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Economic efficiency of *Rhipicephalus microplus* control and effect on beef cattle performance in the Brazilian Cerrado

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Abstract
The cattle tick *Rhipicephalus microplus* causes significant economic losses to cattle production systems and is a main barrier to the introduction of *Bos taurus* breeds and their crosses in Brazil. These breeds have the genetic potential to generate animals that are more productive, but they are also more susceptible to *R. microplus*. One of the alternatives for conventional tick control is the use of strategic control, aiming at delaying or even preventing the development of its resistance to acaricides. The present study aimed to evaluate the economic losses caused by tick infestation on the productive performance of two breeds of beef cattle and to evaluate the economic efficiency of tick strategic control and its impacts on beef cattle production systems. Animal weights were obtained from the literature and were used to calculate the weight loss in kilograms (kg) and the economic loss (US$) caused by *R. microplus* infestation. The cost/loss ratio of performing strategic control was also calculated. The data show that tick infestation causes economic losses to the breeds and groups of animals evaluated and reduces animal performance (weight loss). The results show a loss of US$34.61/animal in the backgrounding phase and US$7.97/animal in the finishing phase for Brangus animals and its crosses. In conclusion, the data show that strategic control is economically efficient for Brangus animals in the backgrounding phase, independent of the methods used for acaricide application.

Keywords *Bos indicus* · *Bos taurus* · Cost · Economic loss · Infestation · Strategic control

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Introduction

Brazil is one of the main beef-producing and beef-trading countries in the world. This position is reflected in the country's ongoing efforts to increase the productivity and quality of the Brazilian product (Gomes et al. 2017).The cattle production systems used in different farms differ in the quantity and quality of the technologies used (Euclides Filho 2008) and in their environmental, social, and economic conditions (Costa et al. 2018). The systems of commercial beef cattle production are divided into the cow-calf segment and the backgrounding and finishing phases, during which the herd is part of the circulating assets of the rural property (Wedekin 2017).

Central Brazil has favorable environmental conditions for the production of beef cattle (Andreotti et al. 2018), which are better adapted to the environmental conditions of this region (Euclides Filho 2008), as seen, for example, in crosses between *Bos taurus* and *Bos indicus* breeds (Menezes et al. 2013). However, a main barrier to the introduction of *B. taurus* and their crosses to the production system is the greater susceptibility of these animals to the cattle tick, *Rhipicephalus microplus* (Acari: Ixodidae) (Madruga et al. 1985; Andreotti et al. 2018).

The cattle tick is widely distributed in Brazil, and its main host is cattle. This parasite is one of the greatest challenges to the livestock industry in Brazil, because as more crossbred animals are introduced, more changes will occur in the parasitological and economic aspects of extensive farming (Andreotti et al. 2018).

Strategic control aims to reduce the tick population in the host or in pastures, and the use of acaricides, although it is the main line of defense, is just one of the tools in the control process. The efficacy of acaricides is based on the knowledge of the parasite biological cycle, which may result in better control, lower cost, and less impact on the environment by reducing the amount of acaricides as well as slowing the progress of tick resistance to the different products used, including populations of multiresistant ticks (Pereira 2008; Reck et al. 2014; Higa et al. 2015, 2016; Andreotti et al. 2019). Recommendations for strategic control involve a series of five treatments, with an interval of 21 days, at the end of the periods unfavorable for tick development in the pasture (Andreotti et al. 2016a).

Taking the economic losses caused by *R. microplus* into consideration is important when cattle production systems are being analyzed (Andreotti et al. 2016a). Estimates suggest that the total economic loss attributable to *R. microplus* infestations in the Brazilian cattle herd is approximately US$ 3.2 million per year (Grisi et al. 2014).

The present study aimed to evaluate the economic losses caused by tick infestation on the productive performance of different breeds of beef cattle and to evaluate the economic efficiency of tick strategic control and its impacts on beef cattle production systems.

Materials and methods

The economic losses caused by *R. microplus* infestations were evaluated for Nellore (*B. indicus*), Brangus and/or their crosses (*B. taurus*), possible weight loss (kg) was considered as a function of the average number of ticks. Considering that the weight loss caused by tick infestation is related to the lack of chemical treatment (Andreotti et al. 2016a).

