Scientia Agraria Paranaensis – Sci. Agrar. Parana.
ISSN: 1983-1471 – Online
DOI: https://doi.org/10.18188/sap.v21i3.29779

PLANT DIVERSITY IMPACTS FORAGE MASS OF PASTURES ESTABLISHED AFTER SOYBEAN HARVEST IN INTEGRATED CROP-LIVESTOCK SYSTEM

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SAP 29779 Received: 20/05/2021 Accepted: 28/08/2022
Sci. Agrar. Parana., Marechal Cândido Rondon, v. 21, n. 3, jul./sep., p. 263-268, 2022

ABSTRACT - Pasture with multiple species is an option for integrated systems, but it is important that competition between forages does not interfere with the productivity of the pasture and, mainly, of the main grass. Therefore, this study aimed to verify if the Paiaguas palisade grass (*Urochloa brizantha* cv. Paiaguas) yield is suppressed in systems with multiple forage species established after soybean harvest and, identify if the species used in mixed pasture improves the total forage mass and, grass morphological and bromatological composition. Treatments consisted of species diversity: no diversity (Paiaguas palisade grass in monoculture), low diversity (Paiaguas palisade grass with *Vigna unguiculata*), medium diversity (Paiaguas palisade grass with *Vigna unguiculata* and *Guizotia abyssinica*), and high diversity (Paiaguas palisade grass with *Vigna unguiculata*, *Fagopyrum esculentum*, *Raphanus sativus*, and *Stylosanthes capitata* e *Stylosanthes macrocephala*). Pastures were established in March, in succession to soybean, and evaluated in June. There was no reduction in forage mass with increasing diversity, however, there was a reduction in the participation of Paiaguas palisade grass in the forage mass, without changing the morphological composition. The increase in species diversity reduced ash and crude protein levels. The increase in plant diversity in the system does not reduce the total available forage mass, however, it considerably reduces the Paiaguas palisade grass participation in the system, with no morphological change in the grass. The increase in diversity reduced the nutritional quality of the pasture, as there was a reduction in the crude protein content and an increase in neutral detergent fiber.
Keywords: Paiaguas palisade grass, forage diversity, mixed pasture.

DIVERSIDADE DE PLANTAS SOBRE MASSA DE FORRAGEM DE PASTOS APÓS COLHEITA DE SOJA EM INTEGRAÇÃO LAVOURA-PECUÁRIA

RESUMO - O pasto com múltiplas espécies é uma opção para sistemas integrados, mas é importante que a competição entre as forrageiras não interfira na produtividade do pasto e, principalmente, da gramínea prinicipal. Por isso, este trabalho teve como objetivo verificar se a produtividade do capim-paiaguas (*Urochloa brizantha* cv. Paiaguas) é suprimida em sistemas com múltiplas espécies forrageiras estabelecidas após a colheita da soja e, identificar se a espécie utilizada em pastagem mista melhora a massa de forragem total e a morfologia e composição bromatológica. Os tratamentos consistiram de diversidade de espécies: sem diversidade (capim-paiaguas em monocultivo), baixa diversidade (capim-paiaguas com *Vigna unguiculata*), média diversidade (capim-paiaguas com *Vigna unguiculata* e *Guizotia abyssinica*) e alta diversidade (capim-paiaguas com *Vigna unguiculata*, *Fagopyrum esculentum*, *Raphanus sativus* e *Stylosanthes capitata* e *Stylosanthes macrocephala*). As pastagens foram estabelecidas em março, em sucessão à soja, e avaliadas em junho. Não houve redução na massa de forragem com o aumento da diversidade, porém, houve redução na participação do capim-paiaguas na massa de forragem, sem alterar a composição morfológica. O aumento da diversidade de espécies reduziu os teores de cinzas e proteína bruta. O aumento na diversidade de plantas no sistema não reduz a disponibilidade total de massa de forragem, contudo, reduz consideravelmente a partição do capim Paiaguas no sistema, sem mudanças morfológicas no capim. O aumento na diversidade reduziu a qualidade nutricional do pasto, com uma redução na proteína bruta e aumento na fibra em detergente neutro.
Palavras-chave: capim-paiaguas, diversidade de forragem, pastos mistos.

