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# Forage Production and Bromatological Composition of Forage Species Intercropped With Soybean

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**Abstract**

Brazil is one the largest soybean and cattle producer worldwide and degrade pasture is one of the major problem in the Cerrado region. Integrated crop-livestock system is a key to increase grower income, to reduce crop yield loss by water deficit during growing season and to reclaim degraded pasture. However, forage production and its quality is important to evaluate under integrated crop-livestock system. The objective of this study was to evaluate forage production and the bromatological composition of different forage species in monoculture and in intercropping with soybean in an oversowing system. A completely randomized block design with four replications in a 5 × 2 + 1 factorial scheme, with five forage species (*Urochloa brizantha* cv. Marandu; *U. ruziziensis*; *P. maximus* cv. Mombaça; *P. infestans* cv. Massai and *P. americanum*) and two cropping systems (monoculture and a consortium with soybeans) and a standard treatment (*P. americanum* in succession with soybeans). The forage productivity and the bromatological composition of the forages were evaluated. The species *U. ruziziensis*, *U. brizantha*, *M. maximum* and *P. infestans* presented higher forage production capacity, when cultivated in consortium with soybeans and in monoculture, in relation to *P. americanum*. The cultivation of the forages *U. ruziziensis*, *U. brizantha*, *M. maximum* and *P. americanum* in monoculture produced higher productivity than that in consortium with soybeans. The forages *U. ruziziensis* and *U. brizantha* intercropped with soybean presented a better nutritional value over the autumn-winter period.

**Keywords:** *Glycine max*, cover crop, nutritional value

## 1. Introduction

Pasture degradation with time has been one of the biggest problems for the development of agricultural activity in Brazil. This activity has been carried out in malformed pastures with inadequate management, mainly in relation to fertilization and weed control, affecting the sustainability of the production systems (Sano et al., 2019; Brito et al., 2018; Bonaudo et al., 2014). Due to the large investments required for pasture formation, restoration and reform, various techniques have been sought to reduce these high investments. Integrated crop-livestock system (ICLS) associated with grain crops in a no-tillage system has been recognised as an alternative for the recovery of degraded areas, increasing the efficiency in the use of inputs and labour, and allowing intensive use of the area with the possibility of economic gains throughout the year (Alves et al., 2017; Franzluebbers et al., 2014; Moraes et al., 2014). Integrated crop-livestock system has presented better sustainability than modern monocultural production systems, which in general rely on the use of large quantities of agricultural inputs (Lemaire et al., 2015; Bonaudo et al., 2014). This system assumes the diversification of crops under no-tillage, the use of improved animals and crops, and correct pasture management (Sano et al., 2019; Alves et al., 2017; Nie et al., 2016).

Most of the areas used for grain production in the Brazilian Cerrado, remain fallow for seven to eight months, with only one harvest per agricultural year, due to unfavourable weather conditions in early autumn, especially water deficit. In the state of Tocantins, which has well defined rainy and dry seasons, forage sowing in February and/or March in the summer season may be an alternative to anticipate forage establishment, increasing forage productivity and quality, as well as straw formation for the no-tillage system (Andrade et al., 2017).

The majority of the studies with ICLS report evaluations with only grain producing crops. However, factors such as the species planted, soil fertility, maturity, harvest, management and climatic conditions (water, temperature and photoperiod) can affect the production of dry matter and bromatological composition. Consequently, the energy content, crude protein (CP) or total digestible nutrients (TDN) of the forages, principally the components of the plant cell wall, such as cellulose and hemicellulose are also affected (Carvalho et al., 2018; Costa et al., 2016).

