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Influence of irrigation and supplementation on performance and ingestive behavior of beef cattle on mixed grass pastures

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ABSTRACT - The purpose of this study was to evaluate the performance of beef cattle with two levels of energy-protein supplementation of low-consumption on African Bermudagrass pasture, overseeded in winter with oat and ryegrass, with or without irrigation. Twenty-four castrated Angus steers (11 months old and had an initial average of 220 kg body weight (BW)) were used in experimental area of 3.6 ha. The experiment was completely randomized in a 2×2 factorial design, with three replicates. The evaluation period was 249 days (July/2019 to March/2020). The treatments were: irrigated pasture with supplementation of 1 g/kg BW or 2.7 g/kg BW and non-irrigated pasture with 1 g/kg BW of supplement or 2.7 g/kg BW. The grazing method was continuous with a variable stocking rate. Irrigation provided pastures with better chemical composition in winter and spring. Irrigation increased the daily accumulation rate in winter (84.6 vs. 45.9 kg DM/ha/day), providing a greater stocking rate (1,702 vs. 1,385 kg/ha) and, consequently, body weight gain per hectare. Supplementation of 2.7 g/kg BW provided a greater stocking rate in winter (1,652 vs. 1,435 kg/ha) and spring (3,096 vs. 2,811 kg/ha), not changing in summer. The association of irrigation and supplementation of 2.7 vs. 1.0 g/kg BW improves the intake pattern by the animal in summer without changing productivity parameters. Irrigation increases productivity and the nutritional value of pasture with higher livestock production per area in periods of water deficit. The supply of 2.7 vs. 1.0 g/kg BW provides a greater stocking rate and body weight gain per hectare.

Keywords: *Cynodon nlemfuensis,* energy-protein supplement, grazing systems, oat pasture, ryegrass pasture

1. Introduction

Tropical grasses are characterized by rapid growth and maturation and are often related to low dry matter (DM) digestibility and animal performance (Boval et al., 2015), while temperate grasses have slower growth but better nutritional value. Regions with subtropical climate have the advantage to improve the forage yield throughout the entire year. The use of perennial tropical grasses and overseeding in winter with temperate species is an option to intensify meat production (Barth Neto et al., 2014).

In recent decades, drought cycles and concentrated rains have become more frequent, with extended periods without rainfall and extreme events even more often. Thus, adjusting production systems to reduce dependence on water from rainfall is a positive strategy to maintain pasture productivity. Therefore, irrigation can increase the biomass production of forage and improve the nutritional quality of the pasture (Jensen et al., 2010; Robins, 2016). Other technologies can be used with irrigation (Jovanovic et al., 2020), as well as the adjustment of forage allowance (Trindade et al., 2012) or supplementation (Barbero et al., 2020) to take advantage of the nutritional contribution of pasture or adjust the ratio of ingested carbohydrates and nitrogen, improving the animal performance.

Supplementation is an option that helps to keep an adequate balance of nutrients and optimizes animals' weight gain and the carrying capacity of pastures (Helbrugge et al., 2008). High daily levels of supplement per animal can reduce pasture intake, making it possible to increase the stocking rate (SR) and provide higher productivity per area (Aguiar et al., 2014; Lazzarotto et al., 2019).

However, the substitution of supplements for pasture usually occurs depending on the amount of supplement and quality of forage. When energy supplements are associated with good quality pastures, the substitution may occur even with low amounts of supplement due to ruminal fermentation conditions (Stockdale, 2000; Machado et al., 2019). When nitrogen availability in the rumen is not synchronized, it can limit microbial protein synthesis, affecting nutrient digestibility (Moraes et al., 2006; Costa et al., 2009) and, consequently, animal production.

Thus, the objective of this study was to determine animal production and ingestive behavior with the hypothesis that pasture irrigation and low levels of energy-protein supplementation in steers on African bermudagrass pasture overseeded with oat and ryegrass would increase animal productivity in grazing systems.

2. Material and Methods

2.1. Ethics committee, location, and experimental area

All research was approved by the Animal Ethics Committee (case no. 2018-017). The experiment was carried out in Dois Vizinhos, Paraná, Brazil (25°44' South and 53°04' West, with an average elevation of 520 m). The evaluation period was from May 2019 to March 2020, in an experimental area of 36,000 m^2, divided into 12 paddocks, in an average of 3,000 m^2 each.

