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Shade controls the ruminating and idleness times of dairy heifers in tropical integrated systems

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Abstract Livestock production has migrated to the Midwest region of Brazil; however, these regions are environmentally unsuitable for livestock specializing in milk production, due to high temperatures. This environment can be improved using inserting trees into the pastures. The objective was to evaluate the effects of adding grazing trees on the behavior of dairy heifers in the Midwest region of Brazil. Piatã grass was managed in: open pasture system, OPS (shade level 0%), the worst treatment for animal production since the solar radiation and temperature are deleterious to animal welfare; moderate shade system (shade level 20%), the supposed adequate system where the animals find shady areas, but there is light available for photosynthesis; and intensive shade system (shade level 70%), the worst treatment for vegetal production since the light is limited for grass growth. Shade was provided by Eucalyptus trees. Heifer behavior was evaluated from 08:30 to 16:00 over three periods. In the OPS, the heifers searched for cow drinkers and remained there for a long time, refreshing themselves by floating in water and muddy places. Heifers demonstrated a behavior of attempting to return to grazing activity under the OPS during the hottest time of the day, but without success. Ruminating activity was not affected by any factor. The shade level affected the distribution of time spent on an activity and the time of day at which each activity happened. The moderate shade level is enough to ensure stability in the daily behavior of dairy heifers.

Keywords Silvopastoral · *Urochloa brizantha* · *Eucalyptus* · Animal behavior

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Introduction

The North and Midwest regions of Brazil contain 55% of the Brazilian cattle herd (IBGE 2013). Part of these regions, the Legal Amazon, is an area that brings together all the states in the Northern region (Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, and Tocantins) and the largest state in the Midwest (Mato Grosso). In the area encompassed by the Legal Amazon, much of the livestock activity is still developed in typically agricultural frontier areas, with different technological levels, but with the predominance of a more extensive model with low use of technology (Dias-Filho 2011, 2013).

Among the many limitations of these regions, the limitation of the climate is the greatest when it comes

to dairy breeds. The high temperatures recorded in these states have a number of undesirable effects on animal reproduction. Silvopastoral system reduces the local temperature and decreases the direct radiation received by the animals (Embrapa 2015). The maximum temperature ranges from 28 °C during the rainy season to 40 °C during the drought season. The high temperatures during the drought season are due to the lack of clouds at this time of the year, which increases the incidence of solar radiation and results in low air humidity due to the lack of rainfall (Alvarez et al. 2013). The region with the largest agricultural and livestock production in the legal Amazon is characterized by an Aw climate, according to Koppen–Geiger's classification (Alvarez et al. 2013).

The intensification of livestock farming is driven by producers who see the incorporation of technology and increased livestock productivity as the most efficient strategies to make it economically sustainable. Thus, considering that the zootechnical indices of pastures in the Legal Amazon and, in particular, in the North and Midwest regions, are still below their real productive potential, it is possible that with the recovery of these areas, the current production of meat and milk from these regions could rise considerably without the need to cut down a single tree (Dias-Filho Dias-Filho 2014).

Silvopastoral systems (SSPs) are an alternative form of land use and farming, based on the consortium of tree crops, pastures, and animals, either simultaneously or sequentially. They present higher biological, economic, social, and ecological sustainability than traditional production systems such as pasture monoculture (Payne 1985; Montagnini 1992). SSPs' main objective is to increase the efficiency of natural resource use and to diversify the production of the property by involving various agricultural activities. Thus, in humid tropical regions, the integration of herds and tree crops can reproduce the ecological benefits of the forest and reduce the environmental impact of deforestation to form pastures (Payne 1985).

The benefits of SSPs have been shown to provide conservation of tropical soils (Veiga et al. 1996). Treetops contribute to the reduction in soil erosion by reducing the impact of rainfall. However, treetop cover is generally dense and the deep root system forms barriers, preventing soil particles from dragging and absorbing nutrients from deeper layers and translocating them to the leaves. After their fall, deposition, and decomposition, leaves become an excellent source of organic fertilizer, improving the physical and chemical characteristics of the soil (Montagnini 1992; Carvalho 1998; Pezo and Ibrahim 1998).

There are other advantages provided by trees in livestock ecosystems, such as the changes to the microclimate, which benefit plants and animals. Treetops also function as windbreaks, decreasing the evaporative demand of the understory herbaceous plants according to microclimatic variations. In drought seasons, soils have higher a moisture content under a canopy than in areas exposed to direct sun and wind; therefore, trees contribute to improving the quantitative and qualitative performance of forage grasses (Anderson et al. 1988; Carvalho 1998).