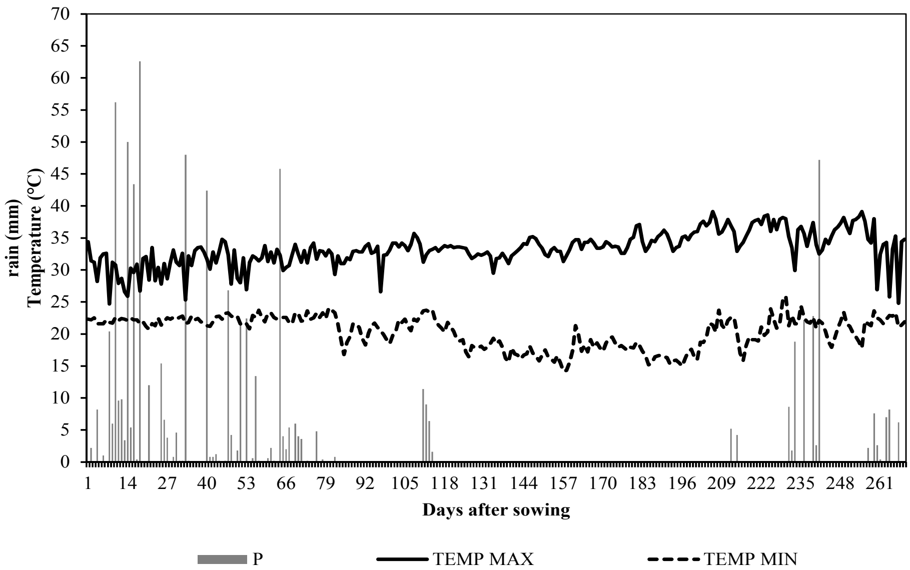
The adoption of ICLS systems is an alternative to partially or totally supply the forage deficit during this season, with the planting of annual forages such as millet or sorghum or perennial species of the genus *Urochloa*, oversown as summer crops. However, the majority of studies with ICLS evaluate the use of *Urocloa brizantha* and *B. decumbens*, with a lack of information about *U. ruziziensis*. In the same way, little information is available about the use of forages from the genus *Pannicum*, necessitating studies that prove the efficiency of these forages in the ICLS system under no-tillage.

In view of the above, the objective of this study was to evaluate forage production and bromatological composition of different forage species intercropped with soybean in an over-sowing system and in monoculture.

## 2. Method

The study was carried out in a long-term experiment on the recovery of degraded pastures, at an experimental site of the Federal University of Tocantins, municipality of Gurupi, located in the south of the State of Tocantins, in the agricultural year 2013/2014. The geographic location is 11º43′45″S latitude, 49º04′07″W longitude and an altitude of 278 m. The predominant climate in the region according to Köppen (1948) is Aw. Characterised as humid tropical, with dry winters, maximum rainfall in the summer and an average annual temperature of 26.1 °C. The soil of the area is a Latossolo Amarelo (Embrapa, 2013).

The climatic data regarding maximum/minimum temperatures and precipitation during the experimental period, recorded by the Meteorological Station of the Federal University of Tocantins, Gurupi Campus, are shown in Figure 1.




Figue 1. Daily rain, maximum and minimum air temperature in Gurupi-TO during 2014 growing season

When the experiment started in 2012 the area was under an intensive farming system, tropical grasses in the winter and soybeans in the summer. However, before implantation, soil samples were collected from the 0 to 0.2 m soil layer for chemical analyses, according to Raij and Quaggio (1983). The soil values were: pH in $CaCl_2$ = 3.98; P = 1.09 mg $dm^{-3}$; K = 32.0 mg $dm^{-3}$; Cu = 0.90 mg $dm^{-3}$; Zn = 0.30 mg $dm^{-3}$; Mn = 12.20 mg $dm^{-3}$; Ca = 0.17 $cmol_c$ $dm^{-3}$; Mg = 0.06 $cmol_c$ $dm^{-3}$; Al = 0.75 $cmol_c$ $dm^{-3}$; H+Al = 4.34 $cmol_c$ $dm^{-3}$; t = 1.06 $cmol_c$ $dm^{-3}$; T = 4.65 $cmol_c$ $dm^{-3}$; m = 70.75%; V = 6.71% ; O.M. = 15.40 g $dm^{-3}$; Sand = 690 g $dm^{-3}$; Silt = 100 g $dm^{-3}$ and Clay = 210 g $dm^{-3}$. 2500 and 1000 kg $ha^{-1}$ of limestone and gypsum, respectively, were broadcast surface applied. 250 kg $ha^{-1}$ of $P_2O_5$ (as simple superphosphate) and 100 kg $ha^{-1}$ of $K_2O$ (as potassium chloride) were also applied via broadcast surface. The limestone applied was dolomitic filler with a Relative Total Neutralising Power (RTNP) = 100%, to increase base saturation to 60%, according to the recommendations proposed by Sousa and Lobato (2004).

Soil was plowed to incorporate the gypsum at the 0-0.40 m soil layer, and then the soil was plowed to incorporate the lime, P and K at the 0-0.20 m soil layer. Soil was tilled with a disk harrow to leveling the soil prior seeding.

