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Effect of Summer Annual Forage and Type of Shade on Grazing Behavior of Beef Stocker Heifers

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Abstract

Heat stress in beef cattle is still one of the issues affecting animal performance in the beef cattle industry. Our objective was to evaluate the effect of two summer annual forages such as alyceclover (*Alysicarpus vaginalis* L.), and pearl millet (*Pennisetum glaucum*) with natural (trees) or artificial shade (80% shade) on grazing behavior and on reducing the heat load of crossbred yearling heifers. On three consecutive years from mid-July to mid-September, 36 (*Bos taurus* × *B. indicus*) heifers (body weight [BW] = 321±11.3 kg) were randomly allotted ($n = 3$) and continuously stocked in 12-1.33 ha paddocks in a 2 × 2 factorial arrangement of treatments (2 forage types and 2 shade types) with three replicates. Heifers grazing on alyceclover gained more ($p = 0.03$) than those grazing pearl millet (0.94 and 0.80 kg, respectively). Grazing behavior variables were not affected ($p > 0.05$) by forage type and forage type x shade type interaction; however, shade type affected grazing and lying time ($p < 0.05$). Time of day (TOD) affected ($p < 0.05$) grazing and standing time, number of steps taken, respiration rate, and panting scores. These negative effects are related with the greatest temperature humidity index between 1100 and 1459 h. When data were analyzed by TOD, the negative effect on grazing behavior variables was not different for heifers with access to natural or artificial shades. Under the conditions of the present experiment, artificial shade provided protection for cattle. Grazing behavior parameters can be used to monitor heat load in grazing cattle.

Keywords: alyceclover, grazing behavior, heifers, pearl millet, THI

1. Introduction

Heat stress is a result of a negative balance between the net amount of energy flowing from the animal and the amount of heat energy produced and received by the animal, causing a greater accumulation of heat than cannot be dissipated (St. Pierre, Cobanov, & Schnikey, 2003). Prolonged exposure to heat stress conditions in cattle reduces feed intake, growth, milk production, and reproductive efficiency (Hahn, 1985). Across the United States, heat stress results in estimated total annual economic losses of $370 million in the beef industry. Beef cattle farms around the country are affected by heat waves (CDFA, 2006; Drovers Cattle Network, 2011) or normal weather conditions (high temperature and humidity like in the Gulf Coast region) that can severely affect animal performance and hence the profitability of the farm. Cattle with access to shade have consistently shown a reduction in core body temperature and respiration rate, although these positive effects are not always linked to improving performance (Mitloehner et al., 2001).

Respiration rate is the most reliable animal based indicator for heat stress because it increases with ambient temperature, lags solar radiation by approximately 1 hour, and is affected similarly in all heat stress categories (Brown-Brandl, Eigenberg, & Nienaber, 2005). Another viable alternative in using body temperature to assess animal heat load would be to monitor the degree of panting or both panting and respiration (Gaughan, Holt, Hahn, & Mader, 2000; Silanikove, 2000). Grazing behavior parameters may offer another tool to evaluate heat stress. Artificial shade is a viable alternative to provide appropriate protection for beef cattle under grazing conditions. Our objective was to evaluate the effect of shade type (natural or artificial) and pasture type on indicators of heat stress and grazing behavior of beef stocker heifers.

2. Materials and Methods

The present study was conducted at the Louisiana State University Agricultural Center (LSU AgCenter) Iberia Research Station (IRS) located in Jeanerette, LA (29°57′54″W latitude; 91°42′54″N longitude; altitude 5.5 m). The soil type is classified as Iberia silty clay loam poorly drained, very-fine, smectitic, hyperthermic, Typic Epiaquerts, with risk of flooding. The area was shaped ("turtle-back") to improve drainage. All procedures involving animals were approved by the LSU AgCenter Institutional Animal Care and Use Committee (A2011-17).

2.1 Weather Data

Monthly information on average temperatures (°C) and rainfall (mm) was obtained from a weather station located at the IRS approximately 540 m from the center of the experimental site used. Monthly average weather data for the last 30 yr (1981-2010) were obtained from the National Weather Service Forecast Office (2016; select Jeanerette, LA).

