https://doi.org/10.22319/rmcp.v15i4.6758

Technical note

The management of irrigated elephant grass intercropped with legumes in the semi-arid region

Jéssica Daisy do Vale Bezerra [a]

João Virgínio Emerenciano Neto [ab*]

Tamiris da Cruz da Silva [a]

Patrick Bezerra Fernandes [c]

Stela Antas Urbano [b]

Felipe Pontes Teixeira das Chagas [b]

Gelson dos Santos Difante [d]

Marcone Geraldo Costa [b]

Antonio Leandro Chaves Gurgel [e]

Francisco Israel Lopes Sousa [b]

Rodrigo da Silva Santos [a]

Ana Beatriz Graciano da Costa [a]

[a] Universidade Federal do Vale do São Francisco. Petrolina, PE, Brazil.

[b] Universidade Federal do Rio Grande do Norte. Macaíba, RN, Brazil.

[c] Instituto Federal de Educação Ciência e Tecnologia Goiano. Rio Verde, GO, Brazil.

[d] Universidade Federal de Mato Grosso do Sul. Campo Grande, MS, Brazil.

[e] Universidade Federal do Piauí. Bom Jesus, PI, Brazil.

Corresponding author: jv.em.neto@gmail.com

Abstract:

The present study aimed to evaluate the production and chemical composition of elephant grass (*Pennisetum purpureum* syn. *Cenchrus purpureus* cv. Mott) intercropped with *Cajanus cajan* (Mandarim and Fava Larga) and *Stylosanthes guianensis* (Bela) compared to its cultivation in monoculture under irrigated management in the semi-arid region. The experiment was conducted at the Campus of Agricultural Sciences of the Federal University of the São Francisco Valley, Petrolina, Brazil. The experiment consisted of the following treatments: elephant grass intercropped with each legume and two monoculture types, one with nitrogen fertilization (200 kg ha^{-1}) and the other without. The legumes helped to improve the quality of the forage canopy, with high levels of crude protein. Nitrogen fertilization increased the mass of forage produced by elephant grass. The cumulative analysis of all the cuts showed that the intercropping between elephant grass and the Bela cultivar achieved the highest yield, with 13.49 Mg ha^{-1}, mainly due to the increase in the population of the Bela, which proved to be superior to the other legumes over the cuts. Based on the results, the intercropping of elephant grass with the Bela cultivar is recommended as the most effective strategy for maximizing forage production in the semi-arid region.

Keywords: *Cajanus,* Stylo, Grass, Forage mass, Crude protein.

Received: 05/08/2024

Accepted: 09/09/2024

Semi-arid regions suffer from seasonality in forage production caused by water scarcity and irregular rainfall(1). In addition, the soils of this region exhibit little organic matter, which reduces the fraction of essential nutrients and soil moisture(2), aggravating the production of food for the nutrition of domestic ruminants. Another point of attention is the limited number of native forage resources with phenotypic plasticity for this region.

To overcome this situation, it is crucial to introduce cultivated forage plants. One promising option is elephant grass (*Pennisetum purpureum* syn. *Cenchrus purpureus*). When the sum of all cuts is performed to evaluate forage yield, up to 40 Mg ha^{-1} of forage mass can be obtained(3). Another advantage is its versatility, which can be used as fresh or preserved fodder animal feed(4,5).

However, elephant grass is very demanding in its fertilization management since it exhibits maximum production potential when between 100 and 200 kg ha^{-1} of nitrogen fertilization is provided(3,6). Therefore, maintaining this grass can be costly for the production system. Despite this, there is a strategy that can be adopted to reduce the maintenance costs of elephant grass: the introduction of forage legumes from tropical climates, as this type of forage can increase nitrogen in the soil by 120 to 150 kg ha^{-1} yr^{-1}[7], reducing dependence on chemical fertilizers, as well as promoting sustainability in the production system.

The introduction of forage legumes, in addition to improving the chemical composition of the soil, will positively influence other agronomic parameters, as observed by Rezende *et al*[8]. When pigeon pea (*Cajanus cajan*) was intercropped with Paiaguas palisade grass (*Urochloa brizantha,* cv. BRS Paiaguás) in the Brazilian Cerrado region, it was they found that this cultivation strategy boosted the efficiency of macronutrient use in the grass, generating increases in forage yield[8]. In the same region, Epifanio *et al*[9] observed that the intercropping of *Stylosanthes* with two cultivars of *Urochloa brizantha* (Piata palisade grass and Paiaguas palisade grass) promoted increases in the forage mass values of the grasses, as well as improvements in the chemical composition of the forage produced.

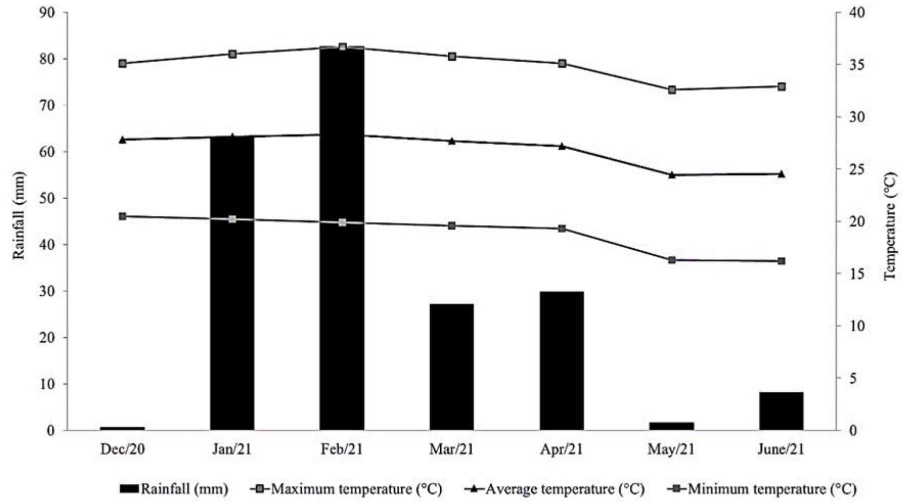
Based on the benefits provided by the forage legumes in the aforementioned systems, the following hypothesis was formulated: tropical climate forage legumes (*Cajanus cajan* and *Stylosanthes*), when intercropped with elephant grass will promote increases in forage yield compared to grass monoculture. In addition, the intercropping will positively impact the chemical composition of the forage produced in the semi-arid region.

