can also be modelled. A decreased coefficient of the milk production efficiency due to GIN can be expected due to fewer applications of anthelmintics. A coefficient of 95 percent is specified in the model as basis for the baseline and alternative solutions (100 percent infers a full efficiency). Therefore, assuming a theoretical maximum production level of 400 liters per year for first lactation goats and 471 liters per adult lactation; at 95 percent efficiency it corresponded to 380 and 447 liters, respectively.

- Milk withdrawal cost: It corresponds to the cost of unsaleable milk after an anthelmintic treatment. In French organic farming, the withdrawal period was 2 days for the use of Fenbendazole and Eprinomectin (active substances of anthelmintic drug) in the period considered (ANSES 2019). The milk withdrawal cost is computed separately for goats at first lactation and adult goats, as follows:

$$\text{Milk withdrawal cost} = \left(G \times \frac{Pr}{L} \times D \times Wd \times P \right) \qquad (1)$$

  where G is the number of goats treated, Pr is the annual production of milk (l/goat), L is the number of annual lactation days (=305), D is the number of drenching, Wd is the number of withdrawal days after each drenching, and P is the price of milk (€1.00/l).
- Drenching cost: This accounts for the cost application of Fenbendazole used as baseline, as well as for the application of Eprinomectin and Levamisole (alternative active substances). The dosage, expressed per 10kg of goat weight, is respectively of 1, 2, and 4ml (Farmacy 2018), with product costs of 0.033, 0.073, and 0.014€/ml, respectively. The average weight of the kids (3 to 7 months), goats of 7 to 12 months, goats at first lactation, adult goats, and billy goats, is 15, 50, 60, 65, and 80kg, respectively (Agridea 2017, Farmacy 2018).
- Feed cost: The baseline corresponds to the use of 600 grams of concentrates per goat a day, or 0.219 ton a year, at a feed cost of €436 per ton. This corresponds to an annual feed cost of €95.48 per goat (€436 $\times$ 0.219 ton) and €11'492 in total (€95.48 $\times$ 120 goats). The use of Sainfoin in the ration can be modelled by increasing the feed cost by a percentage difference. A percentage difference of 5 percent was assumed.
- Labor cost: The baseline proposes 2'400 hours per worker, with an average employee cost of €11.26 per hour, based on Agreste data (2018). The model allows for changes in the labor requirement (expressed in annual percentage change). In order to present an indicator, the model also calculates how many minutes of additional daily work the change represents.
- Gross margin difference (or net effect): It equals the change in saleable milk revenue (milk turnover – milk withdrawal cost) minus the change in the drenching, feed and labor costs.

Step 5: Trade-offs. Trade-offs between farmers' aims and both the economic consequences and social implications of the alternative GIN control practices were discussed and established.

Step 6: Ranking alternatives. Similar to the first step, farmers were asked to rank the different alternative GIN control practices according to their preferences. A score of importance was calculated for each alternative practice by following the same calculation procedure as in the first step.

RESULTS

Acceptance of Alternative Gin Control Practices

Figure 2 presents key results of the focus group survey, while the detailed results are shown in appendix (questions specified in table 2).

