



Forage species in succession to soybean in crop-livestock integration in Eastern Amazon

Espécies forrageiras em sucessão à soja na integração lavoura-pecuária na Amazônia Oriental

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Abstract :

The objective of this study was to evaluate the productivity development in the crop-livestock integration (CLI) system using the forage species *Urochloa ruziziensis* cv. Ruziziensis, *Urochloa brizantha* cv. BRS Piaã, and *Megathyrus maximus* cv. BRS Tamani with soybeans in the Eastern Amazon region. The experiment was conducted in the field using a completely randomized block design with four treatments and five replications. All evaluated forage species demonstrated high productive potential in the Eastern Amazon region. In the context of the CLI system, BRS Tamani cultivar showed early maturity and higher forage yield (2172.1 kg ha⁻¹ of total dry matter), making it suitable for animal production. On the other hand, Ruziziensis cultivar presented advantages in crop succession due to its effectiveness and rapid desiccation (100% efficiency up to 21 days after desiccation, $p < 0.05$). The biomass produced by the forage species had a limited impact on soil fertility and carbon sequestration within a year in the crop-livestock integration system, but it is expected that this contribution will increase over time. Furthermore, the use of this system in the Eastern Amazon region can contribute to better land utilization without losses in soybean production. However, we recommend caution in choosing the forage species according to the objective, whether it is for producing mulch for the next soybean cycle or for animal grazing.

Key words: Carbon sequestration, Dry matter production, Sustainability, Tropical weather

Resumo:

O objetivo deste estudo foi avaliar o desenvolvimento da produtividade no sistema de integração lavoura-pecuária (ILP) utilizando a espécie forrageira *Urochloa ruziziensis* cv. Ruziziensis, *Urochloa brizantha* cv. BRS Piatã e *Megathyrsus maximus* cv. BRS Tamani com soja na região da Amazônia Oriental. O experimento foi conduzido em campo em um delineamento em blocos casualizados com quatro tratamentos e cinco repetições. Todas as espécies forrageiras avaliadas demonstraram alto potencial produtivo na região da Amazônia Oriental. No contexto do sistema ILP, o cultivar BRS Tamani apresentou maturidade precoce e maior produtividade de forragem (2.172,1 kg ha⁻¹ de matéria seca total), tornando-o adequado para produção animal. Por outro lado, o cultivar Ruziziensis apresentou vantagens na sucessão de culturas devido à sua eficácia e rápida dessecação (100% de eficiência até 21 dias após a dessecação, $p < 0,05$). A biomassa produzida pelas espécies forrageiras teve um impacto limitado na fertilidade do solo e no sequestro de carbono dentro de um ano no sistema de integração lavoura-pecuária, mas espera-se que esta contribuição aumente ao longo do tempo. Além disso, a utilização desse sistema na região da Amazônia Oriental pode contribuir para um melhor aproveitamento da terra sem perdas na produção de soja. Porém, recomendamos cautela na escolha das espécies forrageiras de acordo com o objetivo, seja para produção de cobertura morta para o próximo ciclo da soja ou para pastagem de animais.

Palavras-chave: Sequestro de carbono, Produção de matéria seca, Sustentabilidade, Clima tropical

1. Introduction

Brazilian soybean production reached an impressive 166.053,9 million tons during the 2024/25 crop season, with significant contributions from the Amazon region (CONAB, 2024). Additionally, Brazil witnessed the slaughter of 41.9 million cattle in 2023, of which 83.4% originated from pasture-based systems (ABIEC, 2024). Both cattle ranching and soybean cultivation are crucial sectors of the Brazilian economy, but there is still ample room for improvement in terms of sustainability, especially in the Amazon region.

The intensification of crop-livestock integration (CLI) aims to combine agricultural and livestock activities in rotation or succession within the same area, but during different periods. The primary objective of CLI is to increase the efficient utilization of natural resources while minimizing environmental impact, thus providing an option for the restoration of degraded pastures. Degraded pastures represent a significant liability in Brazilian agriculture, according to MAPBIOMAS (2025), in the Brazilian Amazon, 33.97% of the landfills are in this situation. Restoration and recovery efforts could transform these areas into a new frontier for both agricultural production expansion and forest restoration (Barbieri & Feris, 2021).

