academicJournals

Vol. 11(19), pp. 1712-1723, 12 May, 2016
DOI: 10.5897/AJAR2016.10902
Article Number: 1586C6B58448
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Production and nutritional characteristics of pearl millet and Paiaguas palisadegrass under different forage systems and sowing periods in the offseason

Raoni Ribeiro Guedes Fonseca Costa, Kátia Aparecida de Pinho Costa*, Charles Barbosa Santos, Eduardo da Costa Severiano, Patrícia Soares Epifanio, Jessika Torres da Silva, Daniel Augusto Alves Teixeira and Valdevino Rodrigues da Silva

Federal Institute of Education, Science and Technology Goiano, Rio Verde, Campus (Instituto Federal de Educação, Ciência e Tecnologia Goiano, Campus Rio Verde), Rod. Sul Goiana Km 01, Cx. P. 66. CEP 75.901-970, Rio Verde –GO, Brazil.

Received 12 February, 2016; Accepted 1 April, 2016

The intercropping of annual crops with perennial grasses is a production system that is frequently adopted in the Midwest region of Brazil due to its economic viability resulting from the use of the same area for agriculture and livestock. Most agriculture-livestock integration studies have evaluated the use of forage of the genus *Urochloa* in intercropped systems with corn, sorghum and sunflower. Consequently, there is a lack of information regarding pearl millet cultivation when grown simultaneously with tropical forages. Thus, the objective of this study was to evaluate the agronomic characteristics of pearl millet *Pennisetum glaucum* (L.) R. Br as well as the production and nutritional characteristics of Paiaguas palisadegrass (*Urochloa brizantha* cv. Paiaguas) under different forage systems and sowing periods in the offseason. The experiment was conducted at the Federal Institute of Goiás, Rio Verde campus. The experimental design was a randomized complete block with a 5 × 2 factorial arrangement and three replications. There were two sowing periods (February and March) and five forage systems: monocropped pearl millet; monocropped Paiaguas palisadegrass; pearl millet intercropped in rows with Paiaguas palisadegrass; pearl millet intercropped between rows of Paiaguas palisadegrass and pearl millet oversown and intercropped with Paiaguas palisadegrass. The results indicated that the Paiaguas palisadegrass did not affect the pearl millet grain yield, indicating that the intercropping of pearl millet and Paiaguas palisadegrass in the offseason is a promising cultivation technique for the production of grains during the offseason in Southeastern Goiás. However, the second sowing period provided better grain yields and a higher number of sacks per hectare. With respect to forage yield, the Paiaguas palisadegrass sown in oversown pearl millet was impaired by the intercropping and produced low forage yield. With respect to forage quality, the intercropped sowing system did not affect the nutritional characteristics of the Paiaguas palisadegrass.

Key words: *Urochloa brizantha*, agriculture-livestock integration, *Pennisetum glaucum* (L.) R. Br.

INTRDUCTION

Intercropping annual crops with tropical forages has been increasingly adopted by farmers in the Cerrado (Pacheco et al., 2008), because many studies showed the feasibility of intercropping annual crops with various forage species when planted simultaneously (Petter et al., 2011).

In this kind of production system, the producer has the possibility of three ways of use of an area in a single offseason after harvesting summer soybean: the cultivation of an annual grain crop, the use of forage for grazing (livestock) and the production of straw for a no-till system. This system allows greater crop diversification, minimizes risks of crop losses and provides more options for adopting crop rotation and sequences under conservation agriculture system (Horvathy et al., 2012).

Despite the various benefits of intercropping, its agronomic efficiency depends on environmental conditions (Barducci et al., 2009). Additionally, it is important to consider that the establishment of intercrops with forage implies competition between the different crops, especially when sowing occurs simultaneously. The intercropping of annual crops and tropical forage species is possible because of temporal and spatial lags in their growth and biomass accumulation. Among the forage grasses used, those of the genus *Urochloa* stand out (Ikeda et al., 2007; Pariz et al., 2010; Machado and Valle, 2011; Ribeiro et al., 2015). The advantage of using *Urochloa* species in an intercropped system is related to their abundant root systems, which contribute to water infiltration, soil aggregation and aeration (Kluthcouski et al., 2004).

These grasses show good adaptation, tolerance and resistance to abiotic factors and produce high dry matter yield with good nutritional value that is capable to meet animal needs, especially in the dry season (Brighenti et al., 2008). Most research focused on intercropping corn (Maia et al., 2014), sorghum (Horvathy et al., 2014) and sunflower (Souza et al., 2015) with forage grasses. Limited research has been conducted on the use of pearl millet (*Pennisetum glaucum* (L) R. BR) intercropped with grasses of the genus *Urochloa*.

Due to its adaptation to Cerrado region, pearl millet has received attention in recent years, especially with the release of early, high-yield genotypes from genetic improvement programs. Consequently, pearl millet is no longer considered a simple species for cover or straw production in no-till systems (Dan et al., 2009) and has become a high-value crop for forage production, for grazing (Leão et al., 2012), for silage (Costa et al., 2012) and for grain (Costa et al., 2015).

As intercropping of pearl millet with *Urochloa* spp. is largely unexplored particularily, under offseason conditions, there is a need for more information with regard to optimal sowing period, planting systems and sustainable ways of production. The objective of this study was to evaluate the agronomic characteristics of pearl millet, as well as the production and nutritional characteristics of Paiaguas palisadegrass under different intercropping methods and sowing periods in the offseason.

MATERIALS AND METHODS

The experiment was conducted in the field (17°48' S; 50°55' W; and 748 m altitude), in the municipality of Rio Verde, Goiás, Brazil, in 2014 offseason on a Dystroferric Red Latosol (Embrapa, 2013). Before planting, soil samples were collected from the 0 to 20 cm layer to assess physical and chemical characteristics of the experimental plots. Overall, the following values were obtained: 600, 140, and 260 g kg^{-1} of clay, silt and sand, respectively; pH ($CaCl_2$): 6.02; Ca: 3.50 cmol$_c$ dm^{-3}; Mg: 1.43 cmol$_c$ dm^{-3}; Al: 0.05 cmol$_c$ dm^{-3}; Al+H: 5.9 cmol$_c$ dm^{-3}; K: 0.35 cmol$_c$ dm^{-3}; CEC: 11.14 cmol$_c$ dm^{-3}; P: 2.29 mg dm^{-3}; Cu: 3.5 mg dm^{-3}; Zn: 5.1 mg dm^{-3}; Fe: 34.1 mg dm^{-3}; OM.: 37.06 g dm^{-3}.