A completely randomized block design with four replications using a 5 × 2 + 1 factorial scheme, with five cropping systems: 1) soybean intercropped with *Urochloa brizantha* cv. Marandu (Soybean + *U. brizantha*); 2) soybean intercropped with *Urochloa ruziziensis* (Soybean + *U. ruziziensis*); 3) soybean intercropped with *Panicum maximum* cv. Mombaça (Soybean + *P. maximum*); 4) soybean intercropped with *Panicum infestans* cv. Massai (Soybean + *P. infestans*); 5) soybean intercropped with *Pennisetum americanum* (Soybean + Millet). There was a treatment named "standard" which consisted of soybean followed by *Pennisetum americanum* (Soybean/Millet) which is the most common cropping systems in the region. All the forages were also cultivated in monoculture systems.

The plots of intercropped systems were 5 m wide by 21 m in length. For the plant evaluations were considered only the central area of plots, disregarding a meter of the extremities and 0.5 meters from the plot border, comprising a total area of 105 m². In single crop each experimental unit was formed by 2 meters wide and 7 meters in length. For the evaluations were considered only the central area of plots, disregarding 0.5 meters of the extremities and 0.3 meters from the side, comprising a total area of 14 m².

The soybean cultivar SYN1279 RR, early cycle, was planted and prior inoculated with *Bradyrhizobium japonicum*, Semia 5079 and SEMIA 5080, at a dose of 300 g for each 50 kg of seed, at the time of sowing. Fertilizers were applied in furrow at the rate of 120 kg $ha^{-1}$ of $P_2O_5$ (simple superphosphate) and 30 kg $ha^{-1}$ of fertilizer containing micronutrients (Boron, 1.8%; Copper: 0.85%; Manganese: 2.0%; Zinc: 9.0%). Potassium was applied via surface broadcast 10 days before soybean sowing, at the rate of 80 kg $ha^{-1}$ of $K_2O$ (potassium chloride).

Forages were terminated 15 days before soybean sowing (5 November 2013) with glyphosate, at a dose of 1.8 kg $ha^{-1}$ of active ingredient (a.i.). The soybean was sown on November, 20 using no-till planter with 0.45 m row spacing and targeted plant population of 377,000 plants $ha^{-1}$.

The oversowing of the forage species was carried out on February 06, 2014, scattering manually, when the soybean plants reached the R5 reproductive stage (50% of the plants at the "beginning seed" stage). On this date the plots were seeded with forge species for the monoculture treatment. The quantity of seed for the species *U. ruziziensis*; *U. brizantha* cv. Marandu; *P. maximum* cv. Mombaça and *P. infestans* cv. Massai were calculated from the recommended amount for sowing these species in rows, 5 kg $ha^{-1}$ of viable pure seeds, and 15 kg $ha^{-1}$ of viable pure seeds for millet (*P. americanum* cv. ADR 300). To determine the amount of seeds, the Cultural Value (CV) of each species was taken into consideration.

The soybeans were harvested on March 20, 2014, corresponding to a 120-day cycle. For this operation, the experimental units were submitted to mechanical harvesting adopting the cutting height of the platform to allow the insertion of the first pod. After, forage species were sampled to determine their dry matter production from March to June.

For these evaluations the following management was adopted: mechanical cutting of the plants, without material removal, according to the height of each species. The forages *U. ruziziensis*, *U. brizantha*, *P. maximum* and *P. infestans* were considered ready for cutting at a height of 25, 25, 90 and 50 cm and a cutting height of 15, 15, 30 and 25 cm from the soil surface, respectively. *P. americanum* cv. ADR 300 was considered ready for cutting after complete emission of the panicle and the cutting height was 40 cm from the soil surface. The numbers of evaluations of each forage species in the two cropping systems and the cutting days after the soybean harvest are shown in Table 1.

Table 1. Quantity of cuts with their respective numbers of days after sowing of different forage species intercropped with soybean and in monoculture.

| Treatments | Intercropped | | Monoculture | | |
|---|---|---|---|---|---|
| | First cut | Second cut | First cut | Second cut | Third cut |
| | Days after sowing (n) | | | | |
| Soybean/Millet | 100 | 147 | 100 | 147 | - |
| Soybean+Millet | 79 | 119 | 56 | 83 | 119 |
| Soybean+*P. maximum* | 79 | 133 | 56 | 83 | 110 |
| Soybean+*P. infestans* | 91 | 133 | 56 | 83 | - |
| Soybean+*U. brizantha* | 91 | 121 | 56 | 83 | 121 |
| Soybean+*U. ruziziensis* | 79 | 121 | 56 | 83 | 121 |

For the sampling, 4 rectangles measuring 100 × 25 cm were used, randomly distributed within each experimental unit. The material was cut with the aid of a manual mechanical brushcutter, weighed, a subsample was placed in a circulating air oven at 60 °C until constant weight and the dry material production was quantified. In the remainder of the plot, a tractor-mounted horizontal brushcutter was used to cut at heights specific for each species.