Unlike conventional pastures, integrated pastures offer abundant and high-quality forage during the dry season, consequently reducing the high costs of animal feed during this period or providing income opportunities for farmers, furthermore, grass can be used exclusively for the production of straw and soil cover during the dry period of the year. There are many technology packages with different crop combinations for CLI; however, for soybeans, there are still challenges due to their low height and low competition capacity, furthermore, gaps regarding which forage species would be most adapted to this technique have not yet been fully elucidated for the Amazon region. Therefore, intercropping is possible, as it can be performed by seeding grasses at the end of the soybean cycle, avoiding interference with the legume (Borghi *et al.*, 2017).

This system can be considered an evolution in agroecosystems, enabling the sharing of conservation methods and intensified yields. Additionally, the characteristics of CLI can mitigate the adverse effects of climate on crops, especially during the dry season. The presence of crops

(agricultural and livestock) contributes to the sequestration of CO₂ from the atmosphere, and their residues deposited in the soil contribute to the increase in organic matter, and consequently in soil carbon. Furthermore, due to the lack of soil disturbance characteristic of CLI, the organic matter present or deposited is little exposed to the environment, contributing to the persistence of C stocks (Tavanti *et al.* 2020, Abreu *et al.* 2024).

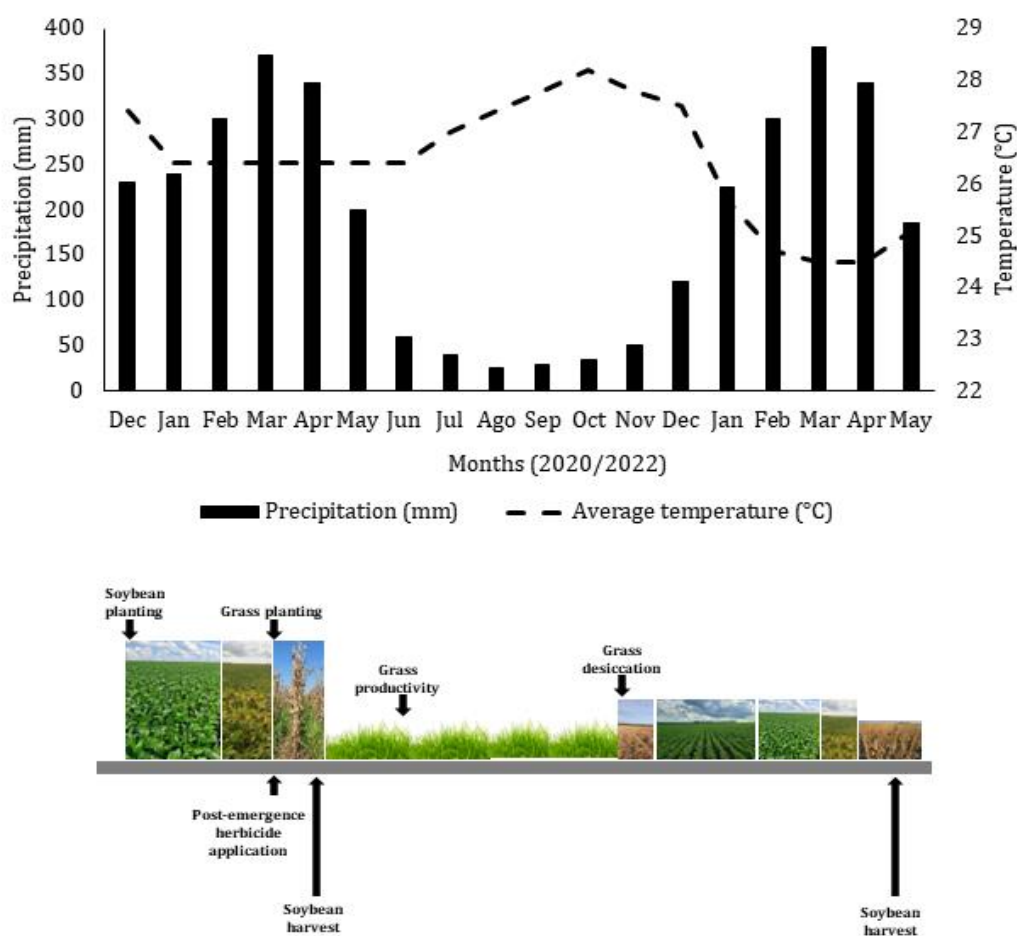
The objective of this study was to evaluate the yield performance of the CLI system with the forage species *Urochloa ruziziensis* cv. Ruziziensis, *Urochloa brizantha* cv. BRS Piatã, and *Megathyrsus maximus* cv. BRS Tamani with soybeans in the Eastern Amazon, seeking to indicate the best species based on answers to the hypothesis that different plants have their own growth and resistance characteristics that would affect their ability to be used in CLI systems.

