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Production, quality of Paiaguas palisadegrass and cattle performance after sorghum intercropping in pasture recovery in an integrated crop-livestock system

Charles Barbosa Santos[1], Kátia Aparecida de Pinho Costa[2*], Wender Ferreira de Souza[2], Victor Costa e Silva[2], Eduardo Valcácer Brandstetter[2], Suelen Soares Oliveira[2], Karen Martins Leão[2], Eduardo da Costa Severiano[2]

[1]University of Rio Verde, Department of Agronomy, Rio Verde, GO - Brazil
[2]Graduate Program in Agricultural Sciences/Agronomy and Animal Science - Goiano Federal Institute, Rio Verde, Goias, Brazil. CNPq Research Productivity Fellow, Rio Verde, GO - Brazil

***Corresponding author: katia.costa@ifgoiano.edu.br**

Abstract

To improve the conditions of livestock areas, integrated crop-livestock systems have proven to be a viable and sustainable alternative for pasture recovery. The objective of this study was to evaluate the production, quality of Paiaguas palisadegrass and cattle performance after intercropping with sorghum in the pasture recovery through an integrated crop-livestock system. The experiment was conducted in an experimental design in a randomized block design with four replicates in a 4 x 4 factorial scheme, with four forage systems: Paiaguas palisadegrass in monocropped, sorghum intercropped with Paiaguas palisadegrass in rows, sorghum intercropped with Paiaguas palisadegrass in interrow, and sorghum intercropped with oversown Paiaguas palisadegrass, evaluated in four seasons of the year (winter, spring, summer, and fall).The forage system did not influence the DM production, nutritive value, stocking rate and weight gain, being that all forms of sowing can be indicated due to the good development of Paiaguas palisadegrass after the sorghum harvest, showing several alternatives for implantation of the crops in intercropping. The summer and fall seasons provided higher forage availability and nutritive value, resulting in greater weight gain and better performance per animal per area. Paiaguas palisadegrass has good potential in pasture formation, recovery, and/or renewal, showing resistance to the dry period of the year (winter and fall).

Keywords: Animal weight gain; *Brachiaria brizantha;* integrated systems; season of the year; sustainability.

Introduction

Pasture areas occupy approximately 20% of Brazil, constituting the largest land-use and cover class. As most of the Brazilian cattle herd is fed on pasture, the pasture areas are relevant to the country's livestock activity. The degradation of pastures is the major problem faced by the Brazilian livestock production. This situation has generated concern because pastures are the basis of the cattle diet. These areas experience reduced carrying capacity and lower animal production, which results in great economic and environmental damage (Euclides et al., 2019).

Integrated crop-livestock systems have helped reduce these degraded areas and promoted pasture recovery in a more economical manner. These systems have been used in Brazil since the 1980s, with positive results. Vincent-Caboud et al. (2019), and Soares et al. (2019) reported that these systems promote use efficiency of these degraded areas and generating benefits to the environment, such as greater carbon sequestration by the root system of forages, greater soil organic matter and animal welfare. For those reasons, the adoption of these systems is growing in Brazil, as they are one of the most sustainable, viable, and competitive technologies that can leverage Brazilian agribusiness (Dias et al., 2020).

Thus, intercropping systems provide increased forage availability or silage production (Souza et al., 2019; Oliveira et al., 2020b; Santos et al., 2020) in the dry season, with sufficient quality for the nutritional maintenance of herds, promoting higher animal weight gain.

Forages of the *Brachiaria* genus are the most used in crop-livestock integration systems. Among them, we highlight the Paiaguas palisadegrass, which was created to meet the requirements of different production systems, thus has high biomass accumulation in the dry seasons (Epifanio et al. 2019), with positive results in intercropping with annual crops in integrated production systems (Costa et al., 2016; Santos et al., 2016; Guarnieri et al., 2019; Oliveira et al., 2020b).

Little is known about the potential of Paiaguas palisadegrass to be used for animal performance after intercropping with sorghum. Identifying the best way to sow these crops simultaneously will provide information on the crop intercropping.

The examined hypothesis was that Paiaguas palisadegrass can be implanted in different forms of sowing with sorghum for the recovery and formation of pastures in integrated systems. The objective of this study was to evaluate the production and quality of Paiaguas palisadegrass and cattle performance after intercropping with sorghum in the pasture recovery through an integrated crop-livestock system.