For this study, we examined a herd with 120 and 260 males in the backgrounding and finishing phases, respectively, based on the study of Correa et al. (2006).

Weight of animals

For the mean live weight (kg), the data in Table 1 were used.

Cost of infestation

According to Honer and Gomes (1990), the average weight loss caused by ticks is 0.22 kg/tick/year. This number was adapted since no specific data are available for cattle in Brazil, and this value was based on a production system with standing cattle and included the effect of parasitic anorexia (Andreotti et al. 2016b). For animals in the backgrounding phase, we considered a weight loss of 0.22 kg/tick/year because animals stay in this phase for one year. For finishing animals, a three-month finishing period was considered; therefore, the loss was 0.055 kg/tick/year.

The average number of ticks per animal was based on Andreotti et al. (2018), who evaluated the tick infestation (*R. microplus*) in Brangus and Nellore animals in Central Brazil in a naturally infested herd, with reference values of 102 ticks/animal/year and 15 ticks/animal/year for Brangus and Nellore, respectively.

The weight loss was estimated using the following formula (Honer and Gomes 1990):

$$\mathrm{W} = \mathrm{w} \times \mathrm{n} \tag{1}$$

where W is the total weight loss (kg), w is the weight loss (kg) per tick (0.22 kg/tick/year), and n is the number of ticks/animal.

$$\%\,\mathrm{Loss} = (\text{total weight loss (kg)}/\text{actual average weight}) \times 100 \tag{2}$$

Cost of treatment

The cost of treatment was estimated according to the strategic control proposed by Andreotti et al. (2016a); this strategic control includes five acaricide applications every 21 days to reduce tick populations. This strategy can prevent the development of larvae for 105 days, larval populations in the pastures and, consequently, reducing infestations on the animals. That number of treatments and the interval between treatments are recommended for contact acaricides (pour-on and spray). Injectable acaricides last 75 days, and thus, fewer treatments are needed. The product dose followed the manufacturer's recommendation.

Several acaricides are on the market with different active principles, efficacies and methods of application (spray, pour-on, and injectable). The commercial products were chosen according to Higa et al. (2016), who evaluated the resistance of *R. microplus* from several regions of Brazil to different acaricides. The methods of application and the classes of the acaricides used in the analyses were as follows: (a) spraying (organophosphates and pyrethroids), (b) pour-on (organophosphates and pyrethroids), and, (c) injectable (macrocyclic lactones).

The price of the products was quoted in the city of Campo Grande, state of Mato Grosso do Sul, Brazil, and converted to US dollars. The dollar value was estimated as

Table 1 Data from the literature used to obtain the average weight (kg) of the animals

Author	Breed	Category	Number of samples	Average Weight
Muniz and Queiroz (1999)	1/2 Aberdeen-Angus + 1/2 Nellore (1AG1NL)	Backgrounding	229	318
	1/2 Brangus (black coat) + 1/2 Nellore	Backgrounding	349	288.5
	1/2 Brangus (red coat) + 1/2 Nellore (1BV1NL)	Backgrounding	150	297.3
Kippert et al. (2008)	1/2 N	Backgrounding	17,883	334
	3/8 N		20,180	308
	Angus		10,860	305
	Angus		88	377.01
Cruz et al. (2009)	Angus × Nellore	Backgrounding	54	349
Everling et al. (2012)	Angus	Backgrounding	13,852	322.69
Junior et al. (2019)	Brangus	Backgrounding	30	404.4
Total / average			63,675	330.39
Muniz and Queiroz (1999)	Nellore	Backgrounding	317	275
Kippert et al. (2008)	Nellore	Backgrounding	100	330
Cruz et al. (2009)	Nellore	Backgrounding	62	276
Benatti et al. (2012)	Nellore	Backgrounding	25	371
				367
				377
				388
Bonatte Junior et al. (2019)	Nellore	Backgrounding	30	386.9
Total / average			534	346.36
Ítavo et al. (2008)	F1 Brangus × Nellore	Finishing	60	505.85
Neto et al. (2009)	F1 Brangus × Nellore	Finishing	18	465.54
Marcondes et al. (2011)	Nellore × Angus	Finishing	12	483
Euclides et al. (2001)	F1 Angus × Nellore	Finishing	16	475
Total / average			106	482.35