The area was prepared by desiccating weeds with an application of Transorb herbicide (glifosato 480 g L^{-1} at a spray volume of 150 L ha^{-1}). Harrowing was performed 30 days after the desiccation, with a disk harrow, to eliminate weeds that escaped herbicide action, followed by subsoiling and additional harrowing. One week before implementing the experiment, harrowing was undertaken again, and the field was sown in furrows using a seeder with an inter-row spacing of 0.50 m. The furrows for sowing the Paiaguas palisadegrass, in the inter-rows, and the oversowing of pearl millet were manually dug using hoes.

The experiment was based on a randomized blocks in a 5 × 2 factorial design, with three replicates. There were five forage systems: monocropped pearl millet; monocropped Paiaguas palisadegrass; pearl millet intercropped in rows with Paiaguas palisadegrass; pearl millet intercropped between rows of Paiaguas palisadegrass and pearl millet oversown and intercropped with Paiaguas palisadegrass, and two sowing periods (February and March). The pearl millet genotype used was ADR 8010 (medium-sized and dual purpose).

Sowing was carried out on February 12 and March 4, along with 240 kg ha^{-1} of P_2O_5 and 20 kg ha^{-1} of Fritted Trace Element-FTE BR 12 (9% Zn; 1.8% B; 0.8% Cu; 2% Mn; 3.5% Fe and 0.1% Mo). Monocropped and intercropped pearl millet was sown at a depth of 3 cm. The Paiaguas palisadegrass was sown in rows at a depth of 6 cm. When intercropped, the Paiaguas palisadegrass was sown at a distance of 0.25 m from the pearl millet rows, and in the oversown system, it was sown in the inter-row (0.25 m distance) 15 days after pearl millet seeding. Fourteen seeds of pearl millet per linear meter and 5 kg of pure viable seeds per hectare of the forage species were used. The plots in all forage systems consisted of eight rows 3.0 m long. The usable area was obtained by only considering the four central rows and eliminating 0.5 m from each row end.

At 30 and 50 days after emergence (DAE), 60 kg ha^{-1} N in the form of urea and 40 kg ha^{-1} K_2O in the form of potassium chloride were applied by casting. Hand weeding was performed weekly up to 50 DAE to control post-emergence weeds. Fall armyworms (*Spodoptera frugiperda*) were controlled using insecticide applications of Losbam 18 ml (1 L ha^{-1}) and Nomolt 1 ml (50 ml ha^{-1}) at 40 and 50 DAE, and there were two fungicide applications (37 and 44 DAE) with Priori Extra (azoxystrobin + cyproconazole) at 0.5 L ha^{-1}. During the experiment, daily rainfall and mean monthly temperature data were monitored (Figure 1).

The following agronomic characteristics of the monocropped and intercropped pearl millet were measured: plant height, stem diameter and panicle size at 30, 60 and 90 DAE. Harvesting of pearl

*Corresponding author. E-mail: katia.costa@ifgoiano.edu.br.

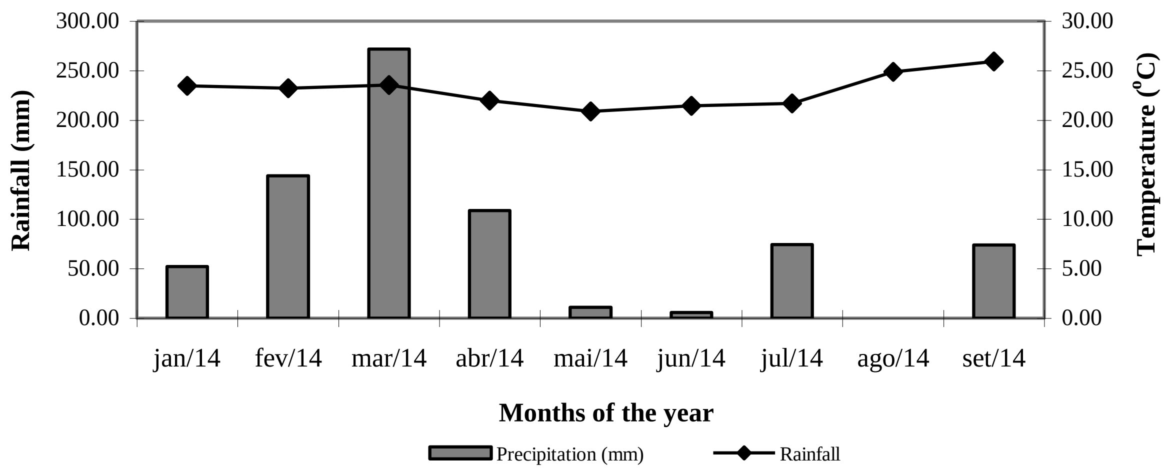

Figure 1. Rainfall and mean temperature recorded from January, 2014 to September, 2014, in Rio Verde-GO, Brazil.

millet was performed manually 115 and 118 DAE, for the first and second sowing dates, respectively, when the plants reached physiological maturity stage. At harvest, the grain yield (grain weight, corrected to 13% moisture), thousand grains weight (in grams, corrected to 13% moisture) and number of sacks per hectare were assessed in each of the usable plot areas.

The Paiaguas palisadegrass plant height was assessed (cm) using a graduated measuring tape, the number of tillers per linear meter were counted and the dry matter yield was measured until the onset of the rainy season (September). The forage was evaluated on successive cuts (0.20 m from the ground), based on samples of 1 m^2 that were randomly collected from each plot.

The first cut occurred at the time of pearl millet harvest on 06/04/14 and 06/24/14 for the first and second sowing periods, respectively. The second cut was conducted 78 days later, on 08/22/14 (first period) and 09/04/14 (second period), due to the low development of the forage grass under low rainfall, that is, the dry season. After both assessment cuts, a standard cut of all plants in the experimental area was carried out, at the same height used for the evaluated plants, and the resulting residue was removed from the area.

The collected material was packed in plastic bags and weighed for the assessment of total dry matter production. Then, the material was transported to the laboratory where a representative (500 g) sub-sample is taken from each plot and dried in a forced-air oven at 55°C. Subsequently, the samples were ground in a Wiley mill, using a 1-mm diameter sieve, and stored in plastic containers for further analysis.

Nutritional analyses were performed to determine the dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) using the methods reported by Silva and Queiroz (2002).

The *in vitro* dry matter digestibility (IVDMD) was assessed using the method described by Tilley and Terry (1963) and was adapted to the artificial rumen developed by ANKON® using the “Daisy incubator” device from Ankom Technology (*in vitro* true digestibility-IVTD). The rumen fluid was collected using two rumen-fistulated male cattle with a mean weight of 550 kg. The animals were maintained on *Urochloa brizantha* cv. Marandu pasture.