The soil is Dystrophic Red Nitosol with a clayey texture. According to the Köppen classification, the climate is Cfa (humid subtropical). The meteorological data of the evaluation period were obtained from the National Institute of Meteorology, located 100 m from the experimental area (Figure 1).

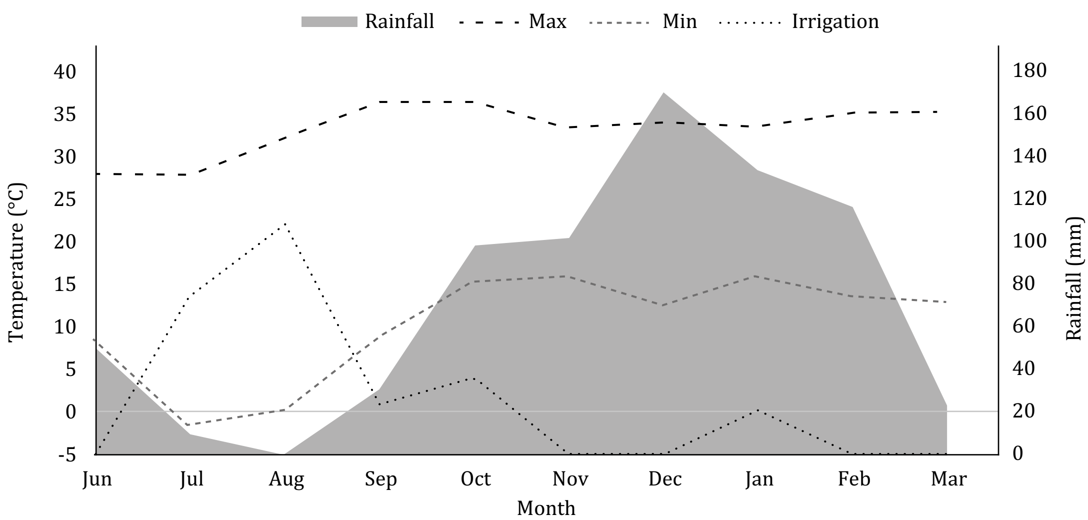

Figure 1 - Accumulated rainfall and average monthly temperature throughout the experimental period.

The area consisted of African Bermudagrass pasture (*Cynodon nlemfuensis* Vanderyst) since 2014. On February 13, 2019 the soil was sampled in the experimental area (Table 1). According to previous soil analysis, the base fertilizer was 170 kg/ha of a commercial formulation NPK 8:20:10. Nitrogen fertilization was 225 kg of N/ha in the form of urea divided into three covering applications, on 07/20/2019, 10/28/2019, and 01/14/2020.

Table 1 - Soil chemical analysis of African Bermudagrass pasture overseeded in winter, with and without irrigation, grazed by supplemented beef cattle

	pH	OM	P	K	Ca	Mg	H+Al	SB	CEC	V
	$CaCl_2$	(g/dm^3)	(mg/dm^3)	cmolc/dm^3						(%)
Irrigated	4.9	33.2	5.80	0.3	6.5	2.2	7.1	9.1	16.2	55.0
Non-irrigated	5.0	35.0	6.96	0.2	5.5	1.8	6.3	7.7	14.0	54.9

OM - organic matter; SB - sum of bases; CEC - cation exchange capacity; V - saturation.

On May 14, 2019, ryegrass cultivars (*Lolium multiflorum* 'BRS Integration') and black oat (*Avena strigosa* 'IAPAR 61') were sown using equipment with in-line direct seeding system, at a density of 22 kg/ha and 45 kg/ha of viable pure seeds, respectively. The African bermudagrass downgrade was performed, with residue close to 5 cm, with a brushcutter, before implementing the temperate species.