Silvopastoral systems improve animal comfort and reduce the high-temperature-induced animal stress under tropical conditions. This improvement is important for animal health and performance, since it suits the microclimatic condition for healthy living. An animal stressed by high temperatures can change its posture to improve the wind benefits for heat dissipation. Heat stress is a common problem in countries with warm and humid weather, and it occurs when the cows produce or absorb more heat than they can dissipate (Kadzere et al. 2001). This phenomenon results in different physical responses: reduced feed intake, increased water intake, alterations in the metabolic rate and maintenance requirements, increased evaporative water loss by sweating and panting, increased respiration rate and heart rate, changes in blood hormone concentrations, and increased body temperature. The animals show no movement and are calmer in order to reduce corporal heat generated from movements and feeding (Ferreira et al. 2011). The grazing behavior pattern changes when the animal is heat-stressed, which results in a reduction in the time spent in grazing and ruminating, which directly affects animal production (Ferreira et al. 2011). Under hot conditions, the animals spend their daytime ruminating and being idle (Ferreira et al. 2011). The animals discontinue their activities and only graze around noon and during the early evening (Ferreira et al. 2011). Dairy cows with no shade access spend more time standing during the day than those with shade access, possibly to increase radiation from the body in an effort to keep cool (Muller et al. 1994). They also tend to crowd around water troughs, with some cows standing with their front feet dipped in the

water, trying to splash water from the trough over their backs (Muller et al. 1994). Cows with shade access were observed at the water trough up to 6.42 times less and lying down up to 1.75 times more than cows with no shade access. The lying down time was highest during the peak hours for dairy cows with shade access (Palacio et al. 2015). When the temperature at the ground surface is higher than the cow's body temperature, the conduction process between the cows and the ground increases, leading to an increase in the thermal load (Palacio et al. 2015). When the cows are standing, the evaporation from their body surface and the distance between the blood vessels is maximal, which causes an increase in the body surface area (Palacio et al. 2015). Dairy cows change their behavior according to the availability of shade in the tropical region (Palacio et al. 2015). This behavior is strongly indicative of the notion that heifers are easily stressed in tropical conditions. Thus, the aim of this research was to evaluate how the shade level influences the parameters determining the behavior of dairy heifers in silvopastoral systems in the Brazilian Midwest region.

Materials and methods

This experiment was carried out at Embrapa Agrossilvopastoril Research Center located at Sinop, Mato Grosso State, Brazil (11°51′43″S, 55°35′2″W, 384 m a.s.l.). In this region, the climate is tropical humid/subhumid [Aw type, with a 25 °C average annual temperature, 76% relative air humidity, and 2020 mm of annual precipitation according to Köppen-Geiger classification (Alvarez et al. 2013)]. Weather data for the experimental period (Fig. 1) were recorded at the Embrapa Agrossilvipastoril weather station by Agritempo (2018).

In a 10 ha area of flat contour land on a Typic Hapludox, Eucalyptus (*Eucalyptus urophilla* × *E. grandis* clone H13) was planted in 2010 along the east–west direction in order to generate two shade regimes. In the first shade regime (moderate shading system, MSS), trees were planted in double rows at the borders, with a plant density of 338 trees ha^{-1}, and 2 m between trees in the rows and 3 m between the rows (83% of the total area was available for pasture in the center). In the second shade regime (intensive shade system, ISS), the trees were planted in triple rows 15 m from each other, with a plant density of 714 trees ha^{-1}; in four rows with 2 m between the trees in rows and 3 m between the rows (58% of the total area was available for pasture). There was a no shade treatment (open pasture system; OPS), in which the trees were absent. The trees had an average height of 12 m when the experiment started (Fig. 2). The pasture area was similar for every shading regime because there were differences in the total width (same length) of the areas (49, 59, and 84 m for OPS, MSS, and ISS, respectively).

Urochloa brizantha (Hochst. ex A. Rich.) Piatã was sown together with maize in February 2011. The adaptation period of the pastures to the grazing strategy was from October to December 2012 and evaluation period was from December 2012 to July 2013. The experimental period was divided into three evaluation periods based on rainfall distribution: (1) rainy season, from December 2012 to February 2013; (2) transition period, from March to May 2013; and (3) drought season, from June to July 2013.

Urea fertilization was divided into two applications of 40 kg N ha^{-1} each time (November 2012 and February 2013).

The pre-grazing sward management was 95% light interception (LI) in all systems (Carnevalli et al. 2006), and the post-grazing height was adjusted to at least 50% of the pre-grazing height (Carvalho et al. 2009). The sward surface height (SSH) was evaluated when these conditions were achieved. Three paddocks from each system were used as sampling units for each treatment for three consecutive and similar days. When the consecutive day was an atypical day, the following day was used. Data collection continued until July 2013, when the rates of herbage accumulation became derisory and did not allow swards to reach the 95% LI as the pre-grazing target.

The grazing animals were crossbred Holstein × Gir dairy heifers with an average body weight of 350 kg and were divided into three homogeneous groups regarding live weight and age, with eight test animals evaluated in each group. Each group had four 7/8 and four and ¾ Holstein heifers.

Drinking water fountains were available firstly outside only and then eventually both inside and outside the paddocks.

The maximum temperature and relative humidity of the study region were measured by a weather station.

