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Thomas Hüe & Chloé Fontfreyde

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Development of a new approach of pasture management to control *Rhipicephalus microplus* infestation

Thomas Hüe¹ · Chloé Fontfreyde²Received: 6 January 2019 / Accepted: 11 April 2019
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Abstract

Despite several decades of chemical control, the cattle tick *Rhipicephalus microplus* remains an important constraint for cattle farmers. The regular use of chemicals has led to the development of tick strains that are multi-resistant to acaricides. New methods of tick control are being developed and combined in integrated tick management programs. Grazing management is one part of these control methods. However, until now, grazing management consisted essentially of resting pastures for 4 to 5 months. This amount of time is generally sufficient to allow for natural tick larvae mortality to occur, but this method often compromises the quality of forages, which is less than optimal at the time of arrival of the animals in the paddock. In this paper, we propose a new approach to pasture management-based tick control that optimizes forage production. It is based on tick development biological parameters, herd management and strategic treatments. This approach was tested for 2 years on two farms raising tick-susceptible European breeds of cattle under tropical conditions. The number of chemical treatments decreased respectively by 82.9% and 70.9%. This cost-effective approach may prove useful in decreasing the number of acaricidal treatments on farms facing high tick loads.

Keywords *Rhipicephalus microplus* · Pasture management · Integrated tick control

Introduction

As for many tropical cattle breeding countries, New Caledonia is plagued by the cattle tick *Rhipicephalus microplus* even though the tick-borne diseases babesiosis and anaplasmosis are absent. In addition to the reduction in weight by animals due to tick's attachment and blood feeding, heavy infestations punctually lead to cattle mortality. Tick control programs have been based on acaricide treatments since their introduction to New Caledonia in 1942. Frequent acaricide treatments have led to the development of acaricide resistances in New Caledonia as

in other tropical beef producer countries (Petermann et al. 2016). Since the 2000s, cattle farmers mainly apply amitraz for tick treatments all year long and macrocyclic lactone anti-parasitic drugs, such as non-residual ivermectin and moxidectin, are punctually used on average once or twice a year. Contrary to macrocyclic lactones that are paying, amitraz is totally free for farmers. Until the 2000s, they treated cattle systematically every 4 weeks. Today, to limit the development of acaricide resistances, Caledonian farmers commonly treat opportunistically, only when they observe ticks on cattle. There is locally no consensus on threshold for tick treatment, so depending on each farmer and the frequency of herd observation, treatments occur sometimes at early stage but often with engorged ticks. Thereby, with this method of control, pastures are regularly reinfested by ticks as invariably some engorged adult females will already have been fallen to the ground before the treatment. Farmers rearing tick susceptible breeds also have limited access to long-lasting acaricides (Ivermectin, Ivomec Gold®, Boehringer Ingelheim or Fluazuron, Acatak®, Novartis). These acaricides are applied exclusively by a technician and the number of treatments is limited to one or two per year.

Current tick control programs are increasingly focused on sustainable integrated tick management and decreased acaricide use. This change is due in part not only to the

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✉ Thomas Hüe
hue@iac.nc

¹ Institut Agronomique néo-Calédonien, Equipe ARBOREAL, BP 73, 98890 Païta, New Caledonia

² Groupement de Défense Sanitaire Animal, Chambre d'Agriculture de Nouvelle Calédonie, BP 111, 98845 Nouméa Cedex, New Caledonia

development of resistances but also to environmental and social considerations such as reducing soil and water pollution with pesticides, reducing farmers' exposition to chemicals, and the increasing demand for greener produced food-stuffs.

Several alternative methods to acaricide treatment are now available to integrated tick programs: such as the use of a tick vaccine tick, pasture management, or the use of resistant breeds. Historically, the tick-susceptible cattle breeds Limousin and Charolais were reared on New Caledonia. Due to the wide development of acaricide resistances, Brahman, Senepol, Droughtmaster, and Belmont Red were introduced in the 2000s and are now bred either in pure breed or crossed with Limousin or Charolais cattle (Hüe et al. 2014). However, there is a strong will to maintain Limousin and Charolais breeds in New Caledonia for their patrimonial value but especially to increase meat productivity and fertility in cross-breeding with tick resistant breeds. Furthermore, a tick vaccine in development in New Caledonia (Hüe et al. 2017) is now being tested on farms. Pasture management is another way to control ticks. Until now, New Caledonian cattle farmers were advised to avoid tick-infested pastures for 3.5 to 4.5 months to allow for natural tick larvae mortality (Barré and Delathière 2010). This measure is efficient but incompatible with a good forage management. Indeed, optimal tropical grass quality and quantity are obtained after 4 and 6 weeks of plant growth (Chambre d'Agriculture de Nouvelle-Calédonie 1989). So, farmers were faced with two conflicting messages: enhance forage quality with rapid pasture rotations or leave pastures unused for several months to decrease tick loads.