Forage dry matter production, from each evaluation, was summed to determine forage dry matter yield over the whole evaluation period. For each treatment the daily forage accumulation was determined, by calculating the ratio of the sum of the dry matter of the evaluated cuts and the number of days until the last cut was carried out.

After each forage harvest to quantify the dry matter production, a subsample of each treatment was separated, ground and then passed through a 1 mm mesh sieve to be used in the determination of the bromatological components.

The fibre content in neutral detergent (FND), fibre in acid detergent (FAD), crude protein (CP), cellulose and hemicellulose were determined using the methodology described by Silva (1990). Estimation of the total digestible nutrient (TDN) content was performed using the formula suggested by Harlan et al. (1991), which is described by:

$$\%TDN = 109.64 - 1.479 \times \%FAD \quad (1)$$

Where, %TDN: percentage of the total digestible nutrients; %FAD: fibre in acid detergent determined in laboratory.

All of the bromatological determinations were carried out in laboratory at Embrapa Milho e Sorgo (Sete Lagoas, MG, Brasil).

Experimental data were subjected to an analysis of variance applying the F test. For comparisons between the means, the Tukey test was performed at 5% probability, with the assistance of the computational application SISVAR (Ferreira, 2011).

**3. Results and Discussion**

Table 2 shows the F values and significance levels for the variables daily forage accumulation, total dry matter yield, acid detergent fibre (ADF), neutral detergent fibre (NDF), cellulose, hemicellulose, crude protein (CP) and total digestible nutrients (TDN). Considering the interaction species versus cropping systems, there was significance for the characteristics daily forage accumulation, total dry matter yield, acid detergent fibre, neutral detergent fibre, cellulose, crude protein and total digestible nutrients. This characterised interdependence between these factors, thus, the cropping systems influenced differentially the expression of the species studied.

For hemicellulose the interaction was not significant, thus characterizing the independence of the studied factors, that is, the cropping systems does not influence the species differentially, therefore, the factors were studied separately.

Table 2. ANOVA (F values) significance for daily forage accumulation (DFA), total dry matter yield (TDMY), acid detergent fibre (ADF), neutral detergent fibre (NDF), cellulose (CE), hemicellulose (HM) crude protein (CP) and total digestible nutrients (TDN) in the forages according to the cropping systems

| Factors | DFA | TDMY | ADF | NDF | CE | HM | CP | TDN |
|---|---|---|---|---|---|---|---|---|
| | ---------- F value ---------- | | | | | | | |
| Forages (F) | 32.96** | 85.75** | 94.68** | 72.50** | 72.50** | 8.76** | 41.98** | 94.86** |
| Cropping systems (CS) | 178.34** | $0.017^{ns}$ | $0.52^{ns}$ | $0.21^{ns}$ | $0.21^{ns}$ | $1.55^{ns}$ | 11.12** | $0.52^{ns}$ |
| F × CS | 19.23** | 6.88** | 10.44** | 4.58** | 4.58** | $0.32^{ns}$ | 6.86** | 10.45** |
| CV (%) | 19.7 | 16.0 | 3.2 | 2.2 | 4.4 | 3.5 | 6.7 | 1.2 |

*Note*. * and ** significance levels of 5 and 1% of probability, respectively.

Table 3 shows the values for the daily forage accumulation and total dry matter productivity for the species intercropped with soybean and in monoculture, evaluated from February to July, 2014. From the results obtained it was verified that only in the monoculture was an effect of the treatments observed. For the characteristic daily forage accumulation (Table 3), the forages *U. brizantha* and *U. ruziziensis* presented higher values than the other forages. In addition, it was observed that the forages *P. maximum*, *P. infestans* and millet were superior to the standard treatment (millet in succession with soybean).

Table 3. Daily forage accumulation and total dry matter yield of the forages according to the cropping systems evaluated from February to June of 2014

| Treatments | Daily forage accumulation | | | Total dry matter yield | | |
|---|---|---|---|---|---|---|
| | Intercropped | Monoculture | Mean | Intercropped | Monoculture | Mean |
| | ---------- $kg\ ha^{-1}$ ---------- | | | | | |
| Soybean/Millet | 11.27 Aa | 11.27 Ac | 11.26 | 1633 Aa | 1633 Ac | 1633 |
| Soybean+Millet | 13.84 Ba | 21.96 Ab | 17.90 | 1646 Ba | 2612 Abc | 2129 |
| Soybean+*P. maximum* | 16.33 Ba | 29.92 Ab | 23.13 | 2172 Ba | 3291 Ab | 2731 |
| Soybean+*P. infestans* | 14.32 Ba | 32.09 Ab | 23.20 | 1905 Aa | 2663 Abc | 2284 |
| Soybean+*U. brizantha* | 17.83 Ba | 57.15 Aa | 37.49 | 2157 Ba | 6915 Aa | 4536 |
| Soybean+*U. ruziziensis* | 17.47 Ba | 50.97 Aa | 34.22 | 2113 Ba | 6167 Aa | 4140 |
| Mean | 15.17 | 33.90 | | 1938 | 3880 | |