Temperature humidity index (THI) was determined according to the Equation (1) outlined by Mader, Davis, and Brown-Brandl (2006):

$$THI = \{[0.8 \times \text{ambient temperature}] + [(\%\ \text{relative humidity}/100) \times (\text{ambient temperature} - 14.4)] + 46.4\} \quad (1)$$

2.2 Pasture Management, Treatments, and Analyses

Alyceclover (*Alysicarpus vaginalis* L.; 12 kg per hectare) and pearl millet (*Pennisetum glaucum*; 22 kg per hectare) were used as a mean of increasing forage nutritive value (compared to bermudagrass) for young beef cattle as suggested by Scaglia & Boland (2014). Every year on early May, Glyphosate (*N*-(phosphonomethyl)glycine (Roundup®; Monsanto Co., St. Louis, MO, USA) was applied for weed control; however, small areas (less than 0.01 hectare) with crabgrass (*Digitaria sanguinalis)* and johnsongrass (*Sorghum halepense* (L.) Pers.) were present within the grazed paddocks approximately 30 to 40 days into the grazing season. Alyceclover and pearl millet were planted using a 4.5 m no-till planter (1590 John Deere®, Moline, IL, USA) with 25.4 cm between rows and at a planting depth of 1.9 cm. All pastures were fertilized 45 days after planting with 60 units of nitrogen (N) per hectare (130 kg per hectare urea; 46-0-0).

Forage mass was determined on day 0, 30, and 60 by clipping using a hand-held clipper (at 2 cm above the ground) inside fifteen-0.25 m^2 quadrats which were randomly placed along each of the paddocks. Samples of forages for nutritive value analyses were hand-plucked from every paddock on day 0, 30, and 60, walking the pastures in a zig-zag pattern and a sample taken every 10 steps. Samples for nutritive value analysis were dried for dry matter (DM) determination in a forced-air oven at 55 °C for 48 hours (AOAC, 2000). Forage samples were ground to pass a 1-mm screen using a Wiley mill (laboratory mill model 4; Arthur H. Thomas Co., Philadelphia, PA, USA). Forage samples were sent for wet chemistry analysis to a commercial laboratory (Dairy One Forage Laboratory, Ithaca, NY, USA). Crude protein was determined by analyzing N content of the samples according to the AOAC (2000) procedure (990.03). Determination of NDF following Van Soest, Robertson, and Lewis (1991) and ADF (AOAC, 2000; 973.18) were made with an automatic apparatus (Ankom 200/220 Fiber Analyzer; Ankom Technology, Macedon, NY, USA), following the procedure of the manufacturer recommended in the operator manual (Ankom Technology, 1997).

On day 0, 30, and 60, vegetative cover was estimated in each paddock using transects. Five 10-m transects were randomly located within each treatment replicate. At 10-cm intervals (100 points in each transect) along each transect, a sharpened point was lowered from above the vegetation and the first plant species intercepting the point was recorded (Heady, Gibbens, & Powell, 1959).

Portable shades were built with 6.25 cm diameter pipe and welded into a 3 m × 3.5 m frame. These structures provided 3.5 m^2 of shade per animal which is more than the 2.3 m^2 recommended for the class of cattle used in this experiment (Higgins, Agouridis, & Wightman, 2011). The structure held a black woven polypropylene cloth (Gempler's; Janesville, WI, USA), which provides 80% shade. These shades were available in half (n = 6; three for each forage type) the paddocks while trees (water oaks; *Quercus nigra*) provide natural shade (3.9 m^2 per heifer) to the other half (n = 6; three for each forage type) of the paddocks. Tree lines and artificial shades had an orientation east to west along one of the short sides of the rectangular-shaped paddocks. Mineral feeders were placed in the middle of all paddocks and the water troughs on the opposite side of the shade. Ambient temperature was determined in three paddocks per shade type (artificial shades and trees) randomly selected using common outdoor digital thermometers (AcuRite 00782A2; Chaney Instrument Co., Lake Geneva, WI, USA) placed approximately 2 m from the ground. Temperature was recorded once a week (Wednesdays) at 0900, 1300, and 1700 h.