This paper describes a new approach to pasture management based on knowledge of tick biology that optimizes forage production and tick management.

Materials and methods

Experimental sites and animals

New Caledonia is a French island in the South Pacific Ocean with an oceanic tropical climate, 1200 km to the East of Australia and 2000 km to the North of New Zealand. Approximately 80,000 head of cattle are raised under extensive conditions by about 650 farmers. The hot and wet season is usually from late December to April. It is followed by a cold season from June to August with possible rain, and the dry season is from September to December. Mean temperatures and rainfall from January 2015 to December 2017 in both areas, Tontouta and La Foa, concerned by this study are presented in Fig. 1. An unusual important rainy phenomenon was observed in November 2016.

Experiment farms

Two farms, with regular high tick pressure and frequent acaricide use were followed over 2 years. Both farms have two herds with separate pastures for each. Information concerning the different herds is summarized in Table 1.

Acaricide resistance testing was conducted regularly on both farms in our lab. Tick strains have been resistant to amitraz since 2011 on farm A and since 2015 on farm B. Ticks on both farms are susceptible to macrocyclic lactones. Amitraz is still used in these two farms and treatments are efficient enough to control tick infestations, and as this acaricide is free for farmers, it is preferred to macrocyclic lactones for tick treatment.

Recommended measures of pasture management were applied for one herd on each farm; these were the experimental batch. The other herd on each farm that was managed with no changes, was considered as the control batch.

Plot of pasture use and treatments for each herd were recorded systematically on a pasture calendar during the study.

Tools developed

A provisional calendar was developed to know when cattle were to be exposed to tick larvae in plot of pasture. The tick *Rhipicephalus microplus* is a monoxenous parasite. It spends around 18 to 23 days on the same cattle to end its development and become a fully engorged female, that will drop off early in the morning (Hitchcock 1955a; Wharton 1970). If this female finds favorable conditions on the ground, she will lay eggs which will hatch after few weeks. The average time from drop off of engorged ticks to egg hatching on New Caledonia were determined by Desquesnes and Vignon in 1987 (Table 2).

So, considering the period of the year, when engorged ticks are observed on cattle, it is possible to estimate when larvae will be active in the plot of pasture where cattle were.

Different tools based on local biological tick parameters were developed during this study. Farm A recorded herd movements by computer. He was provided with a spreadsheet calendar that automatically added hatching and larvae survival periods. A hardback rotating provisional calendar (Cf picture 1) was developed for farmer B to predict the period of larval presence based on the date of engorged adult tick observation.

Picture 1: Hardback rotating provisional calendar

Correctives measures

During the first half of 2016, all farmers' practices were recorded to understand their herd and pasture management and the impact on tick infestations: pastures used by each herd, pasture rotations, date of acaricide treatments, tracks used to go to the dipping installation (pastures crossed or corridors)....