2. Materials and methods

2.1. Experimental environment

The research was carried out in Paragominas, Pará, Brazil, at a latitude of 2°58'46.8"S and a longitude of 47°4'2.7"W. The local climate is tropical rain with a dry season between May to December, classified as Aw according to Köppen. The annual average temperature is 26.3°C, average relative air humidity is 81% (Bastos *et al.*, 2005), and the average rainfall is 1,742.9 mm year⁻¹. In the experimental period the total rainfall and average temperature were 3,393 mm and 26.5°C, respectively (Figure 1).

Figure 1. Experimental scheme
Figura 1. Esquema experimental



The soil of the experimental area was classified as 'Latossolo Amarelo' (Typic Hapludox), being uniform, deep, and clayey. Physical analysis of the soil indicated composition of 730, 40 and 230 g kg⁻¹ of clay, sand and silt, respectively, in the 0-20 cm layer. Chemical analyses showed pH (H₂O) – 5.2; P – 12.5 mg kg⁻¹; K – 7.0 g kg⁻¹; Ca – 6.4 g kg⁻¹ and Mg – 1.5 g kg⁻¹ using extraction by ion exchange resin; H+Al – 3.80 cmol_c kg⁻¹ by pH SMP (potential acidity); CEC (Cation exchange capacity) – 8.44 cmol_c kg⁻¹; V – 54.9%, OM (Organic matter) – 1.9 % extraction by Sodium Dichromate and colorimetric determination (Claessen *et al.*, 1997). Fertilization management was realized with 50 kg ha⁻¹ of P₂O₅ and K₂O in January 2021.

2.2. Experimental design

A randomized complete block design was used with four treatments and five replications. Treatments included a control (soybean-alone system) and three environments of soybean in succession of forage grasses *Urochloa ruziziensis* cv. Ruziziensis, *Urochloa brizantha* cv. BRS Piatã and *Megathyrsus maximus* cv. BRS Tamani. Experimental design was a plot comprising eight soybean lines spaced by 0.6 m, with 10 m of length.

2.3. Establishment and conduction of the experiment

Soybean NS8383 RR of maturation group 8.3 with an average cycle of 111-121 days was grown on January 25th, 2021 (crop 2020/21), while the grasses were oversown onto soybean in stage R7 during maturity, at the beginning of defoliation (April, 8 of 2021), followed by post-emergence herbicide application (April, 23 of 2021), Figure 1.

Grasses were sowed manually by broadcast sowing according to the intercrop recommendation by Ceccon (2015). Crop densities were equivalent to 28.7, 22, and 11 kg ha⁻¹ according to cultural values of 22, 25, and 51%, respectively, for species *Urochloa ruziziensis* cv. Ruziziensis, *Urochloa brizantha* cv. BRS Piatã, and *Megathyrsus maximus* cv. BRS Tamani.

Sequentially, soybean TMG2383 of the maturation group 8.3 with an average cycle of 112-116 days was grown in December 2021 (crop 2021/22) under straw of desiccated grass (Figure 1).

2.4. Experimental evaluations

Dry matter production of forage was evaluated through a sampling by plot collected close to the ground with a sampler of 1 x 1 m on 60 days after sowing. Samples were weighed and sub-sampled to determine the dry matter content and, consequently, the yield estimate, besides morphological components separation.

Morphological components were separated manually as stem, leaf, and senescent material. The forage and plant component samples were dried in a forced-air circulation oven at 105°C for 72 hours. The leaves were ground in a Willey mill for analysis of definitive dry matter (G-003/1), crude protein (INCT N-001/2) by the micro-Kjeldahl method, ash (muffle incineration INCT M-001/2), neutral detergent fiber (INCT F-002/2), acid detergent fiber (INCT F-004/2), and hemicellulose using the autoclave method described by Detmann *et al.* (2021).

Before the next soybean sowing (crop 2021/22), the grasses were desiccated (November 2021) using 1.3 L ha⁻¹ of glyphosate along with 100 mL ha⁻¹ of oil (manufacturer's recommendation). The control efficiency of forages was realized by visual evaluation at the 21st day after herbicide application through a sample of 1 x 1 m with attributed notes from zero (all tiller live) to 100 (all tiller died) according to method described by Machado & Assis (2010).