2.2. Experimental design and feeding management

The experiment was completely randomized in a 2×2 factorial arrangement, with three replicates (paddocks). Two quantities of supplementation were evaluated based on the animals' body weight (BW) on pastures with or without irrigation. The treatments were: irrigated pasture with supplementation of 1 g/kg BW or 2.7 g/kg BW and non-irrigated pasture with supplementation of 1 g/kg BW or 2.7 g/kg BW. The evaluation periods were selected according to the available forage species: winter, from 07/15/2019 to 10/15/2019; spring, from 10/16/2019 to 01/07/2020; and summer, from 01/08/2020 to 03/20/2020, totaling 249 days of experiment.

Twenty-four castrated Angus steers (11±1 months old and initial average of 220±10 kg BW) were used. The adaptation period to the environment, facilities, and husbandry were 15 days. The animals were given anthelmintic drug at the beginning of the experiment and every 90 days. Supplements were offered daily at 10:00 h in plastic troughs, and the quantities were adjusted every two weeks by weighing the steers. Two compositions of supplements were used, one for winter and the other for spring and summer (Table 2), depending on the forage species.

2.3. Pasture management and irrigation

The grazing method was continuous with a variable SR. Two testers per paddock were used. The adjustments in forage mass (FM) were based on the pasture height, maintained at 15-20 cm (Tiecher et al., 2016). The measurements were performed every 15 days with a ruler at 20 random points within each paddock. When necessary, regulator animals were used, and they had similar characteristics and weights to the testers.

The irrigation system was the conventional sprinkler, activated when the soil water potential reached the value of 10 matric potential (−kPa). The water volume to be applied was based on the water retention curve in the soil and kPa readings obtained by digital tensiometers and vacuometers at 20 cm depth. The total volume applied was 264 mm, ranging from 18 to 36 mm/day. The highest demand for irrigation was in winter with applied volumes of 207 mm and smaller applications during spring and summer, with 36 and 21 mm, respectively (Figure 1).

Table 2 - Ingredients and nutritional composition of supplements offered to cattle on African Bermudagrass pasture overseeded in winter, with and without irrigation

Ingredient (%)	Winter	Spring/Summer
Ground corn	48.0	48.0
Corn gluten	10.7	11.7
Soybean meal	11.7	10.8
Limestone	8.3	3.0
Dicalcium phosphate	7.1	7.1
Sodium chloride	6.5	6.5
Palm fat	5.4	5.4
Urea	-	5.2
Mineral premix[1]	2.2	2.2
Flavomycin	0.1	0.1
Nutritional composition (%)		
Crude protein	12.7	27.3
Total digestible nutrients	72.4	72.4
Calcium	5.1	3.2
Phosphorus	1.5	1.5
Sodium	2.3	2.3
Magnesium	0.02	0.02
Ethereal extract	7.4	7.5

[1] Mineral premix: Ca, 220 g/kg; Co, 41 mg/kg; Cu, 900 mg/kg; S, 10 g/kg; F, 500 mg/kg; P, 40 g/kg; I, 55 mg/kg; Mg, 2000 mg/kg; Mn, 500 mg/kg; Se, 11 mg/kg; Na, 150 g/kg; Zn, 1820 mg/kg.

2.4. Chemical analysis of pasture

Forage samples for chemical analysis were obtained by the hand-plucking technique (De Vries, 1995). A composite sample per paddock was collected every 15 days. Then, they were weighed and dried in a forced air oven at 55 °C for 72 h to determine the partially DM content. The samples were ground in a Wiley mill, using sieves with 1 mm mesh. Chemical analyses were performed for the contents of DM, ash, and crude protein (CP) (AOAC, 2012), and neutral detergent fiber (NDF) and acid detergent fiber (ADF) by the methodology of Van Soest et al. (1991).

2.5. Pasture and animal evaluations

Forage mass was estimated every 21 days in winter and 28 days in spring and summer. Forage samples were clipped 0.5 m^2 close to the ground in four random representative spots of each paddock. The samples were weighed, homogenized, and divided into two sub-samples. One for the pasture DM, and another for structural separation and determination of the leaf:stem ratio, and then dried in forced-air oven at 55 °C for 72 h. Daily accumulation rate of forage was evaluated on the same days as the FM, using two exclusion cages per paddock, according to the double pairing technique described by Campbell (1966).