2.3 Cattle Management and Variables Determined

In three consecutive years, 36 crossbred (at least 5/8 *Bos taurus* and 3/8 or less *B. indicus* influence) heifers (15 to 16 months of age; body weight [BW] = 321±11.3 kg) were randomly allotted (n=3) to 12 paddocks (1.33 ha; 2.3 heifers per hectare; 724 kg BW per hectare) in a 2 x 2 factorial arrangement with three replicates each in a continuous low stocking rate for a 60-day grazing period (mid-July to mid-September of each year). Previous experience with summer annual forages indicated a high risk of poor stands due to variable rainfall at the early stages of plant growth. This issue factored in the decision of using low stocking rates since the main objective of the study was to determine the effect of shade type on the response of these animals to environmental distress and its influence on grazing behavior. Regardless, information on pastures and animal performance are presented to better describe the production system during the experimental period. On two consecutive days (to reduce the effect of filling), heifers were weighed and body condition score (BCS) determined, values averaged (day -1 and 0, day 30 and 31, day 59 and 60) and presented as those on day 0, 30, and 60. On day 0 of the experimental period, heifers were dewormed with 1% w/v ivermectin (Ivomec Plus Injectable; Merial, Duluth, GA, USA). Fresh water and mineral mix that guaranteed 12% Ca, 6% P, 10% NaCl, 2.50% Mg, 0.75% K, 0.0043% Cu, 0.00012% Se, 0.0067% Zn, 200,000 IU of Vitamin A (Lone Star 126; Lone Star Feeds, Corpus Christi, TX, USA) were provided *ad libitum*.

2.4 Grazing Behavior

Every year, grazing behavior recordings were conducted through the entire grazing season on one heifer per treatment replicate, each wearing an animal activity monitor. This monitor (IceTag™, version 2.004, IceRobotics, Midlothian, Scotland, UK) was attached to a Velcro® strap on the left rear leg just above the metatarsophalangeal joint. These units measured animal activity 8 times per second with an internal accelerometer. Time spent standing, active, lying, and number of steps taken by each heifer were recorded. Data were downloaded from the on-board memory to a personal computer and analyzed by IceTagAnalyser™ software (version 2.009; IceRobotics). Raw activity monitor data were transformed using the procedure of Aharoni et al. (2009) to partition out the amount of time spent standing still, grazing, and walking without grazing. In brief, the data were first summarized into 5-minute intervals. If less than 10 steps were taken during that interval, the animal was considered to be standing still; if between 10 and 80 steps were taken, the animal was considered to be grazing; and if more than 80 steps were taken, the animal was considered to be walking without grazing. Information obtained from each animal activity monitor was summarized by day (24-hour periods) and time of the day (TOD): 0700-1059, 1100-1459, 1500-1859; 1900-2259; 2300-02.59, and 0300-6:59.

In year 3, behavior data recorders developed by the Institute of Grassland and Environmental Research and made by Ultra Sound Advice (London, UK) were used (Champion, Rutter, & Penning, 1997; Rutter, Champion, & Penning, 1997). The data from the devices were analyzed with Microsoft® Windows™ based software (GRAZE; Ultra Sound Advice, version 0.801). The devices consisted of a computerized data logger, halter-mounted jaw movement sensor, and a custom made halter. The data logger was attached to the halter on the left side of the neck of four randomly selected animals, one in each treatment. Dummy loggers were attached to each of the animals for a 10-day adaptation period. On day 17 (period 1) and day 43 (period 2), the recorders were placed on the animals starting at 0730 taking approximately 15 minutes on each heifer. Data were collected in 24 hour periods over a 5 day period. Every day, all the heifers in the treatment replicate were taken to the working facilities and the animal with the device passed through the chute, batteries of the data logger changed and the group was taken back to the pasture. Based on the GRAZE output, number of grazing and ruminating mastications were calculated.

Every year, for five consecutive days per period from 0700 to 1900 hours, respiration rate (RR) and panting score (PS) were determined on all the animals by three observers. Every hour, RR was determined by counting the number of flank movements over 10 seconds and then converting this count to breaths per minute (bpm). Panting score was measured (following the same criteria as RR) using the 8-point scale defined by Gaughan, Mader, & Holt (2008) after a modification to the 0 to 4.5 scale (Mader, Davis, & Brown-Brandl, 2006), where PS= 0 describes an animal under no heat load, and PS = 4.5 describes a severely heat-stressed animal.