*Note*. Values followed by the same lowercase letter, presented vertically, and uppercase letters horizontally are not significantly different according to Tukey's test at 5% of probability.

For the characteristic productivity of total dry matter, the treatments showed the same tendency as forage accumulation, due to the direct relationship between these two characteristics. However, it was observed that the forages *P. infestans*, millet and millet post-soybean did not differ, presenting the lowest dry matter yields, although millet and *P. infestans* did not differ from *P. maximum*. These results are similar to those described by Andrade et al. (2017), where the straw yield and agronomic performance of soybean intercropped with forage species under no-tillage, observed lower dry matter yields for *P. infestans* and millet.

The lower total dry matter yields observed for these forages can be explained, in the case of *P. infestans* grass, by having a lower frequency of cutting than other forages in monoculture (Table 1), resulting in lower total dry matter production. For millet and millet post-soybean, the low productivity may be related to the characteristic that the plant has a marked reduction in the production of biomass after cuts. This decrease is directly related to the residual height left after harvest, which in the present study was 40 cm.

According to Campana et al. (2018), successive sprouting and good dry matter production for millet occur when the cutting height is between 50 and 100 cm from the soil. Trindade et al. (2017) stated that cutting closer to the soil has the disadvantage of eliminating potential sprouting points, which impairs the vigour of plant regrowth. Therefore, different cutting heights directly affect the availability and quality of forage from this specie.

In relation to the cropping systems, it was observed that monoculture produced higher values for the daily forage accumulation and the total dry matter productivity in relation to intercropping with the treatments millet, *P. maximum*, *P. infestans*, *U. brizantha* and *U. ruziziensis*. The daily forage accumulation presented values of approximately 8, 14, 18 and 19 kg ha$^{-1}$ for millet, mombaca, *P. infestans*, *U. brizantha* and *U. ruziziensis*, respectively. While the increase in total productivity was approximately 966, 1119, 758, 4758 and 4054 kg ha$^{-1}$ for millet, mombaca, *P. infestans*, *U. brizantha* and *U. ruziziensis*, respectively.

These results can be attributed to the amount of nutrients available for the forages in each cropping system. For the monoculture, the forages were fertilized before sowing, while under intercropping the forages used the residual fertilizer from soybean. This fact most probably provided greater amount of nutrients in the soil available for the plants in monoculture, resulting in greater development and consequently higher forage productivity.

Another likely explanation is related to the amount of solar radiation incident on the forages under each cropping system. Under intercropping, oversowing occurred when the soybeans were at the R5 stage, thus, from this stage until soybean harvest, the forages germinated and developed, but showed slower development due to the shading caused by the soybean plants. On the other hand, for monoculture, the forages received more sunlight during the first 45 days after sowing, since there was no shading, resulting in an increase in photosynthesis and the consequent increase in forage development and production.

Ikeda et al. (2013) studied the interference in maize and *Urochloa brizantha* intercropping and Castagnara et al. (2014) studying soybean and *Urochloa brizantha* intercropping, also attributed the fall in production to shading caused by the annual crops used in the intercropping system. Lopes et al. (2017), reported that shading caused by $C_4$ plants, generally resulted in a lower production of dry matter.

The mean FAD values differ among the forages, independent of the cropping system used (Table 4). Using intercropping, the forages millet and *P. infestans* presented the highest values of FAD (38.33 and 37.77 dag kg$^{-1}$, respectively). The forages *P. maximum* and millet post-soybean, presented intermediate ADF values, while the forages *U. brizantha* and *U. ruziziensis* presented the lowest means. Under monoculture, the treatments with the highest means were millet and *P. maximum* (37.10 and 35.74 dag kg$^{-1}$, respectively). Although *P. maximum* did not significantly differ from millet post-soybean and *P. infestans*.