INTRODUCTION

The region midwest of Brazil stands out nationally as an important grain producer, in which agriculture has a high technological level. However, the continuous use of soil in monoculture can cause organic matter reduction (BELTRÁN et al., 2018), which reduces soil fertility and consequently decrease crop yield. To reverse these reduction conditions in yield, the use of integrated crop-livestock systems (ICLS) is an alternative for the degraded areas recovery, both pastures and crops. Forage use in predominantly agricultural systems increases straw production for no-tillage, restructures soil physical and chemical properties, increases forage mass and grain yield (CRUSCIOL et al., 2014; COSTA et al., 2020).

After the soybean harvest, grass cultivars of the *Urochloa* genus are commonly used in cattle production

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systems, as they are productive forages in the off-season (CORREIA and GOMES, 2015). In this context, one of the highlights is the *Urochloa brizantha* cv. BRS Paiaguas, which is easy to establish and has high forage accumulation, good nutritional value and has high potential production during the dry season (VALLE et al., 2013). In addition, the forage legumes inclusion enhances the system since they are nitrogen fixators, which can reduce the need for fertilization (MNDZEBELE et al., 2020).

Some examples of legumes are *Vigna unguiculata* BRS Tumucumaque (Cowpea beans) and *Stylosanthes macrocephala* (Campo Grande stylosanthes), which favor pasture quality and soil biological characteristics, ensuring better performance in soybean production (FRANCO et al., 2020). Other forages examples that synergistically improve the system are *Guizotia abyssinica* (iger), *Fagopyrum esculentum* (buckwheat), *Raphanus sativus* (forage turnip), has a high capacity for cycling nutrients, such as nitrogen and phosphorus, and has good development in acidic soils. They can also be used for animal feed, as they reach higher nutritional values than grasses (CARVALHO et al., 2013; TESFAY and TESFAY, 2013; GÖRGEN et al., 2016).

However, in addition to improvements in soil chemistry and physics, there must be a synergism between the forages, so that competition and forage mass reduction does not occur, which directly impacts the stocking rate and system productivity. Therefore, this study aimed to verify if Paiaguas palisade grass (*U. brizantha* cv. BRS Paiaguas) yield established after soybean harvest is suppressed in systems with multiple forage species, as well as to identify if the species used in intercropping improves the total forage mass and, grass morphological and bromatological composition.

MATERIAL AND METHODS

The experiment was carried out at the Girassol Farm, located in Pedra Preta – Mato Grosso State, Brazil (16° 48' 51.21" S and 54° 04' 19.85" W; 732 m of altitude), in an *Aw* climate region, in the Köppen classification (ALVARES et al., 2013). Rainfall, maximum, minimum, and average temperature data were collected according to the months of implementation of the experiment until the collection of forage samples (Figure 1), which are available at the Instituto Nacional de Meteorologia (INMET). The trial period was from March to June 2018.

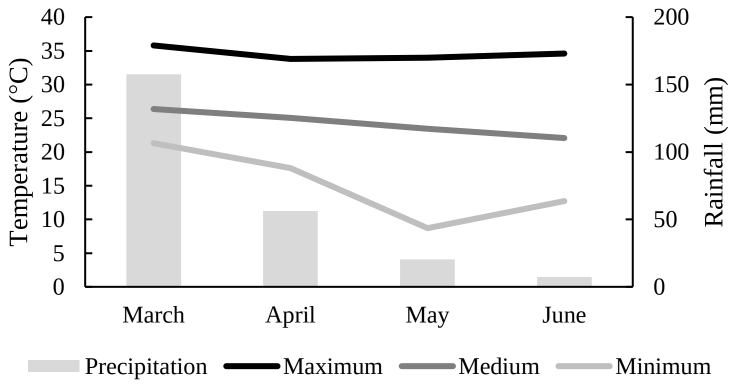

FIGURE 1 - Rainfall (mm) and temperature (°C) on the experimental area. Source: INMET.

The soil is classified as Oxisol, with the following chemical and textural characteristics: pH = 5.6; Al^{3+} = 0.06 $cmol_c$ dm^{-3}; Ca^{2+} = 3.0 $cmol_c$ dm^{-3}; Mg^{2+} = 1.08 $cmol_c$ dm^{-3}; K = 0.27 $cmol_c$ dm^{-3}; P = 13 mg dm^{-3}; CEC (pH 7) = 8.7 $cmol_c$ dm^{-3}; base saturation = 57%; organic matter = 43 g kg^{-1}; clay = 450 g kg^{-1}; silt = 360 g kg^{-1}; and sand = 190 g kg^{-1}.