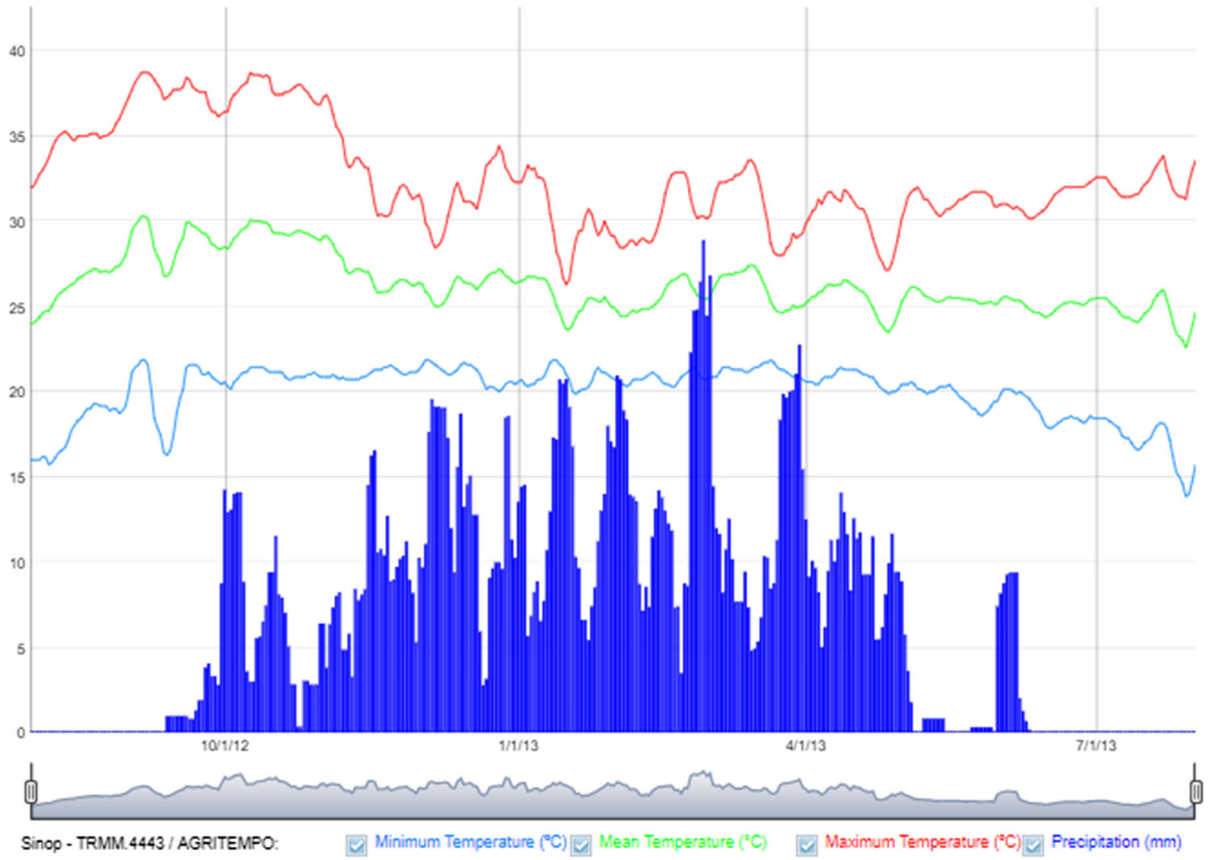

Fig. 1 Weather data for the experimental period at Sinop, Mato Grosso state, Brazil (Agritempo 2018)

Data for the representative days of each period were collected and presented every 60 min for 24 h.

The animal behavior assessments were performed at 15-min intervals, starting at 08:30, with readings ending at 16:00. During this time interval, it was possible to detect the movement of the animals caused by the presence of the sun and high temperatures. The information collected regarding animal behavior included posture (standing or lying down), localization (sun or shade), and activity (rumination or idleness) collected through observations by the researcher. The dataset of grazing activities was published in Mello et al. (2017) and is only discussed here when necessary.

The dataset was analyzed using the combined experiments technique, according to Moore and Dixon (2015), in which each treatment was an independent experiment. The number of replications was three (sampling paddocks) and the variation sources were the regimes (OPS, MSS, and ISS) and evaluation seasons (rainy, transition, and drought). Data were analyzed using the Mixed Procedure of SAS® (SAS Inst. 2012) with repeated measures and using the restricted maximum likelihood (REML) method. The experimental error and paddocks (experimental units) were considered as random effects and all the remaining sources of variation and their interactions considered as fixed effects. An average comparison, as necessary, was performed by the PDIFF method.

Compliance with ethical standards

Statement of animal rights

The authors whose names are listed above certify that they have not committed a willful act of abuse, cruelty, or neglect of the animals included in this study. The Ethics Committee for Animal Use of Embrapa Agrosilvopastoral, Sinop, Mato Grosso state, Brazil, approved the study under number 003/2015.