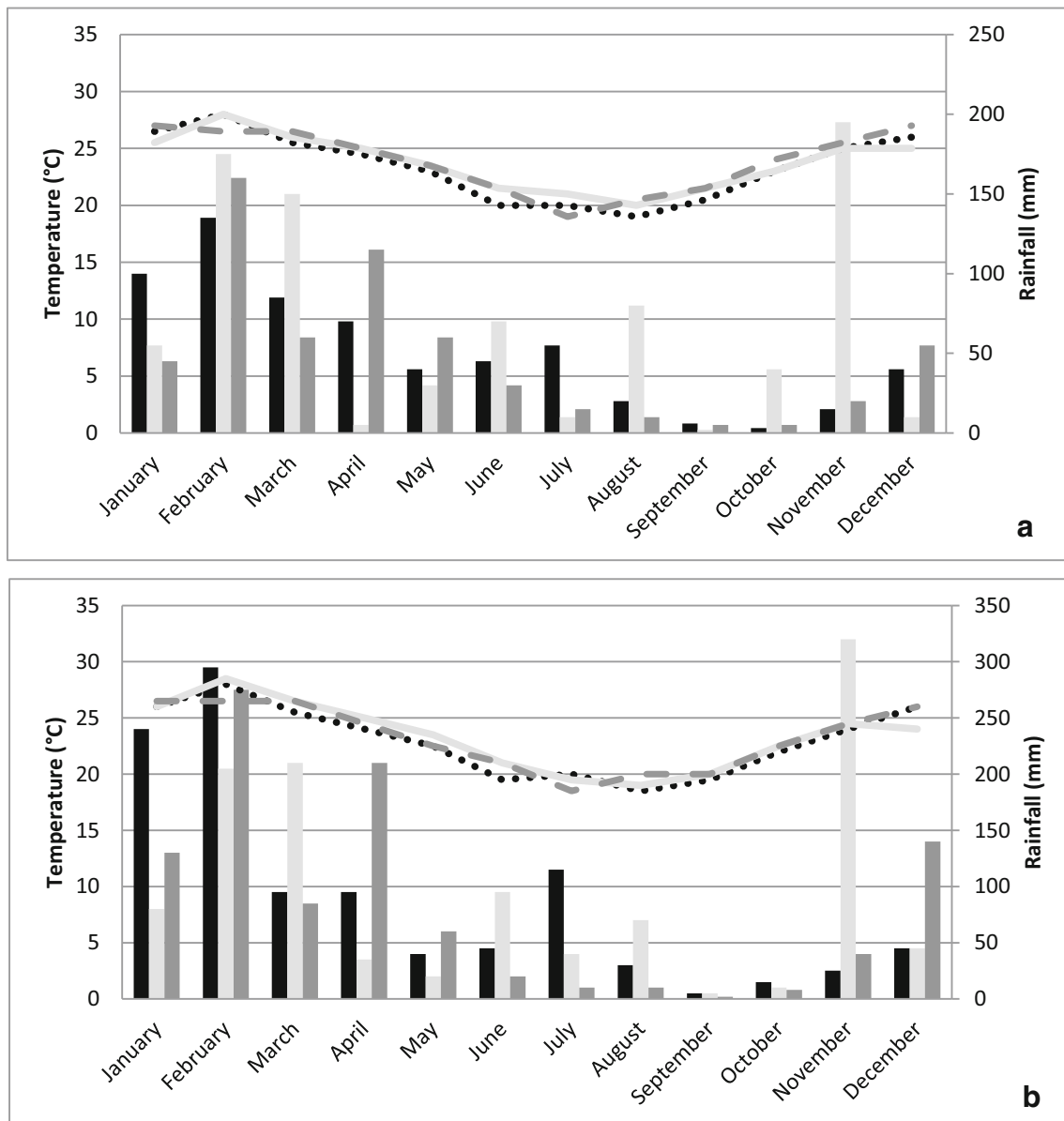


Fig. 1 Mean temperatures and rainfall at **A** Tontouta (Farm A) and **B** La Foa (Farm B) in 2015 (black), 2016 (light gray), and 2017 (dark gray)

Following corrective measures were then recommended and implemented in the two farms during the second half of 2016 and 2017.

The first corrective measure was to strictly dedicate pastures to each herd in order to avoid pasture re-infestation by another herd. In Farm B, the control herd crossed a pasture used by the experimental herd each time it was mustered for acaricide treatment. Engorged ticks were shed in transit, thereby re-infesting the crossed pasture. Animals from the experimental herd were thereby regularly infested when they stayed here. The corrective measure was to find a new track to avoid this pasture.

As previously explained, engorged ticks drop off from cattle in the morning. The second measure was therefore to only move herds in the afternoon when they needed to be treated

against ticks, thereby limiting the spreading of engorged ticks en route to the dipping installation. Depending on facilities, cattle were either treated in the afternoon and released immediately after or kept in the stock-yard at night and treated the next morning. In this last case, the area for the night should not be a grass area, considered as favorable environment for ticks' survival, at the risk of seeing cattle reinfested few months after by crossing this area. Various options were identified to respond that, as the use of a without-grass area, or in case of grass areas, the use of two areas, one dedicated to cattle infested by ticks before a treatment, and one to cattle using the stock-yard for other occasions.