Data were subjected to analysis of variance and the means were compared using Tukey’s test, with a significance level of 5%. Statistical analyses were performed using SISVAR 4.6 statistical software (Ferreira, 2011).

RESULTS AND DISCUSSION

The pearl millet height at 30, 60 and 90 DAE was not influenced (P>0.05) by forage system or by the interaction between forage system and sowing period. Therefore, it can be inferred that the Paiaguas palisadegrass plants did not influence the pearl millet development.

However, there was a significant effect (P<0.05) of sowing period on pearl millet height. The first sowing period resulted in lower plant height at 30 DAE over all forage systems. This result may be related to the uneven distribution of rainfall in February (Figure 1), with frequent dry spells observed at the beginning of emergence, which impaired the initial plant development. At 60 and 90 DAE, only the monocropped pearl millet plant height was influenced, with greater height measured for the first sowing period (Table 1). Notably, pearl millet is a plant that is sensitive to short days because it blooms in photoperiods lower than 12 h (Leão et al., 2012) and thus later sowing accelerates vegetative stage and advances blooming, which may have caused the lower plant height of monocropped pearl millet during the second sowing period.

Coimbra and Nakagawa (2006), who assessed the effect of sowing and cutting regimes on biomass and grain yield of forage millet, reported a mean height of 89.3 cm when the millet was sown in April and 210.9 cm when the millet was sown in September.

When assessing the stem diameter at 30 and 60 DAE,

Table 1. Plant height of monocropped pearl millet and pearl millet intercropped with Paiaguas palisadegrass under different forage systems at 30, 60 and 90 DAE.

Forage systems	Sowing periods	
	First	Second
	Plant height at 30 DAE (cm)	
Monocropped pearl millet	43.46[b]	76.33[a]
Row pearl millet × Paiaguas palisadegrass	42.60[b]	68.40[a]
Inter-row pearl millet × Paiaguas palisadegrass	42.20[b]	69.00[a]
Oversown pearl millet × Paiaguas palisadegrass	44.33[b]	75.53[a]
CV (%)	15.72	
	Plant height at 60 DAE (cm)	
Monocropped pearl millet	204.0[a]	185.6[b]
Row pearl millet × Paiaguas palisadegrass	186.3[a]	175.3[a]
Inter-row pearl millet × Paiaguas palisadegrass	195.0[a]	187.6[a]
Oversown pearl millet × Paiaguas palisadegrass	193.3[a]	189.3[a]
CV (%)	4.07	
	Plant height at 90 DAE (cm)	
Monocropped pearl millet	215.0[a]	198.0[b]
Row pearl millet × Paiaguas palisadegrass	192.3[a]	184.3[a]
Inter-row pearl millet × Paiaguas palisadegrass	206.3[a]	193.6[a]
Oversown pearl millet × Paiaguas palisadegrass	207.3[a]	194.6[a]
CV (%)	4.82	

Means followed by different letters within a row (sowing periods) differ according to Tukey's test at 5% probability level.

there was no significant effect (P>0.05) of the forage systems. However, at 90 DAE for both sowing periods, the lowest stem diameter was obtained for pearl millet intercropped in rows with Paiaguas palisadegrass. These results are attributed to the increased competition between the plants for water, light, nutrients and physical space, as the sowing of both species was carried out in the same row. At 90 days, low rainfall occured (Figure 1) and further increased plant competition for water.

In contrast, for the inter-row intercropping and oversown systems, there was no negative influence on the development of the pearl millet due to competition with the *Urochloa* plants, indicating the potential of these sowing systems. This is certainly due to both species being grasses, featuring the same C4 photosynthetic metabolism and thus efficiently using the available light (Taiz and Zaiger, 2010), in addition to having highly efficient root systems with respect to soil water and nutrient use.

When comparing the sowing dates, Table 2 shows that sowing in the first period resulted in a smaller stem diameter at 30 DAE compared with the second period, due to the lower rainfall in early stages. The opposite trend was observed at 60 DAE, when a larger stem diameter was obtained for the first sowing date. The main factor contributing to the greater stem diameter during the first period was certainly related to a better water balance during the post-sowing period (Figure 1), which favored plant development, and also to the plasticity of the species in using the best environmental conditions, coupled with the longer vegetative stage thanks to favorable photoperiod.

The panicle size at 60 DAE for the first sowing date was not affected (P>0.05) by forage system. However, at 90 DAE, there was an effect (P<0.05) of the forage system, where the lowest value was obtained in oversown pearl millet intercropped with Paiaguas palisadegrass (Table 3). Regarding to the second sowing date, only monocropped pearl millet differed (P<0.05) from the intercropped system in rows, with higher values for the panicle size at 60 and 90 DAE. This result is due to the competition of plants in this sowing system, as observed in the stem diameter assessment at 90 days.

Durães et al. (2003) reported that environmental factors affect plant growth rate and development. Temperature, in particular, influences the amount of grains at the time of

Table 2. Stem diameter of monocropped pearl millet and pearl millet intercropped with Paiaguas palisadegrass under different forage systems at 30, 60 and 90 DAE.

Forage systems	Sowing periods	
	First	Second
	Stem diameter at 30 DAE (mm)	
Monocropped pearl millet	0.20^{Ab}	0.90^{Aa}
Row pearl millet × Paiaguas palisadegrass	0.20^{Ab}	0.73^{Aa}
Inter-row earl millet × Paiaguas palisadegrass	0.20^{Ab}	0.83^{Aa}
Oversown pearl millet × Paiaguas palisadegrass	0.20^{Ab}	0.90^{Aa}
CV (%)	15.18	
	Stem diameter at 60 DAE (mm)	
Monocropped pearl millet	1.33^{Aa}	0.113^{Ab}
Row pearl millet × Paiaguas palisadegrass	1.23^{Aa}	0.096^{Ab}
Inter-row pearl millet × Paiaguas palisadegrass	1.26^{Aa}	0.100^{Ab}
Oversown pearl millet × Paiaguas palisadegrass	1.23^{Aa}	0.106^{Ab}
CV (%)	8.77	
	Stem diameter at 90 DAE (mm)	
Monocropped pearl millet	1.50^{Aa}	1.46^{Aa}
Row pearl millet × Paiaguas palisadegrass	1.03^{Bb}	1.10^{Ba}
Inter-row pearl millet × Paiaguas palisadegrass	1.30^{Aa}	1.53^{Aa}
Oversown pearl millet × Paiaguas palisadegrass	1.16^{ABb}	1.46A^{a}
CV (%)	11.08	

Means followed by different letters within a column (forage systems) and row (sowing periods) differ according to Tukey's test at 5% probability level.

