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Forage and Nutritional Potential of Sudan Grass in Integrated Systems in Lowlands

Potencial Forrageiro e Nutricional do Capim Sudão em Sistemas Integrados em Terras Baixas

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Abstract
Integrated crop-livestock systems (ICLS) have the potential to increase productivity with greater environmental sustainability by combining forage, livestock, and grain crop components. However, there are countless possible ICLS arrangements, for which research results are still incipient. Therefore, the objective of this study was to evaluate the forage potential of Sudan grass (cultivated under different integrated crop-livestock production systems—ICLS) in rotation with rice, ryegrass (for cattle grazing), and soybean. The study was conducted in the years 2020, 2021, 2022, 2023, and 2024 at the Experimental Station of the Rio Grande do Sul Rice Institute (IRGA), in the municipality of Uruguaiana, RS, Brazil. The experiment followed a randomized block design, with four treatments and three replications. Different ICLS systems were adopted, involving summer crops (rice and soybean), winter pasture (ryegrass), and summer pasture (Sudan grass). The following parameters were evaluated: dry matter (DM) yield, mineral matter (MM), organic matter (OM), acid detergent fiber (ADF), neutral detergent fiber (NDF), crude protein (CP), total digestible nutrients (TDN), and dry matter digestibility (DMD) to assess the nutritional value of the produced forage. Additionally, climatic variables such as precipitation and temperature were associated with Sudan grass productivity in lowland areas. There was no significant effect of year on the evaluated variables; however, total DM yield was numerically lower in 2023 due to a severe drought that occurred in the

region. It can be concluded that ICLS are feasible in lowland areas and increase land productivity compared to traditional systems with fallow periods during the off-season.

Keywords: Integrated Crop-Livestock Systems. Nitrogen Fertilization. Nutritional Parameters. Rice. Soybean.

Resumo
Sistemas integrados de produção agropecuária (SIPAs) possuem potencial para aumentos de produtividade com maior sustentabilidade ambiental por meio da associação dos componentes forrageiro, animal e lavoura de grãos. Porém, existem infinitas diversas possibilidades de arranjos de SIPAs, para os quais, resultados de pesquisa ainda são incipientes. Assim, objetivou-se avaliar o potencial forrageiro do capim Sudão (cultivado em diferentes sistemas de integração de produção agropecuária (SIPA) com rotação entre arroz, azevém (para pastejo de bovinos) e soja. O estudo foi conduzido nos anos de 2020, 2021, 2022, 2023 e 2024 na Estação Experimental do Instituto Riograndense do Arroz (IRGA), no município de Uruguaiana-RS. Foi conduzido sob delineamento em blocos casualizados, com quatro tratamentos e três repetições. Foram adotados diferentes sistemas SIPA contemplando culturas de verão (arroz e soja), pastagem de inverno (Azevém) e pastagem de verão (Capim Sudão). Avaliou-se a produtividade de matéria seca (MS), matéria mineral (MM), matéria orgânica (MO), fibra detergente ácido (FDA), fibra detergente neutro (FDN) e proteína bruta (PB), nutrientes digestíveis totais (NDT) e digestibilidade da matéria seca (DIGMS) para obter-se o valor nutricional da forragem produzida. Bem como associar as variáveis climáticas, como precipitação e temperatura à produtividade do capim-sudão em terras baixas. Não houve significância dos anos para as produções estudadas, porém, a PMS total foi numericamente menor no ano de 2023 devido à estiagem severa que ocorreu na região. Conclui-se que os SIPAS são viáveis em terras baixas e aumentam a produtividade das áreas quando comparados aos sistemas tradicionais com pousio nas entressafras.

Palavras-chave: Sistemas Integrados de Lavoura e Pecuária. Fertilização Nitrogenada. Parâmetros Nutricionais. Arroz. Soja.

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1 Introduction

In the Western Frontier of Rio Grande do Sul, the predominant biome is the Pampa, characterized by extensive areas of natural grasslands, which are currently infested by *Eragrostis plana* (commonly known as capim-annoni) and used for cattle grazing under extractive systems. With the introduction of agricultural activities, these areas have increasingly been converted for irrigated rice cultivation, involving soil disturbance and intensive use of agricultural inputs (Malaguez *et al.*, 2017).