Table 4. Amounts of acid detergent fiber (ADF) and neutral detergent fiber (NDF) of the forages according to the cropping systems evaluated from February to June of 2014

| Treatments | ADF | | | NDF | | |
|---|---|---|---|---|---|---|
| | Intercropped | Monoculture | Mean | Intercropped | Monoculture | Mean |
| | ---------- dag kg$^{-1}$ ---------- | | | | | |
| Soybean/Millet | 34.47 Ab | 34.47 Ab | 34.47 | 69.65 Aa | 69.65 Aa | 69.65 |
| Soybean+Millet | 38.33 Aa | 37.10 Aa | 37.72 | 71.15 Aa | 69.99 Aa | 70.57 |
| Soybean+*P. maximum* | 34.93 Ab | 35.74 Aab | 35.33 | 68.82 Aa | 68.60 Aa | 68.71 |
| Soybean+*P. infestans* | 37.77 Aa | 34.17 Bb | 35.97 | 71.46 Aa | 67.71 Ba | 69.58 |
| Soybean+*U. brizantha* | 28.34 Bc | 30.31 Ac | 29.33 | 61.81 Ab | 62.93 Ab | 62.37 |
| Soybean+*U. ruziziensis* | 26.97 Bc | 30.38 Ac | 28.67 | 58.69 Bb | 61.55 Ab | 60.12 |
| Mean | 33.47 | 33.69 | | 66.93 | 66.74 | |

*Note*. Values followed by the same lowercase letter, presented vertically, and uppercase letters horizontally are not significantly different according to Tukey's test at 5% of probability.

Regarding the cropping systems, significant differences were found only for the *P. infestans*, *U. brizantha* and *U. ruziziensis* treatments, under monoculture the *U. brizantha* and *U. ruziziensis* forages presented higher ADF values compared to the intercropping system. However, for *P. infestans* grass the behaviour was inverted, presenting a lower ADF mean under monoculture. Pariz et al. (2010) evaluated the bromatological composition of different forage species, under intercropping with maize and in monoculture, and found lower ADF values under intercropping for *U. brizantha* and *U. ruziziensis* grasses, corroborating the results from the present study.

For the characteristic NDF, the studied treatments had significant effects under both cropping systems (Table 4). The millet post-soybean, *P. maximum* and *P. infestans* treatments differed from the *U. brizantha* and *U. ruziziensis* treatments, which presented the lowest NDF values. Values higher than those found in the present study were reported by Castagnara et al. (2014), in the summer period, working with a crop-livestock integration system, in which *Urocloa brizanta* cv. *U. brizantha* presented an FND content of 78.1%.

Comparing the two cropping systems, significant differences were found only for the forages *P. infestans* and *U. ruziziensis*, which presented opposite behaviours. *P. infestans* grass presented the highest NDF value when intercropped with soybean, while for *U. ruziziensis* the highest value was found in monoculture.

The highest values of ADF and NDF were observed with *P. infestans* with intercropping in relation to monoculture, which was probably due to the timing of the cuts in each cropping system, since with intercropping the *P. infestans* grass took more days to reach the cutting point (Table 1). This is probably due to the shade produced by the soybeans during the initial development of the grass, thus leading to higher forage lignification that increased the fibre content. According to Fluck et al. (2018), with increasing physiological age, the plant tends to increase the levels of the cell wall components, causing loss of forage quality more quickly.

It is important to highlight that the higher the ADF value, the lower the digestibility, while NDF is negatively correlated with forage intake, considering levels of 40% ADF and 60% NDF as limiting digestibility and intake, respectively (Costa et al., 2018). Thus, with the exception of *U. ruziziensis* grass in the intercropping system, NDF levels were generally higher than 60%. So, despite the different fertilization and specific management for each forage, the cropping systems produced forages with a high NDF content. However, the ADF levels were lower than 40% in both cropping systems, inferring forage with lower consumption, but with good digestibility.

Table 5 shows the levels of cellulose and hemicellulose in the forage species under the different cropping systems. When comparing the forage species, it was observed that the lowest cellulose contents were obtained by the millet post-soybean, millet, *P. maximum* and *P. infestans* treatments, differing from the *U. brizantha* and *U. ruziziensis* treatments in both cropping systems.

When comparing the cropping systems, significant differences were observed for only *P. infestans* and *U. ruziziensis* (Table 5). *P. infestans* grass presented lower cellulose values when grown in consortium with soybean, unlike *U. ruziziensis* grass where higher values were observed using the same cropping system. In the intercropping system, the decomposition of the straw and plant residues from the previous year, probably increased the availability of nutrients in the soil, principally nitrogen for the forages. This in turn improved their nutritional values, in the case of *P. infestans* grass it was the reduction in cellulose content and for *U. ruziziensis* grass the reduction in the ADF and NDF content (Table 4).