2.5 Statistical Analyses

The experiment design was a 2 × 2 factorial arrangement of treatments with three replicates. Forage type (alyceclover or pearl millet) and type of shade (natural vs. artificial) were the main factors. Data were analyzed with PROC GLM of SAS (SAS Inst., Inc., Cary, NC, USA). Forage mass and nutritive value data were analyzed for forage type, year, and their interaction. For botanical composition, absolute cover was calculated by dividing species intercepts by total intercepts (Oates, Undersander, Gratton, Bell, & Jackson, 2011). The cover estimates were categorized into the different components: main species (alyceclover or pearl millet), bare soil, and weeds. Partial average daily gain (ADG) per period (period 1 from day 0 to 30 and period 2 from day 31 to 60), total ADG (day 0 to 60), and beef productivity per hectare were analyzed for main factors and their interaction. In all cases, paddock was the experimental unit. Daily (24 hours) data (time spent standing, active, lying, and number of steps) from behavior recordings, number of grazing and ruminating mastication, respiration arte, and panting score were analyzed following the experimental design described using day as the repeated measure. Pedometer data (grazing, standing, and lying time, and number of steps), RR and PS were also analyzed for the effect of TOD (0700-1059, 1100-1459, 1500-1859; 1900-2259; 2300-02.59; 0300-6:59). Least squares means are reported for all variables with means separated by Tukey's adjustment. A significance level of $\alpha \leq 0.05$ was set for all analyses.

3. Results and Discussion

3.1 Weather Data

On average, year 2 had the greatest rainfall followed by year 1, despite the small precipitation in August of that year (Figure 1). In addition, August in year 2 had an average temperature 5 ºC greater than the average historic temperature for the month. These rainfall and temperatures in year 2 may have positively impacted forage production and hence animal gains. Temperatures for year 1 and 2 were above the 30 year historic average while temperatures on year 3 were average. Ambient temperature determined under the artificial shades and trees (data not shown) with common outdoor digital thermometers indicated that, on average, there was a difference of approximately 1.7 ºC more under the artificial shades at all times.

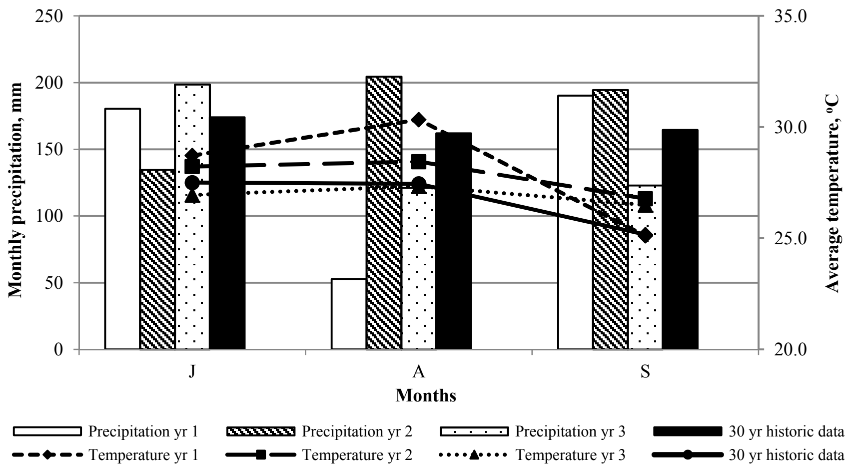

Figure 1. Monthly precipitation (mm), average temperature (ºC), and 30 yr historic averages at the experimental site

3.2 Forage and Animal Production

Figures 2 and 3 showed the 3-year average botanical composition of the experimental pastures. Pearl millet (Figure 2) presence in the pastures was greater than that of alyceclover (Figure 3). Due to the difference in plant architecture, stands of pearl millet were denser helping to shade potential weeds and/or covering soil that otherwise would be bare.

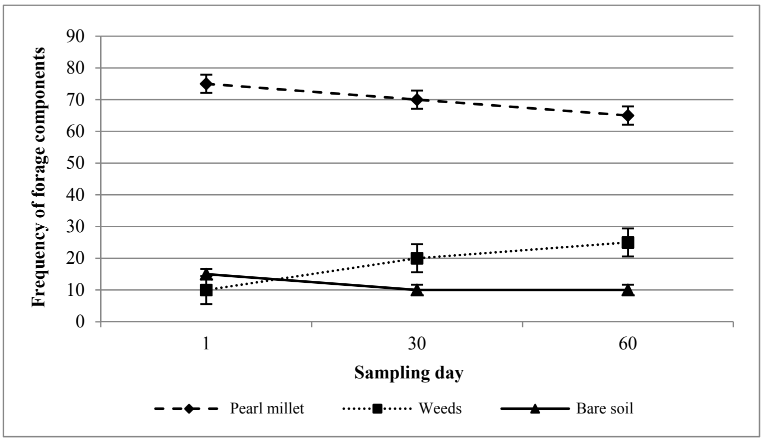

Figure 2. Frequency (%) of forage components in pearl millet experimental pastures (average and SE of 3 years)