In addition to the suppression of the native biome for rice farming, the reduction in grazing land has not been accompanied by a corresponding decrease in the number of beef cattle. Consequently, the remaining native pastures are subjected to overstocking and overgrazing, leading to degradation of both the soil and the native biome.

In this context, integrated crop-livestock systems are beneficial as they promote environmental conservation. However, they also require crop rotation to break the cycles of pests, diseases, and weeds, thereby enhancing productive sustainability. Ryegrass is the forage species traditionally used in the winter, rotated with rice in cultivated areas to produce forage and improve soil structure (Pavinato *et al*., 2014).

Nevertheless, for the summer season, research results and technical recommendations on suitable forage crops remain scarce. As a result, areas not cultivated with rice are often left fallow, a management strategy that promotes weed reinfestation and soil degradation due to exposure to climatic factors.

The use of a summer forage crop represents a promising alternative for soil protection, weed control, forage production, and straw deposition for soil cover (Borghi *et al*., 2008). One such alternative is Sudan grass (*Sorghum sudanense*), a tropical grass species belonging to the Poaceae family, which has been used for livestock production (Mezzomo *et al*., 2020a). Sudan grass is an annual summer forage species that adapts well to a variety of soil types (Mezzomo *et al*., 2020b), establishes rapidly, and shows good tolerance to water deficit (Mezzomo *et al*., 2021). Moreover, it is a tall plant with high digestibility for animals, due to its greater leaf area index and thin stems (Mezzomo *et al*., 2020c), which result in lower lignin intake (Silveira *et al*., 2015).

Because it is a highly digestible grass species, it enhances livestock productivity during the typically dry summer season. When managed properly, its growing cycle can extend into the fall, a period in which other forage species face limiting conditions for vegetative development (Silveira *et al*., 2015). Furthermore, compared to other annual grasses, Sudan grass stands out for its high biomass production, ability to regenerate after grazing or cutting, and strong root and shoot growth performance (Bibi *et al*., 2010).

Therefore, the present study aimed to evaluate the forage performance of Sudan grass over five years of cultivation in rotation with rice in Integrated Crop-Livestock Production Systems in lowland areas.

2 Material and Methods

2.1 Description of the experimental site

The experimental trial was conducted in an area located at the experimental station of Colégio Agrícola Municipal Luiz Martins Bastos, Uruguaiana, Rio Grande do Sul, Brazil (29°50'44.6"S 57°05'11.6"W), during the years 2019 to 2021. The area belongs to IRGA (Figure 1). The regional climate is classified as Cfa (humid subtropical) with no defined dry season, with an average annual precipitation of 1,113.7 mm. The mean temperature of the hottest months is 32.5 °C, while the coldest months average 14.4 °C, resulting in an annual average temperature of 19.7 °C (Wrege *et al*., 2017).

Prior to the beginning of the experiment, the soil—classified as Ebânico Chernozem (Santos *et al*., 2018) - was sampled for chemical analysis and presented the following characteristics: P (Mehlich extractor) = 1.4 mg dm^{-3}; organic matter = 2%; pH (H_2O) = 5.7 mol L^{-1}; H + Al = 4.15 cmolc dm^{-3};

Al^{3+} = 0.0 cmolc dm^{-3}; K = 0.23 mg dm^{-3}; Ca^{2+} = 15.12 cmolc dm^{-3}; Mg^{2+} = 24.9 cmolc dm^{-3}; CEC = 21.4 cmolc dm^{-3}; Al saturation = 0%; K saturation = 0.37%; Mg/K ratio = 74.6; Ca/Mg ratio = 2.45; Ca/K ratio = 185.

Figure 1 - Schematic map showing the location of the experimental plots

Source: the authors.

Under Previous Cultural Management, The Area Was Subjected To Annual Succession Of Summer Crops (Soybean And Rice), And From April To September, Ryegrass Was Cultivated For Grazing By Beef Cattle.