The experiment was designed in randomized blocks, with 4 treatments and 3 replications, totaling 12 experimental plots. On average, each experimental plot had 3.2 ha, which resulted in an area of 38.4 ha. Treatments consisted of different systems with forage diversity, implanted in succession to soybean: no diversity: *Urochloa brizantha* cv. BRS Paiaguas (Paiaguas palisade grass) in monoculture; low diversity: Paiaguas palisade grass + *Vigna unguiculata* cv. BRS Tumucumaque (cowpea bean); medium diversity: Paiaguas palisade grass + cowpea bean + *Guizotia abyssinica* (niger); high diversity: Paiaguas palisade grass + cowpea bean + *Fagopyrum esculentum* (buckwheat) + *Raphanus sativus* (forage turnip) + *Stylosanthes capitata* e *S. macrocephala* (stylosanthes Campo Grande).

Before the experiment implementation, the area was cultivated for more than 20 years with soybeans in the harvest, and in the off-season, these cultures were cultivated: corn or cotton or *Sorghum sudanense* as the cover plant. About five years before the implementation of the experiment (2013-2018), the area was cultivated with soybean, and in the off-season *Urochloa* was grazed with a stocking rate of 2.5 AU ha^{-1}.

In September 2017, the animals were removed from the area and, thirty days later, soybean seeding was carried out, in which there was fertilization with 500 kg ha^{-1} of NPK (00-18-18). All necessary cultural treatments for the cultivation of soybeans were carried out. Soybean was harvested in February 2018 and treatments were implemented in March 2018, with Paiaguas palisade grass seeded in row, with a sowing rate of 4 kg ha^{-1} and 17 cm spacing in all treatments, except high diversity. Cowpea was seeded in row in all treatments, with a spacing of 45 cm and a population of 110 thousand plants per hectare (5 seeds per meter). In high diversity, a sowing rate of 15 kg ha^{-1} (turnip, stylosanthes, buckwheat, and Paiaguas) distributed by broadcast was used. After the plant's emergence, the presence of Sudan grass (*Sorghum sudanense*) was observed in all treatments, since it was a cover plant used for a long period in the experimental area.

In June 2018, before the entry of the animals, to assess the forage mass, a 0.25 m² (0.50 x 0.50 m) steel square was used and all the vegetable mass inside the frame was harvested close to the ground, being collected three samples per experimental plot. All forage mass collected was weighed and then botanically separated, so that all species involved in the study were separated, as well as weed. After botanical separation, the morphological separation of Paiaguas palisade grass (leaf blades, stem + sheath, and dead material) was performed. Samples forage mass were subjected to drying in an air circulation oven, at 55 ± 5ºC for 72 h, and weighed to quantify dry matter and for bromatological analysis. To calculate the weed percentage, consider the relationship between the weed mass and the system forage mass.

Forage samples collected were ground to 1.0 mm in a Willey knife mill for chemical analysis. Ash, neutral detergent fiber (NDF) and neutral detergent insoluble protein (NDIP) was obtained according to Detmann et al. (2021). Crude protein (CP) was obtained using the Kjeldahl method (DETMANN et al., 2021).

Thus, after data tabulation analysis of variance was performed and the means when significant, were compared by the Scott-Knott cluster test ($p<0.05$), using SISVAR (Version 5.6; FERREIRA, 2019). Regression analysis was used to describe the pasture support capacity according to grazing days.

RESULTS AND DISCUSSION

Species diversity did not influence the forage mass produced (Table 1). Thus, it was observed that there was plant growth compensation between the systems adopted. It was observed that the increase in diversification observed in the treatments low, medium, and high species diversity did not reduce the proportion and mass of Paiaguas palisade grass in the total forage mass, but comparing the high diversity system with the monoculture system, the diversification decreased the Paiaguas palisade grass proportion by approximately 40% (Table 1; Figure 2).

TABLE 1 - Forage mass (MF) and percentage of Paiaguas palisade grass, cowpea, niger, buckwheat, sudangrass, forage turnip, sthylosanthe, and weed in succession to soybean in an integrated agricultural production system.

System	No diversity	Low diversity	Medium diversity	High diversity	SEM[1]
FM (kg ha^{-1})	6823 a*	5850 a	5640 a	5937 a	836.95
Paiaguas grass (%)	68 a	37 b	34 b	27 b	6.88
Cowpea (%)	-	22 a	24 a	24 a	4.51
Niger (%)	-	-	0.36	-	0.181
Buckwheat (%)	-	-	-	19	2.88
Sudangrass (%)	32 a	41 a	41 a	30 a	5.95
Forage turnip (%)	-	-	-	0.28	0.142
Sthylosanthes (%)	-	-	-	-	-
Weed (%)	0.4 b	8.8 a	6.8 a	0.6 b	2.37

*Average followed by the same lowercase letter in the line, do not differ from each other by the Scott-Knott test ($p>0.05$). [1]Standard error of the mean.