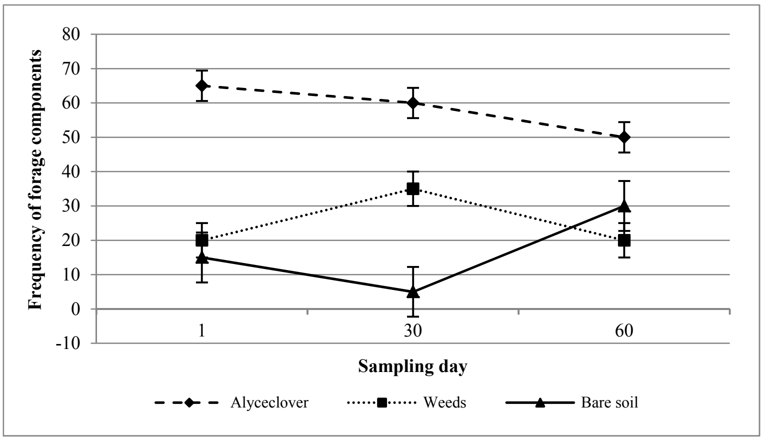

Figure 3. Frequency (%) of forage components in alyceclover experimental pastures (average and SE of 3 years)

This impacted the frequency of each factor observed for each of the experimental pastures on day 30 and 60 (Figures 2 and 3). Weed frequency presence in alyceclover pastures varied from 20 to 39% which is typical for this legume planted under no-tilled conditions (Bagley, Valencia, & Sanders, 1985). Grazing started (day 0) when pearl millet was on average 51 cm tall (3,990 kg DM per hectare) while alyceclover was 37 cm (2,522 kg DM per hectare). Forage mass in these pastures did not change ($p = 0.11$) from day 0 to 30, although a reduction ($p = 0.02$) in alyceclover was observed on day 60 (1,355 kg DM per hectare). A year effect was observed for forage mass production. Forage production in year 2 (3,678 kg DM per hectare) was greater ($p = 0.03$) than in the other two years (2,342 and 3,003 kg DM per hectare, for year 1 and 3 respectively). Greater rainfall and temperatures (above the historic average) may have contributed to this response. Forage production of summer annual grasses is closely related to weather conditions, mainly adequate rainfall during late spring and early summer (Teutsch, 2009). Nutritive value parameters were affected by forage type ($p < 0.05$) but not by year ($p > 0.05$). As expected, nutritive value for alyceclover (a legume) was greater ($p < 0.05$) than pearl millet (Table 1); however, nutritive value parameters for the latter were adequate for yearling heifers as those used in the present experiment (NRC, 1996). Most forage systems in the Gulf Coast states are based on warm season perennial grasses, such as bermudagrass (*Cynodon dactylon*) and/or bahiagrass (*Paspalum notatum*), but these grasses do not meet the nutrient requirements of young growing animals (Scaglia & Boland, 2014). There was no shade type or forage type x shade type interaction effect on ADG or beef produced per hectare (Table 2); hence, the main effect of forage type ($p = 0.03$) is discussed. Because of the difference between forage type's nutritive value, animal performance was greater ($p = 0.03$) for heifers grazing alyceclover (Table 2) although no impact on BCS was observed ($p > 0.05$; data not shown). The weight gain difference for the experimental period (day 0 to 60) is explained by the ADG difference due to pasture type from d 31 to 60 (0.84 and 0.63 kg for alyceclover and pearl millet, respectively). Alyceclover maintained a greater nutritive value throughout the period despite its reduction in frequency (Figure 3) and hence in forage mass.

Table 1. Pasture type and year effect on nutritive value of the experimental pastures

Item[2]	Pasture[1]			Year			
	AC	PM	SEM	1	2	3	SEM
CP	21.0a	12.9b	2.59	14.2	16.3	13.1	2.10
NDF	43.5b	53.7a	3.01	55.5	53.9	57.8	2.45
ADF	36.6b	47.4a	4.01	45.6	44.5	48.6	3.03
TDN	61.9a	57.1b	1.22	59.9	63.0	58.2	1.99

Note. [1] Pasture: AC = Alyceclover; PM = Pearl millet; [2] CP = Crude protein, NDF = Neutral detergent fiber, ADF = Acid detergent fiber, TDN = Total digestible nutrients; [a,b] Within a row means without a common superscript differ ($P < 0.05$).

Table 2. Average daily gain (ADG; kg) and beef produced per hectare (kg/ha).