2.2 Experimental Design and Production Systems Adopted as Treatments

A randomized complete block design was adopted, with three replications, totaling 12 experimental units. The experimental area encompasses approximately 12 hectares, with each experimental unit (EU) measuring around 1 hectare. The treatments consisted of different integrated crop-livestock production systems, representing distinct strategies of pasture and crop succession in lowland areas (Table 1).

Table 1 - Proposed integrated crop-livestock production systems – Uruguaiana, Rio Grande do Sul, Brazil

System	ILP[1]	No-tillage	2020/2021	2021/2022	2022/2023	2023/2024
			Crop / Off-season	**Crop / Off-season**	**Crop / Off-season**	**Crop**
I	No	No	Rice / Fallow	Rice / Fallow	Rice / Fallow	Rice
II	Yes	Yes	Rice / Ryegrass	Rice / Ryegrass	Rice / Ryegrass	Soybean
III	Yes	Yes	Soybean / Ryegrass	Soybean / Ryegrass	Soybean / Ryegrass	Rice
IV	No	Yes	Sudan grass / Ryegrass	Sudan grass / Ryegrass	Sudan grass / Ryegrass	Sudan grass

[1]ILP = Integrated crop-livestock system.
Source : research data.

System I is the most commonly implemented in lowland areas. It is a system without the introduction of livestock activity during the fallow period of rice cultivation, and it also lacks pasture cultivation or management.

System II involves irrigated rice cultivation combined with the introduction of annual ryegrass pastures during the off-season, established via overseeding and without soil disturbance.

System III is identical to System II; however, the main crop is soybean, which has shown increasing prominence in lowland environments.

System IV represents a purely livestock-based system under no-tillage conditions, without integration of agricultural crops. Nevertheless, it is a strategic system for year-round forage production and has the potential to provide support to the other systems in commercial farming operations.

2.3 Establishment and Management of Experimental Crops

The crops within the different systems were managed according to official technical recommendations regarding seed inoculation and/or treatment, sowing density and method, liming, fertilization, application of fungicides, insecticides, herbicides, among others. In System III, soybean was irrigated by intermittent flooding whenever necessary. For rice, a continuous flooding irrigation system was adopted.

A randomized block design was used, with three replicates. The block layout aimed to isolate areas with similar soil characteristics, allowing the formation of uniform plots (blocks). Each experimental unit (EU) measured approximately 1 hectare.

Evaluations were carried out in January of each year from 2020 to 2024, with pasture establishment occurring in November of the previous year (2019, 2020, 2021, 2022, and 2023). Assessments were always conducted prior to animal entry into the paddocks.

Sudangrass (cv. BRS Estribo) was used in all evaluation years. A seeding rate of 30 kg/ha was adopted, along with 350 kg/ha of compound fertilizer 05-30-15 (N-P_2O_5-K_2O). Sudangrass was sown via broadcast seeding followed by incorporation using a light harrow, aiming for minimal soil disturbance.

2.3 Summer Pasture Evaluations

For productive assessments, when the pasture reached the recommended grazing height of 50 cm at the apical meristem (Silveira *et al*., 2015), samples were collected using a square frame of known area to determine fresh biomass production. After drying, dry matter production (DMP) was determined.

These measurements were taken for the total forage offered (total DMP). Forage production was evaluated using the double sampling technique with a metal square frame of 0.25 m² (50 x 50 cm). Botanical composition was also assessed, quantifying the proportions of sudangrass and *Echinochloa crus-galli* (barnyardgrass), the latter being a prevalent weed in the sudangrass pastures and contributing significantly to the total forage biomass (Gardner, 1986).

Sudangrass was established in only one of the treatments; therefore, it was evaluated with three samples per plot in each of the three experimental units (replicates). Structural evaluations of the summer pastures included plant height (cm), leaf length (cm), number of leaves per plant, leaf-to-stem ratio, and plant density of sudangrass. These measurements were taken both for the established sudangrass and the weed pasture (barnyardgrass).