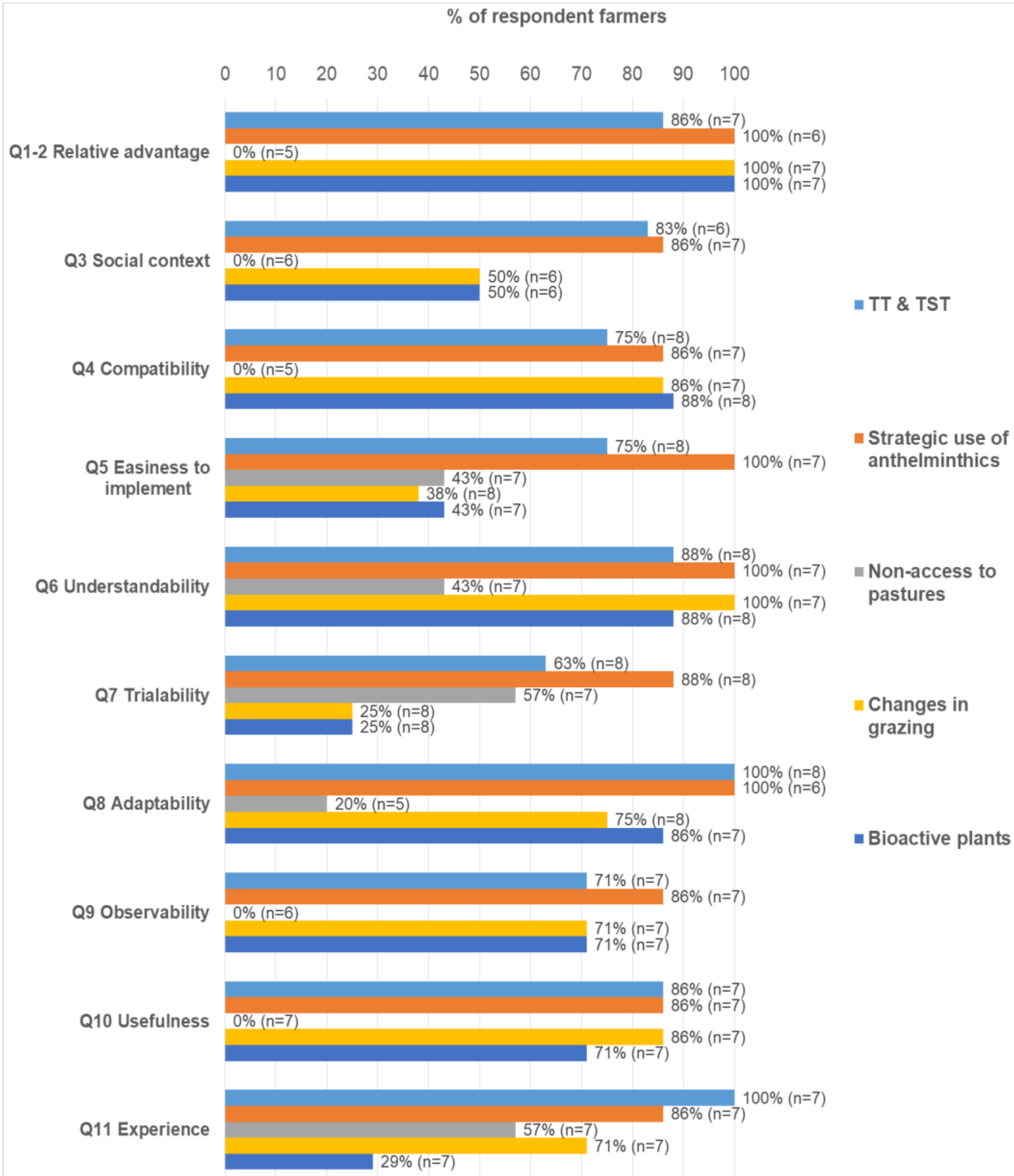
The results indicate that the practice of keeping young goats indoors was the least adopted one, with only three farmers out of a total of eight who answered positively (38 percent). The low adoption rate of this practice is associated with several limitations:

- None of the respondent farmers (0/5) to question 1 (and for this practice) strongly agreed or agreed that it is more effective (higher relative advantage) than the current practices (or previous ones if already adopted);
- None of the respondent farmers (0/5) to question 4 strongly agreed or agreed that it is in line with their beliefs and social values (e.g. animal welfare);
- Only 43 percent of the respondent farmers (3/7) to question 5 strongly agreed or agreed that it is easy to use or implement;
- Only 43 percent of the respondent farmers (3/7) to question 6 strongly agreed or agreed that it is easy to understand;
- Only 20 percent of the respondent farmers (1/5) to question 8 strongly agreed or agreed that it is easy to adapt.

In addition, the decision to adopt the practice of keeping young goats indoors was little influenced by the surrounding social context (farm neighbors, social pressure, and views of others) as none of the respondent farmers (0/6) to question 3 strongly agreed or agreed that the surrounding social context played a role in that regard.