Fig. 2 Photograph of experimental area. *OPS* open pasture system, *MSS* moderate shade system, *ISS* intensive shade system

Results

The maximum temperatures during this experiment were 35, 32, and 34 °C during the rainy season, transition period, and drought season, respectively (Table 1). The relative humidity ranged from 72 to 68% on average, from the rainy to the drought season (Table 1); however, the daily variation was higher. On the evaluation days, the maximum temperature is shown every 60 min in Fig. 3. The largest differences in relative humidity between the evaluated periods occurred from noon to night. In the morning, the relative humidity (RH) was high, but it always decreased after noon. In the rainy season and transition period, it reduced from 95 to 60%, and in the drought season, the reduction was from 85 to 40% (Fig. 3). The maximum temperatures show different behavior compared to many regions of the world. The thermal amplitude in the rainy season is smaller due to the constant presence of clouds limiting the increase during the day. In the drought season, this amplitude increases, with the maximum ranging from 20 °C at night to more than 30 °C after noon, and 35 °C can easily be reached as shown by the averages in Fig. 3. Even a high of 40 °C was frequently observed. High temperatures coupled with low relative humidity promoted a very uncomfortable thermal sensation for any animal exposed to these conditions.

The shading levels affected the idleness activity during the three periods of the year ($P < 0.0001$). During the rainy season, the OPS condition (no shade) showed a higher average frequency of idleness activity

Table 1 Temperature, relative humidity, and insolation during the experimental period

	Temp max (°C)	Temp min (°C)	Temp median (°C)	RH (%)	Insolation (h day^{-1})
Rainy season	36.9	22.3	29.6	72.2	7.97
Transition	35.6	20.6	28.1	72.4	8.33
Drought	36.1	18.5	27.3	68.7	8.60

RH relative humidity

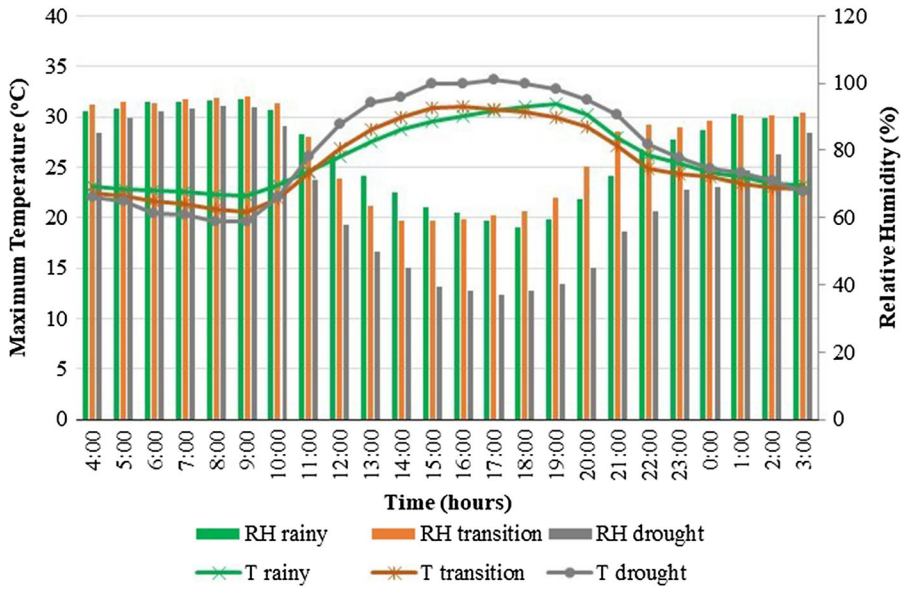

Fig. 3 Daily variation in the maximum temperature and relative humidity on typical days of each evaluated period. *T* temperature, *RH* relative humidity

(54.6%) than the ISS (41.7%) and MSS (34.1%) conditions ($P < 0.001$). The animals did not show a preference for any time of the day for idleness during this season (Fig. 4). At all times on a bright day, 20–60% of the heifers were found to be idle. The highest frequencies were observed at 13:00 and 15:00 in the OPS condition. In ISS and MSS conditions, idleness activities did not have a significant peak, being instead distributed equally throughout the day (Fig. 4).

The daily average frequency of heifers ruminating during rainy season was higher in the MSS condition (35.1%) than the ISS (25.8%) or OPS (19.5%) conditions ($P < 0.0050$) (Fig. 5). The animals were observed to ruminate at any time of the day, albeit the highest frequency was between 11:15 and 13:45, with 38% of the heifers ruminating. There were two main ruminating peak times (12:15 and 13:30) in the OPS condition involving 40–54% of the heifers (Fig. 5). In the MSS condition, 83% of the heifers were involved in ruminating activity at 11:30, and approximately 50% of the heifers were ruminating between 13:00 and 15:00. In the ISS condition, a reasonable number of animals (20–40%) were involved in ruminating activities during the daytime; at only two periods (11:00 and 14:30) were less than 20% of the heifers found to be ruminating (Fig. 5).