	Pasture[1]		Shade[2]		p value		
	AC	PM	NS	AS	Pasture	Shade	Pasture × Shade
ADG (kg), d 0 to 30	1.04	0.90	0.97	0.95	0.07	0.81	0.71
ADG (kg), d 31 to 60	0.84a	0.63b	0.81	0.77	0.04	0.60	0.69
ADG (kg), d 0 to 60	0.92a	0.80b	0.91	0.83	0.03	0.18	0.84
Beef produced, kg/ha	128.9	111.1	123.5	112.3	0.10	0.32	0.88

Note. [1] Pasture: AC, Alyceclover; PM, Pearl Millet; [2] Shade: NS, natural shade (trees); AS, artificial shade.

Daily gains were greater than those obtained by Bagley et al. (1985), who reported 0.77 and 0.61 kg/day for steers (initial BW = 318 kg) grazing alyceclover and pearl millet, respectively; however, initial stocking rates were greater (6 and 12 steers per hectare, for alyceclover and pearl millet, respectively) than in the present experiment (2.3 heifers per hectare). Bermudagrass, a summer perennial grass is commonly used in the Gulf Coast region during this time of the year. Heifers of similar age and weight (14-16 months of age and 311± 13.8 kg of BW) grazing bermudagrass (var. 'Jiggs') at a similar stocking rate (2.5 heifers per hectare) gained 0.65 kg/day (Scaglia, unpublished data) during the same time period. This is not a surprise since summer annual forages have greater nutritive value than summer perennial forages (Ball, Hoveland, & Lacefield, 2007). Closely related with a low stocking rate (3.4 and 5.4 kg DM/kg BW of grazing pressure on day 0) used in the experiment is the low productivity per unit of land (129 and 111 kg per hectare, for alyceclover and pearl millet, respectively). Greater stocking rates on these same forages allowed for 330 (1.3 kg DM/kg BW on day 0) and 526 kg per hectare (1.1 kg DM/kg BW on day 0) of beef produced, for alyceclover and pearl millet, respectively (Bagley et al., 1985).

3.3 Temperature Humidity Index Effect on Grazing Behavior, Respiration Rate, and Panting Score

There was no forage type or forage type x shade type interaction ($p > 0.05$) on any of the variables determined; however, shade type had an effect on time of grazing ($p = 0.03$), standing ($p = 0.04$) and lying ($p = 0.04$; Table 3). Several of the studies dealing with heat stress have been conducted under feedlot conditions (Mitloehner et al., 2001; Mader et al., 2006; Mader, Dahlquist, Hahn, & Gaughan, 1999). Even though this segment of the beef cattle industry is economically very important, there are classes of beef cattle (most females and bulls) that spend most of their lifetime under grazing conditions. These conditions require the animal to walk more (hence spending more energy) for feed, water, and shade than under a feedlot setting; thus, grazing behavior as a measurement of cattle response to heat stress can be another viable option to use by producers because data are relatively easy to acquire.

Table 3. Effect of forage and shade type on grazing behavior variables and heat stress indicators

Item	Forage[1]		Shade[2]		p values		
	AC	PM	NS	AS	Forage	Shade	Forage × Shade
Grazing, min	547	570	555a	495b	0.21	0.03	0.06
Standing, min	397	353	380b	470a	0.11	0.04	0.08
Walking, min	85	78	81	98	0.59	0.44	0.33
Number of steps	1791	1858	1692	1747	0.41	0.09	0.09
Lying, min	367	401	433a	385b	0.88	0.04	0.10
Grazing mastication per day	5567	5933	4852	5013	0.75	0.05	0.52
Ruminating mastication per day	29111	28423	36587	31282	0.63	0.07	0.88
Respiration rate[3]	102	95	109	99	0.55	0.66	0.54
Panting score[4]	0.9	0.8	0.9	0.7	0.77	0.89	0.69

Note. [1] Pasture: AC, Alyceclover; PM, Pearl Millet; [2] Shade: NS, natural shade (trees); AS, artificial shade; [3] Respiration rate in breaths per minute; [4] Panting score following a scale where PS = 0 describes an animal under no heat load, and PS = 4.5 describes a severely heat-stressed animal.