Table 3. Panicle size of monocropped pearl millet and pearl millet intercropped with Paiaguas palisadegrass under different forage systems at 60 and 90 DAE.

Forage systems	Sowing periods	
	First	Second
	Panicle size at 60 DAE (cm)	
Monocropped pearl millet	25.10^{Aa}	25.86^{Aa}
Row pearl millet × Paiaguas palisadegrass	25.43^{Aa}	23.18^{Bb}
Inter-row earl millet × Paiaguas palisadegrass	25.13^{Aa}	24.92^{ABa}
Oversown pearl millet × Paiaguas palisadegrass	23.63^{Aa}	24.07^{ABa}
CV (%)	4.39	
	Panicle size at 90 DAE (cm)	
Monocropped pearl millet	26.60^{Aa}	28.06^{Aa}
Row pearl millet × Paiaguas palisadegrass	27.33^{Aa}	24.13^{Bb}
Inter-row earl millet × Paiaguas palisadegrass	27.00^{Aa}	27.00^{ABa}
Oversown pearl millet × Paiaguas palisadegrass	23.90^{Ba}	25.76^{ABa}
CV (%)	5.09	

Means followed by different letters within a column (forage systems) and row (sowing periods) differ according to Tukey's test at 5% probability level.

Table 4. Grain yield, thousand grain weight and sacks per hectare of monocropped pearl millet and pearl millet intercropped with Paiaguas palisadegrass under different forage systems.

Forage systems	Sowing periods	
	First	Second
	Grain yield (kg ha^{-1})	
Monocropped pearl millet	2008^{Ab}	2614^{Aa}
Row pearl millet × Paiaguas palisadegrass	2264^{Ab}	2592^{Aa}
Inter-row pearl millet × Paiaguas palisadegrass	2338^{Ab}	2974^{Aa}
Oversown pearl millet × Paiaguas palisadegrass	2041^{Ab}	2360^{Aa}
CV (%)	21.29	
	Thousand grain weight (g)	
Monocropped pearl millet	9.61^{Aa}	8.33^{Aa}
Row pearl millet × Paiaguas palisadegrass	9.61^{Aa}	7.66^{Aa}
Inter-row pearl millet × Paiaguas palisadegrass	9.58^{Aa}	8.56^{Aa}
Oversown pearl millet × Paiaguas palisadegrass	9.21^{Aa}	7.65^{Aa}
CV (%)	13.48	
	Sacks per hectare	
Monocropped pearl millet	37.39^{Ab}	43.57^{Aa}
Row pearl millet × Paiaguas palisadegrass	39.41^{Ab}	43.21^{Aa}
Inter-row pearl millet × Paiaguas palisadegrass	38.97^{Ab}	49.58^{Aa}
Oversown pearl millet × Paiaguas palisadegrass	39.34^{Aa}	36.01^{Aa}
CV (%)	19.68	

Means followed by different letters within a column (forage systems) and row (sowing periods) differ according to Tukey's test at 5% probability level.

harvest. Under low temperatures, the amount of grains is probably reduced by the direct effect of spikelet death, spikelet sterility or male sterility, combined with the photoperiod. Temperature is also a major factor in productivity because the delay in sowing causes an acceleration of the crop cycle, thereby reducing the vegetative stage and advancing blooming.

Costa et al. (2005), who compared the yield and biomass of different cultivars of millet, observed panicle lengths of 32.2 cm (BRS 1501), 35.5 cm (SounaII) and 59.9 cm (ENA2), which were higher values than those observed in the present study.

When comparing sowing periods, Table 3 shows that only the pearl millet intercropped in rows with Paiaguas palisadegrass was affected, with a smaller panicle size for the second sowing period. According to Madhusudhana and Govila (2001), the mean panicle length has a direct effect on grain yield.

The grain yield, thousand grain weight and number of sacks per hectare of pearl millet were significantly similar (P>0.05) for allforage systems and for both evaluation periods (Table 4). This proves the feasibility of the intercropped systems because the Paiaguas palisadegrass did not hinder pearl millet development with respect to final grain yield.

However, regarding sowing time, average grain yield obtained in the second sowing period was higher over all forage systems. A similar result was observed for the number of sacks per ha^{-1} except for the isolated case where oversown pearl millet was intercropped with Paiaguas palisadegrass; in this system, the sacks per ha^{-1} did not differ between the evaluated periods. Moreover, sowing date had no significant effect on thousand grain weight.

The average pearl millet grain yield was similar to that obtained by Costa et al. (2005), who evaluated millet genotypes sown in two periods. These authors reported a millet grain yield of 2.456 kg ha^{-1} for ENA 2 cultivar.

Geraldo et al. (2000) reported thousand grain weight values of 6.8 g in cultivar BN2, 6.8 g in IAPAR, 12.0 g in HKP3 and 12.1 g in Guerguera. These values were lower than that found in the present study for cultivar ADR 8010. The difference in results may be due to the different hybrids used in the studies, e.g., ADR 8010 is a hybrid derived from genetic improvement that has a high yield potential.

Based on these results, it can be stated that even under intercropping conditions, where there is greater competition for light, water and nutrients, the intercropped pearl millet was not affected by the presence of Paiaguas palisadegrass for either sowing period, showing the interest of an agriculture-livestock integration system for

Table 5. Plant height (cm) and number of tillers of monocropped Paiaguas palisadegrass and Paiaguas palisadegrass intercropped under different forage systems and sowing periods.