Taken individually, the other practices have been adopted by at least 50 percent of the attendant farmers (4/8), while 75 percent of the attendant farmers (6/8) declared to have already adopted the practice of strategic use of anthelminthic treatments, which had the highest adoption rate. Furthermore, 88 percent (7/8) to 100 percent (7/7) of the respondent

Figure 2: Share of the Respondent Farmers Who Strongly Agreed or Agreed to Each of the Questions Addressed in the Focus Group Survey



Note: In total 8 farmers participated to the survey but not all of them answered to all questions and sub-questions. The n value for each sub-question is specified on the right of each corresponding bar. The acronym "Q" means "Question" and refers to questions 1 to 11 in table 2 (second column). The acronym "Q1-2" refers to both questions 1 and 2 in table 2.

farmers to the question 6 (for the corresponding practices) strongly agreed or agreed that these other practices, taken individually, are easy to understand. Then, 75 percent (6/8) to 100 percent (8/8 and 6/6) of the respondent farmers to question 8 strongly agreed or agreed that these practices, taken individually, are easy to adapt. Finally, 75 percent (6/8) to 88 percent (7/8) of the respondent farmers to question 4 strongly agreed or agreed that these practices, taken individually, are in line with farmers' personal beliefs and social values.

Specifically, 75 percent (6/8) and 100 percent (7/7) of the respondent farmers to question 5 strongly agreed or agreed that TT & TST, and the strategic use of anthelmintic treatments, are easy alternative GIN control practices to use or implement, respectively. Additionally, 71 percent (5/7) and 86 percent (6/7) of the respondent farmers to question 11 strongly agreed or agreed that they already have many experiences on similar practices as TT & TST, and the strategic use of anthelmintic treatments, respectively. TT & TST, and the strategic use of anthelmintic treatments, also had the highest rate of adoption, with 63 percent (5/8) and 75 percent (6/8) of the total number of attendant farmers who answered positively, respectively.

However, only 38 percent (3/8) and 43 percent (3/7) of the respondent farmers to question 5 strongly agreed or agreed that introducing changes in the grazing management and the use of bioactive plants are easy to use or implement, respectively. In addition, only 25 percent (2/8) of the respondent farmers to question 7 strongly agreed or agreed that changes in the grazing management and using bioactive plants can be easily tested without requiring much effort. These practices are also two of the least three adopted ones, with only four farmers out of a total of eight who answered positively (50 percent).

Cost-benefit Analysis

The assessment of alternative practices implied an overall reduction in drenching (number of applications) of 17 percent for adult goats, goats at first lactation, and billy goats. The young dairy goats aged 7 to 12 months and kids (3-7 months) were no longer treated as they were then housed until first parturition.

The results of the economic assessment that have been challenged and validated in the focus groups are presented in Table 3. The penultimate column indicates the effect of applying the combined alternative GIN control practices compared to the original baseline i.e. compared to the situation that prevailed before the legislative change in 2016 in the milk withdrawal period that applies after using Fenbendazole. In fact, this milk withdrawal time was increased the 1st January 2016 from 2 to 16 days in French organic farms (ANSES 2019). The last column indicates the effect of applying the combined alternative GIN control

Table 3: Results of the Cost-benefit Analysis of the Farm Modelling

	Component	Effect based on original baseline	Effect based on new baseline
Output	Milk turnover (€/year)	0	0
	Milk withdrawal (€/year)	+505	+7694
Inputs	Drenching (€/year)	-135	-135
	Feed (€/year)	-575	-575
Partial net effect	**Partial Gross Margin difference excluding labor cost** (€/year)	**-205**	**+6984**
	Labor (€/year)	- 2063	- 2063
Full Net effect	**Full Gross Margin difference including labor cost** (€/year)	**-2268**	**+4921**

practices compared to the new baseline, i.e. compared to the situation after the legislative change in milk withdrawal period in 2016.

The components of the gross margin difference are discussed below:

- Milk turnover effect: Both the change in the growth rate of the goats and the milk production efficiency (“resistance” level to GIN), influencing the milk production level and turnover, were discussed with stakeholders. The stakeholders stated that they had not observed any clear evidence on the effect of the GIN control practice of keeping young goats indoors. Therefore, no effect on their growth rate and thus on milk production and turnover was clearly identified. Furthermore, no evidence was acknowledged concerning the direct effect of the different alternative GIN control practices on GIN infection. The stakeholders highlighted the difficulty of isolating an individual factor from the others. Farmers agreed on the assumption for milk price (€1.00/l).
- Milk withdrawal effect: It was emphasized that before the 1st January 2016, the withdrawal time for Fenbendazole in French organic farms was increased from 2 to 16 days (ANSES 2019). The stakeholders suggested using this new regulation as baseline for the comparison;

therefore, in addition to the baseline of 2 days withdrawal, we created a new baseline that met the new legislative rule of 16 days withdrawal. When taking the new regulation as baseline for comparison, the use of Eprinomectin instead of Fenbendazole, decreased the overall milk withdrawal cost by €7'694.