Soil in a layer of 0-0.20 m was sampled to evaluate soil fertility and organic carbon before sequential soybean sowing (December 2021), comprising five subsamples per plot.

Emergence of soybean under the straw occurred in January 2022 (16 days after sowing), with seedlings counted in 10 linear meters.

Soybean yield and the 1000-grain weight from the 2021/22 crop were determined through the harvest of 20 linear meters in the center of the plot. Harvest plants and grains were mechanically separated, then weighed and sub-sampled for humidity determination. Grain yield was adjusted to 13% of humidity by equations 1 and 2.

Equation 1. Discount equation

$$\text{Discount (\%)} = [(\text{Initial humidity} - 13) \times 100] / (100 - 13) \quad (1)$$

Equation 2. Adjustment equation

$$\text{Adjusted mass (g)} = \text{Sample mass} - [\text{Sample mass} \times (\text{Discount}/100)] \quad (2)$$

2.5. Statistical analysis

The statistical model used was described in equation 3:

$$Y_{ij} = \mu + T_i + \beta_j + \epsilon_{ij} \quad (3)$$

Y_{ij} = value of the response variable in the i -th treatment and j -th block; μ = overall mean; T_i = effect of the i -th treatment; β_j = effect of the j -th block and ϵ_{ij} = experimental error associated with the observation.

Data were analyzed to identify outliers as influencing in the analysis procedure, and were thus disregarded after being tested individually. Following this, variables were submitted to a normality study by Shapiro-Wilk. Variables non-attended in normal criteria were analyzed by BOX-COX from package “fpp” of the R software or nonparametric of Kruskal-Wallis. Data were analyzed by ANOVA using “emmeans” and “agricolae” packages from R software (R Core Team (2019). Significant effects among treatments were analyzed using the comparison study by Tukey with $p < 0.05$.

3. Results

3.1. Chemical composition and dry matter production of forage grasses

Total dry matter production was about 40,9% higher in BRS Tamani compared to Ruziziensis cultivars, while BRS Piatã cultivar showed no difference compared with both BRS Tamani and Ruziziensis (Table 1). BRS Piatã and Ruziziensis, on the other hand, presented as a late material as it obtained 39 and 11.7% of senescent material compared to BRS Tamani, respectively (Table 2).

Table 1. Total dry matter production of forage grass and morphological components as leaves, stem and senescent material at 60 days after sowing in soybean intercrop

Tabela 1. Produção total de matéria seca da gramínea forrageira e componentes morfológicos como folhas, caule e material senescente aos 60 dias após a semeadura em soja consorciada

Treatments	Dry matter production			
	Total	Leaves	Stem	Senescent material
	kg ha ⁻¹			
Tamani	2172.1 a	1306.4 a	532.3 a	152.8 a
Ruziziensis	1285.5 b	801.9 b	446.2 a	45.7 ab
Piatã	1447.8 ab	991.5 ab	405.0 a	17.9 b
<i>p</i> -value	0.042	0.028	0.651	0.0008
CV (%)	37.0	31.9	36.9	112.0

Different letters in the same column differ statistically at 0.05 probability by Tukey test. CV: coefficient of variation
 Letras diferentes na mesma coluna diferem estatisticamente com probabilidade de 0,05 pelo teste de Tukey. CV: coeficiente de variação.

BRS Tamani grass was highlighted as having a higher crude protein content in leaves, however, it was similar to Piatã (Table 2). Tamani was superior 35% to Ruziziensis. Contents of ash, NDF, NDA, and hemicellulose in leaves showed similar values among the treatments (Table 2).

Table 2. Crude protein (CP), ash, neutral detergent fiber (NDF), acid detergent fiber (ADF) and hemicellulose (Hemicel) of leaves at 60 days after sowing in soybean intercrop

Tabela 2. Proteína bruta (PB), cinza, fibra em detergente neutro (FDN), fibra em detergente ácido (FDA) e hemicelulose (Hemicel) de folhas aos 60 dias após semeadura em soja consorciada

Treatments	CP	Ash	NDF	ADF	Hemicel
			%		
Tamani	16.0 a	8.7	50.8	23.8	27.2
Ruziziensis	11.8 b	8.6	48.2	22.4	25.7
Piatã	13.0 ab	8.1	49.9	24.8	26.4
<i>p</i> -value	0.043	0.544	0.785	0.761	0.752
CV (%)	20.3	10.9	8.5	17.0	10.4

Different letters in the same column differ statistically at 0.05 probability by Tukey test. CV = coefficient of variation
 Letras diferentes na mesma coluna diferem estatisticamente com probabilidade de 0,05 pelo teste de Tukey. CV = coeficiente de variação.