Table 1 (continued)

Author	Breed	Category	Number of samples	Average Weight
Goes et al. (2003)	Nellore	Finishing	8	437
Cavalcante et al. (2005)	Nellore	Finishing	24	466.9
Ítavo et al. (2008)	Nellore	Finishing	60	485.2
Neto et al. (2009)	Nellore	Finishing	18	462.9
Baroni et al. (2010)	Nellore	Finishing	48	432.00
Marcondes et al. (2011)	Nellore	Finishing	12	449
Bicalho et al. (2014)	Nellore	Finishing	54	457.3
				475.1
				418.8
				461
				442.5
				492
				447.2
				473.1
Total / average			224	457.14

an average of values from 2016 to 2019, and these were obtained from the Center for Advanced Studies in Applied Economics 2019.

The cost of control was estimated using the formula below (Honer and Gomes 1990), which was adapted for the variables available for the calculations:

$$CT = \left\{ (C_o + C_p) \times N_a \right\} \times A \tag{3}$$

where CT is the cost of treatment, C_o is the operational cost, C_p is the product cost, N_a is the number of animals per application, and A is the total number of applications.

The labor force necessary for product application was included in the calculation of the operational costs (C_o):

$$C_L = (S/WH)/AT \tag{4}$$

where C_L is the cost of labor, S is the salary, WH is the number of hours worked per day, and AT is the number of animals treated/day.

The number of treatments was 120 and 260 applications/day for animals in the backgrounding and finishing phases, respectively, according to the scenario stipulated for the present study.

To estimate the economic loss, we used the formulas previously described by Mello et al. (2019), adapted according to the information available for the present study.

$$VA = (\text{weight estimate} \times \text{yield estimate}) \times \text{US\$/kg} \tag{5}$$

$$VAI = (\text{weight estimate} \times \text{yield estimate}) \times \text{US\$/kg PV} \tag{6}$$

$$L_{Ec} = VA - VAI \tag{7}$$

$$ImL = \left(CT/L_{Es} \right) \times 100 \tag{8}$$

where VA is the value of an uninfested animal, VAI is the value of an infested animal, PV is live weight, weight estimate is the average weight in kg, yield estimate is the 50% carcass yield, US$ is the price paid per kg of live weight, L_{Ec} is the economic loss, ImL is the impact of treatment costs on economic loss, and L_{Es} is the estimated loss.

Results

The average weights of the animals were 482.35 and 330.39 kg for the Brangus, and 457.14 and 346.36 kg for the Nellore in the finishing and backgrounding categories, respectively.

Economic loss relative to weight (kg)

The total weight loss (kg) is shown in Fig. 1. Brangus animals had the largest weight loss, regardless of the category, with 1.2% live weight loss for finishing and 6.8% loss for backgrounding animals. On the other hand, Nellore animals had a live weight loss of 0.2% and 1.0% for the finishing and backgrounding phases, respectively.

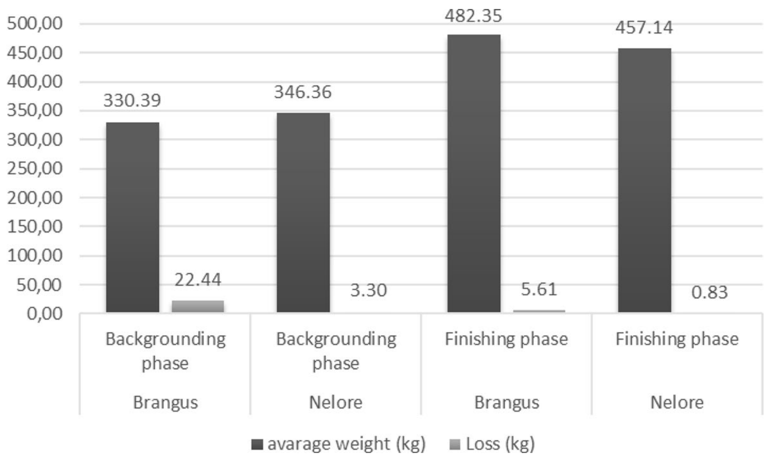

Fig. 1 Estimated weight loss (kg) of animals infested with *Rhipicephalus microplus*