Results

The values of dry matter (DM) and leaf:stem ratio of Paiaguas palisadegrass were not significant ($p>0.005$) for the different forage systems. On the other hand, the forage accumulation rate was influenced by the forage system. Season had a significant effect ($p<0.005$) on all variables (Table 1). The highest DM production was obtained in the spring, differing ($p<0.005$) from the other seasons, which showed similar results to each other (Table 1). The leaf:stem ratio showed a higher proportion of leaves in the summer ($p<0.005$).

The forage accumulation rate was higher when the Paiaguas palisadegrass was intercropped with sorghum in the interrow ($p<0.005$), followed by intercropping in the row and intercropping with oversown Paiaguas palisadegrass (Table 1). Among the seasons, the lowest forage accumulation rate was obtained in winter and fall, followed by summer and spring (Table 1).

When evaluating forage quality, it was observed that the crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), *in vitro* dry matter digestibility (IVDMD) and total digestible nutrients (TDN) levels were not influenced by the forage system ($p>0.005$) (Table 2), but there was a seasonal influence on the variables.

The highest CP and lowest NDF and ADF were observed in the summer and fall, differing from spring and winter (Table 2). The highest IVDMD value was obtained in the summer, followed by fall, spring, and winter. Fall was the season with the highest TDN, differing from the other seasons (Table 2).

The phosphorus concentration did not show a significant difference ($p>0.005$) between the forage systems, unlike potassium, which was affected ($p<0.005$) by the system. A significant difference ($p<0.005$) was also observed in the phosphorus and potassium concentrations between seasons (Table 3).

Analysing the potassium concentration, the Paiaguas palisadegrass in monocropped had a higher concentration than the other forage systems. Analysing by season, the highest value was obtained in the fall. Phosphorus was highest in the summer and fall and the lowest in the spring and winter (Table 3).

The stocking rate, average daily gain, and live weight/area of the animals did not significantly differ ($p>0.005$) between the forage systems. However, there was a significant effect ($p<0.005$) of season (Table 4). Fall had a 49% higher average daily gain than winter (Table 4). Winter also had a lower stocking rate, 39% less than the average of the spring, summer, and fall seasons. For the gain per area, there was a significant difference ($p<0.005$) only between the fall and winter, which had the lowest value.

The correlation analysis showed that there was a significant correlation ($p<0.001$) between the total DM production, the average daily gain, and the gain per area. The forage quality was directly reflected in the average daily gain of the animals and weight gain per area. In this sense, the CP, IVDMD, and TDN levels of forage were positively correlated with animal performance (Table 5).

The fibre fractions NDF and ADF were negatively correlated with the performance of the animals, i.e., as the fibre content decreased the average daily gain and live weight/area increased.

Discussion

The higher DM production of Paiaguas palisadegrass in the spring (Table 1) is due to the longer interval between the harvesting of the sorghum crop and the entry of the animals, providing greater forage development due to its vigorous and rapid regrowth capacity (Epifanio et al. 2019), even in periods of low rainfall and temperature (Figure 1). These traits put it among the most suitable forages for integrated crop–livestock systems (Costa et al. 2016; Santos et al. 2016; Guarnieri et al. 2019; Muniz et al. 2021).

Even in fall and winter, Paiaguas palisadegrass produced enough forage to feed the animals, with an average of 2979 kg ha^{-1}. It is noteworthy that this was possible in first-year pastures in an integrated crop-livestock system, where the forage plant used soil nutrients from the annual crop fertilization residues (Dias et al. 2021). This increased the nourishment of the forage and promoted its growth potential, even in periods of low rainfall.

The higher leaf:stem ratio in the spring and summer can be explained by the greater amount of rainfall that occurred in both seasons (Table 1). On the other hand, in the periods of low water availability, the leaf:stem ratio was lower. These results corroborate those found by Lemos et al. (2014), who emphasize that tropical grasses decrease leaf production and increase stem elongation under low water availability.

Evaluating the weight gain of heifers and the productivity of Paiaguas palisadegrass and Piata palisadegrass, Euclides et al. (2016) observed a leaf:stem ratio of 1.48, a result that was similar to that observed in the present study in the spring season.