Heat stress has long been known to adversely affect rumen health (Mishra, Martz, Stanley, Johnson, Campbell, & Hilderbrand, 1970) due to a variety of biological and management reasons (Bernabucci, Bani, Ronchi, Lacetera, & Nardone, 1999; Bernabucci, Lacetera, Baumgard, Rhoads, Ronchi, & Nardone, 2009; Kadzere, Murphy, Silanikove, & Maltz, 2002). Heat-stressed cows consume less feed and consequently ruminate less resulting in decreased buffering agents (ruminating is the primary stimulant of saliva production) entering the rumen (Bernabucci, Lacetera, Baumgard, Rhoads, Ronchi, & Nardone, 2010). In the present study, since there was no effect of forage type or shade type on number of grazing or ruminating mastication (Table 3), the differences in grazing time (555 and 495 minutes for natural and artificial shade, respectively) may not have been related to dry matter intake (DMI). Heifers with artificial shade (under which the temperature was 1.7 ºC greater than under the trees) spent more time standing and less time lying down than those with access to natural shade (Table 3). This behavior is used as a mean of dissipating heat as indicated for steers grazing bermudagrass under similar conditions (Scaglia & Boland, 2014).

Grazing behavior variables (except walking time), RR, and PS of grazing heifers were affected by TOD (Table 4). Heifers spent less time grazing ($p = 0.04$) and more time standing under the shade ($p = 0.02$), regardless of type of shade, between 1100 and 1500 h which is the peak of THI during the day (Figure 4). Lying time was greatest ($p < 0.05$) from midnight to 0300 h but only different to the morning (0700 to 1100 h) and the mid-afternoon (1500 to 1900 h) hours. Respiration rate was greatest ($p < 0.05$) from 1100 to 1459 h and from 1500 to 1859 h compared to early morning hours (0700 to 1059 h). Panting score was greatest ($p = 0.01$) from 1100 to 1459 h compared to PS from 0700 to 1059 h.

Table 4. Effect of time of day on grazing behavior variables and heat stress indicators

Item	Time of day						
	0700-1059	1100-1459	1500-1859	1900-2259	2300-0259	0300-0659	SEM
Grazing, min	140a	27b	127a	133a	31b	59b	27
Standing, min	46b	129a	51b	30b	49b	77ab	31
Walking, min	8	2	13	16	9	18	8
Number of steps	410b	89d	697a	259c	63d	299bc	63
Lying, min	10c	61ab	31bc	51ab	121a	79ab	40
Respiration rate[1]	101b	113a	108a	n.d.	n.d.	n.d.	2.8
Panting score[2]	0.6b	1.4a	0.8ab	n.d.	n.d.	n.d.	0.3

Note. [1] Respiration rate in breaths per minute (n.d. = no data); [2] Panting score following a scale where PS = 0 describes an animal under no heat load, and PS= 4.5 describes a severely heat-stressed animal; [a,b,c,d] Within a row means without a common superscript differ ($P < 0.05$).

In the 1960's, it was accepted that temperature and humidity affect animals' physiology which in turn affects how they behave including all the activities related to grazing behavior (Ehrenreich & Bjugstad, 1966). Additionally, the trend that started decades ago of selecting higher producing cattle with great growth rate and metabolic activity increases body heat load, thus amplifying heat stress in cattle (West, 1994). Environments of high temperatures and humidity are detrimental to the productivity of commercial animal agriculture.

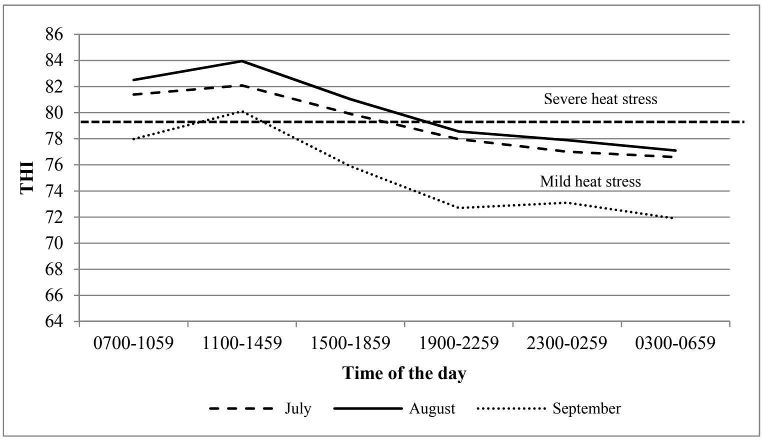

Figure 4. Average temperature humidity index (THI) at different time of the day during the experimental period