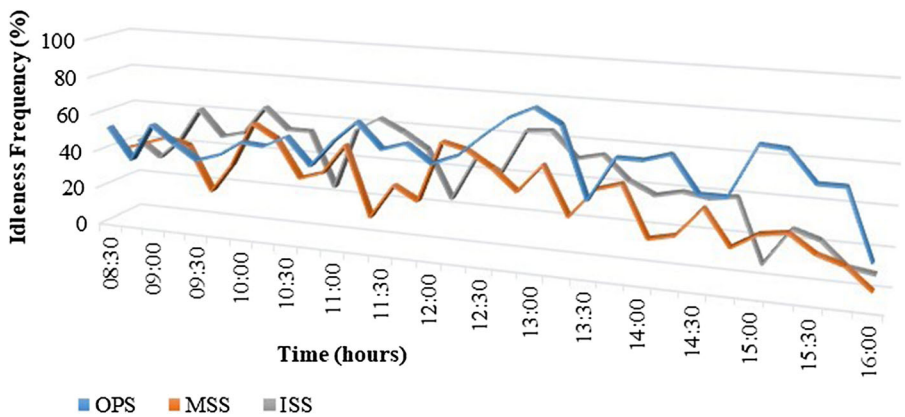

Fig. 4 Frequency of idleness activities of dairy heifers during the rainy season in systems under tropical conditions. *OPS* open pasture system. *MSS* moderate shade system, *ISS* intensive shade system

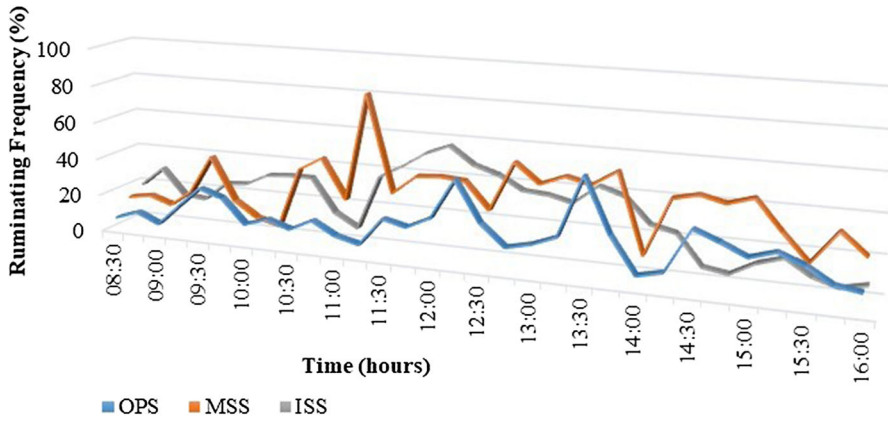

Fig. 5 Frequency of ruminating activities of dairy heifers during the rainy season in systems under tropical conditions. *OPS* open pasture system, *MSS* moderate shade system, *ISS* intensive shade system

During the transition period, the OPS and MSS conditions reported a similar average frequency of animals involved in idleness activity (26.9%), which was higher than that in the ISS condition (19.7%), ($P = 0.0001$) (Fig. 6). Despite the averages being similar, in shading systems, there were peaks with higher frequencies of idle heifers during the transition period than rainy season. In the ISS condition, there were two main peaks at 12:45 and 15:45 when more than 80% of heifers were idle. In the MSS condition, these main peaks occurred at 12:30 and 13:30. In the OPS condition, approximately 20–30% of the heifers were idle from 10:00 to 15:00 (Fig. 5).

The ruminating activity during the transition period did not always follow the same pattern as idleness activity. In the OPS condition, there was a similarity between the idleness and ruminating activities, with approximately 20% of the heifers ruminating during the day. However, in the MSS condition, there was coincidence only at 13:00, and in the ISS condition, the ruminating activity occurred at 11:00, an hour before of idleness (Fig. 7).

During the drought season, the OPS condition showed an increased average frequency of animals involved in idleness activity (29.2%) compared to the other systems (16%) ($P < 0.0001$). Following a similar behavior pattern to the previous seasons, during this season, some peaks of idleness activity were noted during the day (Fig. 8). The OPS condition showed two peaks of idleness activity; the first started at 10:00 and finished at 13:00, followed by the second from 13:30 to 15:00. The heifers swapped idleness activity for ruminating activity a few times during the day. The ISS and MSS conditions had a peak of idleness at 12:00.

During the drought season, the average heifer ruminating frequency was lower in the OPS and MSS conditions (16%) than in the ISS condition (23.8%)