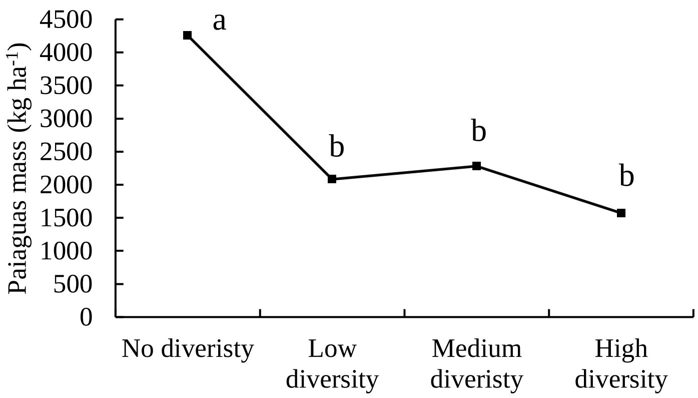

FIGURE 2 - Paiaguas palisade grass mass in succession to soybean in an integrated agricultural production system. Average followed by the same lowercase letter, do not differ from each other by the Scott-Knott test ($p>0.05$).

Among the forages and legumes, cowpea was the main legume that had more growth in the multi-specie pasture which was present in the proportion of 22 to 24% (Table 1), being the only forage present in the low, medium, and high diversification systems. Vendramini et al. (2012) also observed reduction on herbage accumulation rate of

Bahiagrass when intercropped with cowpea, while Corriher-Olson et al. (2013) verified the reduction in bermudagrass mass only when cowpea was established with high seeding rate. Buckwheat, had small participation and was present only in the system with high diversity (Table 1). One cause of the suppression of Paiaguas palisade grass may be the emergence speed due the establishment in march when there is a reduction on rain.

Sudangrass was a cover plant used by the property before the experiment implementation, so there was expressive participation in the total forage mass (Table 1). However, there was no difference in the proportion of this grass, which demonstrates that there was the same influence on all treatments.

The Campo Grande stylosanthes development was not observed in the system with high diversity, which demonstrates the difficulty of establishing this plant in this condition of multi crop pasture and in the end of the rainy season. Results observed by Lopes et al. (2011) showed that with increasing tillering of *Urochloa brizantha* cv. Xaraes as a result of phosphate fertilization there was a reduction in the plants number of stylosanthes Mineirao (*Stylosanthes guianensis* cv. Mineirão). Likewise, Rodrigues et al. (2018) observed low participation of Campo Grande stylosanthes in intercropping with *Urochloa brizantha* cv. marandu.

Similarly, niger and forage turnip had low participation in the plant population representing 0.36% and 0.28% of the forage mass in the high diversity pasture, respectively (Table 1). The low presence in forage turnip may be associated with poor adaptation to tropical climate regions, as in experiments in the Rio Grande do Sul state, evaluating sowing rates, forage turnip contributed most for the yield when intercropped with black oats (*Avena strigosa*) (SILVA et al., 2007), which demonstrates greater forage turnip adaptability in temperate climates. On the other hand, buckwheat represented 19% of the forage mass of the high diversity treatment, which demonstrates the adaptability of this crop to this diversification system and adequacy in the sowing rate used, being a good alternative for feeding ruminants (GÖRGEN et al., 2016).

Regardless of systems, there was low weed emergence (Table 1). There was a lower weed presence in the no diversity and high diversity systems (Table 1). The Paiaguas palisade grass competitiveness was able to suppress the weed. However, there was an increase in the weed proportion in low and medium diversity. In high diversity, the inserted plants, mainly buckwheat (Table 1), even though they reduced the participation of Paiaguas palisade grass, were also able to suppress weed. Thus, the high plant diversity system is a good alternative for weed control, considering that weed can compete for nutrients with grass reducing forage growth (PEREIRA et al., 2019).

It was observed that species diversity did not change the morphological composition of Paiaguas palisade grass, as the percentage of the leaf blade, stem+sheath, and dead material did not vary statistically (Figure 3). Commonly when there is competition, grasses tend to elongation the tiller to expose the younger leaves to light in the upper part of the canopy also increasing senescence (SBRISSIA et al., 2020), however, these effects were not noted.