The third measure was to predict the risk of larvae in a pasture based on previous tick observations on animals, season and tick survival parameters. With the provisional

Table 1 Presentation of the two farms and herds

	Farm A		Farm B	
	Experimental herd	Control herd	Experimental herd	Control herd
Breed of cows	Charolais	Charolais	Charolais	Crossbreed (<i>taurus x indicus</i>)
Breed of bull(s)	Blonde d'Aquitaine	Blonde d'Aquitaine	Brahman	Crossbreed
Average number of beasts per herd	7	23	86	341
Number of pastures per herd	3	3	5	9
Total surface of pastures per herd	14 ha	24 ha	81 ha	183 ha
Treatment	Spray		Spray	
Status to amitraz	Resistant		Resistant	
Status to macrocyclic lactones	Susceptible		Susceptible	

calendar, we were able to predict the presence or not of tick larvae for each pasture prior to the introduction of animals. Several options were available: (1) if eggs had not yet hatched in a plot of pasture, it could be used freely; (2) if a plot was infested and enough forage resources were available in other plot, it could be rested for the length of larval activity (1.5 to 2.5 months depending on the season, cf. Table 2) even though the forage quality would decrease as previously mentioned; or (3) if the plot was infested and the forage was needed, then animals were introduced but closely monitored between 2 and 2.5 weeks later to estimate tick infestation and decide whether an acaricide treatment would be necessary or not. It is safer to control animals visually — and even manually if needed to feel small ticks in the coat — in a corridor as ticks are still small at this stage and might not be seen in field. It was essential to control, and treat if needed, before 3 weeks to avoid a new generation of engorged ticks that will reinfest pastures. We define here that these treatments are strategic treatments, that means treatments are based on a plan determined by the knowledge of the ecology of the ticks to break their cycle. Cattle were not systematically treated when moving from a plot to another as we know the risk of tick infestation for the plot from where they come out. So, we only check when the herd goes out a risky plot and/or 2 to 2.5 weeks after animals come into a risky plot. If required, long lasting acaricides were scheduled during the period when larvae were active in most plots of pasture. These products are active during 5 to 6 weeks and tick larvae fixed on animals during this period will be killed before reaching adult stage. So, the rotations were planned to maximize larvae captured in pastures by cattle.

On the control herd, farmers continued to manage animals and treat as usual. Considering that the first effects were observed at the end of 2016 and that farmer A reorganized his herds in December 2017, the monitoring periods were defined from December 2015 to November 2016 and from December 2016 to November 2017.

Indicators

The development of number of acaricidal treatments in experimental and control herds was compared to assess the efficacy of this new pasture management method. In order to compare the number of treatments, we consider the number of treatments with short-lasting acaricide — including amitraz and macrocyclic lactones with short residual period — and the number of treatments with long-lasting acaricides. To compare both of these treatments, we consider that in terms of acaricide protection period, a long-lasting acaricide treatment is equivalent to three short-lasting acaricides. Indeed, the residual activity of short- and long-lasting products is null and 6 weeks, respectively (Gomes et al. 2015; Barré and Delathière 2010). With an average of 3 weeks for the development of ticks on cattle, minimum delays to retreat after a short- or long-lasting acaricide treatments are respectively 3 and 9 weeks.

A Student test was used to compare the number of treatments on control herds and experimental herds between December and November of the following year in 2015 and 2016, with a risk $\alpha = 5\%$.

Table 2 Biological parameters of free-living stages in New Caledonia (in months)

	December to March	April to May	June to September	October to November
From drop off to egg hatch = eggs in the parcel	1.5	2	2.5	2
Survival of 80% of larvae = larvae in the parcel: danger*	1.5	2	2.5	2
Total	3	4	5	4

*The remaining 20% were not active enough to represent a source of infestation for cattle (Desquesnes and Vignon 1987)

Results

The development of tick treatments per herd in control and experimental herd before (December 2015–November 2016) and after (December 2016–November 2017) the application of corrective measures is presented in Table 3.