The leaf:stem ratio is highly important to the nutrition of ruminants and is associated with the ease of feeding on the most nutritious parts of the forage plant (Epifanio et al. 2019). In pastures under continuous stocking, the leaf:stem ratio may become an important indicator of the ease of forage prehension by the animal, as the amount of dead matter can hinder the access of the animal to green leaves, which would limit the forage intake.

In addition, the greater amount of stalks and dead material will directly affect the canopy structure, the forage intake, and consequently the animal performance (Difante et al. 2009). Our data show that Paiaguas palisadegrass during the rainy season showed a canopy structure that favoured grazing by the animals.

The higher leaf accumulation rate obtained when sorghum was intercropped with Paiaguas palisadegrass (Table 1) was due to the lower interference of sorghum on the grass development, since the forage was sown in the interrow at 0.25 m from the sorghum, decreasing competition for water, light, nutrients, and physical space. This form of sowing has been one of the most used in a intercropped between annual and tropical forage crops, due to less competition between crops (Santos et al. 2020).

The rainfall during the summer (Figure 1) contributed to the better development of the forage and, consequently, to a greater amount of leaves (Table 1). Thus, there was an increase in CP in this period (Table 2).

The levels of CP in all forage systems (Table 2) met the protein requirements of the heifers (CP content is equal to or higher than 70 g kg^{-1}, Van Soest, 1994) without compromising their performance. This reveals the importance of integrated crop–livestock systems in providing quality forage during the off-season, a period in which there is usually low forage quality due to seasonal production.

The lower levels of NDF and ADF in the summer and fall (Table 2) were due to the higher rainfall in those seasons (Figure 1), favouring the greater production of Paiaguas palisadegrass (Table 1) and improving the supply of forage and stocking rate. These outcomes favour higher animal consumption since the fibre fractions have negative correlations with intake and digestibility (Epifanio et al. 2019). Moreover, in these same seasons, the animal stocking rate was high, i.e., grazing controlled stem growth. This favours the structural components of the pasture, directly influencing the reduction in NDF and ADF, thus affecting the forage nutritional value.

The above characteristics make Paiaguas palisadegrass an excellent alternative for use in an integrated crop-livestock system to provide a high quantity and quality of food during the off-season.

The highest levels of NDF and ADF obtained in the winter months (Table 2) were due to the reduction in tillering and the higher proportion of stalks in this period due to the low temperatures and short days (Figure 1), which are directly reflected in the lower proportion of leaves, which increased the fibre fractions, making a large part of the CP inaccessible to rumen microorganisms (Oliveira et al., 2020a).

The increase observed in IVDMD during the summer is associated with changes in chemical composition, such as lower NDF and ADF levels. This certainly increased the availability of readily digestible carbohydrates to rumen microorganisms. Furthermore, these values might have been influenced by the higher rainfall and temperature (Figure 1), resulting in a higher leaf:stem ratio and higher-quality forage (Table 1).

It is also worth noting that the control of stem elongation by grazing is an efficient method to ensure a good canopy structure and avoid loss of material and accumulation of dead leaves, all of which lead to higher nutritional value (Anjos et al. 2016).

TDN levels ranged from 523 to 533 g kg^{-1} DM, which are close to the values proposed by Van Soest (1994) of approximately 555 g kg^{-1} DM for most tropical grasses. This parameter can vary according to the climatic conditions, soil, and plant cutting age. TDN is an essential variable because energy and protein are usually the most limiting factors for ruminant growth.

Knowledge of the mineral requirements (nitrogen, phosphorus, and potassium) of forage plants is key to pasture management because they affect the production and quality of the pasture to be supplied to the animals (Detmann et al. 2014). According to Darch et al. (2020) minerals are essential elements in the diets of livestock, which regulate metabolic processes and provide cellular structure. In addition, the supply of minerals through the availability of forage decreases the cost of feed for the animals.

The highest concentrations of potassium were obtained in Paiaguas palisadegrass in monocropped, followed by the interrow and oversown system (Table 3), which may be related to the lower competition in these sowing systems, where forages do not compete in the same row for water and nutrients, providing better forage development conditions.