It must be emphasized, though, that the direct effect of management change implied a reduced drenching cost of only €505, as shown by the comparison based on the original baseline (2 days withdrawal). In other words, the change in legislation largely explains (+€7189) the positive effect seen on milk withdrawal cost (+€7694) when taking the new baseline (16 days withdrawal) as basis for comparison. In effect, the farm model shows that with the new regulation the use of Fenbendazole by goat farmers would prohibit the sale of the milk for 16 days, implying an annual total cost of €8'215. This annual cost is composed of the cost for adult goats of €7'146 and of the cost for first lactation goats of €1'069.

- Drenching effect: In both baselines, the cost of Fenbendazole was €79 for the entire herd. The economic modelling shows that the use of the alternative treatments, Eprinomectin and Levamisole, increase the GIN control cost by €135. In effect, the use of Eprinomectin and Levamisole had a total cost of €170 and €44, respectively. Farmers agreed on the assumptions for price, number of applications, and dosage of the products.
- Feed effect: The use of Sainfoin was assumed to increase the overall feed cost by 5 percent, corresponding to an increased cost of €575 a year. As there was no stakeholders' disagreement, this assumption was kept. However, the absence of clear evidence on the effect of Sainfoin on GIN in farm conditions was highlighted.
- Labor effect: An increase of 5 percent in the labor requirement was modelled for the alternative GIN control practices, corresponding to a total additional 240.12 hours of work per year and to an extra total daily work time of 39 minutes (19.5 minutes per worker). The stakeholders considered this estimation was too high and also suggested that the baseline working hours for a full-time worker (2'400) was overestimated. In agreement with the stakeholders, this baseline working hours was reduced to 1,800 a year. The total additional daily work was also adjusted to 30 minutes (15 minutes per worker), corresponding to a total additional 181.14 hours of work per year and to an annual extra labor cost of €2'063, given the hourly labor cost of €11.26.

Based on the new baseline, the alternative GIN control practices modelled thus increased the enterprise gross margin (full net effect) by €4’921 annually (€41/productive goat). However, when considered against the original baseline of 2 days milk withdrawal (pre 2016), the full net effect was negative, as it equaled €-2’268 (€-19/productive goat).

Furthermore, the increased labor cost represented an opportunity cost since there was no paid employee on the typical farm. If labor was also excluded from the analysis based on the original baseline, the full net effect remained slightly negative of €-205 (€-1.71/productive goat). However, the full net effect was positive of €6’984 (€58.20/productive goat) when excluding labor but including the milk withdrawal effect associated to the alternative product withdrawal periods i.e. when taking the new regulation as baseline for comparison.

Other Aspects

General barriers. The extra labor requirement was identified as an economic barrier but only by one farmer and not convincingly (“maybe”). Two farmers also identified the adoption of a new practice as an economic risk (i.e. that may result in significant economic loss) and barrier. The TT & TST strategy was considered more at risk than systematic treatments, which particularly applies to those who have less husbandry experience. Aside from being an economic issue, the extra labor requirement was identified as a social barrier (risk of burnout) by another farmer. Two farmers also highlighted the lack of information on the state of research, and another one stressed a lack of consistency among veterinarians in terms of fecal samples interpretation (potentially leading to incorrect management decisions). Additionally, one farmer underlined the lack of skills of some veterinarians with goats.

Preferences. When defining aims at the beginning of the focus group, farmers mostly highlighted aims of an economic nature such as the maximization of the economic margin and the system viability. The definition of these aims supported farmers in defining their preferences on the potential use of alternative GIN control practices. The preferred alternatives are specified in table 4.