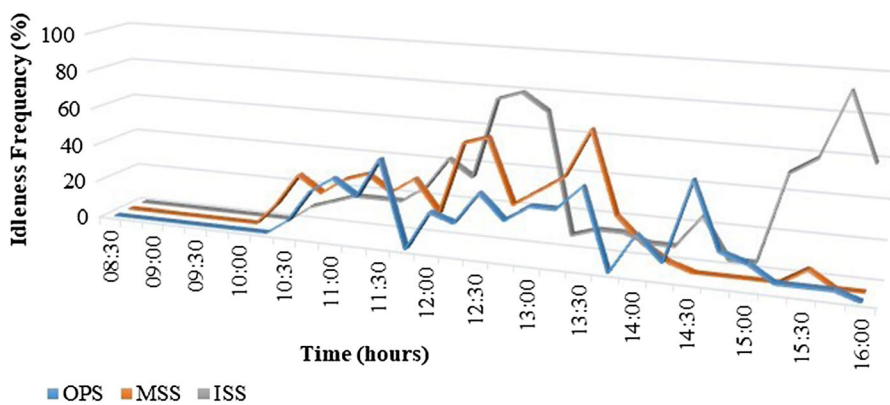

Fig. 6 Frequency of idleness activities of dairy heifers during the transition from the rainy to drought season in systems under tropical conditions. *OPS* open pasture system, *MSS* moderate shade system, *ISS* intensive shade system

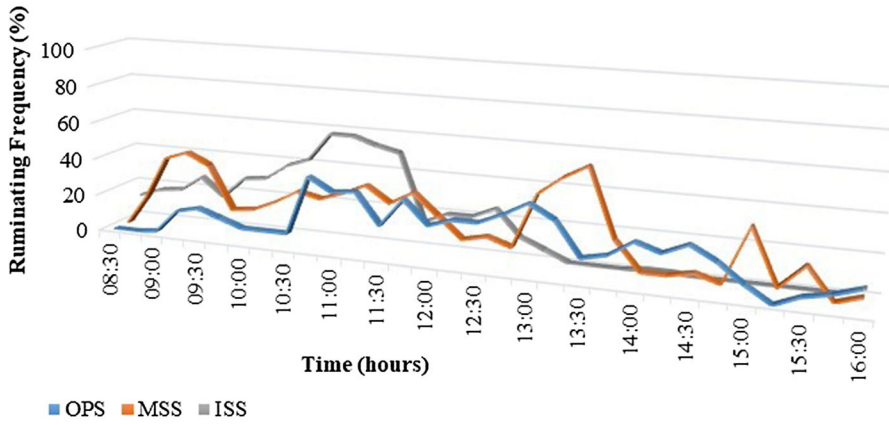

Fig. 7 Frequency of ruminating activities of dairy heifers during the transition from the rainy to the drought season in systems under tropical conditions. *OPS* open pasture system, *MSS* moderate shade system, *ISS* intensive shade system

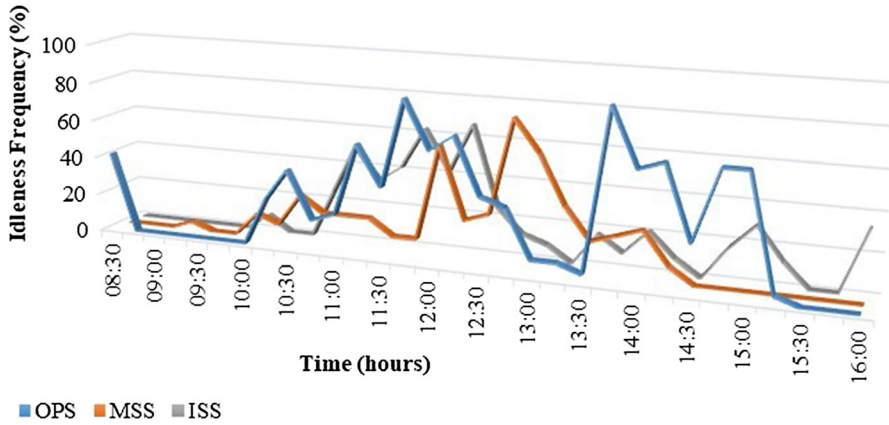

Fig. 8 Frequency of idleness activities of dairy heifers during the drought season in systems under tropical conditions. *OPS* open pasture system, *MSS* moderate shade system, *ISS* intensive shade system

(Fig. 9). In the OPS condition, the number of animals ruminating was limited between 10:00 and 14:15. Ruminating animals were noted between 12:00 and 13:30 in the MSS condition, whereas in the ISS condition, two peaks in ruminating frequency were observed between 12:45 and 15:45, with a high proportion of the heifers involved in this activity.

The animals spent more time being idle under the OPS treatment (2 h 48 min; 36% of their total time) than the animals in the other systems (2 h; 26.5% of their total time) ($P = 0.0594$). However, a large

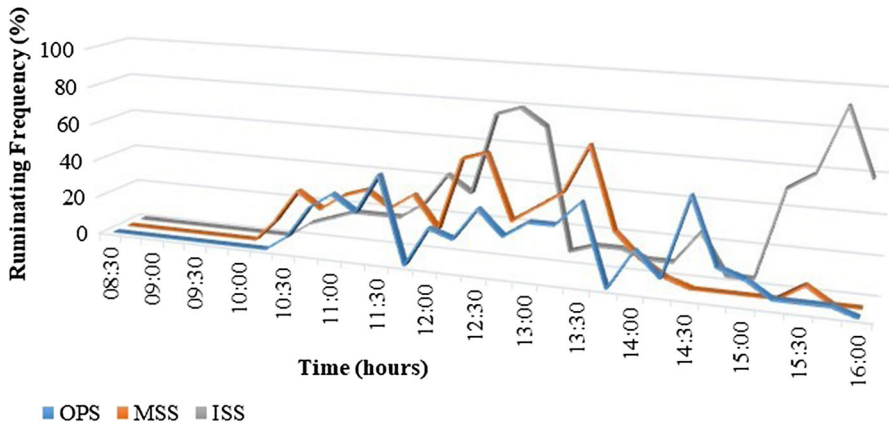

Fig. 9 Frequency of ruminating activities of dairy heifers during the drought season in systems under tropical conditions. *OPS* open pasture system, *MSS* moderate shade system, *ISS* intensive shade system