The botanical composition was again assessed in terms of sudangrass and barnyardgrass due to the significant presence of the latter in the pastures and its contribution to the forage mass offered to the animals.

The data obtained allowed for the calculation of forage production for both species during each grazing cycle and for the entire experimental period involving sudangrass pasture.

2.5 Laboratory Analyses

After sample grinding, forage quality was determined using laboratory methods. Analyses included mineral matter/ash content (MM, %), organic matter (OM, %), crude protein (CP), neutral detergent fiber (NDF, %), and acid detergent fiber (ADF, %) as described by Silva and Queiroz (2009), and in vitro dry matter digestibility (IVDMD, %) following Tilley and Terry (1963). Total digestible nutrients (TDN, %) were estimated according to Bolsen (1996), and dry matter yield (kg DM/100 kg LW or %LW) according to Mertens (1997).

2.6 Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) using Fisher's F-test, and treatment means were compared using Tukey’s test at a 5% significance level.

3 Results and Discussion

Although no significant differences were observed among years for the studied productions, total dry matter production (DMP) was numerically lower in 2023 due to a severe drought that affected the region during this period. This lack of statistical significance for forage production (Table 2) highlights the productive stability of sudangrass over the years, reinforcing its rustic potential in regions with variable climatic conditions and supporting its technical recommendation as a primary option both for forage production and for crop rotation in integrated systems. However, despite its stability, sudangrass is responsive to water availability, increasing its dry matter yield under irrigation conditions (Mezzomo *et al*., 2021).

The average pasture yield exceeded 15,000 kg/ha of dry matter, even with the presence of barnyardgrass, which limits forage productivity. Although barnyardgrass infestation negatively affects sudangrass productivity, it may be considered a positive aspect regarding soil cover and contributes to the forage supply for livestock. Furthermore, due to its different height (shorter than sudangrass), barnyardgrass allows for more efficient canopy occupation, aiding in light interception and dry matter accumulation, thereby enhancing overall pasture productivity.

This forage production supports a stocking rate that helps flexibilize beef cattle herds on farms (Mezzomo *et al*., 2020a), providing high-quality forage for more demanding categories such as cows with calves at foot. Even under barnyardgrass infestation, sudangrass presented satisfactory DMP values when compared to those reported by Silveira *et al.* (2015), confirming the findings of Souza and Inomoto (2019), who reported the high dry matter production potential of sudangrass even under abiotic stress conditions.

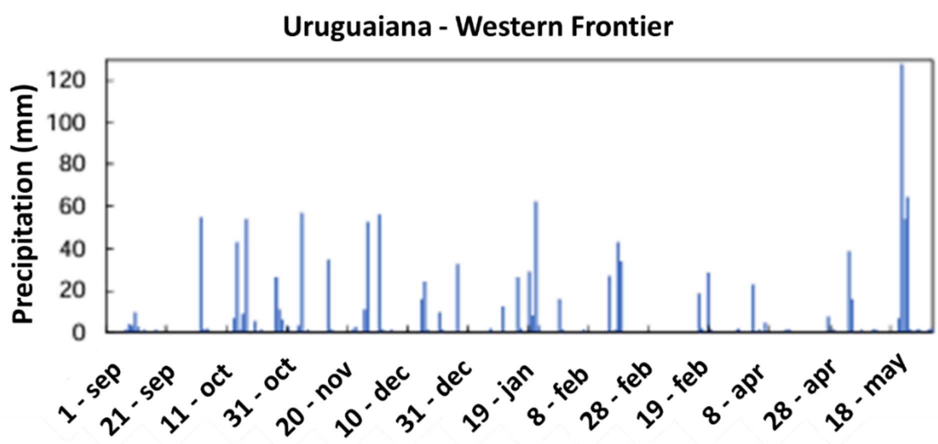
Table 2 - Total Dry Matter Production (DMP), Barnyardgrass DMP, and Sudangrass DMP in pasture cultivated under an integrated crop-livestock production system in lowland areas in succession to ryegrass pasture

Year	**DMP**	**Barnyardgrass DMP**	**Sudangrass DMP**
2020	15710a	3533a	12177a
2021	17458a	3926a	10902a
2022	15630a	3515a	9761a
2023	13593a	3057a	10536a
2024	15436a	3498a	10725a
Average	15598	3508	10844
CV (%)	38.74	27.65	56.57
SEM	1424	228	1445
LSD	5317	869	5397
P value	0.306	0.075	0.693

*Means followed by the same lowercase letter in the column do not differ statistically according to Tukey's test (5%). CV: coefficient of variation; SEM: standard error of the mean; LSD: least significant difference; P value: significance according to Fisher's F-test.
Source : research data.