The change in grazing management was by far the most interesting or promising alternative considered by farmers (score of 0.86 out of 1). It was ranked first by farmers but was only perceived as potentially interesting for the future and merely general views were expressed. It was highlighted that a better grazing management can reduce the infestation level while also increasing grazing productivity. In turn, it was seen as a way to increase the milk turnover and to reduce costs on feed purchasing. The resulting lower level of infestation was also seen as a key factor to reduce drenching cost. However, a higher labor requirement was highlighted. Discussed examples of change in grazing management were as follows:

- Rotational grazing whereby grazing livestock are regularly moved between portions of the pasture (paddocks), reducing the risk of exposure to GIN infection through minimizing contact with infective larvae. As larvae only survive for a limited time period on pastures, it is possible to introduce goats to a given paddock only when the population of infective larvae is considered sufficiently low.
- Decrease in the stocking rate in order to reduce the risk of infection by spatial dispersion of infective larvae (principle of dilution).

The genetic selection of animals against parasites, which was identified by farmers in both focus groups is in second position, with a preference score of 0.14 (perceived as potentially interesting for the future). This alternative was not modelled nor surveyed given the high complexity of the practice and lack of relevant available data to support the model.

The other GIN control practices obtain a null score, but the use of bioactive plants appear of interest, as four farmers ranked it second. It must be underscored, though, that farmers only had a vague perception of the potential benefits and costs of this practice due to a perceived lack of scientific evidence, in practice, on the effect of bioactive plants on GIN infection. Moreover, two farmers placed TT & TST in second place, and one farmer in third position. Two different farmers placed the strategic use of anthelminthic treatments and the elimination of infected goats in third position. Finally, one farmer placed the use of essential oils (e.g. Sainfoin and oak leaves) in second position, while farmers stressed the lack of clear evidence on the effect of the practice consisting of not allowing the access to pastures to young goats.

DISCUSSION AND CONCLUSION

This study aimed to evaluate the costs, benefits, and acceptance of alternative GIN practices by farmers on a modelled typical French organic dairy goat farm in the Occitanie and Auvergne-Rhône-Alpes regions. To represent a theoretically optimum adoption of the four alternative approaches, a farm model scenario that adopted all the four alternative approaches was modelled.

Table 4: Ranking of Alternative GIN Control Practices by the French Goat Farmers

Alternative GIN practices	Score of importance
Changes in grazing management	0.86
Genetic selection for parasite control	0.14
Use of bioactive plants	0
Targeted Treatments (TT) and Targeted Selected Treatments (TST)	0
Using essential oils	0
Strategic use of anthelmintic treatments	0
Elimination of infected goats	0
The non-access to pastures for young goats	0

Note: In total 7 farmers participated in the ranking exercise.

It was shown that the adoption of these alternatives, as a replacement to systematic drenching with Fenbendazole, was economically more profitable (higher gross margin). As this result was due to an overall decrease in costs, the hypothesis was not confirmed that these alternative GIN control practices are costlier to implement than the traditional mode of treatments. When compared to a baseline that included the extended milk withdrawal time (16 days) since 2016 for Fenbendazole, a gross margin gain of €4’921 on the typical organic farm (€41/productive goat) was calculated. This is an important finding as farmers strongly highlighted economical goals when defining their aims. This gain was mainly caused by an overall decrease of €7’694 in the milk withdrawal cost, due to a reduction in drenching and alternative product withdrawal periods. The change in practices caused negligible increased drenching cost (€135.21) and an increased feed cost (€575), while the additional labor increased the costs by €2’063. The latter is not minor, though, it only accounts for an opportunity cost, as there was no paid employee on the typical farm. The extra labor requirement was only considered as an economic issue by one farmer and not persuasively.

The literature indicates similar results in the sheep sector. Targeted treatments that were optimized, as recommended by researchers, based on a marker of infection e.g. fecal egg count showed an average annual saving of €790 through a TT approach in UK sheep flocks, with an average decrease of 35 percent in the number of anthelmintic applications

(Kenyon and Jackson 2012). In the present case study, though, the drenching was only reduced by 17 percent for adult goats, goats at first lactation, and billy goats. Furthermore, the stakeholders stressed the difficulty to identify and measure effects of the alternative practices on GIN infection and on production level due to the difficulty to isolate one reason from the others, supporting literature findings (Hoste et al. 2006; Charlier et al. 2014; Zanzani et al. 2014). That said, the difficulty of perceiving effects might mean that a more targeted use of anthelmintic can in fact allow efficient GIN control in French goat systems, as it was suggested by Hoste et al. (2002).