Table 5. Cellulose and Hemicellulose of the forages according to the cropping systems evaluated from February to June of 2014

| Treatments | Cellulose | | | Hemicellulose | | |
|---|---|---|---|---|---|---|
| | Intercropped | Monoculture | Mean | Intercropped | Monoculture | Mean |
| | ---------------------------------- dag $kg^{-1}$ ---------------------------------- | | | | | |
| Soybean/Millet | 30.35 Ab | 30.35 Ab | 30.35 | 35.18 | 35.18 | 35.18 a |
| Soybean+Millet | 28.85 Ab | 30.01 Ab | 29.43 | 32.82 | 32.90 | 32.85 bc |
| Soybean+*P. maximum* | 31.17 Ab | 31.40 Ab | 31.29 | 33.90 | 32.86 | 33.38 b |
| Soybean+*P. infestans* | 28.54 Bb | 32.30 Ab | 30.42 | 33.69 | 33.54 | 33.62 ab |
| Soybean+*U. brizantha* | 38.19 Aa | 37.08 Aa | 37.63 | 33.47 | 32.62 | 33.04 bc |
| Soybean+*U. ruziziensis* | 41.31 Aa | 38.45 Ba | 39.88 | 31.72 | 31.17 | 31.45 c |
| Mean | 33.07 | 33.26 | | 33.46 | 33.05 | |

*Note*. Values followed by the same lowercase letter, presented vertically, and uppercase letters horizontally are not significantly different according to Tukey's test at 5% of probability.

With respect to the hemicellulose content of the different forage species, the values varied from 31.17 to 35.18%. The lowest average was observed in the *U. ruziziensis* treatment, although it did not differ from *U. brizantha* and millet and the highest was observed in the post-soy millet, although it did not differ from the *P. infestans* value (Table 5).

According to Fernandez & Rodriguez (2013), cellulose forms the major part of the ADF, with hemicellulose forming part of the NDF, which is calculated using the difference between NDF and ADF, and is more digestible than cellulose. Thus, it is interesting to raise the hemicellulose content and reduce cellulose, since ruminants transform these components through their bacterial flora into short-chain fatty acids (SCFA), mainly acetic, propionic and butyric, which represent the largest source of energy when these animals feed on forage.

For the average crude protein (CP) levels, significant differences were observed between the forage species, both in intercropping with soybean and in monoculture (Table 6). In the intercropping system, the species *U. ruziziensis* and *U. brizantha* presented higher crude protein content, different from the other species in the study. The lowest levels were observed for the species *P. infestans*, *P. maximum* and millet post-soybean. In monoculture, again the species *U. brizantha* and *U. ruziziensis* presented the highest levels of crude protein in comparison to the other treatments, except *P. infestans* grass. On the other hand, millet, *P. maximum* and *P. infestans* presented similar responses, differing from the millet post-soybean, which produced the lowest level (11.72%).

The highest levels of crude protein were observed for forages from the genus *Urocloa* (*U. brizantha* and *U. ruziziensis*) and the lowest from the genus *Pannicum* (*P. infestans* and *P. maximum*), both under intercropping and monoculture. This could be related to the minimum harvesting height of the forages and also to the height of the plant at the moment of the evaluation. For *Urocloas*, harvesting height 25 cm, with a cutting height of 15 cm above ground level. Due to this type of management the material collected was younger with high protein levels and low fibre content (Table 4), consequently the plant grew less, favouring nutrient concentration over vegetative development. In contrast, the forages from the genus *Pannicum*, the harvesting height was 50 and 80 cm and the cutting height 25 and 30 cm above ground level, for *P. infestans* and *P. maximum*, respectively. Thus, the more fibrous tissues were collected with a lower protein content, as the plant favours vegetative growth, reducing the concentration of nutrients.