The 2019/2020 crop season was influenced by the ‘El Niño’ phenomenon; however, it did not present its traditional climatic conditions but rather transient conditions. The start of the season was marked by significant rainfall and floods that affected the region, beginning with around 400 mm in October 2019. Subsequently, the region entered a drought period from November 2019 to April 2020. The drought intensified in December, with just over 50 mm of precipitation, resulting in a water deficit of -21.8% for the period in the municipality of Uruguaiana/RS (Figure 2). Although Sudangrass is known to be tolerant of water deficiency, caution should be exercised during periods of extreme drought. A lack of water to meet the crop's evapotranspiration needs may negatively impact forage productivity (Mezzomo *et al*., 2020c).

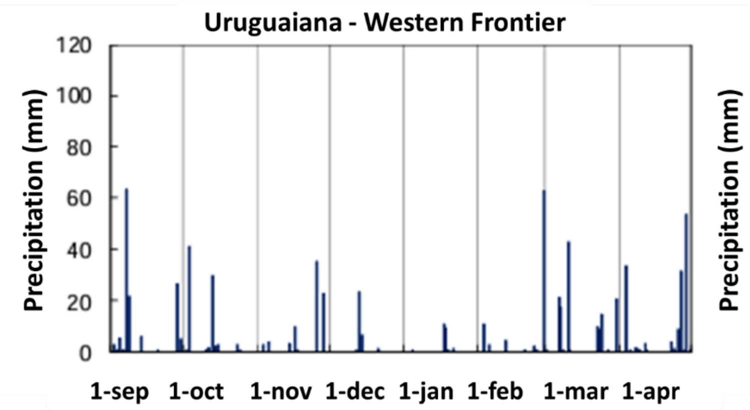
Figure 2 - Precipitation chart during the 2019/2020 crop season in Uruguaiana, Rio Grande do Sul



Source: IRGA (2020).

In the 2020/2021 crop season, the predominant climatic phenomenon was 'La Niña', typically associated with long drought periods and reduced precipitation. However, in this season, its impact was mild in the region, resulting in slightly below-average precipitation and temperatures above the historical averages, without significantly compromising the development of the crops. However, the reduction in dry matter production observed between the 2020/2021 and 2021/2022 crops may be related to the intensification of 'La Niña' effects, which combined low precipitation volumes with high temperatures and more intense heat waves, especially in January 2022. The significant decrease in rainfall starting in the second half of October 2021, just before the sowing of Sudan grass, may have hindered the initial establishment of the forage (Figure 3).

Figure 3 - Precipitation chart during the 2021/2022 crop season in Uruguaiana, Rio Grande do Sul



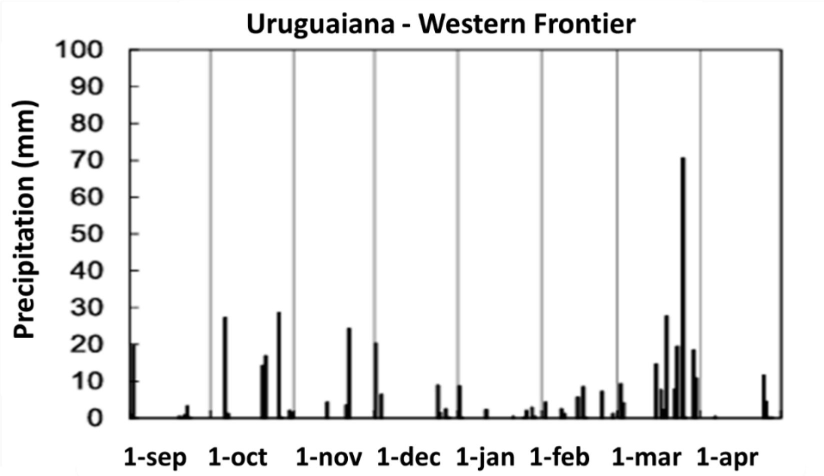
Source: IRGA (2022).