Higher rainfall during the summer (Figure 1) contributed to higher phosphorus and potassium concentrations (Table 3). This is explained by the fact that moisture favours the absorption of nutrients by Paiaguas palisadegrass. Considering that phosphorus has low soil mobility, moisture facilitates its transport into the root system of the forage plant. This is due to the effect of phosphorus on root growth and the tillering of grasses, because phosphate fertilization is responsible for 80% of the tillering of forage species when combined with efficient pasture management (Euclides et al. 2019). In addition, this grass has a high potential for response to nitrogen fertilization (Epifanio et al. 2019).

The amounts of nitrogen, phosphorus, and potassium available in the soil after intercropping with the annual crop are of great importance, especially in intensive grazing systems, where these nutrients are deficient. One of the great advantages of integrated systems and the use of soil nutrients for pasture after harvesting the annual crop is that such a system promotes the recovery of degraded pastures, where fertilization accounts for the highest cost (Euclides et al. 2019).

The phosphorus concentrations required for beef cattle can range from 0.5 to 2.5 g kg^{-1} (NRC, 2001). Thus, Paiaguas palisadegrass had adequate concentrations of nnitrogen and phosphorus within each season, so the animals did not need to be supplemented with these nutrients, generating greater savings for the producer.

The forage growth influences the pasture carrying capacity throughout the year, which affects the stocking rate. Thus, the highest stocking rates were observed in seasons with higher grass growth (spring, summer, and fall) due to the better climatic conditions (Table 4). The stocking rate was high throughout the experiment with grazing animals. Thus, the carrying capacity was higher in pastures formed under an integrated crop–livestock system, showing the advantages of this system. In real Brazilian livestock production conditions, the stocking rate is usually less than 1 AU ha^{-1} (animal unit), compromising animal performance indices.

The forage systems did not influence the average daily gain of the animals (Table 4), showing that any form of sowing favours the recovery of degraded pasture. Notably, in all seasons, the DM availability remained above 4197 kg ha^{-1} (Table 1). Even during the dry season, the availability of forage seems not to have limited animal consumption. This demonstrates the potential of Paiaguas palisadegrass to produce forage, even under conditions of low rainfall and a high stocking rate throughout the year.

Fall was the most favourable season for the average daily gain of animals (Table 4). This response may be associated with topdressing fertilization that occurred at the end of December and later contributed to better forage development in the fall. On the other hand, in the winter season there was a reduction in the stocking rate and average daily gain of the animals due to the influence of the climatic season, affecting the development of forage. Furthermore, lower leaf herbage mass, leaf blade proportion, leaf removal and forage nitrogen concentration reduce animal performance in period of reduced precipitation (Oliveira et al. 2019). Evaluating the average daily gain of grazing animals with Paiaguas palisadegrass, Euclides et al. (2016) found that a higher weight gain per animal was obtained in the rainy season than the dry season, corroborating the results obtained in this study.

The pastures in integrated crop-livestock systems have advantageous characteristics over conventional pastures, such as higher forage DM availability in the dry season, which explains the improvement in animal performance in this period.

Table 1. Dry matter (DM), leaf:stem ratio and forage accumulation rate (FAR) of Paiaguas palisadegrass in different forage systems and seasons.

Forage systems	DM kg ha^{-1}	Leaf:stem ratio	FAR kg ha^{-1}
Paiaguas in monocropped	4,795	0.82	473.46 c
Sorghum x Paiaguas in the row	4,573	1.02	701.00 a
Sorghum x Paiaguas in the interrow	4,187	1.06	575.68 b
Sorghum x Paiaguas in the oversown	4,236	0.90	570.21 b
S.E.M[a].	0.10	0.02	10.1
P-value	0.326	0.144	0.004
Seasons			
Spring	7,348 a	1.58 a	590.75 a
Summer	3,484 b	1.25 a	401.75 b
Fall	3,009 c	0.66 b	200.83 c
Winter	2,950 c	0.62 b	207.00 c
S.E.M[a].	0.10	0.02	10.1
P-value	0.020	<0.001	<0.001

Means followed by the same letter do not differ by Tukey's test at 5% probability. [a]Standard error of the mean.