The average daily weight gain (ADG) was performed at the end of each season by individual weighing of the tester animals, preceded by solid and liquid fasting for 14 h. Stocking rate was obtained by the sum of the animals' average body weight in the days of experiment. Body weight gain per hectare (BWG) was obtained by multiplying the ADG of the tester animals by the number of animals per hectare and days on the pasture.

2.6. Ingestive behavior

Two evaluations of animal behavior were carried out within the seasons with intervals of approximately 30 days. Each evaluation had 24 consecutive hours, beginning and ending at 8:00 h on days without rains. It was performed through visual evaluations of the 24 animals (two testers per paddock), at ten-minute intervals with a stopwatch, following the methodology of Jamieson and Hodgson (1979). All testers were monitored, and grazing time, rumination, idleness, and trough (supplement intake) recorded. Six evaluators performed the evaluations in 8-h shifts. The observers followed the herd at a distance, ensuring that the animal behaved undisturbed. Flashlights were used at night to observe the animals.

Three evaluations of each animal were performed in the morning and three in the afternoon for daily displacement and intake pattern. The time for the animal to perform 20 bites was measured as a reference for estimating the daily bite rate, following the methodology of Hodgson (1982). Rumination time per bolus was evaluated following the methodology of Johnson and Combs (1991), counting the number of chewings per ruminal bolus. Also, the time and number of steps in ten feeding stations were recorded to estimate the number of daily stations and time per feeding station. A feeding station was defined as a half-cylinder shape available in front of and on each side of the animal when its feet are stationary (Ruyle and Dwyer, 1985), while the footstep was defined as each movement of the forelegs.

2.7. Statistical analysis

Statistical analyses were performed within each season of the year. The data were subjected to variance analysis through the GLIMMIX procedure of SAS (Statistical Analysis System, 2013) with the best data distribution adjustment. Gaussian, gamma, and beta ($0<x<1$ data) distributions were tested. The animal was added to the mathematical model for animal behavior and performance analyses as a random effect. For adjusting the variance and covariance matrix that best fitted the data, we used the corrected Akaike value (Littell et al., 1998). The animal effect was removed from the general mathematical model for analyses of pasture data and total animal production:

$$Y_{ijk} = \mu + I_i + S_j + A_k + (I \times S)_{ij} + \varepsilon_{ijk},$$

in which S = supplementation; I = irrigation; A = animal; and ε_{ijk} = experimental error. Means were compared by the F-test. In case of significant effect of the irrigation × supplement interaction, the means were compared by the Tukey-Kramer test. The critical level of probability of error considered for the data was 10% (P = 0.10). The statistical package SAS® OnDemand was used for data analysis.

3. Results

3.1. Productive characteristics of the pasture

Irrigation provided pastures with better nutritional conditions for the animals (Table 3). During winter, the pastures presented higher ash (9.2 vs. 8.7%) and CP (24.0 vs. 22.3%) contents and lower NDF (61.3 vs. 64.0%) contents compared with the non-irrigated pastures. In spring, the irrigated pastures presented higher ash (7.4 vs. 6.9%) and CP (23.8 vs. 22.9%) contents, and lower NDF (65.4 vs. 68.7%) and ADF (25.9 vs. 28.7%) levels. There was no irrigation effect for summer. Supplementation level of did not influence the quality of pasture for any season.

Treatments did not influence average height, FM, and leaf:stem ratio (Table 4), evidencing the similar management of pastures. In winter, the daily accumulation rate was 44.64% higher for the irrigated system (84.6 vs. 45.9 kg/ha/day).

Table 3 - Chemical composition of African Bermudagrass pasture overseeded in winter, with and without irrigation, grazed by supplemented beef cattle