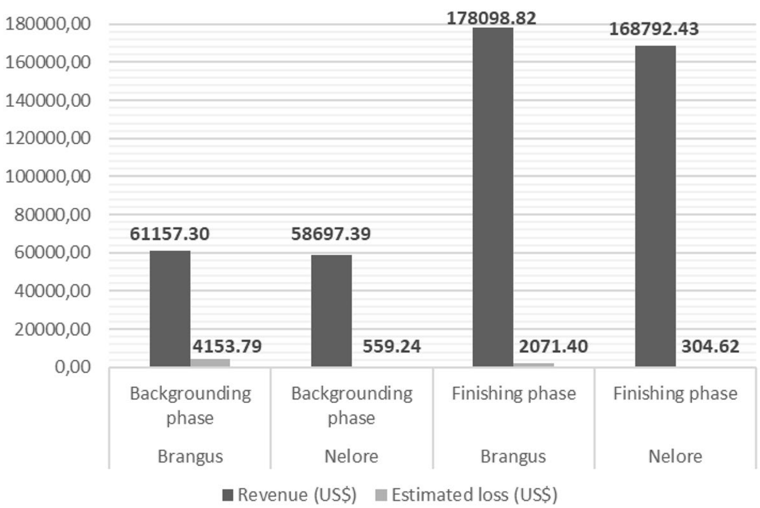

Fig. 2 Comparison of estimated revenue (US$) and economic loss (US$) in animals infested with *Rhipicephalus microplus* for a herd with 120 backgrounding animals and a herd of 260 finishing animals

Figure 2 shows the economic losses caused by tick infestations for each breed and animal phases. Tick infestations caused greater economic loss to Brangus animals than to Nellore animals, and the animals in the finishing phase had an economic loss of US$ 2071.40, whereas the animals in the backgrounding category had an economic loss of US$ 4153.79. Tick infestations caused lower economic loss to Nellore than to Brangus animals, regardless of the phase.

Cost of infestation

The amount paid for animals in the finishing phase was US$2.84/kg regardless of the breed. For animals in the backgrounding phase, the price was US$1.41/kg for Nellore and US$1.54/kg for Brangus.

The estimated value of a Brangus animal in the finishing category was US$ 685.00/animal, with a loss of US$7.97/animal due to tick infestation. For animals in the backgrounding phase, the estimated value was US$ 509.64/animal, with a loss of US$ 34.61/animal. Nellore animals had an estimated value of US$649.20/animal, with a loss of US$1.18/animal, and US$ 489.11, with a loss of US$ 4.66/animal, for the finishing and backgrounding phases, respectively.

Cost of treatment

The cost of treatment was estimated for the three methods of application separately. For spraying, the cost of treatment was US$2.25/animal, regardless of breed and phase because the volume of acaricide applied per animal is not affected by the animal's weight. Taking into account the 260 finishing animals and one application in a three-month period, the cost of treatment was US$107.89. For the 120 animals in the backgrounding phase and five applications in a year, the total cost of treatment was US$ 269.60.

For Brangus animals, the cost of treatment relative to the economic loss was 5.6% and 6.5% for animals in the finishing and backgrounding phases, respectively, whereas for Nellore animals, the cost of treatment relative to the economic loss was 38.4% and 48.2% for animals in the finishing and backgrounding phases, respectively (Fig. 3).

The cost of pour-on control for animals in the finishing and backgrounding phases was US$0.55/animal and US$1.85/animal, respectively. The relationship between the cost of pour-on treatment and economic losses was 6.5% for Brangus animals, 39.7% for Nellore animals in the backgrounding phase, and 145.1% for Nellore animals in the finishing phase (Fig. 4).