Considering the development of the number of tick treatments in control herds in each farm, the reduction of tick treatments for the Farmers 1 and 2, in the experimental herds, are respectively 82.9% and 70.9%.

For control herds, the Student test shows no significant difference between the average number of treatments before and after the application of corrective measures (p value = 0.55). Regarding experimental herds, the p value is very slightly superior to alpha (p value = 0.051).

Discussion

The approach developed in these two farms decreased acaricide treatments by 82.9% and 70.9%. The initial difference concerning the number of acaricidal treatments for the Farmer B between the two herds is due to the herd composition. In this farm, the control herd is mainly composed of cross-breed cows *Bos taurus* \times *Bos indicus*, whereas the experimental herd is composed of Charolais cows much more tick susceptible (cf. Table 1).

The number of farms included in this study is too low to obtain robust results but it was difficult to identify farmers agree to change their pasture management and above all to keep a control herd exposed to tick infestations during this 2-year period.

The reduction of the number of acaricide treatments is not significant (p value = 0.051), but it has to be interpreted more in details. Indeed, before and during 2016, farmers were treating when they observed ticks on cattle and heavy infestations with several hundreds of engorged ticks are common in New Caledonia. Farmer B reported such an infestation in

March 2016 in his Charolais herd, when two cows died from tick infestation. From 2017, it was recommended to control experimental herds 2.5 weeks after introduction on an at-risk pasture and to treat if needed. During these controls, tick counts were achieved and no engorged ticks were observed. Thus, in 2016, acaricide treatments were in response to tick observations in all herds, whereas in 2017, they were mainly done to prevent tick infestations in experimental herds.

Corrective measures are based on knowledge of tick biology concerning the non-parasitic stages, from engorged adult female drop off to hatching and taking account the larval survival period. Hitchcock (1955a) recorded that the majority of engorged tick dropped off between 6:00 and 10:00 am. Wharton (1970) confirmed that the great majority of engorged females had fallen by 9:00 am to 9:30 am depending on the season but noticed that they can begin to fall down during the night.

In New Caledonia, Bianchi and Barré (2003) studied the factors involved in the detachment of engorged ticks in the morning, after the night rest. The movement of animals is one of these factors and the longer this movement is, the higher the proportion of engorged tick detachment. This highlights the rule of cattle to spread ticks within the farm, if the herd is moved in the morning to go to the dipping installation, especially if it needs to cross several pastures to go to these installations.

Duration of preoviposition, oviposition, egg development, and survival of tick larvae depend on temperature and humidity and vary between studied areas. The period from detachment to hatching can take from 3 to 4 weeks in ideal conditions to 6 months (Legg 1930; Harley 1966; Hitchcock 1955b). Tick larvae can survive up to 8 months in laboratory conditions (Hitchcock 1955b) but field observations indicate a maximal survival period of 6.5 months (Legg 1930; Harley 1966). In New Caledonia, Desquesnes and Vignon (1987) studied these different periods of non-parasitic stages of *R. microplus* and estimated that it takes between 6 and 10 weeks from the detachment of engorged ticks to egg

Table 3 Comparison of the number of acaricidal treatments between December 2015–November 2016 and December 2016–November 2017 for experimental and control herds

Years:	Dec 2015–Nov 2016			Dec 2016–Nov 2017			Trend (%)
Acaricidal treatments:	SLA	LLA	Total	SLA	LLA	Total	
Farmer A	10	1	13	5	2	11	– 15.4
Control herd							
Farmer A	7	1	10	1	0	1	– 90.0
Experimental herd							
Farmer B	9	0	9	7	0	7	– 22.2
Control herd							
Farmer B	11	2	17	4	0	4	– 76.5
Experimental herd							

SLA short-lasting acaricide, LLA long-lasting acaricide

Total: SLA + 3 LLA

hatching depending on the season. In the same study, they observed that tick larvae can survive from 10 to 14 weeks but 80% of these ticks died after 6 weeks in summer and 10 weeks in winter and the remaining 20% larvae are not active enough to represent a source of infestation for cattle.