Forage systems	Sowing periods	
	First	Second
	Plant height - First cut	
Monocropped Paiaguas palisadegrass	91.66^{Aa}	73.00^{Ab}
Row pearl millet × Paiaguas palisadegrass	85.33^{ABa}	66.33^{ABb}
Inter-row pearl millet × Paiaguas palisadegrass	73.33^{ABa}	55.00^{Bb}
Oversown pearl millet × Paiaguas palisadegrass	53.33^{Ca}	39.33^{Cb}
CV (%)	7.83	
	Plant height - Second cut	
Monocropped Paiaguas palisadegrass	63.66^{Aa}	58.00^{Aa}
Row pearl millet × Paiaguas palisadegrass	47.33^{Aa}	41.00^{Aa}
Inter-row pearl millet × Paiaguas palisadegrass	52.00^{Aa}	49.00^{Aa}
Oversown pearl millet × Paiaguas palisadegrass	22.33^{Ba}	22.66^{Ba}
CV (%)	23.31	
	Number of tillers - First cut	
Monocropped Paiaguas palisadegrass	320.66^{Ab}	478.00^{Aa}
Row pearl millet × Paiaguas palisadegrass	298.33^{Aa}	285.33^{Ba}
Inter-row pearl millet × Paiaguas palisadegrass	327.33^{Aa}	271.00^{Ba}
Oversown pearl millet × Paiaguas palisadegrass	230.33^{Ba}	209.33^{Ca}
CV (%)	20.20	
	Number of tillers - Second cut	
Monocropped Paiaguas palisadegrass	263.33^{Aa}	272.33^{Aa}
Row pearl millet × Paiaguas palisadegrass	187.66^{Ba}	168.00^{Ba}
Inter-row pearl millet × Paiaguas palisadegrass	205.33^{Ba}	177.00^{Ba}
Oversown pearl millet × Paiaguas palisadegrass	159.00^{Ca}	145.00^{Ca}
CV (%)	9.13	

Means followed by different letters within a column (forage systems) and row (sowing periods) differ according to Tukey's test at 5% probability level.

the production of grains in the offseason.

U. brizantha cv. BRS Paiaguas

The height of Paiaguas palisadegrass was affected (P<0.05) by the interaction between forage system and sowing period (Table 5). It was observed that over both periods, the height of the first cut of the monocropped Paiaguas palisadegrass and where this species was intercropped (in rows with pearl millet and in the inter-rows between pearl millet) was higher than that measured in the oversown system.

Notably, oversowing method dramatically affected forage development. This is due to the fact that the grass was established 15 days after pearl millet seeding sown, which resulted in higher interspecific competition between the plants as the millet was already at the 2 stage when the Paiaguas palisadegrass was sown. This caused shading in the early stages of the grass growth and consequently reduced the quantity and quality of radiation intercepted by the lower stratum of the canopy affecting Paiaguas palisadegrass growth.

Similar plant height results were obtained by Seidel et al. (2014), who found that the mean height of *U. brizantha* cv. MG4, when simultaneously planted, was 88 and 78.75 cm in a row and inter-row sowing system, compared with heights of 33.25 and 35.75 cm when the grass was sown 25 days after the sowing of corn, equivalent to decreases of 62.22 and 54.61%, respectively.

Regarding to sowing periods, Table 5 shows that for the first cut, the second sowing date resulted in lower heights in all forage systems. This was due to the uneven distribution of rainfall in February (Figure 1) when a drought occurred during early emergence and impaired the initial plant development.

When evaluating the plant height of the second cut (Table 5), it was observed that the lowest heights in both periods were measured when Paiaguas palisadegrass was intercropped with oversown pearl millet. Even after pearl millet harvest, Paiaguas palisadegrass did not exhibit the same development as that reported for other forage systems. In this context, it can be inferred that this sowing method is an ineffective cultivation technique for cattle pasture during the offseason.

In contrast, the similar plant height measured during the second cut of monocropped Paiaguas palisadegrass compared with row and inter-row intercropping indicates that the pearl millet did not negatively affect the development of Paiaguas palisadegrass, as there was no competition for resources. The upright growth of both forage crops contributed to the favorable outcome of the intercropping.

The sowing period did not influence ($P>0.05$) plant height measured at the time of the second cut in any of the forage systems. Note that Paiaguas palisadegrass and pearl millet have high water use efficiency but under low water availability (Duraes et al., 2003), the presence of pearl millet can lead to increased competition and strongly interfere with the development of the palisadegrass, as observed in the present study. The absence of a sowing period effect at the time of the second cut reinforces this statement, as in the absence of pearl millet, the forage exhibited the same performance at the second cut as that observed at the first cut, indicating that the shadow produced by the plants might reduce forage. Both species have the same C4 photosynthetic metabolism and are therefore highly dependent on light to achieve their optimum photosynthetic rate. In addition, these species have a highly efficient root system with respect to water and soil nutrient use and are therefore considered highly competitive (Taiz and Zaiger, 2010).

The intercropping of Paiaguas palisadegrass with oversown pearl millet negatively affected ($P<0.05$) the number of tillers (Table 5) in the first cut in the first sowing period. The low amount of available light for Paiaguas palisadegrass, when shadowed by pearl millet, hampered the emergence and development of new side buds that give rise to new tillers, thus reducing their numbers (Soares et al., 2009). However, for the row and inter-row intercropped systems, the results were similar to the monocropped Paiaguas palisadegrass. The highest number of tillers was measured in monocropped Paiaguas palisadegrass for the second sowing period.

Seidel et al. (2014) reported a lower number of tillers for *U. brizantha* cv. MG4 than that observed in the present study, that is, 62.75 and 68.25 in the row and inter-row system under simultaneous sowing with corn and 163.67 and 149 in the row and inter-row oversown system (25 DAE), respectively, verifying that in contrast to the observations in the present study, shading by corn induced a higher tillering rate. In the present study, reduced tillering in the overseeded system is due to lower quantity and quality of light intercepted by the canopy. Tillering is induced by the perception of blue light by the phytochromes located in the basal and axillary buds and also the pattern red: far red. And thus the low intensity and luminous quality reduced induction of tillering.

Considering sowing periods within forage systems, only the monocropped Paiaguas palisadegrass exhibited a significantly ($P<0.05$), higher number of tillers with the second period sowing. This result corroborates the higher plant height in the first sowing period. The size of the leaf blade is a major factor in the production of new tillers, as stated earlier regarding the quality of light reaching the lower strata, which can be reduced due to increased light interception by the canopy, thereby delaying the development of axillary buds in tillers (Soares et al., 2009). This explains the higher number of tillers observed in the second sowing period, during which a lower plant height was measured.

The dry matter yield was affected ($P<0.05$) by forage systems, in which oversown system exhibited the lowest average yield; The dry matter yield (was 70.0 and 59.0% lower for the first sowing period and 50 and 56.8% lower for the second sowing period for the first and second cuts, respectively, indicating that planting under this system did not provide a satisfactory dry mass yield (Table 6).

The dry matter yields registered in the present study were similar to those given by Leonel et al. (2009), that is, 7.568 kg ha^{-1} in exclusive marandu grass cultivation. Pariz et al. (2010) reported yields of 4.128 and 4.168 kg ha^{-1} for *Urochloa* intercropped with corn in rows and by casting. Machado and Valle (2011), evaluating the agronomic performance of *Urochloa* grass genotypes in succession to soybean for three years (2007, 2008 and 2009), found that Paiaguas palisadegrass (B6 lineage) yielded 4.541, 5.299 and 6.116 kg ha^{-1} of dry matter, respectively.