Although the plant is resistant to water stress, when high temperatures persist for a certain period, it interferes with tillering and biomass accumulation. Thus, one alternative to increase forage production and improve quality would be the irrigation method (Mezzomo *et al*., 2020b). Grasses, during periods of intense thermal stress, may exhibit larger cell wall sizes and reduced digestibility due to increased stem growth (Gois *et al*., 2023). This is because temperature accelerates plant maturity, affecting tissues and structural composition, resulting in higher cellulose, hemicellulose, and lignin, while reducing cellular content, such as soluble carbohydrates and proteins (Ramos *et al*., 2022).

These results highlight the vulnerability of the lowland production system to interannual climate variations, reinforcing the need for management strategies that consider climate monitoring and the selection of cultivars more tolerant to abiotic stresses.

Still under the effects of 'La Niña', the 2022/2023 crop season faced significant losses in various crops, including Sudan grass, which showed a significant decrease in productivity in the same experimental area presented previously. The 2023 crop season had the lowest dry matter production (DMP), as Sudan grass was drastically affected and ceased its growth by the end of the first half of February 2023, when the experiment had to be terminated due to drought and temperatures that dried up the Sudan grass plots. The municipality experienced an anomaly of -705mm for the period and historical drought indices (Figure 4).

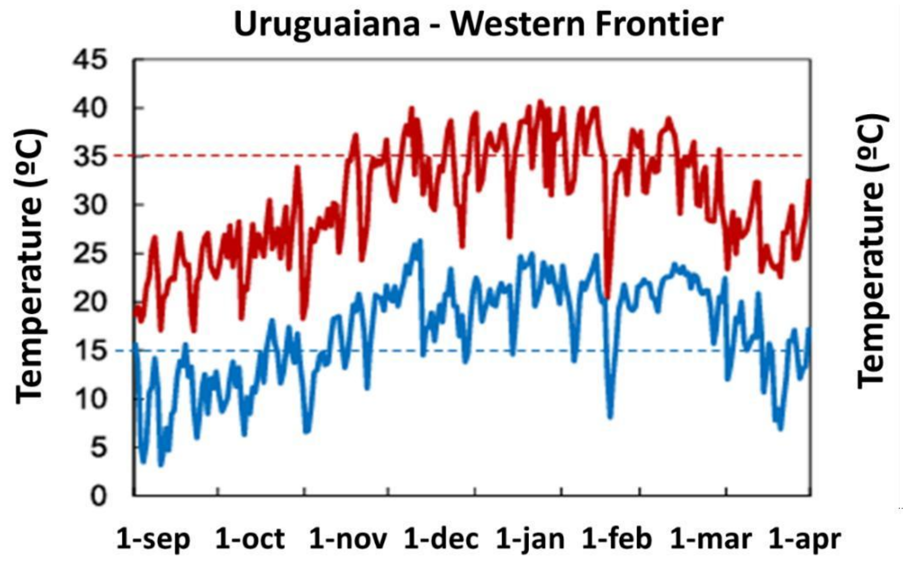
Figure 4 - Precipitation chart during the 2022/2023 crop season in Uruguaiana, Rio Grande do Sul



Source: IRGA (2023).

In the Western Border region, the municipality of Uruguaiana had the highest number of days with maximum temperatures above 35 ºC from November 2022 to March 2023 (Figure 5).

Figure 5 - Temperatures recorded during the 2022/2023 crop season in Uruguaiana, Rio Grande do Sul



Source: IRGA (2023).

Due to the aforementioned climatic events, the variations in the productivity of Sudan grass over the years can be explained.