Variable (%DM)	Management system				SEM	P-value[1]		
	Non-irrigated		Irrigated					
	Supplement (g/kg BW)							
	1	2.7	1	2.7		I	S	I×S
				Winter				
DM (%)	24.9	25.5	24.7	24.8	0.3	0.240	0.313	0.469
Ash	8.8	8.6	9.5	9.0	0.1	0.006	0.095	0.446
CP	22.8	21.9	23.5	24.6	0.9	0.019	0.986	0.342
NDF	63.8	64.3	60.7	62.0	0.7	0.009	0.301	0.629
ADF	27.3	29.4	27.6	27.9	0.7	0.415	0.158	0.278
				Spring				
DM (%)	27.1	27.0	26.0	25.7	0.3	0.003	0.520	0.789
Ash	6.8	7.1	7.3	7.5	0.1	0.018	0.144	0.850
CP	22.8	23.0	23.4	24.3	0.9	0.042	0.583	0.716
NDF	68.3	69.0	64.9	65.8	0.5	0.003	0.203	0.874
ADF	28.2	29.3	25.6	26.2	0.5	0.007	0.137	0.720
				Summer				
DM (%)	26.3	26.6	26.6	26.3	0.5	0.944	0.992	0.540
Ash	6.9	7.1	6.9	6.8	0.1	0.398	0.945	0.429
CP	22.6	22.6	21.2	21.5	0.4	0.129	0.733	0.745
NDF	69.8	68.9	68.8	68.7	1.1	0.607	0.696	0.756
ADF	29.4	29.0	27.8	30.7	0.9	0.997	0.237	0.095

BW - body weight; DM - dry matter; CP - crude protein; NDF - neutral detergent fiber; ADF - acid detergent fiber; SEM - standard error of the mean.
[1] P-value for irrigation effects (I), supplementation (S), and the interaction between them (I×S).

Table 4 - Average height, forage mass (FM), leaf:stem ratio (L:S), and daily accumulation rate (DAR) of African Bermudagrass pasture overseeded in winter, with and without irrigation, grazed by supplemented beef cattle

Variable	Management system				SEM	P-value[1]		
	Non-irrigated		Irrigated					
	Supplement (g/kg BW)							
	1	2.7	1	2.7		I	S	I×S
				Winter				
Height (cm)	17.2	18.6	19.3	21.3	1.7	0.195	0.340	0.863
FM (kg DM/ha)	1,666	1,733	1,604	1,425	154.5	0.263	0.724	0.452
L:S	1.02	1.11	0.89	0.97	0.14	0.371	0.579	0.947
DAR (kg DM/ha)	47.7	44.1	77.5	91.8	11.5	0.010	0.656	0.464
				Spring				
Height (cm)	15.4	15.8	14.0	14.9	0.7	0.141	0.381	0.740
FM (kg DM/ha)	2,032	2,298	2,276	2,555	244.2	0.335	0.296	0.978
L:S	0.54	0.53	0.54	0.54	0.02	0.935	0.856	0.798
DAR (kg DM/ha)	84.4	90.7	98.3	91.4	9.6	0.467	0.974	0.510
				Summer				
Height (cm)	21.9	22.9	20.9	22.3	1.1	0.497	0.339	0.833
FM (kg DM/ha)	3,568	3,919	4,273	3,787	289.8	0.352	0.820	0.186
L:S	0.42	0.39	0.36	0.40	0.02	0.335	0.776	0.126
DAR (kg DM/ha)	96.4	115.9	114.5	119.1	11.3	0.375	0.316	0.530

BW - body weight; SEM - standard error of the mean.
[1] P-value for irrigation effects (I), supplementation (S), and the interaction between them (I×S).

3.2. Animal production

Individual ADG was not influenced by irrigation or supplementation (P>0.10) (Table 5). The highest supplementation level (2.7 g/kg) provided a higher SR in winter (1,652 vs. 1,435 kg/ha), spring (3,096 vs. 2,811 kg/ha), and in the total period of experiment (2,828 vs. 3,193 kg/ha). Supplementation level showed no difference for summer. The SR increase in the supplementation with 2.7 g/kg provided higher BWG for spring (617.8 vs. 554.9 kg/ha) and total of the entire evaluated period (1,746 vs. 1,579 kg/ha).