A negative effect of oversowing on the dry matter yield of the MG4 grass was reported by Seidel et al. (2014), who found decreases of 81.7 and 62.5% when the forage was sown 25 days after the corn with row and inter-row systems, respectively,.

The sowing periods did not affect ($P>0.05$) the dry matter yield of the forage systems in both cuts (Table 6). The second cut provided the lowest yield, due to low regrowth in the absence of rainfall with decreasing temperatures (Figure 1).

For the two cuts, the leaf:stem ratio differed significantly ($P<0.05$) between forage systems, with monocropped Paiaguas palisadegrass, showing the lowest ratio compared to intercropped systems. This result is probably due to increased growth and development of the grass under a monocropped system, which resulted in a higher

Table 6. Dry matter yield (kg ha^{-1}) and leaf:stem ratio of monocropped Paiaguas palisadegrass and Paiaguas palisadegrass intercropped under different forage systems and sowing periods.

Forage systems	Sowing periods	
	First	First
	DM - First cut	
Monocropped Paiaguas palisadegrass	7.408^{Aa}	6.320^{Aa}
Row pearl millet × Paiaguas palisadegrass	5.488^{Aa}	4.332^{Aa}
Inter-row pearl millet × Paiaguas palisadegrass	5.379^{Aa}	4.265^{Aa}
Oversown pearl millet × Paiaguas palisadegrass	2.169^{Ba}	2.590^{Ba}
CV (%)	21.67	
	DM - Second cut	
Monocropped Paiaguas palisadegrass	2.574^{Aa}	2.450^{Aa}
Row pearl millet × Paiaguas palisadegrass	2.183^{Aa}	2.281^{Aa}
Inter-row pearl millet × Paiaguas palisadegrass	2.038^{Aa}	2.619^{Aa}
Oversown pearl millet × Paiaguas palisadegrass	1.272^{Ba}	1.058^{Ba}
CV (%)	14.8	
	Leaf:stem ratio - First cut	
Monocropped Paiaguas palisadegrass	0.940^{Ba}	0.894^{Ba}
Row pearl millet × Paiaguas palisadegrass	1.392^{Aa}	1.261^{Aa}
Inter-row pearl millet × Paiaguas palisadegrass	1.299^{Aa}	1.268^{Aa}
Oversown pearl millet × Paiaguas palisadegrass	1.240^{Aa}	1.234^{Aa}
CV (%)	13.32	
	Leaf:stem ratio - Second cut	
Monocropped Paiaguas palisadegrass	1.020^{Ba}	1.010^{Ba}
Row pearl millet × Paiaguas palisadegrass	1.423^{Aa}	1.223^{Aa}
Inter-row pearl millet × Paiaguas palisadegrass	1.280^{Aa}	1.353^{Aa}
Oversown pearl millet × Paiaguas palisadegrass	1.276^{Aa}	1.230^{Aa}
CV (%)	7.68	

Means followed by different letters within a column (forage systems) and row (sowing periods) differ according to Tukey's test at 5% probability level.

leaf:stem ratio due to the elongation of the leaf blade. These results were more favorable than those observed by Leonel et al. (2009), who reported a leaf:stem ratio of approximately 1.0 when intercropping corn with marandu grass. However, the leaf:stem ratio was similar across all forage systems (P>0.05) for the two sowing periods.

Higher contents of NDF and ADF were measured in the first cut of the monocropped Paiaguas palisadegrass forage system of both sowing periods; these values differed (P<0.05) from those obtained in intercropped systems (Table 7). This may be associated to the higher leaf:stem ratio of intercropped systems, which resulted in a higher amounts of fibers.

The NDF and ADF contents were similar (P>0.05) in the second cut. It should be noted that pearl millet was no longer present at the time of the second cut; thus, there was more uniform growth of the forage, even in the periods (August and September) when rainfall was not stable.

The NDF and ADF results obtained in the present study were similar to those reported by Pariz et al. (2010), who evaluated the bromatological composition of *Urochloa* cultivars intercropped with corn, and found NDF contents ranging from 66.4 to 74.3% and from 70.3 to 78.1%, and ADF contents ranging from 40.0 to 43.1% and from 41.6 to 49.5% for mulato and marandu grasses, respectively.

When evaluating the sowing periods, Table 7 shows that the NDF contents of the first and second periods were similar (P>0.05) across all forage systems, and the same result was found for the ADF contents of the first

Table 7. Contents of NDF (%) and ADF (%) of monocropped Paiaguas palisadegrass and Paiaguas palisadegrass intercropped under different forage systems and sowing periods.

Forage systems	Sowing periods	
	First	First
	Contents of NDF - First cut	
Monocropped Paiaguas palisadegrass	74.12^{Aa}	74.04^{Aa}
Row pearl millet × Paiaguas palisadegrass	68.38^{Ba}	69.59^{Ba}
Inter-row pearl millet × Paiaguas palisadegrass	68.78^{Ba}	70.56^{Ba}
Oversown pearl millet × Paiaguas palisadegrass	68.07^{Ba}	68.68^{Ba}
CV (%)	4.20	
	Contents of NDF - Second cut	
Monocropped Paiaguas palisadegrass	67.15^{Aa}	65.57^{Aa}
Row pearl millet × Paiaguas palisadegrass	65.44^{Aa}	62.24^{Aa}
Inter-row pearl millet × Paiaguas palisadegrass	63.80^{Aa}	63.37^{Aa}
Oversown pearl millet × Paiaguas palisadegrass	66.36^{Aa}	63.18^{Aa}
CV (%)	4.25	
	Contents of ADF - First cut	
Monocropped Paiaguas palisadegrass	47.86^{Aa}	46.71^{Aa}
Row pearl millet × Paiaguas palisadegrass	44.19^{Ba}	40.76^{Ba}
Inter-row pearl millet × Paiaguas palisadegrass	42.99^{Ba}	41.91^{Ba}
Oversown pearl millet × Paiaguas palisadegrass	43.89^{Ba}	40.26^{Ba}
CV (%)	7.68	
	Contents of ADF - Second cut	
Monocropped Paiaguas palisadegrass	39.91^{Aa}	33.34^{Ab}
Row pearl millet × Paiaguas palisadegrass	39.55^{Aa}	35.16^{Ab}
Inter-row pearl millet × Paiaguas palisadegrass	37.87^{Aa}	35.22^{Ab}
Oversown pearl millet × Paiaguas palisadegrass	39.62^{Aa}	33.45^{Ab}
CV (%)	5.02	

Means followed by different letters within a column (forage systems) and row (sowing periods) differ according to Tukey's test at 5% probability level.

cut. However, the second sowing period resulted in lower ADF levels for the second cut, with an average value of 34.29%.