The Scientific Committee on Animal Health and Animal Welfare (SCAHAW, 2001) suggested that the threshold temperature where adverse effects on DMI, growth, and feed efficiency are readily apparent for beef cattle is 30°C with a relative humidity less than 80% and 27 °C with a relative humidity over 80% (Hahn, 1999). The 3 year-average THI that heifers were exposed throughout the grazing seasons is reported by TOD in Figure 4. Also included on it is the definition (dotted lines) of mild and severe heat load (THI of 72 and 79, respectively). Armstrong (1994) reported that *B. taurus* cattle (i.e., British and continental breeds) exhibited mild heat load when the THI is above 72 (lower dotted line in Figure 4). When THI is at or greater than 79, *B. taurus* cattle exhibited severe heat load (Hahn & Mader, 1997). In the present experiment, heifers were crossbred with a genetic make-up of ¾ to 5/8 *B. taurus* and ¼ to 3/8 *B. indicus*. *Bos indicus* cattle (i.e., Brahman, Nellore, etc.) are well adapted to tropical conditions (high temperature, high humidity, external parasite resistance, etc.) which make them (and their crosses with *B. taurus* cattle) an excellent strategy to use them in the Gulf Coast region (Frisch & Vercoe, 1984; Finch, 1984; Bennett, Finch, & Holmes, 1985). Sprinkle et al. (2000), working with Angus, Brahman × Angus, and Tuli × Angus lactating and non-lactating cows, reported that in early summer the Tuli × Angus cows spent more time in the shade than the Brahman × Angus and less time during late summer. These results were probably due to the fact that in early summer only 19% of the hourly time periods had a THI less than 72; however, there were 59% of the hourly time periods that had a THI between 72 and 79 and 22% of the hourly periods with a THI exceeding 79. These authors concluded that Brahman crosses had a better adaptation to elevated temperatures than Tuli crosses (Sprinkle et al., 2000). Scaglia and Boland (2014), under similar weather conditions to those in the present experiment, observed that between 0600 h and midnight for all four months of grazing season (June to September) THI was above that considered to provoke mild heat stress on cattle. Even more dramatic to observe was the fact that the THI for June, July, and August between 0600 and 2100 h would cause a severe heat load (Scaglia & Boland, 2014). Similar data were observed for the present experiment (Figure 4). Even though it was reported in feedlot conditions, during heat stress, eating behavior decreased (7.1 vs. 9.1%), drinking behavior increased (3.1 vs. 1.7%), standing behavior increased (48.1 vs. 42.0%), lying behavior decreased (41.1 vs. 44.3%), and agonistic behavior decreased (2.6 vs. 0.2%) for heat stressed cattle vs. those in a thermoneutral zone, respectively (Brown-Brandl et al., 2006). Scaglia and Boland (2014) reported that steers spent less time grazing, walking and lying and more time standing (to dissipate heat) during the period of peak THI as well as during the first 3 months of the grazing period. In the present experiment a similar impact (except for walking time) was observed due to THI.

Quantification of heat stress is complicated by acclimation of animals (Robinson, Ames, & Milliken, 1986) and breed differences in their susceptibility to it (Hammond, Chase, Bowers, Olson, & Randel, 1998; Gaugham, Mader, Holt, Josey, & Rowan, 1999). In the present experiment, heifers were born and raised at the IRS and had a similar (1/4 to 3/8) *B. indicus* influence which make them an appropriate model for the study. Results from performance trials with shaded and unshaded feedlot cattle have shown inconsistent results (Mader et al., 2006). Lack of performance improvement from shaded treatments can be explained by the ability of cattle to acclimate and compensate for a short-term suppression in feed intake and growth resulting from a heat stress event (Hahn, 1982; Mader et al., 1999). During times of high solar radiation, high temperature, and high humidity, a reduction of solar radiation may be a method of reducing heat stress (J. K. Blackshaw & A. W. Blackshaw, 1994; Valtorta, Leva, & Gallardo, 1997; Paul, Turner, & Larson, 1999), improving animal well-being and preventing death in extreme cases.

4. Conclusions

In the present study, artificial shades that provided 80% interference promoted an acceptable environment for grazing cattle. Despite the fact of not having a negative control (no shade), it was possible to determine the negative effect of greater THI (through TOD) on grazing behavior, RR, and PS of crossbred yearling heifers. It can be assumed that with no shade available these negative effects demonstrated under these experimental conditions would have been greater. Grazing behavior variables such as grazing and standing time can be used to evaluate the heat load of grazing cattle during summer. Further research to generate data that can allow a response curve on the effect of THI on grazing behavior is warranted.

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