In the bromatological composition, significance was observed only for MM, FDA, FDN, PB, NDT, DIGMS, and VRF (Table 3). The lowest values of MM, PB, NDT, DIGMS, and VRF, as well as the highest values of FDA and FDN, occurred in the 2023 and 2024 crop years. The occurrence of excessive fiber content interferes with food intake capacity, digestibility, microbial protein synthesis, and energy supply (Alves *et al*., 2016), negatively affecting animal performance. This result is attributed to the adverse climatic conditions recorded during the period, which hindered the development of forages and reduced their nutritional value. When working with Sudan grass in comparison to sorghum and millet, Rodrigues *et al*. (2020) found high fiber content in the forage offered to animals.

PB values lower than 7% limit ruminal function in ruminants, hindering the utilization of other nutrients and animal performance (Van Soest, 1994). Comparisons with other studies on tropical forages also showed similar results, where low PB values were correlated with progressive increases in fiber and lignin values (Detman *et al*., 2021). Rodrigues *et al*. (2020) and Missio *et al*. (2024), working with Sudan grass, found results similar to those obtained in this study.

Likewise, high values of FDA, and especially FDN, limit the consumption of DM, as observed in the inverse relationship between FDN and CMSPV (Mertens, 1992). Neutral detergent fiber (FDN) corresponds to the portion of the feed made up of the components of the cell wall that are insoluble in neutral solution. This portion has slower degradation compared to cellular constituents or can be completely resistant to digestion (Alves *et al*., 2016). This result occurs due to the filling effect, where the rumen, filled with fibrous content, low digestibility, and low nitrogen compound availability, provides the animal with a feeling of satiety, causing it to reduce intake.

FDA also has an inverse relationship with DIGMS, such that high levels of FDA are negatively correlated with DIGMS, reducing its levels (Bolsen, 1996). Similarly, VRF characterizes the nutritional potential of a given forage in relation to alfalfa, considered as the standard forage in this analysis, i.e., with a VRF of 100%. In 2023 and 2024, the VRF was lower than those obtained with the forages in other years of the study, with values of 54.30 and 48.96%, respectively. This means that only these percentages would be utilized by animals in comparison to alfalfa.

Table 3 - Nutritional value of Sudan grass pastures cultivated in an integrated agro-ecosystem production system in lowlands following ryegrass pastures

Ano	MM	MO	FDA	FDN	PB	CMSPV	NDT	DIGMS	VRF
2020	15.7a	84.30a	45.80b	75.80b	4.80c	1.58a	52.80a	53.20a	65.31a
2021	16.2a	83.80a	44.70b	77.10b	5.70b	1.56a	53.60a	54.10a	65.25a
2022	14.5a	85.50a	38.80b	77.20b	7.40a	1.55a	57.70a	58.70a	70.70a
2023	10.4b	89.70a	52.00a	82.90a	6.60a	1.45a	48.50b	48.40b	54.30b
2024	8.5b	91.50a	57.30a	84.10a	4.50c	1.43a	44.80b	44.30b	48.96b
Average	13.06	86.96a	47.72	79.42	5.80	1.51	51.48	51.74	60.90
P value	0.002	0.852	0.007	0.008	0.001	0.985	0.002	0.001	0.003
DMS	4.21	14.21	5.18	6.28	0.85	0.35	5.24	5.18	7.25

*Averages followed by the same lowercase letter in the column do not differ statistically by the Tukey test (5%). CV: coefficient of variation. EPM: standard error of the mean. P value: significance by the Fisher F test. DMS: minimum significant difference. MM (%): mineral matter, ash. MO (%): organic matter. FDA (%): acid detergent fiber. FDN (%): neutral detergent fiber. PB (%): crude protein. CMSPV (%): Dry matter intake per live weight. NDT: total digestible nutrients. DIGMS (%): dry matter digestibility. VRF (%): relative forage value.
Source: research data.