Interestingly, the potential use of the alternative GIN control practices considered here, had important social as well as economic implications. Based on the theory of innovation diffusion by Rogers and the theory of planned behavior, the survey on social aspects has shown that the ease in use or in implementation, together with the experience, were associated to a higher adoption of the four modelled alternative GIN practices. The hypothesis was thus confirmed that the ease in use or implementation of these alternative GIN control practices are associated to a higher adoption of these alternatives. However, the results did not clearly show that the effectiveness or relative advantage of these alternatives had an influence on their adoption.

In general terms, the role of the ease of use and test innovations, and of the experience, in driving farmers' adoption, is a common finding in the literature (Millar and Connell 2010; Ngwira et al. 2014; Pignatti, Carli and Canavari 2015; Freeman and Mubichi 2017). More specifically, the indoor young goat practice is faced with several barriers and was the least adopted one, probably as it conflicts with organic principle of access to pasture. Additionally, two farmers identified the risk taking as a general barrier to innovation uptake, where the lower risk of performing systematic drenching was highlighted. Moreover, it is interesting to see that farmers also underscored external limiting factors, that is, the lack of information on the scientific research undertaken as well as the variability of interpretations between veterinarians and the deficit in skills for some of them on dairy goats.

Farmers placed by far the strategy of changing the grazing management in first position, with an importance score of 0.86 out of 1, despite its limitations in terms of social barriers (easiness to implement and easiness to test on farm). It is hypothesized that farmers believe this non-chemical approach to controlling GIN is one of their only long-term options, though it is difficult to approach on a specialized goat farm with little option for mixed grazing. The implementation of genetic selection for parasite control was ranked in second position (0.14) as this option is not yet readily available to farmers, despite extensive research. The use of bioactive plants was also well-considered but perceived (through the survey on social aspects) as not very easy to use or implement and to test, and was adopted at a very low level. These elements tend to show that, despite the current presence of significant social barriers, French organic dairy goat farmers are open to change. A similar result was found in a survey conducted on French organic sheep farms (Cabaret et al. 2009). The authors have shown that organic farmers were open to a TST approach while conventional ones were more skeptical to the idea.

The results presented in this article must be interpreted with a little caution. Indeed, the change in regulation and products used largely explains the relative profitability of the four alternative GIN control practices modelled; and an absence of change in regulation may have brought a different figure. When excluding the drenching cost effect associated to the change in regulation as well as the labor opportunity cost, the annual gross margin decreased by €205 (€1.71/productive goat). Additionally, the slightly increased drenching cost may not necessarily be interpreted negatively as it is associated with the change in products used. An overall reduction in drenching (number of applications) of 17 percent for adult goats, goats at first lactation, and the billy goats was observed. This indicates that the little increase in drenching cost was only due to the higher cost of the alternative products used. However, it can be expected that the reduction in drenching will be associated with a decreased risk of goat resistance to anthelminthic treatments and therefore support a more sustainable dairy goat farm business model in the future. Finally, economic and social factors are not meant to be mutually self-exclusive and neither economic nor social aspects should be considered alone. For instance, the non-access to pastures for young goats could be a promising alternative practice, economically speaking, but it seems not to be ethically acceptable.

These findings imply a need to generate further knowledge on alternative GIN control practices as well as a need for a closer link between farmers and the research and extension sector. Controlled research trials, combined with on-farm implementation support are possible ways to deepen existing knowledge and make alternative practices easier and less risky to adopt.

A stepwise approach based on SDM and innovation theories was developed to guide the participatory evaluation process and address the different facets of adoption by organic dairy goat farmers. The developed approach proved to work well, with the identification of farmers' aims that helped them to reflect the influence of social aspects and to value the different alternatives. Discussions were also enriched by the variety of opinions expressed by a diversity of stakeholders. The expertise provided by the technical advisers helped the identification of elements required in the SDM process. A similar observation was made by Martin et al. (2011) who used the SDM approach to assess the problem of sea level rise in Florida: "SDM provides an effective framework for collaborative research, because the development and identification of each of the elements of the SDM process may require different kinds of expertise. For instance, social scientists, economists, and psychologists can help with the identification of objectives" (p. 200). The use of a farm livestock model in a focus group context was also demonstrated to work well, with the possibility of participative modelling together with stakeholders.