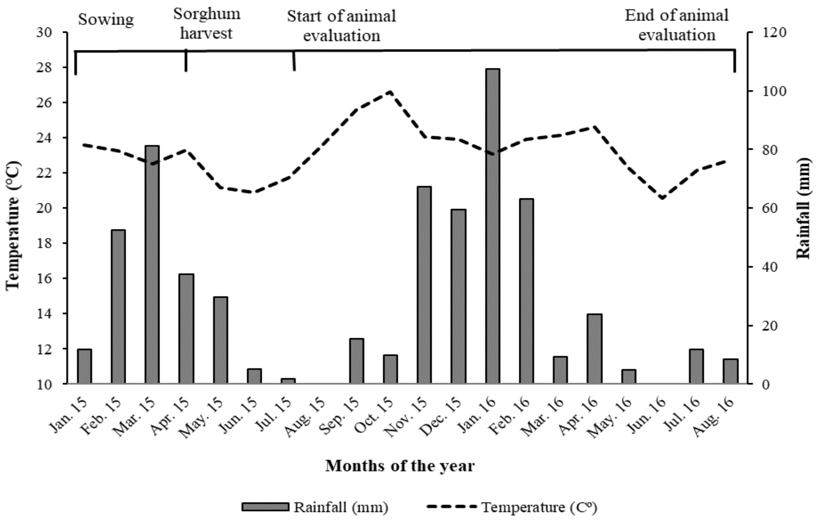

Figure 1. Monthly rainfall and mean daily temperatures recorded from January 2015 to August 2016 in Rio Verde, Goias.

Table 2. Crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), *in vitro* dry matter digestibility (IVDMD), and total digestive nutrient (TDN) of Paiaguas palisadegrass in different forage systems and seasons.

Forage systems	CP	NDF	ADF	IVDMD	TDN
			g kg^{-1} of DM*		
Paiaguas in monocropped	77.1	762.6	449.2	541.1	533.3
Sorghum x Paiaguas in the row	76.4	777.3	461.9	536.6	523.3
Sorghum x Paiaguas in the interrow	78.5	763.9	460.2	530.6	532.4
Sorghum x Paiaguas in the oversown	75.0	722.4	451.8	533.4	526.6
S.E.M.[a]	1.9	3.3	2.7	3.3	2.4
P-value	0.703	0.067	0.258	0.168	0.131
Seasons					
Spring	58.3 b	775.3 a	458.1 b	513.8 c	517.8 c
Summer	101.8 a	704.9 b	408.9 c	591.0 a	534.4 b
Fall	91.1 a	711.0 b	389.7 c	555.0 b	558.9 a
Winter	55.8 b	780.1 a	476.4 a	481.3 d	504.4 d
S.E.M.[a]	1.9	3.3	2.7	3.3	2.4
P-value	<0.001	<0.001	<0.001	<0.001	<0.001

Means followed by the same letter do not differ by Tukey's test at 5% probability. *DM: dry matter; [a]Standard error of the mean.

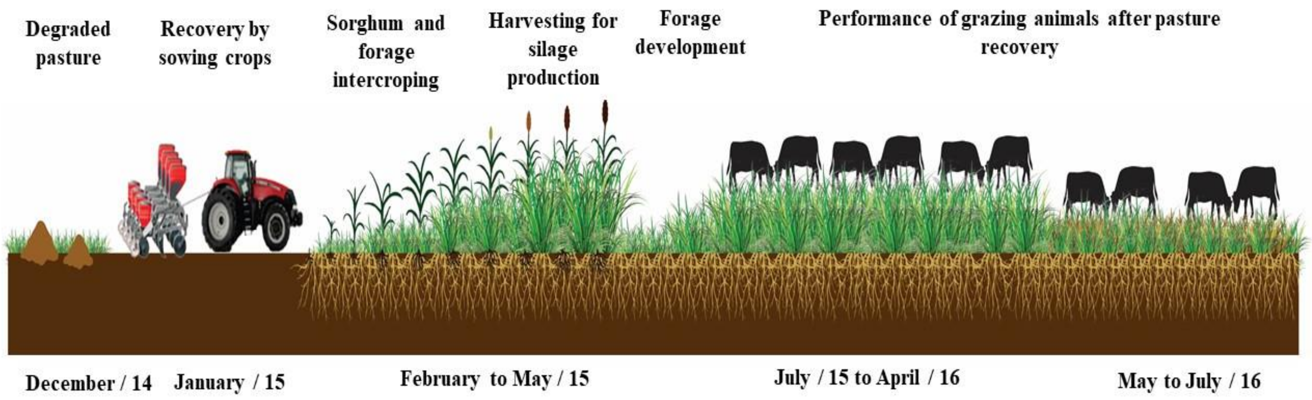

Figure 2. Diagram of forage systems in pasture recovery through intercropping of sorghum with *Paiaguas palisadegrass* in an integrated crop-livestock system, covering all evaluation stages.