The NDF and ADF contents of the second cut were lower compared to the first cut due to the fact that cutting was carried out after a shorter growth cycle. In addition, after pearl millet harvest, there was resumption of growth of new tillers, which was also influenced by the onset of the rainy season (September), providing better quality forage. This proves that pearl millet intercropped with Paiaguas palisadegrass can be considered an excellent alternative for use in an agriculture-livestock integration system in the offseason when there is low forage yield and quality.

The evaluation of the CP contents of the first and second cuts showed significant (P>0.05) similarity between forage systems and sowing periods (P>0.05) (Table 8). The CP contents obtained in the present study were similar to those found by Maia et al. (2014), who evaluated the bromatological composition of forage grasses of the genus *Urochloa* in the offseason, after the harvest of corn in a crop-livestock integration system, and found mean CP contents ranging from 9.0 to 13.4%, in September and October, respectively. Machado and Valle (2011) found CP contents ranging from 11.9 to 15.5% for Paiaguas palisadegrass (B6 lineage).

Van Soest (1994) reported that cellulolytic rumen bacteria have satisfactory development if the CP content is equal to or above 7.0%. Therefore, it can be concluded that all CP contents obtained across all forage systems and sowing periods should meet the nutritional requirements. Thus, the procedure has proven to be

Table 8. Contents of CP (%) and IVDMD (%) of monocropped Paiaguas palisadegrass and Paiaguas palisadegrass intercropped under different forage systems and sowing periods.

Forage systems	Sowing periods	
	First	First
	Contents of CP - First cut	
Monocropped Paiaguas palisadegrass	12.44^{Aa}	12.57^{Aa}
Row pearl millet × Paiaguas palisadegrass	11.68^{Aa}	12.24^{Aa}
Inter-row pearl millet × Paiaguas palisadegrass	12.85^{Aa}	12.69^{Aa}
Oversown pearl millet × Paiaguas palisadegrass	11.88^{Aa}	12.52^{Aa}
CV (%)	5.83	
	Contents of CP - Second cut	
Monocropped Paiaguas palisadegrass	13.20^{Aa}	14.16^{Aa}
Row pearl millet × Paiaguas palisadegrass	14.29^{Aa}	13.57^{Aa}
Inter-row pearl millet × Paiaguas palisadegrass	13.55^{Aa}	14.68^{Aa}
Oversown pearl millet × Paiaguas palisadegrass	14.40^{Aa}	14.09^{Aa}
CV (%)	6.23	
	Contents of IVDMD - First cut	
Monocropped Paiaguas palisadegrass	47.41^{Ba}	48.45^{Ba}
Row pearl millet × Paiaguas palisadegrass	51.73^{Aa}	52.86^{Aa}
Inter-row pearl millet × Paiaguas palisadegrass	53.97^{Aa}	52.77^{Aa}
Oversown pearl millet × Paiaguas palisadegrass	52.25^{Aa}	56.44^{Aa}
CV (%)	8.54	
	Contents of IVDMD - Second cut	
Monocropped Paiaguas palisadegrass	54.66^{Aa}	49.83^{Aa}
Row pearl millet × Paiaguas palisadegrass	55.00^{Aa}	49.24^{Aa}
Inter-row pearl millet × Paiaguas palisadegrass	55.90^{Aa}	54.11^{Aa}
Oversown pearl millet × Paiaguas palisadegrass	48.53^{Aa}	51.98^{Aa}
CV (%)	8.71	

Means followed by different letters within a column (forage systems) and row (sowing periods) differ according to Tukey's test at 5% probability level.

relevant in terms of quality forage production in the offseason period – characterized by a lack of forage to meet animal production demand; the offseason period when there is usually low forage availability due to the seasonality of forage production.

The IVDMD was affected by the forage systems (P<0.05) in the first cut in both sowing periods, where the monocropped Paiaguas palisadegrass had a lower value compared to intercropped systems (Table 8). This result may be associated with a higher leaf:stem ratio in this monocropped system, which resulted in higher contents of NDF and ADF (Table 7). According to Fernandes et al. (2002), an increase in digestibility is associated with changes in the chemical composition, such as a decrease in NDF, ADF contents and hemicelluloses content, while providing readily digestible carbohydrates for rumen microorganisms.

Regarding the sowing periods, the IVDMD values were similar (P>0.05), confirming that sowing period had no significant effect on forage quality. Maia et al. (2014) found higher IVDMD values for genotypes of *Urochloa* intercropped with corn, ranging from 68.5 to 77.58%. The difference from values registered in our study is due to the time of assessment, as the corn was harvested in February in the case of Maia et al. (1014) trial, while in the present study, the pearl millet was harvested in July.

Conclusion

The intercropping of pearl millet with Paiaguas palisadegrass in the offseason proved to be a promising technique for grain production in Southeastern Goiás, where the Paiaguas palisadegrass did not affect the pearl millet grain yield. However, delayed sowing period (March …th) provided better grain yield and a higher number of sacks per hectare.

Regarding forage yield, Paiaguas palisadegrass grown with oversown pearl millet is impaired by intercropping. With respect to the forage quality, the intercropped sowing system did not affect the nutritional characteristics.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

We thank the Goiás State Research Support Foundation (FAPEG - Fundação de Amparo a Pesquisa do Estado de Goiás) for financing the project.

REFERENCES

Barducci RS, Costa C, Crusciol CAC, Borghi É, Putarov TC, Sarti LMN (2009). Produção de *Brachiaria brizantha* e *Panicum maximum* com milho e adubação nitrogenada. Arch. zootec. 58(1):211-222.

Brighenti AM, Sobrinho FS, Costa TR, Rocha WSD, Martin CE, Ferreira LHC (2008). Integração Lavoura-Pecuária: A cultura do girassol consorciada com *Brachiaria ruzizienses*. Embrapa Gado de Leite, Juiz de Fora MG. [s.n.]. (Embrapa Gado de Leite. Circular Técnica, 96). P 10.

Coimbra RA, Nakagawa J (2006). Época de semeadura e regimes de corte na produção de fitomassa e grãos de milheto forrageiro. Rev. Bras. Milho Sorgo 5(1):89-100.

Costa ACT, Geraldo J, Pereira MB, Pimentel C (2005). Unidades térmicas e produtividade em genótipos de milheto semeados em duas épocas. Pesqui. Agropecu. Bras. 40(12):1171-1177.