Table 5 - Average daily gain (ADG), stocking rate (SR), and body weight gain per hectare (BWG) of supplemented beef cattle on African Bermudagrass pasture overseeded in winter, with and without irrigation

Variable	Management system				SEM	P-value[1]		
	Non-irrigated		Irrigated					
	Supplement (g/kg BW)							
	1	2.7	1	2.7		I	S	I×S
				Winter				
ADG (kg/day)	1.42	1.43	1.51	1.37	0.05	0.770	0.305	0.227
SR (kg/ha)	1,265	1,506	1,605	1,799	88.2	0.024	0.093	0.838
BWG (kg/ha)	449.9	531.7	630.4	620.2	30.6	0.008	0.382	0.269
				Spring				
ADG (kg/day)	0.905	0.872	0.723	0.828	0.08	0.285	0.333	0.589
SR (kg/ha)	2,666	3,103	2,957	3,090	76.7	0.110	0.045	0.188
BWG (kg/ha)	587.6	620.3	522.2	615.4	29.7	0.193	0.047	0.336
				Summer				
ADG (kg/day)	0.678	0.706	0.704	0.784	0.03	0.235	0.224	0.551
SR (kg/ha)	4,316	4,566	4,164	4,892	270.0	0.957	0.123	0.899
BWG (kg/ha)	463.8	502.5	504.9	603.5	37.2	0.097	0.282	0.755
				Experimental period of 249 days				
ADG (kg/day)	1.001	1.003	0.956	0.995	0.2	0.354	0.473	0.502
SR (kg/ha)	2,749	3,125	2,908	3,261	111.0	0.153	0.019	0.584
BWG (kg/ha)	1,501	1,654	1,657	1,839	76.2	0.144	0.031	0.604

BW - body weight; SEM - standard error of the mean.
[1] P-value for irrigation effects (I), supplementation (S), and the interaction between them (I×S).

The SR in winter was 18.5% higher (P<0.10) for irrigation (1,702 vs. 1,385 kg/ha). Irrigation showed a positive response for gain per area (P<0.10) of 21% in winter (625.3 vs. 490.8 kg/ha) and 13% in summer (554.2 vs. 483.1 kg/ha). There was no difference in SR and BWG for irrigation in spring.

3.3. Displacement pattern and ingestive behavior

Grazing time was longer (+9.3%) in summer for animals supplemented with 1 g/kg compared with those supplemented with 2.7 g/kg (Table 6). Neither irrigation nor supplementation influenced other activities (P>0.10) throughout the experiment. Supplementation level was not influenced through time, even when the offered daily quantity was increased as the animals' live weight increased.

Irrigation provided a higher (P<0.10) number of daily bites (17,653 vs. 26,354 bites) and number of steps (6,229 vs. 4,814) in winter (Table 7). In summer, the number of daily chewings (22,035 vs.

Table 6 - Ingestive behavior of supplemented beef cattle on African Bermudagrass pasture overseeded in winter, with and without irrigation

Variable (min)	Management system				SEM	P-value[1]		
	Non-irrigated		Irrigated					
	Supplement (g/kg BW)							
	1	2.7	1	2.7		I	S	I×S
				Winter				
Grazing	581.6	552.5	633.3	549.1	36.3	0.546	0.161	0.488
Rumination	397.5	412.5	392.5	483.3	34.5	0.400	0.173	0.327
Idleness	446.7	457.5	395.8	390	36.8	0.146	0.959	0.829
Trough	14.1	17.5	18.3	17.5	2.3	0.388	0.576	0.388
				Spring				
Grazing	548.7	542	557	551	30.4	0.849	0.775	0.986
Rumination	391.2	460	384	426.6	31.5	0.554	0.100	0.729
Idleness	482.5	422.5	484	443.3	28.2	0.670	0.081	0.708
Trough	17.5	15	15	18.3	2.0	0.854	0.853	0.174
				Summer				
Grazing	516.6ab	504.1ab	532.5a	448.3b	24.6	0.227	0.050	0.065
Rumination	391	393	415	461	27.3	0.110	0.418	0.455
Idleness	518.3	515	475.8	513.3	31.8	0.434	0.633	0.464
Trough	13.3	18	15.8	16.6	2.2	0.787	0.202	0.352

BW - body weight; SEM - standard error of the mean.
[1] P-value for irrigation effects (I), supplementation (S), and the interaction between them (I×S).
Means followed by different letters, regarding I×S interaction, differ from each other by the Tukey-Kramer test ($P \leq 0.10$).