3.2. Improvements in soil fertility

Chemical characterization of soil fertility showed effects of treatments only for Cation exchange capacity (CEC) (Table 3).

Table 3. Chemical characteristics of soil fertility

Tabela 3. Características químicas da fertilidade do solo

Treatments	PH	P*	S	K	Ca	Mg	H+Al	CEC**	BS	V
	CaCl ₂	mg kg ⁻¹			cmol _c kg ⁻¹			cmol _c kg ⁻¹		%
Control	5.81	28.2	9.9	1.7	6.6	1.4	2.03	6.97 a	49.4	71
BRS Tamani	5.69	30.9	9.5	1.4	6.8	1.5	2.21	7.18 a	49.7	68
Ruziziensis	5.68	35.0	12.0	1.3	5.1	1.3	2.09	6.05 b	39.6	65
BRS Piatã	5.81	24.4	11.2	1.2	6.4	1.4	1.97	6.67 ab	47.0	70
<i>p</i> -value	0.695	0.625	0.280	0.099	0.072	0.336	0.185	0.013	0.088	0.142
CV (%)	3.5	41.3	32.8	29.2	27.8	14.6	9.57	15.9	23.5	8.9

*P = using extraction by ion exchange resin. **CEC = Cation exchange capacity. Different letters in the same column differ statistically at 0.05 probability by Tukey test. CV: coefficient of variation.

*P = usando extração por resina. **CEC = Capacidade de troca catiônica. Letras diferentes na mesma coluna diferem estatisticamente a 0,05 de probabilidade pelo teste de Tukey. CV: coeficiente de variação.

All data of Al content and Al saturation (m%) absent of Table 1 were consequence of analysis presented in experimental soil comprised, respectively, values under 0.1 and 0. The highest values of CEC were obtained for the control and BRS Tamani forage grass, however without difference from Piatã. Treatment with Ruziziensis showed lower CEC, although with similarity among control and Tamani (Table 3). The organic C (SOC) and soil organic matter showed similarity to CEC and showed lower values than Ruziziensis forage grass, for which SOC was 10.1 g kg⁻¹ while it was, on average, 13 g kg⁻¹ for other treatments (Table 4).

Table 4. Soil Organic Carbon (SOC) and organic matter in soil (O.M.) after crop forage grasses *Megathyrsus maximus* cv. BRS Tamani, *Urochloa ruziziensis* cv. Ruziziensis, *Urochloa brizantha* cv. BRS Piatã and control

Tabela 4. Carbono orgânico do solo (SOC) e matéria orgânica no solo (O.M.) após cultivo de gramíneas forrageiras *Megathyrsus maximus* cv. BRS Tamani, *Urochloa ruziziensis* cv. Ruziziensis, *Urochloa brizantha* cv. BRS Piatã e controle

Treatments	SOC*	O.M.**
	g kg ⁻¹	
Control	13.1 a	22.6 a
BRS Tamani	13.0 a	22.4 a
Ruziziensis	10.1 b	17.4 b
BRS Piatã	12.8 a	22.0 a
<i>p</i> value	<0.001	<0.001
CV (%)	23.4	23.5

*Soil Organic Carbon and Organic Matter by Sodium Dichromate extraction and colorimetric determination. Different letters in the same column differ statistically at 0.05 probability by Tukey test. CV: coefficient of variation

*C orgânico e matéria orgânica do solo pela extração em Dicromato de sódio e determinação por colorimetria. Letras diferentes na mesma coluna diferem estatisticamente com probabilidade de 0,05 pelo teste de Tukey. CV: coeficiente de variação.

3.3. Forage grass desiccation

The visual evaluation in forages, indicated that the desiccation treatment was highly effective in controlling weeds and achieving complete suppression (100%) of Ruziziensis, resulting in total desiccation of tillers and plants. However, BRS Tamani and BRS Piatã exhibited greater resistance to desiccation, with an average of only 30% of these grasses dying after 21 days of desiccation ($p<0.05$).