Table 3. Concentrations of phosphorus and potassium in the shoot of Paiaguas palisadegrass in different forage systems and seasons.

Forage systems	Phosphorus (g kg^{-1})	Potassium (g kg^{-1})
Paiaguas in monocropped	1.13	19.0 a
Sorghum x Paiaguas in the row	1.17	18.4 b
Sorghum x Paiaguas in the interrow	1.15	17.4 c
Sorghum x Paiaguas in the oversown	1.12	18.1 b
S.E.M.[a]	0.03	0.30
P-value	0.532	0.008
Seasons		
Spring	0.90 b	14.3 d
Summer	1.38 a	19.7 b
Fall	1.40 a	21.4 a
Winter	0.85 b	17.4 c
S.E.M.[a]	0.03	0.30
P-value	<0.001	<0.001

Means followed by the same letter do not differ by Tukey's test at 5% probability.
[a]Standard error of the mean.

Table 4. Stocking rate (SR), average daily gain (ADG), and weight gain per area (G/A) of animals in Paiaguas palisadegrass pasture in different forage systems and seasons.

Forage systems	SR	ADG	G/A
	AU ha^{-1}	kg day^{-1}	kg ha^{-1} year^{-1}
Paiaguas in monocropped	4.18	0.351	87.28
Sorghum x Paiaguas in the row	4.20	0.371	94.39
Sorghum x Paiaguas in the interrow	4.33	0.346	88.02
Sorghum x Paiaguas in the oversown	4.16	0.366	96.24
S.E.M.[a]	0.06	0.02	2.2
P-value	0.159	0.962	0.478
Seasons			
Spring	4.09 a	0.364 ab	99.60 a
Summer	4.50 a	0.344 ab	98.07 ab
Fall	4.87 a	0.483 a	103.6 a
Winter	3.21 b	0.242 b	75.95 b
S.E.M.[a]	0.06	0.02	2.2
P-value	<0.001	0.026	<0.001

Means followed by the same letter do not differ by Tukey's test at 5% probability (p<0.05).
[a]Standard error of the mean.

Table 5. Correlation of the variables average daily gain (ADG) and weight gain per area (G/A) with dry matter (DM), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), *in vitro* dry matter digestibility (IVDMD), and total digestive nutrient (TDN).

Correlation	ADG	G/A
DM	0.038	0.020
CP	0.495**	0.51**
NDF	-0.599 **	-0.63**
ADF	-0.603**	-0.67**
IVDMD	0.442**	0.51**
TDN	0.600**	0.63**

** Significant at 1% probability and ^{ns} not significant by Pearson's correlation: 0.00 to 0.39 is a weak correlation ( ); 0.40 to 0.69 is a moderate (*) correlation; 0.70 to 1.00 is a strong correlation (**). Adapted from Dancey and Reidy (2006).

Table 6. Chemical and physical characteristics of the soil before the implementation of the experiment.

pH	Ca	Mg	Al	Al + H	K_2O	CEC	V
$CaCl_2$			$cmol_c$ dm^{-3}				%
5.51	2.20	0.91	0,01	3.30	0.09	6.51	49.2
P (Mehlich)	Cu	Zn	Fe	MO	Clay	Silt	Sand
	mg dm^{-3}					g kg^{-1}	
0.34	2.2	0.4	14.4	28.70	500	220	280

CEC: cation exchange capacity

The DM production and pasture quality (CP, IVDMD, and TDN) directly affected the average daily gain and live weight per area, and they were positively correlated with the main animal-performance parameters (Table 5). This fact is probably due to the improved nutritional value and improved nutrient digestion of Paiaguas palisadegrass, which result in increased intake, yielding better performance among animals raised in Paiaguas palisadegrass pastures, even during a period of low forage availability (Muniz et al., 2022).