Table 7 - Daily displacement and intake pattern of supplemented beef cattle on African Bermudagrass pasture overseeded in winter, with and without irrigation

Variable (n/day)	Management system				SEM	P-value[1]		
	Non-irrigated		Irrigated					
	Supplement (g/kg BW)							
	1	2.7	1	2.7		I	S	I×S
				Winter				
Stations	4,434	4,023	4,279	3,641	433.0	0.551	0.252	0.801
Steps	5,962	6,496	5,237	4,391	769.0	0.098	0.754	0.374
Bites	17,066	18,240	29,748	22,960	2,253	0.005	0.375	0.151
Chewings	24,648	26,238	23,380	30,915	2,577	0.586	0.119	0.301
Boli	682	538	581	644	71.0	0.935	0.583	0.183
				Spring				
Stations	3,276	4,365	3,596	3,060	403.0	0.364	0.549	0.112
Steps	4,170	5,572	4,928	4,241	562.0	0.829	0.622	0.176
Bites	24,791	28,100	23,495	22,294	2,041	0.093	0.650	0.282
Chewings	22,675	26,847	21,510	25,209	2,251	0.556	0.109	0.958
Boli	563	590	570	599	57.0	0.891	0.644	0.975
				Summer				
Stations	5,130ab	4,702b	6,591a	4,412b	206.0	0.510	0.001	0.003
Steps	3,666ab	3,636ab	4,558a	2,735b	299.0	0.988	0.004	0.005
Bites	17,985b	22,817ab	29,401a	21,268b	1,341	0.001	0.472	0.001
Chewings	21,841	22,230	25,146	29,358	1,628	0.004	0.206	0.311
Boli	586	531	567	626	48.0	0.439	0.991	0.252

BW - body weight; SEM - standard error of the mean.
[1] P-value for irrigation effects (I), supplementation (S), and the interaction between them (I×S).
Means followed by different letters, regarding I×S interaction, differ from each other by the Tukey-Kramer test ($P \leq 0.10$).

27,252) showed better results for the irrigated areas. There was interaction in summer between irrigation and supplementation level for the number of stations, steps per station, and bites. Animals that received 1 g/kg visited more stations, presented more steps per station, and had higher bite rate than those that received 2.7 g/kg on irrigated pasture. However, when the pasture was not irrigated, the supplement level did not affect the animal's ingestive behavior.

4. Discussion

4.1. Winter period

The higher SR for supplemented animals was insufficient to increase the gains per area. This is a consequence of the positive response of irrigation that provided similar results between the supplementation levels for irrigated pasture, i.e., in a pasture with available mass, high CP, and lower fiber contents than tropical pastures, 1.0 or 2.7 g/kg BW of supplement have no difference on animal performance. In the present study, forage intake was not determined. However, differing from protein supplements, the energy supplements do not stimulate any increase in forage intake (Machado et al., 2019). The difference observed in SR probably resulted from the substitution of supplement intake for pasture (Stockdale, 2000).

The lack of response for animal performance, both individually and per area, to the increase in the supplement level is due to the pasture quality this season. According to Reis et al. (2009), the nutritional value of the pasture is essential for deciding the quantity and quality of supplement that will be provided. Lima et al. (2012) reported that high quality of ingested forage reduces the effect of supplementation levels on individual animal performance. In addition to quality, the FM in all treatments was satisfactory (above 1425 kg/ha). Lippke et al. (2000) reported performance limitation for FM below 850 kg DM/ha. The high quality and forage supply provided by the overseeding of temperate species in tropical pastures is a viable alternative for intensive cattle production (Leanne Dillard et al., 2018), and resulted in high weight gain, in our study, for animals of this category on pasture (1.43 kg/day) during winter.

Irrigation helps to reduce the effects of water stress, providing water that helps to potentiate the maintenance of tissue turgor. This is important for photosynthesis as it accelerates plant growth, providing more tillers per area and greater leaf size, which results in better forage quality (Floss, 2006). This confirms what occurred in the present study. The irrigated pastures presented a higher biomass production of temperate species in winter and better quality (Table 3), especially regarding protein and fiber contents (high CP and low NDF) and higher accumulation rate (Table 4). It increased SR (18.5%) and BWG (21.5%) of irrigated pasture.