Table 6. Crude protein and total digestible nutrients of the forages according to the cropping systems evaluated from February to June of 2014

| Treatments | Crude protein | | | Total digestible nutrients | | |
|---|---|---|---|---|---|---|
| | Intercropped | Monoculture | Mean | Intercropped | Monoculture | Mean |
| | dag $kg^{-1}$ | | | | | |
| Soybean/Millet | 11.72 Abc | 11.72 Ac | 11.72 | 63.71 Ab | 63.71 Ab | 63.71 |
| Soybean+Millet | 12.95 Ab | 13.88 Ab | 13.41 | 61.01 Ac | 61.87 Ac | 61.44 |
| Soybean+*P. maximum* | 12.06 Bbc | 13.73 Ab | 12.89 | 63.39 Ab | 62.83 Abc | 63.11 |
| Soybean+*P. infestans* | 10.75 Bc | 14.54 Aab | 12.64 | 61.40 Bc | 63.92 Ab | 62.66 |
| Soybean+*U. brizantha* | 16.13 Aa | 16.49 Aa | 16.31 | 68.00 Aa | 66.62 Ba | 67.31 |
| Soybean+*U. ruziziensis* | 17.68 Aa | 16.35 Aa | 17.02 | 68.96 Aa | 66.58 Aa | 67.78 |
| Mean | 13.55 | 14.45 | | 64.41 | 64.26 | |

*Note*. Values followed by the same lowercase letter, presented vertically, and uppercase letters horizontally are not significantly different according to Tukey's test at 5% of probability.

In relation to the cropping systems, significant differences were observed only with the forages *P. infestans* and *P. maximum* and presented a higher crude protein content when cultivated in monoculture. This fact can be attributed to the better luminosity and fertilization conditions, coupled with the higher growth characteristic of these forages in monoculture. In intercropping the forages were cultivated using the soybean nutrient residue and in the first 45 days, development was reduced due to shading by the soybean plants. Thus, the decomposition of soybean crop and straw residues from the previous year did not provide a satisfactory amount of nutrients, especially nitrogen, allowing the forages to increase vegetative growth with increased nutritional value.

The concentrations of CP observed for the species in both cropping systems are consistent with those described in other studies, such as Medeiros et al. (2011) working with *Urocloa brizantha*, with two cuts (45 and 60 days) and Krutzmann et al. (2014) that evaluated the bromatological composition of different gramineae forages intercropped with soybean using four different sowing times. These values could adequately attend the minimum protein requirements for ruminants. However, diets with CP content lower than 7% limit voluntary intake and reduce digestibility because of the negative nitrogen balance.

According to Lana et al. (2016), when forage CP content is lower than 7%, digestion is reduced due to inadequate nitrogen levels for the rumen microorganisms, reducing their numbers and consequently reducing digestibility and dry matter intake. Thus, higher CP content is necessary to attend the protein demands of the animal. In this study, the observed average CP content was over 10%.

With respect to the total digestible nutrients (TDN), significant differences were observed between treatments in both cropping systems (Table 6). In intercropping with soybean, as observed with CP, the forages *U. brizantha* and *U. ruziziensis* presented the highest means, in comparison to the other species tested. *P. maximum* and the millet post soybean treatments presented similar levels, differing from only *P. infestans* and millet, which presented the lowest levels. The same behaviour was observed in monoculture, except for *P. infestans* grass which presented values similar to the *P. maximum* and millet post-soybean treatments, differing from millet, which showed the lowest value.

The behaviour observed for the treatments, for both cropping systems, are directly related to the FAD content, since the TDN calculation is performed from the FAD values. Higher fibre content signifies lower nutrient levels. However, in all the treatments, independent of the cropping system, presented means above 55%, which according to Costa et al. (2015), are values ideal for tropical forages.

Regarding the cropping systems, significant differences were found for the *P. infestans* and *U. brizantha* forages, with higher values being observed for *P. infestans* in monoculture and for *U. brizantha* under intercropping. This contrary behaviour observed in these forages is probably due to the height that each forage has to reach before cutting and the time elapsed to reach this stage. In *P. infestans* grass, two cuts were made under both cropping systems, however, in monoculture the time elapsed was shorter, allowing the collection of newer, less fibrous tissues and consequently with higher nutrient content. On the other hand, *U. brizantha* grass in monoculture suffered three cuts, while under intercropping only two cuts were made during the same period (Table 1). As the bromatological indicators were calculated including the average number of cuts, probably, in monoculture there was an increase in the number of tillers, due to the stimulation caused by a larger number of cuts, resulting in an increase in fibre content, mainly in the third cut, which consequently reduced the mean TDN content.

## 4. Conclusion

The species *Urochloa ruziziensis*, *U. brizantha*, *P. maximum* and *P. infestans* presented a higher forage production capacity, under both the monoculture and intercropping with soybeans, in relation to *P. americanum.* The cultivation of the forages *Urochloa ruziziensis*, *U. brizantha*, *P. maximum* and *P. americanum* in monoculture, presented higher forage production in relation to intercropping with soybeans. The forages *Urochloa ruziziensis* and *U. brizantha* when sowed in intercropping, presented a better nutritional value over the autumn-winter period.

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