A common limitation of a participatory approach is the duration of the focus group or workshop as the attention of the stakeholders tend to decrease with time (Quiédeville et al. 2017). This limitation occurred in this study, as the survey on social aspects was a bit more time-consuming than expected. In future similar studies, it could be merged with the general identification of barriers to adoption. A software such as MAXQDA could then be used to perform a discourse analysis (Kuckartz 2010). Another limitation associated to the participatory design is the overall limited quantitative assessment and absence of econometric analysis on the determinants to innovation uptake, which could give a more precise picture of the situation. However, considering the time and financial constraints, we believe that the present approach is a satisfactory trade-off.

ENDNOTES

[1] For comparative purposes, on December 9, 2020, 1 euro was equal to 1.21 U.S. dollars (see: https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html).

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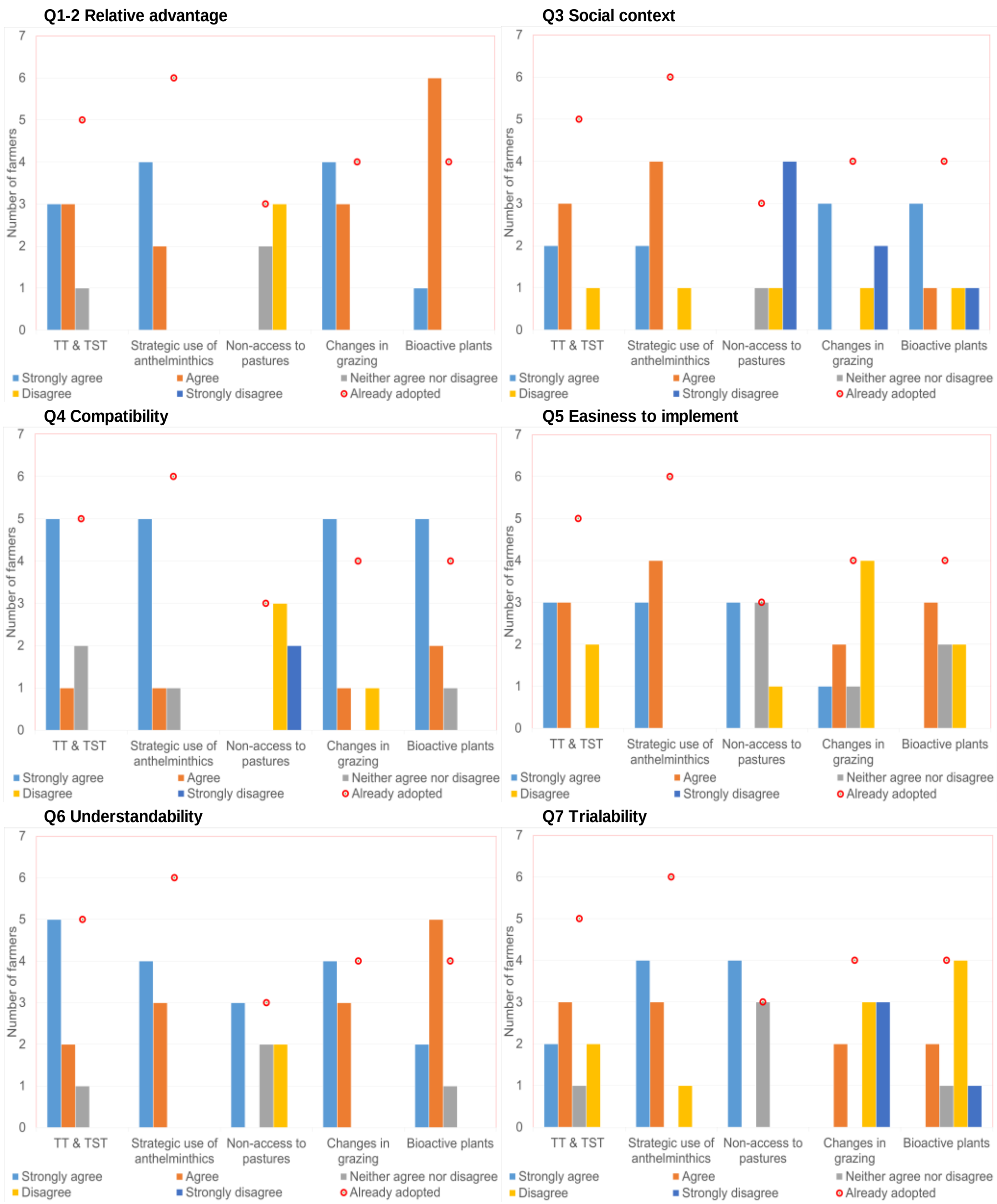
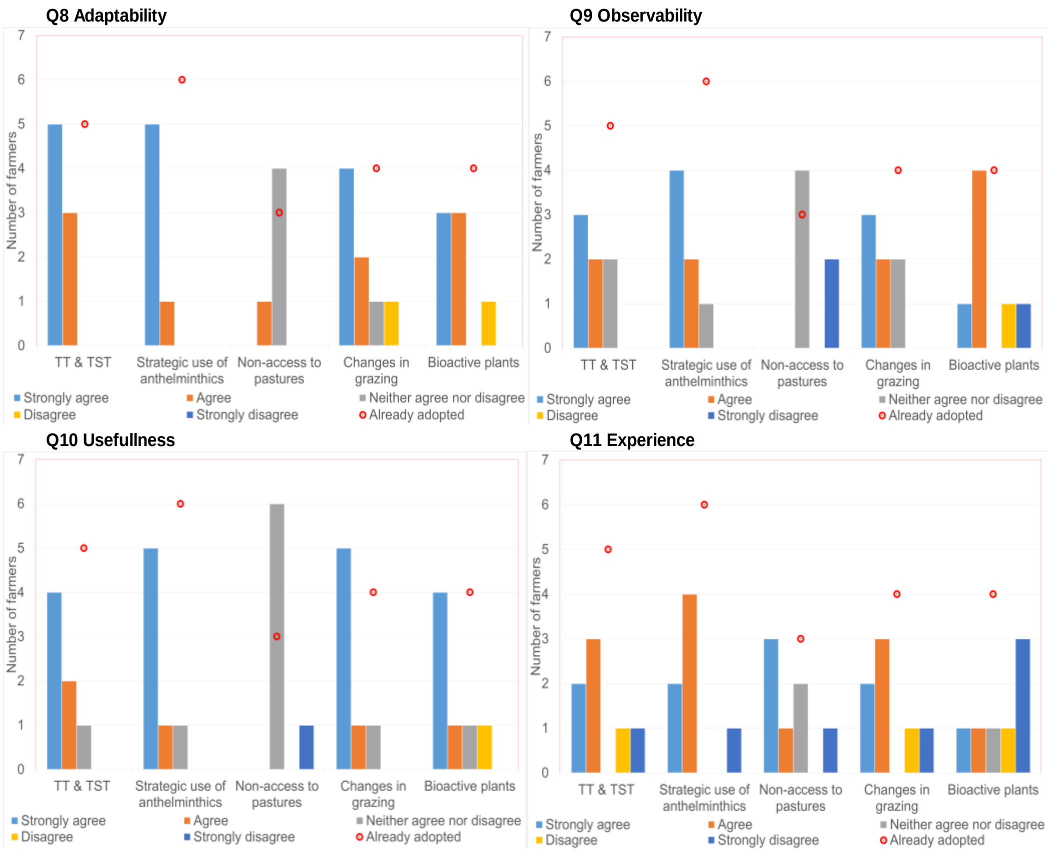
APPENDIX

Figure 3 – Questions 1-7 of the focus group survey on farmers' acceptance of alternative GIN practices



Note: This figure reports the level of farmers' acceptance on the alternative GIN control practices in terms of their relative advantage (Q1-2), social context (Q3), compatibility (Q4), easiness to implement (Q5), understandability (Q6) and "trialability" (Q7). The acronym "Q" means "Question" and refers to questions 1 to 7 in table 2 (second column). The acronym "Q1-2" refers to both questions 1 and 2 in table 2.

Figure 4 – Questions 8-11 of the focus group survey on farmers' acceptance of alternative GIN practices



Note: This figure reports the level of farmers' acceptance on the alternative GIN control practices in terms of their adaptability (Q8), observability (Q9), usefulness (Q10) and experience (Q11). The acronym "Q" means "Question" and refers to questions 8 to 11 in table 2 (second column).