Bite rate and total number of bites depend on characteristics inherent to the structure and quality of forage, leading to greater ease or difficulty in which the animal prehend the forage (Trevisan et al., 2004). Irrigated pastures showed a higher accumulation rate and protein content, with low fibrous content, which may have contributed to the greater number of steps between stations and a greater number of bites. According to Venturini et al. (2018), high accumulation rates lead to high regrowth rates and new leaves, where the animal achieves good selectivity. Caram et al. (2021) mentioned that by controlling forage allowance, FM, and pasture height, animals prioritize quality in the morning and quantity in the afternoon, integrating and changing the grazing-demand pattern.

4.2. Spring/summer period

The substitution effect occurs when the animal decreases the forage intake to feed on concentrate (Klein et al., 2015). Although the forage intake was not measured in the present study, the increase in SR in the pasture with supplemented animals, with 2.7 g/kg BW, suggests the substitution of concentrate feed for pasture since the growth rate of pasture was similar. The difference in SR reflected the higher BWG (+10.4%) in this treatment. Although there was no significant interaction, it was observed that the greatest effect of supplementation on SR was in non-irrigated treatments (11.0 against 2.7% increase). That was where the pasture presented higher fiber content but did not affect the animals' individual performance.

With the increase in rainfall (Figure 1) from spring onwards, the benefit of irrigation on forage production was nullified. However, the irrigated pastures showed better quality in spring, probably due to previous management (winter), and greater persistence of ryegrass due to the irrigation in winter that extended the vegetative cycle. This effect was not observed during summer, which only had African bermudagrass pasture. Nevertheless, this improvement was insufficient to express differences in the animals' performance.

The present study was evaluated for 249 days. The irrigation effect varies greatly depending on periods and years. However, its need has become increasingly significant, especially in regions with undefined drought periods. On these occasions, irrigation is necessary and benefits the system, directly and indirectly, acting both in the period of water restriction and in subsequent periods (Vogeler et al., 2016).

With the good volume of rainfall during summer, the irrigation did not change the productive characteristics of the forage, individual performance, and SR. However, there was a higher BWG because of the association between SR and ADG, as both presented small numerical advantages for irrigated pastures, showing that the effect of irrigation in previous periods allows a better pasture structure, even with similar productivity characteristics (Farias Filho et al., 2018).

The longest rumination times and shortest idle times in spring for animals supplemented with 2.7 g/kg (Table 6) prove that the supplementation level changes the animals' ingestive behavior. Animals supplemented with protein tend to increase forage intake by better degradation efficiency and synchronization between protein and energy available in the rumen (Machado et al., 2019). For this reason, they spend more time ruminating and less in idleness. The shorter grazing time in summer for animals with a higher supplement level on irrigated pasture is a direct response to the supplement intake that met the nutrient demand of animals, and less time was required to search for food.

4.3. Total period (249 days)

In the total experimental period, no effect of irrigation was observed, but the BWG was +171 kg/ha higher for irrigation. In more intensive production systems, irrigation assists in specific moments of water deficit and allows greater control of animal production by reducing the oscillation in biomass yield. It indirectly benefits the production system with a smaller use of dietary supplementation, reducing costs over the years (Vogeler et al., 2016).

Supplementation of 2.7 g/kg BW provided BWG of +201.9 kg/ha in the entire experiment compared with a lower supplementation. It was observed that the amount of supplement was not enough to change the animals' individual gain. That is a consequence of the supply and quality of forage, but it is an interesting tool to increase the carrying capacity of the pasture. Tambara et al. (2021) observed that in tropical pastures, the maximum gains per area occur with energy supplementation above 10 g/kg BW and protein of 5 g/kg BW, i.e., even with the low supplementation level in the present study, it is possible to intensify the system. Although the interaction between irrigation and supplementation was insignificant, the BWG with both technologies was +338 kg/ha.

5. Conclusions

Irrigation in winter African bermudagrass pasture overseeded with oat and ryegrass increases accumulation rate forage and, consequently, animal production. Supplementation up to 2.7 g/kg BW increases stocking rate with a direct influence on weight gain per area without any change in average daily gain, with a more significant effect in spring.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

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