difference in idleness time was apparent during the different seasons. During the rainy season, the heifers spent 3 h 24 min being idle (44% of the total time), whereas during the transition period and the drought season, the time spent was 1 h 45 min (22.6% of the total time) ($P = 0.0001$). This fact indicates that high temperature alone was not sufficient to induce changes in the daily routine of the animals; instead, high temperature combined with high air relative humidity had an effect.

The time spent ruminating during the evaluated period of the day (1 h 32 min) was similar in every system ($P = 0.1960$) and season ($P = 0.2102$). The heifers spent 20% of their time in ruminating activities in every system and season evaluated; however, the time spent in idleness activity varied with the time not used for grazing activities. This variation was noted to be 20–46% from the rainy to the drought season. There was an evolution of the daily activities of the animals over the season.

The animals were observed to lie down under available shade; however, the total time during the day that the animals spent lying down was the same (2 h 03 min; 26.7% of the total time) in the three systems ($P = 0.5197$). During the rainy and drought seasons, this total time was similar (2 h and 10 min; 28% of the total time), whereas during the transition period, this time was reduced (1 h 48 min; 23% of the total time) ($P = 0.0456$). Despite this statistical difference, the time data were quite similar. The shade preference to idleness and ruminating activities was observed in 70% of the animals. Obviously, the animals under the OPS treatment remained in sunny areas. The preferential time for seeking shade was 09:45 to 12:00, which is the hottest period of the day. During the hottest season (drought season), 84% of the animals in the ISS condition sought shaded areas, whereas only 39% of the animals in the MSS condition did the same.

Discussion

During the rainy season, more animals were involved in idleness activities, probably due to the animals avoiding grazing in the rain (Mello et al. 2017). This situation worsened when the animals had no tree protection against the sun and rain. Commonly, farmers believe that the presence of trees in a pasture encourages idleness in animals, which would result in the animals not grazing satisfactorily. However, these results showed that the presence of trees inside a pasture decreased the idleness time since the animals experienced good grazing conditions during a bright day. In the subtropical region, the presence of trees modified the time and frequency of grazing and idleness; however, it did not influence the time and frequency of the rumination activity (Souza et al. 2010).

The major difference between the systems during the rainy season was the location selected by the animals for idleness. In the OPS condition, the heifers searched for cow drinkers and spent most of their time around there, where they refreshed themselves by spraying water and remaining in muddy places. This activity added water to the muddy puddles of rainwater, which were the preferred places for heifers to refresh themselves during the days with high relative humidity (87%) and high temperature (35–36 °C) (Fig. 2). According to Geraldo et al. (2012), a muddy place can act as an alternative to relieve heat stress in the absence of shade. Schutz et al. (2010), in their experiment in temperate regions, observed that the time spent around the cow drinker increased when little or no shade was provided to the animals. Cows spent more time standing during the day in pastures with no shade than those with shade, possibly to increase radiation from the body in an effort to keep their body cool. They also tended to crowd around cow drinkers, with some cows even standing with their front feet dipped in the water, trying to splash water from the drinker over their backs (Muller et al. 1994). Most heifers (61%) showed no movements during the hottest hours of the day in these muddy puddles. This uncomfortable condition was a common observation in the Brazilian Midwest region during the rainy season. The heifers would stay there for most of the day, performing grazing activities after 16:00 and at night (Mello et al. 2017). The heifers' posture around the cow drinker involved no movement; they laid down on the mud with their mouth open, with no grazing activities (Mello et al. 2017). In contrast, heifers remained under trees in the shade systems, lying down ruminating or grazing. They spent approximately 60% of their time lying down during the day and 59% of their time at night (Albright and Arave 1997).

Grazing activity was detrimentally affected by the unsuitable conditions under the OPS treatment, but

became a pleasant activity in the presence of trees in this experiment (Mello et al. 2017). Cows with shade access grazed up to 1.5 times more than those without access to shade, except when the temperature–humidity index was above their comfort threshold (> 72), during the hottest part of the day under the Canada conditions (Palacio et al. 2015). According to Magalhães et al. (2006), high temperatures associated with high air relative humidity directly affects animal comfort and physiological functions, which can harm the daily routine of the animals. When the daily routine of an animal is disturbed, a reduced performance can be expected since a stressed animal has an increased body temperature, respiratory rate, and sweating. Heifers revealed a tendency to try and return to grazing activity in the OPS condition during the hottest time of the day, when the ruminating and idleness activities decreased; however, since this action was impossible, the animals returned to the cow drinker until later (Mello et al. 2017).