The negative correlation of NDF and ADF with the parameters average daily gain and live weight per area reinforces the importance of pasture management in integrated crop-livestock systems, such as controlling the elongation of stems, which have low availability of non-fibre carbohydrates required by growing beef cattle.

Some aspects should be considered when adopting integrated systems that aim to optimize productivity per area. Paiaguas palisadegrass showed potential to increase the amount of animal product per area, in addition to maintaining pasture sustainability throughout the year (Figure 2), using the soil nutrients applied to the annual crop. In addition, integrated crop-livestock systems are a promising farming system for silage production (Oliveira et al. 2020b), and after harvesting, pasture is formed at low cost, in a sustainable manner, and over a lower arable area than conventional systems for pasture recovery.

Thus, it is clear that the integrated systems, regardless of the sowing system, have good potential because they ensure an adequate diet for the heifers and enable them to meet their voluntary intake of DM and their protein and mineral requirements.

Materials and methods

Characterization of the area and treatments

The experiment was conducted in the cattle sector of the Goiano Federal Institute, Rio Verde Campus, Goias, in a Dystrophic Red Latosol, at 748 m altitude, 17°48'S and 50º55'W, from January 2015 to August 2016. The history of the previous area was *Brachiaria brizantha* cv. Marandu pasture, implemented more than 30 years ago and in an advanced stage of degradation, due to low forage production, bare soil and high infestation of weeds and termites.

Before the implementation of the experiment, soil samples were collected to determine the chemical and physical characteristics of the 0-20 cm layer of the soil (Table 6).

The previous area (marandu palisadegrass) was desiccated with the application of the herbicide glyphosate at 2,058 g a.i. ha^{-1} with a broth volume of 150 L ha^{-1}. Thirty days after crop desiccation, disking was performed with a disk harrow, followed by leveling with a disk. Over the course of the experiment, rainfall and mean monthly temperature data were monitored daily (Figure 1).

The experiment was conducted in an experimental design in a randomized block design with four replicates in a 4 x 4 factorial scheme, with four forage systems: Paiaguas palisadegrass in monocropped, sorghum intercropped with Paiaguas palisadegrass in rows, sorghum intercropped with Paiaguas palisadegrass in interrow, and sorghum intercropped with oversown Paiaguas palisadegrass, evaluated in four seasons of the year (winter, spring, summer, and fall). The project was approved by the Research Ethics Committee (REC) of the Federal Goiano Institute, protocol nº 004/2014.

Figure 2 provides a diagram of the forage systems in pasture recovery through intercropping of sorghum with Paiaguas palisadegrass in an integrated crop–livestock system, with diversification of activities and maximizing land use.

Implementation and maintenance of forage systems

The area of each plot (treatment) was 1042 m^2, divided into 16 enclosures with electric fence. The sorghum used was the Buster hybrid of red grain, without tannin and of low size, and the *Brachiaria* species was BRS cv. Paiaguas.

The planting of the forage systems was performed mechanically on January 24, 2015, with the application of 240 kg ha^{-1} of P_2O_5 and 20 kg ha^{-1} of FTE BR 20, in the sources of simple superphosphate and frits, respectively.

In monocropped and intercropping the sorghum was sown at a depth of 3 cm. In the Paiaguas palisadegrass monocropped, the grass was sown at a depth of 3 cm; in the row, it was sown at a depth of 6 cm; in the interrow, it was sown at a depth of 3 cm and 0.25 m from the sorghum row; and in the oversown treatment, it was sown at a depth of 6 cm and 0.25 m from the sorghum row, 15 days after the sorghum had been sown (Santos et al., 2020).

At 15 days after sowing (DAS), 80 kg ha^{-1} of nitrogen and 40 kg ha^{-1} of K_2O (potassium oxide), in the form of urea and potassium chloride, were applied. On 05/04/2015, all forage systems were harvested for silage by a row forage harvester at 20 cm height above the soil (Oliveira et al. 2020b).