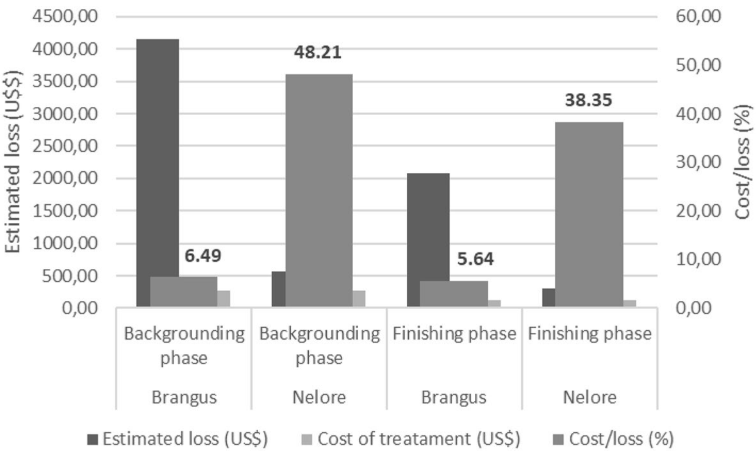

Fig. 3 Relationship between spraying costs and economic losses due to *Rhipicephalus microplus* infestation

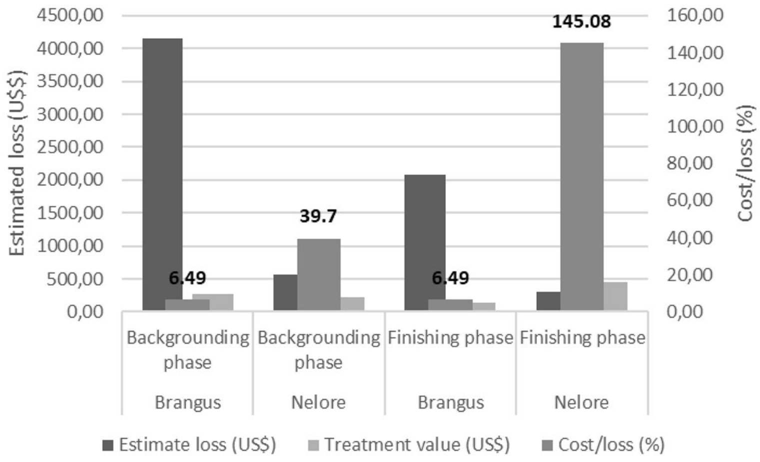

Fig. 4 Relationship between the cost of pour-on treatment and economic losses due to *Rhipicephalus microplus* infestation

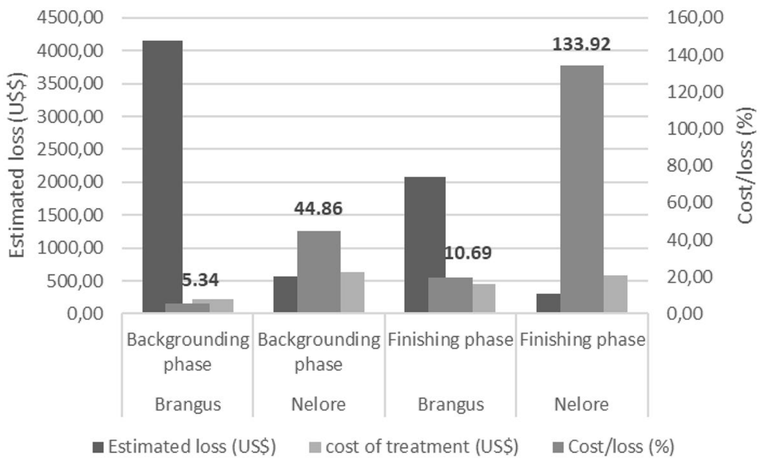

Fig. 5 Relationship between the cost of injectable treatments and economic losses due to *Rhipicephalus microplus* infestation

The costs of the injectable treatment for animals in the backgrounding and finishing phases were US$2.09/animal and US$1.70/animal, respectively. The lowest cost/loss ratio was observed for Brangus animals in the backgrounding phase, and the largest, for Nellore animals (Fig. 5).

The figures above show the economic efficiency for all treatments for Brangus animals regardless of the category.

Discussion

The results of the present study demonstrate that Nellore and Brangus animals and their crossbreeds lose weight when infested with *R. microplus*. The highest weight losses were observed in Brangus animals, mainly in the backgrounding phase, during which they lost 6.89% of their live weights. By extrapolating the data to a herd with more animals, the losses become more evident. For example, for 1000 animals in the backgrounding phase, the loss would total 22,440 kg/year, and for the same number of animals in the finishing phase, the total loss would be 5610 kg in three months. These data demonstrate a negative effect on the animals' meat production performance. Crosses between European (adapted or not) and zebu breeds generally result in animals with good reproductive capacity in tropical environments, and these animals are better at gaining weight (Filho 2008; Euclides et al. 2014).