Considering only the shade systems, ISS revealed the highest frequency and time of idleness activity. Both the shade systems reported 5–7 °C lower temperatures than that of the OPS condition. However, the temperature of the shaded region was similar in both the shade systems. The system with more trees (ISS) could reduce the wind speed (Soares et al. 2009). These authors verified a lower wind speed when the trees were densely planted, although this was not sufficient to impact on the animals. The heifers interrupted their activities to indulge in idleness after 10:00, when the sun was high and bright, during the transition period in all the systems (Fig. 6). In the OPS condition, no high peak in idleness between 10:00 and 15:00 (20–40%) was observed; the result was similar during the rainy season (Fig. 4). In contrast, in the MSS condition, the heifers showed a different behavior. In the MSS condition during the transition period, a peak in the frequency of animals displaying idle behavior was observed from 12:00 to 13:30, whereas a low frequency was observed from 10:00 to 12:00, with approximately 20% of the animals involved in idleness activity (Fig. 6). However, in the ISS condition, two peaks were noted; the first between 12:00 and 13:30 and the second after 15:30 (Fig. 6).

The ruminating activity, considered as a physiological and involuntary activity, did not change and was not affected by any factor (system or season). The factors changed the distribution of the time spent in each activity and the time of day of these activities, but not the total time. The animal compensated for their daily routine changes by modifying their grazing (Mello et al. 2017) and idleness activities. The alteration in the frequency of these activities throughout the period is indicative of behavioral changes to reduce the body heat production to relieve heat stress (Pires et al. 1998). When the environmental temperature rises, rumination activity decreases. In an experiment conducted by Tapki and Sahin (2006), the rumination activity decreased from 18% during the morning period to 15% at noon. However, protection against the sun's radiation might eliminate this difference. Shultz (1984) showed that cows under a shaded structure spent more time in rumination activity than those with no shade access at a temperature of approximately 35–40 °C. Blackshaw and Blackshaw (1994) also stated that the rumination activities increased when the cows had access to shade. A high-milk-producing cow ruminated less than low-milk-producing cows when the ambient temperature was high. This difference can be explained by the fact that cows have a lower rate of metabolic heat generation when rumination is less (Kadzere et al. 2001).

The ruminating and walking times did not change during the experimental period. However, the heifers redistributed their time spent grazing (Mello et al. 2017), ruminating, and in idleness activities during the day. The animals modified their posture to adjust to the thermal environment (Pires et al. 1998). An increased grazing time was noted during the daytime from the rainy to the drought season in this experiment (Mello et al. 2017). This fact can be associated with the reduction in the length of a day and the decline in the ability of the animals to graze during the night. According to Phillips (1993), the expected distribution of dairy cow activities over a 24-h period would be 8% walking, 10% standing, 13% lying down, 4% drinking, 27% ruminating, and 38% grazing. The idleness and ruminating activities could also be occurring when the heifers are lying down or standing. The animals spent more time lying down in the OPS and ISS (30.5%) conditions during the rainy season than in the MSS condition (26.2%) ($P = 0.0002$). During the transition period, 22.5% of the animals were lying down during the experimental time ($P = 0.6596$), whereas during the drought season, a difference reappeared ($P = 0.0002$), evidencing that more animals were

lying down in the OPS and ISS conditions (33.2%) than in the MSS condition (24.9%). In the MSS condition, a smaller proportion of the animals laid down and those that did laid down later and got up earlier than the animals in the other systems, therefore, the availability of shade was not a restrictive factor. During this period, since the number of trees present was high and the animals did not have many options of sunny areas, they had to stay under the shade.

Most of the time, the rumination and idleness activities of the animals occurred precisely at the hottest times of the day (Fig. 3) when the animals stopped grazing. According to Mello et al. (2017), the highest frequency of grazing animals occurred in the morning, and only animals that were in the shaded systems returned to grazing after 14 or 15 h. The animals in the OPS condition only returned to grazing after 16 h. Thus, in the OPS condition where the weather conditions were the most aggressive, from 10:00 to 16:00, the animals remained idle or ruminated, even without access to a more pleasant environment.

Conclusions

The presence of trees in the pasture alters the daily routine activities of dairy heifers, allowing their idleness and rumination activities to be interspersed more with their grazing activities during the day. In grassland without trees, these animals spend a significant amount of time being idle rather than performing important tasks such as grazing.

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Authors' contributions Roberta Aparecida Carnevalli conceived and designed experiments, got funding, implemented experimental area, trained students, analyzed data, and wrote the paper; Andrea Cristina Tavares de Mello carried out field experiments, processed, and analyzed data, and defended her master's degree; Larissa Fernanda Garcia, Admar Junior Coletti, and Diego Batista Xavier helped in conducting the experiment and collecting data. All authors critically revised the manuscript and approved of the final version.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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