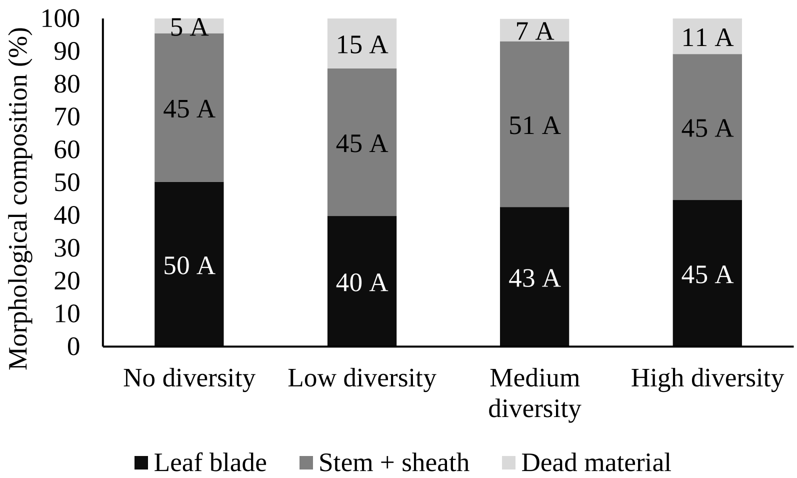

FIGURE 3 - Percentage of the leaf blade, stem + sheath, and dead material of Paiaguas palisade grass in succession to soybean in an integrated agricultural production system. Average followed by the same uppercase letter in the same characteristic, do not differ from each other by the Scott-Knott test (p>0.05).

In the Paiaguas palisade grass monoculture (no diversity) there was a higher content of ash and a lower of NDF (Table 2). The low and medium diversity systems had the highest NDF contents, followed by the high diversity system (Table 2). Cell-wall carbohydrates of plants are less digestible carbohydrates in the rumen. Thus, when NDF levels are increased in the plant, there is a tendency to reduce dry matter digestibility (ORTEGA-AGUIRRE et al., 2015).

The highest crude protein levels were verified in pastures no and low diversity, and as well as higher crude protein content associated with a NDF was evidenced in these treatments (Table 2). Even with the observed crude protein reduction, pastures showed high CP contents above

70 g kg^{-1} as recommended by Lazzarini et al. (2009) which contribute to the microorganism's development the rumen improving grass digestibility. Even with a difference in the NDIP content in relation to dry matter, there is no effect of species diversity on the NDIP content in relation to the crude protein content (Table 2), so the pastures had an average of 30% of NDIP (Table 2).

TABLE 2 - Percentage of ash, insoluble neutral detergent fiber (NDF), crude protein (CP) e neutral detergent insoluble protein (NDIP) of forages in succession to soybean in an integrated agricultural production system.

System	Ash	NDF	CP	NDIP	NDIP
	% DM				% CP
No diversity	10.8 a*	66.6 c	16.0 a	4.9 a	31 A
Low diversity	9.6 b	72.4 a	15.0 a	4.6 a	31 A
Medium diversity	9.1 b	72.7 a	13.8 b	4.0 b	29 A
High divertsity	9.5 b	70.3 b	13.6 b	4.0 b	29 A
SEM[1]	0.342	0.384	0.446	0.181	0.181

*Average followed by the same uppercase letter in the line column, do not differ from each other by the Scott Knott test (p>0.05). [1]Standard error of the mean.

Thus, the plants diversification systems seeded simultaneously favor the no-tillage system since the forage mass does not decrease and, therefore, the straw availability in the soil is the same. However, although diversification has not compromised the forage mass, in cases of sporadic rains in the off-season, it is likely that the animals present in the diversified pastures are kept for a shorter period in the system, compared to the system without diversification, since the others species used do not have the same regrowth potential as the Paiaguas palisade grass, which was suppressed in pastures with several species. Thereby, new research must be carried out to test plant populations that reduce competition between forage plants and favor the development of main grass in the system.

CONCLUSIONS

The increase in plant diversity in the system does not reduce the total available forage mass, however, it considerably reduces the Paiaguas palisade grass participation in the system, with no morphological change in the grass.

The increase in diversity reduced the nutritional quality of the pasture, as there was a reduction in the crude protein content and an increase in neutral detergent fiber.

ACKOWLEDGMENTS

To Fazenda Girassol for experimental site availability and funding, and to Universidade Federal de Rondonópolis (UFR).

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