3.4. Forage intercropped effects on soybean of succession

Seedling emergence of soybean sown under straw from previous treatments was not affected, nor were the grain yield or the 1000 grain weight (Table 5).

Table 5. Soybean emergence and productive parameters under straw from treatments

Tabela 5. Emergência e parâmetros produtivos da soja sob palha dos tratamentos

Treatments	Seedling emergence	Grain yield	Mass of thousand grains
	seedling/m linear	kg ha ⁻¹	g
Control	9.2	3933.5	177.5
BRS Tamani	8.1	4031.6	193.3
Ruziziensis	8.6	4304.9	188.1
BRS Piatã	7.8	4531.6	189.8
<i>P</i> -value	0.526	0.057	0.113
CV (%)	23.3	10.3	5.1

Different letters in the same column differ statistically at 0.05 probability by Tukey test. CV: coefficient of variation
Letras diferentes na mesma coluna diferem estatisticamente com probabilidade de 0,05 pelo teste de Tukey. CV: coeficiente de variação.

4. Discussion

4.1. Improvements in soil fertility

Soil fertility parameters in experimental areas can be classified in a transition phase from low to medium levels. The experimental area has few years of cultivation under management aiming fertility construction, that comprising managements as soil fertility corrections and no tillage adoption.

The absence of the influence from treatments in soil fertility parameters can be a consequence of the short evaluation time under the new system of consortium, mainly the small interval between plant desiccation and soil sampling. The results of decomposition biomass can contribute to soil fertility and organic matter, mainly CEC, however can take time. According to studies from Santos *et al.* (2014), decomposition and nutrients release (except N) dynamic from maize straw intercropped with *Urochloa ruziziensis* occurred around 70 days after desiccation.

Benefits to soil fertility are verified mainly after straw and radicular system decomposition, thus, Costa *et al.* (2021) observed the cropping system affecting soil pH, exchangeable Ca, and Mg, which were most favorable in the cropping systems with palisade grass in succession to sorghum.

Recalcitrant compounds, as lignin and cellulose, comprised in ADF were similar contents among forages, however Ruziziensis comprised lower total production of biomass with lower content of crude protein, that summed with its characteristic stem, usually more lignified compared to other species can take more time to mineralization, consequently, explain the lower contribution to contents of organic matter and CEC. The similarity among treatments for control, BRS Piatã and BRS Tamani cultivars, to values of organic matter, CEC and SOC can be justified by a possible faster straw decomposition, in the control treatment case, by the from present weeds. Higher exposition of soil after crop harvest can promote deleterious effects over organic matter content in soil, mainly under extreme temperatures and humidities from the Amazon.

Soybean is indicated as a great crop option for CLI due to its ability to fixate nitrogen in soil, and its classification as plant type C₃ providing a residue of fast degradation. This combination allows the nutrients and high yield of biomass in roots and leaves deposited as litter to be used as organic matter supply for grasses (Alves *et al.*, 2020). Bieluczyk *et al.* (2020) reported C₄ plants were the main source of soil organic matter in integrated farming systems, and the crop period provided high labile organic matter inputs to the soil.

Synthesis of the existing literature has highlighted root trait combinations or intercrop that might promote complementation between species and, also, indicates that spatial and temporal trait plasticity could vary in importance for mixed, relay, and agroforestry intercrops (Homulle *et al.*, 2022). There is also a chemical complementation which refers to the ability of species to mobilize different chemical forms of nutrients, of which the most frequent refers to the ability of legumes to fixate nitrogen from the atmosphere, which other species cannot do (Duchene *et al.*, 2017).

Different forage dry matter production and consequently, of the residual straw can affect the C dynamic in soil. Additionally, the C index is used to infer soil health changes with distinct sensitivity to management (Locatelli *et al.* 2022). Bieluczyk *et al.* (2020) evaluated CLI for intensification of production systems using corn intercropped with BRS Piatã grass, resulting as a relevant strategy to increasing soil C stocks at the rate of 0.28 Mg C ha⁻¹ yr⁻¹ from 2010 to 2016.

Our results for organic C in soil showed sensible results in the first year of CLI corroborating Carvalho *et al.* (2010). These authors related the efficiency of grass use in succession of soybean for restocking supplies of C in soil, however it is a gradual process taking as much as five years to be expressive as a monoculture of pasture.