Costa KAP, Guerra Filho IA, Assis RL, Guimarães KC, Cruvinel WS, Epifânio PS, Gouveia RR (2012). Silage quality of pearl millet cultivars produced in different cutting ages. Sem: Ciênc. Agric. 33(3):1189-1198.

Costa NR, Andreotti M, Ulian NA, Costa BS, Pariz CM, Teixeira Filho MCM (2015). Acúmulo de nutrientes e tempo de decomposição da palhada de espécies forrageiras em função de épocas de semeadura. Biosci. J. 31(3):818-829.

Dan HDA, Barroso ALD, Dan LGD, Tannús VR, Finotti TR (2009). Seletividade de herbicidas aplicados na pós-emergência da cultura do milheto (*Pennisetum Glaucum*). Rev. Bras. Milho Sorgo 8(3):297-306.

Durães FOM, Magalhães PC, Santos FG (2003). Fisiologia da planta de milheto, Circular Técnica 28, Sete Lagoas, 65 p.

EMBRAPA (2013). EMBRAPA SOLOS - Empresa Brasileira De Pesquisa Agropecuária –Centro Nacional de Pesquisa de Solos. Sistema Brasileiro de Classificação de Solos. Embrapa CNPS, 3 ed. Rio de Janeiro. 353 p.

Fernandes LO, Reis RA, Rodrigues LRA, Ludic IL, Manzan RJ (2002). Qualidade do feno de Brachiaria decumbens Stapf. submetido ao tratamento com amônia anidra ou ureia. Rev. Bras. Zootec. 31(3):1325-1332.

Ferreira DF (2011). Sisvar: A computer statistical a nalysis system. Ciênc. Agrotecnol. 35(6):1039-1042.

Geraldo J, Rossiello ROP, Araújo AP, Pimentel C (2000). Diferenças em crescimento e produção de grãos entre quatro cultivares de milheto pérola. Pesqui. Agropecu. Bras. 35(7):1367-1376.

Horvathy NA, Silva AG, Teixeira IR, Costa KAP, Assis RL (2014). Consórcio de sorgo granífero e braquiária na safrinha para produção de grãos e forragem. Rev. Caatinga 27(3):132-141.

Horvathy NA, Silva AG, Teixeira IR, Simon GA, Assis RL, Rocha VS (2012). Consórcio sorgo e braquiária para produção de grãos e biomassa na entressafra. Rev. Bras. Milho Sorgo 7(1):743-749.

Ikeda FS, Mitja D, Vilela L, Carmona R (2007). Banco de sementes no solo em sistemas de cultivo lavoura-pastagem. Pesqui. Agropecu. Bras. 42(11):1545-1551.

Kluthcouski J, Stone LF, Aidar H, Cobucci T (2004). Integração lavoura - pecuária e o manejo de plantas daninhas. Inf. Agron. 106:1-20.

Leão HF, Costa KAP, Dias FJS, Severiano EC, Collao-saenz EA, Simon GA (2012). Production and bromatological composition of pearl millet genotypes for pasture manned in different cutting Heights. Biosci. J. 28(6):903-912.

Leonel FP, Pereira JC, Costa MG, De Marco JP, Lara LA, Queiroz AC (2009). Comportamento produtivo e características nutricionais do capim-braquiária cultivado em consórcio com milho. Rev. Bras. Zootec. 38(1):177-189.

Machado LAZ, Valle CB (2011). Desempenho agronômico de genótipos de capim-braquiária em sucessão à soja. Pesqui. Agropecu. Bras. 46(11):1454-1462.

Madhusudhana R, Govila OP (2001). Selection strategy for yeld improvement in pearl millet (*Pennisetum glaucum* (L.) R. Br.). Indian J. Genet. Plant Breed. 61(2):167-168.

Maia GA, Costa KAP, Severiano EC, Epifanio PS, Flávio NJ, Ribeiro MG, Fernandes PB, Silva JFG, Gonçalves WG (2014). Yield and Chemical composition of *Brachiaria* forage grasses in the offseason after corn harvest. Am. J. Plant Sci. 5 (1):933-941.

Pacheco LP, Pires FR, Monteiro FP, Procópio SO, Assis RL, Carmo ML, Peter FA (2008). Desempenho de plantas de cobertura em sobressemeadura na cultura da soja. Pesqui. Agropecu. Bras. 43(1):815- 823.

Pariz CM, Andreotti M, Azenha MV, Bergamaschine AF, Mello LMM, Lima RC (2010). Massa seca e composição bromatológica de quatro espécies de braquiárias semeadas na linha ou a lanço, em consórcio com milho no sistema plantio direto na palha. Acta Sci. Anim. 32(2):147-154.

Petter FA, Pacheco LP, Procópio SO, Cargnelutti FA, Volf MR (2011). Seletividade de herbicidas à cultura do milho e ao capim-braquiária cultivadas no sistema de integração lavoura-pecuária. Sem: Ciênc. Agrotechnologia 32(1):855-864.

Ribeiro MG, Costa KAP, Silva AG, Severiano EC, Simon GA, Cruvinel WS, Silva VR, Silva JT (2015). Grain sorghum intercropping with *Brachiaria brizantha* cultivars in two sowing systems as a double crop. Afr. J. Agric. Res.10 (39):3759-3766.

Seidel EP, Gerhardt IFS, Castagnara DD, Neres MA (2014). Efeito da época e sistema de semeadura da *Brachiaria brizantha* em consórcio com o milho, sobre os componentes de produção e propriedades físicas do solo. Sem: Ciênc. Agrotechnologia 35(1):55-66.

Silva DJ, Queiroz AC (2002). Análise de alimentos: métodos químicos e biológicos. Viçosa- MG: UFV. 235 p.

Soares AB, Sartor LR, Adami PF, Varella AC, Fonseca L, Mezzalira JC (2009). Influência da luminosidade no comportamento de onze espécies forrageiras perenes de verão. Rev. Bras. Zootec. 38(3):443-451.

Souza FR, Silva IM, Pellin DMP, Bergamin AC, Silva RP (2015). Características agronômicas do cultivo de sunflower consorciado com *Brachiaria ruziziensis*. Rev. Ciênc. Agron. 46(1):110-116.

Taiz L, Zeiger E (2010). Plant physiology. 5aed. Sunderland, Sinauer Associates. 700p.

Tilley JMA, Terry RA (1963). A two stage technique for *in vitro* digestion of forages crops. J. Brit. Grassl. Soc. 18:104-111.

Van Soest PJ (1994). Nutritional ecology of the ruminant. 2 ed. Ithaca: Cornell. 476 p.