After the plants were harvested from the forage systems, cover fertilization was conducted in all systems, with the application of 80 kg ha^{-1} of nitrogen and 30 kg ha^{-1} of K_2O. The Paiaguas palisadegrass remained at rest for 94 days to allow regrowth and development. The long rest period was due to the low precipitation obtained during this period, which limited development of the grass.

Evaluation of animal performance

On 08/25/2015, the animals entered the area for evaluation of animal performance and forage production. The grazing method was continuous stocking, with a variable stocking rate.

The animals used were of the Nelore breed and included 32 females, with a mean age of 12 months (heifers) and mean initial weight of 180 kg. Evaluations were performed over a year, for all seasons of the year, with winter being the first season evaluated.

All animals received water and a complete mineral mixture *ad libitum* in the area of each enclosure, in addition to sanitary management (vaccination and deworming). Every 28 days, the animals were weighed after 16 hours of fasting. The weight gain per area was calculated by multiplying the average daily gain of the test animals by the number of animals kept in the paddock per month.

The stocking rate was calculated by multiplying the average weight of the test animals by the number of days they remained in the paddock (Petersen and Lucas Junior, 1968). The live weight per area was calculated by multiplying the average daily gain of the test animals with the stocking rate and grazing number.

In December 2015, maintenance fertilization was applied with application of 80 kg ha^{-1} nitrogen and 50 kg ha^{-1} of K_2O were applied in the form of urea and potassium chloride. After fertilization, the Paiaguas palisadegrass was not grazed for 28 days to allow better forage development.

Evaluation of productive characteristics

Samples were collected from Paiaguas palisadegrass, according to the grazing cycle of the animals, every 28 days to evaluate the dry matter production, leaf blade:stem ratio forage accumulation rate (FAR). During this period, eight cuts were performed: two cuts per season, with a 28-day interval and eight grazing cycles.

The forage mass was quantified by means of two samplings per 0.50 x 0.50 m (0.25 m2) square enclosures, arranged between rows, by cutting the forage contained inside the square at 20 cm above the soil, with those values expressed in kg ha^{-1}. The samples were separated; fractionated into the leaf, pseudostem (stem + sheath), and dried in a forced circulation oven at 55°C for 72 hours, for leaf blade:stem ratio. The forage accumulation rate was determined by using two exclusion cages per enclosure. Every 28 days, the cages were placed in points representative of the mean enclosure height, with mass and morphological composition similar to the grazing areas. After each cut, made close to the ground and inside each cage, the exclusion cages were relocated in the enclosures. The forage accumulation rate was obtained by means of the difference between the forage masses collected inside (current cut) and outside (previous cut) of the cages, considering only the green portion of the plant.

Evaluation of forage quality

Chemical composition analyzes were performed to determine for dry matter (DM), crude protein (CP), according to the methodologies described by the AOAC (1990). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were estimated by the method described by Mertens (2002). The content of total digestible nutrients (TDN) was calculated by the equation proposed by Chandler (1990). The *in vitro* dry matter digestibility (IVDMD) was adapted to the artificial rumen developed by ANKOM® (Daisy Incubator - *in vitro* true digestibility - IVTD), using the technique described by Tilley and Terry (1963). Nutrient concentrations (phosphorus and potassium) were determined according to the methods of Malavolta et al. (1997).

Statistical analysis

The variables were submitted to analysis of variance in R version R-3.1.1 (2014), using the ExpDes package (Ferreira et al. 2014). The means were compared by the Tukey test at 5% probability. To compare the forage between seasons, the analyses were carried out by the repeated measures over time model.

The Pearson coefficient was estimated, and its statistical significance was validated by Student's t test, using the color.test function of R to study the association between variables. A probability level of 1% was considered significant in all the tests.

Conclusion

The forage system did not influence the DM production, nutritive value, stocking rate and weight gain, being that all forms of sowing can be indicated due to the good development of Paiaguas palisadegrass after the sorghum harvest, showing several alternatives for implantation of the crops in intercropping. The summer and fall seasons provided higher forage availability and nutritive value, resulting in greater weight gain and performance per animal per area.

Paiaguas palisadegrass has good potential for pasture formation, recovery, and/or renewal, showing resistance to the dry period of the year ((winter and fall). This cultivar may be a new alternative for different production systems. The crop-livestock integration system proved to be a promising and viable technique for pasture recovery with greater sustainability.

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