4.2. Quality and dry matter production of forage grasses

Dry matter production differed among forage species, however all of them showed productive potential at 60 days after sowing. Silva *et al.* (2020) observed up to 8 Mg ha⁻¹ in dry matter production of Ruziziensis in 168 days after grass sowing in intercropping with maize. However, in general, grass sowing intercropping with maize occurs in the beginning of the rainy season, while grass sowing under CLI using soybean consists of an adverse environment at the end of the rainy season.

Difference among dry matter production of forage species, mainly in the morphological components is an important parameter for pasture use, considering preferential intake of leaves by ruminants. According to Vasconcelos (2020), BRS Tamani cultivar is characterized by high growth under intensive management, and is therefore a viable alternative to maximize biomass forage production.

The high quantity of senescent material observed in the Tamani species indicates the necessity of early management to reduce losses, besides guaranteeing use for animals in grazing or mechanical harvest. According to Embrapa (2015), this forage must be managed in a rotation system with rest periods of less than 28 days.

Similar production of Ruziziensis and Piatã stems is justified for both species which have decumbent growth habits, typical of the *Urochloa* genus, with use of stems as an important way of using available space.

Dry matter content, as well as ash, NDF, ADF, and hemicellulose in leaves were similar among species. This could be justified as the same tissue was analyzed, besides the plants being exposed to the same management and edaphic environment.

The superior crude protein in leaves along with a higher proportion of leaves highlighted Tamani at 60 days after sowing, reinforcing this species as an option of grass in the CLI. Generally, crude protein content in traditional pastures during the dry season is low, however in CLI with soybean, the status of newly formed forages promoted desirable bromatological composition, important for animal nutrition. Crude protein of forage leaves intercropped with maize decreased linearly from 19.95% to 9.7% between harvest cuts of 50 to 195 days after sowing (Kishel *et al.* 2021).

4.3. Forage grass desiccation

Ruziziensis showed easy control through desiccation compared to evaluated forage species, corroborating with Ceccon & Concenço (2014). These authors cited Ruziziensis as an easily desiccated forage species, which is an important characteristic for CLI dynamic.

There was low effectiveness in the control of Tamani and Piatã up to 21 days after desiccation. The result indicates the necessity of early desiccation for these species, or studies about new products or doses. Desiccation effectiveness depends on forage species, mass, herbicide doses, and available time between desiccation and soybean sowing (Ceccon, 2019).

4.4. Intercropped forage effects on succession of soybean

Remaining straw from forage grass has a function of soil protection, mainly in the rainy season. According to Silva *et al.* 2024 the straw also protects the soil from direct solar radiation keeping the temperature mild and retaining the moisture, which can support seed germination, besides development and production of crops. On the other hand, excess straw, and the way it is accumulated, as well as clumps, can be damaging to plantability, however in this study, remaining straw from forages showed no influence on soybean emergence.

Despite the clumps, typical to *Megathyrus* genus growth habit, the soft and thin Tamani stems showed no damage to soybean emergence, different from the results of Franchini *et al.* (2014), in which soybean plant population was significantly affected by grazing pressure, i.e., lowering the grazing pressure promoted higher dry mass on the soil surface. These authors justified that the high

straw dry matter may have reduced the soybean plant population because of the physical barrier that may have hindered the externalization of the seedling stalks, and impaired seed deposition at appropriate depths for seedling emergence as a consequence of the planter double discs which may have incorporated straw into the furrow, leading to a reduced soil-seed contact, thus impairing the seed germination.

The similarity among treatments for yield and mass of grains showed the requirement of longer periods for answers in relation to soybean productivity. However, the adequate management of high-performance crops in rotation under no-till requires an understanding of the release of nutrients by surface mulch. Costa *et al.* (2021) observed that the number of pods per plant was affected by the cropping system, and was greater when soybean was cultivated under straw produced by guinea grass sown in succession to sorghum.

5. Conclusions

According to the purposes of the crop-livestock integration system, Tamani is an earlier forage plant with greater potential for use in animal feed due to the volume and quality of dry matter production. Ruziziensis shows advantages to the succession of crops due to effectiveness and fast desiccation, while Tamani and Piatã show higher resistance to desiccation, which may compromise the logistics of the next crop sowing.

Biomass from the forage species has low effectivity on fertility and C sequestration in a period of one year under a crop-livestock integration system.

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