In previous studies, the knowledge about survival of larvae was used to justify pasture rest time (Harley and Wilkinson 1964; Wharton et al. 1969; Wilkinson 1957; Wilkinson 1964). This period could be up to 4.5 months (Wharton et al. 1969) which is inconsistent with quality forages especially under New Caledonian climatic conditions. The innovation of this study consists in the fact that farmers can adapt their rotation plan, herd and pastures management considering both forage production and the risk of tick infestation in each plot of pasture. They can use an “at risk” plot if it is the best period in terms of forage production, and control and treat animals if needed before ticks end their cycle, avoiding a new contamination of plots. If farmers could avoid using a pasture with tick larvae — during the rainy season for example — grass could potentially be cut and/or transformed (silage, hay...) for use during the dry season.

The development of easy-to-use automatic or hardback rotating provisional calendar makes this planning easy to define by farmers themselves.

Knowing when to use long-lasting acaricides is also a crucial advantage of this method. Cattle treated with long-lasting acaricides are very useful for collecting and killing tick larvae in pastures but the use of these products should be limited as they are supposed to promote the development of tick resistance (Kunz and Kemp 1994). As they are active against larval stages, knowledge of the presence of tick larvae in paddocks helps to determine when the use of long-lasting acaricide will be the most efficient and what will be the best plan of rotation to collect larvae and decrease tick pressure in pastures. Therefore, the new tick management method presented in this study should be systematically utilized on farms using long-lasting acaricides in order to decrease larvae in plots of pasture. The proper length of stay per paddock has to be determined for each pasture and is mainly dependent on stocking rate. Sutherst et al. (1977) estimated, with experimental and theoretical studies, that with a stocking rate of about two beasts per hectare, cattle picked up between 30 and 70% of the larvae in a week, compared with 50 to 85% with five beasts per hectare. Further studies are required to validate these results.

The aim of this study and the current policy in New Caledonia is not the eradication of cattle tick but the control of tick population at a low level. This approach is due to the failure of several decades of systematic treatments and the absence of tick-borne disease that is compatible with the presence of few ticks. With this method, a small population of ticks can survive in pastures and a constant monitoring by the farmer must be

maintained to ensure the effectiveness of this approach. This point is even more important in these two farms, as tick strains began to be resistant to amitraz allowing the potential survival of ticks during strategic treatment.

Beyond these first results, an important change is the vision of tick infestation by farmers. From the moment they understand how tick populations evolve within and between paddocks with visual tools, they move from a passive position where they observe and suffer from tick infestation on cattle to an active role where they can anticipate and manage future infestations. Moreover, until now, they were treating when they observed ticks and most of the time, animals were already impacted and pastures reinfested. They can now break tick cycles and avoid pasture reinfestation by timing treatments strategically.

Besides the knowledge of tick biology, a key of this approach is sharp understanding of herd management on each farm that implements this tick control strategy. It is essential to take time to identify all the points where tick dispersion can occur — i.e., disposition of pastures, livestock movements within the farm and between plots — in order to adapt corrective measures to each farm. These measures may require investment but, in this study, these results are obtained without any substantial financial investment for the farmers and are based only on the registration of herd rotations and observations of tick infestations, strategic acaricide use and minor adaptations of herd management. Changing for non-chemical methods to control ticks is always a great challenge, especially when acaricides are free and still efficient. These alternative methods are always more time-consuming and more constraining. In this study, these two farmers are deeply attached to this tick-susceptible breed, acaricide resistances are more and more extended in Caledonian farms, and a beginning of amitraz resistance was observed in these two farms — even if it can still be used and mainly efficient. They thereby considered this method as a last chance to maintain this breed. Caledonian farmers are now divided into two categories: those who have changed for tick-resistant cattle and those who want to keep their tick-susceptible breeds, leave to change their cattle and pasture managements.

However, this method faces the challenge of farmers' autonomy in collecting and analyzing data. Farmers should be supported by technical services at least every 1 or 2 months during 2 years. It would be interesting to develop farmers' groups to increase their autonomy and comprehension, and benefit from economies of scale regarding the financing of technical support. Today, this method was transferred to the technical services in charge of tick control. In December 2018, 32 farmers were already involved with this strategy.

This approach needs to be tested now in other livestock rearing conditions, intensive vs extensive, dairy farms ..., and be adapted if needed.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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