The results of the present study demonstrate that tick infestations cause economic losses; thus, producers have lower profits, and these profits could be used for the purchase of replacement animals, which comprise the most expensive item of the backgrounding-finishing system, followed by the expenditures for minerals and concentrates (Wedekin 2017). Animals in the finishing phase had the highest revenues estimated in US$ 346,891.20, and the economic loss caused by tick infestation in this same category was US$ 2376.00. For animals in the backgrounding phase, the revenue was US$ 118,956.20, which is lower than that found for the finishing phase, and the loss for animals in the backgrounding phase was higher, totaling US$ 4713.03. We evaluated the backgrounding and finishing phases because they represent two important stages in beef cattle production systems. The backgrounding phase is when the animal develops muscle mass and bone structure, and finishing is when the animal gains weight by faster deposition of muscle and fat. At slaughter, the most important aspect of body composition is the proportion of muscle and fat in the carcass because it determines most of the animal's economic value and affects the efficiency and costs of meat production (Berg and Butterfield 1979).

Nellore animals compose most of the beef cattle herd of Central Brazil because they are more adaptable to tropical conditions (Wedekin 2017). In our study, Nellore animals had little economic and weight loss due to tick infestation because this breed is more resistant to ticks. According to Veríssimo (1999), animals with 25 or fewer ticks on one side, which would result in low or almost no economic loss, are resistant to ticks.

Strategic control aims to reduce the tick population on animals through lower applications of acaricides (Andreotti et al. 2019). The analyses of the strategic control costs demonstrate that strategic control is economically viable for Brangus animals in the backgrounding phase, regardless of the method of application. Thus, the strategic control contributes to the development of the Brangus' genetic potential and to a more efficient production system. Bonatte Junior et al. (2019) reported that high tick counts in Brangus animals coincide with the postweaning period, when the animals are highly stressed, which may affect their immunological resistance and favor parasitism. Brangus animals that received no treatment had the lowest weight gain, greater number of ticks and higher expenses for bovine babesiosis and anaplasmosis prophylactic treatments and myiasis curative treatments (Bonatte Júnior et al. 2019).

For the other categories, the relationship between the cost of treatment and economic losses due to *R. microplus* infestation varies according to the method of application. In Nellore animals, control is not necessarily economically efficient; thus, for Nellore animals, the use of acaricides should be analyzed case by case. According to Andreotti et al.

(2018), in a situation where tick infestation has little effect on pure *B. indicus* animals such as Nellore, acaricides should not be used; however, when *B. taurus* and *Bos indicus* animals are raised in the same environment, the tick population tends to increase, thereby requiring the use of acaricides.

In 2018, Brazil produced 10.96 million carcass weight equivalents, which was an increase of 12.8% over 2017. The state of Mato Grosso do Sul has a cattle herd of 21,670,275 head with beef genetic traits (Abiec 2019). Therefore, the potential exists for beef production, and strategic control can help reduce tick infestations and, consequently, increase productivity.

The hypothetical analysis performed in this study, which analyzed, in terms of the technical and financial performance of beef production, the economic losses caused by tick infestation by considering weight loss in kilograms (Honer and Gomes 1990), while also updating data on the number of ticks (Andreotti et al. 2018), corroborated other studies that showed the tick *R. microplus* causes economic losses to the beef cattle production system (Gomes 1990; Grisi et al. 2014; Andreotti et al. 2018). The data suggest that it is important to compare the productivity loss to the economic efficiency of the strategic control because, when the cost of control is compared to the economic losses caused by tick infestations (cost/loss), the control may be economically efficient for reducing tick infestations.

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Author contributions MPCAC, RCB and RA: designed the study, analyzed the data and wrote the manuscript; MVG and JCB: analyzed the data.

Compliance with ethical standards

Conflict of interest There were no conflicts of interest that may have biased the work reported in this paper.

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