The results presented (Table 3) show that, in particular, the crude protein (CP) levels are significantly low, and the other parameters characterize a forage with low nutritional value. This outcome is attributed to the lowland soil conditions, where soil fertility is still under development. Additionally, the low water availability during the experimental period shortened the vegetative cycle of the plants, causing them to enter the reproductive phase prematurely. This led to sharp reductions in nutritional value, as evidenced by increases in NDF and ADF, and reductions in CP, TDN, and DMD levels. The high occurrence of weedy grass also contributed to the low nutritional values.

When considering forage production over the years, total dry matter yield was highest in 2022 (Table 3). The same result was observed for the dry matter yield of Sudan grass, which was also higher, as the dry matter yield of weedy grass was lower that year. Due to favorable climatic conditions for plant establishment in November 2021, following sowing, the Sudan grass pasture was efficiently established, with good plant stand and dense pasture formation, which suppressed the growth of weedy grass, the main weed in the study area. In other years, greater difficulties in establishing Sudan grass favored the growth of weedy grass.

In 2020 and 2022, the apical meristem was higher above ground level compared to other years (Table 3). This result may be associated with higher grazing heights at the time of evaluation and also with the forage’s growth cycle. Although the evaluations were always conducted the same number of days after sowing, climatic factors may have either accelerated or delayed plant growth, which could have affected this result. However, the plant height of Sudan grass was not affected by year and remained consistent across the study period, with an average height of 126 cm (Table 3).

Table 4 - Productive and structural characteristics of Sudan grass and the invasive weedy grass in pasture established under an ILP (Integrated Crop-Livestock) system grazed by Bradford heifers, following a summer crop/ryegrass succession – System IV

Year	Total DM Yield (kg/ha)	Weed Grass DM Yield (kg/ha)	Sudan Grass DM Yield (kg/ha)	Height of Sudan Grass Apical Meristem (cm)	Height of Sudan Grass Plants (cm)
2020	12510b	4006a	8504b	43a	121a
2021	11680b	4207a	7473b	29c	123a
2022	22940a	2387b	20553a	43a	137a
2023	15710b	3533a	12177b	38b	127a
2024	12095b	4107a	7989b	36b	122a
Média	14987	3648	11339	38	126
p value	0.000	0.002	0.000	0.025	0.892
DMS	5125	528	4525	4.25	18.05

Means followed by the same lowercase letter in the column do not differ statistically according to Tukey's test (5%). CV: coefficient of variation; SEM: standard error of the mean; LSD: least significant difference; *P* value: significance according to Fisher's *F* test.
Source: research data.

In addition to the plant height of Sudan grass, the height of weedy grass plants was also measured. It was lower in 2022, when the Sudan grass pasture showed higher productivity and suppressed the growth of weedy grass, also reducing its dry matter production (Table 3).

The plant density of Sudan grass was higher in 2022 (Table 4), justifying the higher dry matter yield of the pasture that year (Table 3).

The structural parameters - leaf length and number of leaves per plant—remained constant in pastures over the years (Table 4), which is an expected result, as these are morphogenetic characteristics of the plants.

However, the leaf-to-stem ratio was lower in 2022 (Table 3). In that year, due to the higher plant density of Sudan grass (Table 3), there may have been competition for light and stem elongation. This elongation resulted in a greater dry weight of stems compared to the dry weight of leaves in the forage offered. Evaluation of this parameter is very relevant in forage plant studies, as most of the nutritional value and digestibility are found in the leaves, and increases in stem proportion reduce the nutritional value of the produced forage.

4 Conclusion

It is concluded that the forage performance of Sudan grass cultivated in rotation with rice in an Integrated Crop-Livestock System (ICLS) on lowlands has high productive and nutritional potential, especially when grown in succession to ryegrass. This type of system proved to be viable and efficient in soil use when compared to ryegrass. However, Sudan grass showed reduced productivity in years with high temperatures combined with water deficits—conditions common during the summer in lowland areas. Although it is a tropical plant, it proved susceptible to low productivity under very high temperatures and prolonged drought periods typical of summer in lowlands.

Nonetheless, these results affirm that proper forage management combined with production system planning is essential for the success of ICLS in environments with great climatic variability.

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