This study aimed to evaluate forage availability and the chemical composition of elephant grass intercropped with forage legumes, compared to the monoculture managed irrigated in the semi-arid region.

The experiment was conducted in the experimental area at the Campus of Agricultural Sciences of the Federal University of the São Francisco Valley (UNIVASF), in Petrolina, Brazil (09º23'55'' S, 40º30'03'' W, an altitude of 391 m). The experiment began in December 2020 and ended in June 2021.

The climate of the region is semi-arid, with rainfall concentrated in the summer, low annual rainfall (435 mm), high potential evapotranspiration rates (1,520.9 mm), and a significant water deficit over the year. The weather data for the period studied (Figure 1) was monitored by the UNIVASF weather station, located approximately 50 m from the experimental area.

Figure 1: Rainfall and average, maximum, and minimum temperatures during the experimental period



The experimental design was randomized blocks with four blocks (replication) and five cultivation systems associated with four cuts. The treatments were: elephant grass (*Pennisetum purpureum* Schum., cv Mott) intercropped with the Mandarim cultivar (*Cajanus cajan* cultivar Mandarin); Elephant grass intercropped with Fava Larga (*Cajanus cajan* cv. Fava Larga); Elephant grass intercropped with Bela (*Stylosanthes guianensis* cv. Bela); Elephant grass in monoculture with nitrogen fertilization (200 kg^{-1} ha^{-1} yr^{-1}); Elephant grass in monoculture without fertilization.

The soil in the area is classified as Argissolo Amarelo, sandy/medium texture(10). For the chemical characterization of the soil, samples were collected at the 0-20 cm soil layer at random points in the area. These were sent for analysis in the laboratory to determine the chemical parameters. Based on the analysis results, there was no need to correct the active acidity of the soil (Table 1).

Table 1: Soil chemical characteristics in the 0-20 cm layer

pH	OM	P	K	Ca	Mg	Na	Al	H+Al	SB	CEC	V
	g kg^{-1}	mg dm^{-3}	cmol dm^{-3}								%
6.80	8.80	31.0	0.07	2.30	0.60	0.04	0.00	0.33	2.98	3.31	90

pH= active acidity; OM= organic matter, P= phosphorus, K= potassium, Ca= calcium, Mg= magnesium, Na= sodium, Al= aluminum, H+Al= potential acidity, SB= sum of bases, CEC= cation exchange capacity, V= base saturation.

The elephant grass was established in March 2018 utilizing horizontal cuttings in furrows 20 cm deep and spaced 100 cm apart. The legumes were sown in October 2020 between the rows of elephant grass in a system of pits with a spacing of 20 cm between pits. Five seeds

were sown per pit for the cultivars of pigeon pea (Madarim and Fava Larga). For the stylo (Bela), 0.5 grams of seed were sown per pit. The area of the plots was 2 x 5m (10 m²).
The evaluation cuts were made at 45-d intervals, totaling four cuts in 6 mo. Irrigation was conducted by drip irrigation, with two rows per block arranged 0.5 m from the edge and 1.0 m between rows, with an average flow rate of 1.3 L h^{-1}, applying an average water depth of 6.5 mm h^{-1}. The irrigation shift was 24 h, four hours at a time, five days a week.

Morphogenesis evaluations were conducted on three tillers of elephant grass in each experimental unit, starting seven days after each cut, with a 7-d interval between evaluations. Each tiller was marked with a colored ribbon and new tillers were selected at each cut.

The data collected was the number of live leaves (expanded and expanding), the number of senescent and dead leaves by manual counting, the length of the pseudostem (stem + ligule) from the base of the soil to the ligule of the last expanded leaf, and the length of the leaf blade (expanded and expanding), from the ligule to the apex of the leaf blade. The data collected was used to estimate the Leaf appearance rate (LAR, leaf tiller d^{-1}) - the difference between the number of final and initial leaves divided by the interval of days between measurements; the leaf elongation rate (LER, cm tiller d^{-1}) - calculated as the difference between the sums of the final and initial leaf lengths (expanded and expanding) divided by the interval of days between measurements; stem elongation rate (SER, cm tiller d^{-1}) - calculated as the difference between the final and initial length of the stem divided by the interval of days between measurements; leaf lifespan (LLS, days) - the interval from leaf emergence to 50 % senescence; and phyllochron (Phyl, days) being the inverse of the LAR rate.
To analyze the structural characteristics, the tiller population density (TPD, m²) was first measured by manual counting at three different points in a known area (0.25 m² quadrant), and six tillers close to the ground were collected from each experimental unit. The following were measured on the tillers: number of live leaves (NLL, leaves $tiller^{-1}$) by manual counting and final leaf length (FLL, cm) from the base of the ligule to the end of the leaf blade using a graduated ruler.

For the height assessments, the canopy height (CH, cm) of the elephant grass and the plant height (PH, cm) of the legumes were measured using a stick graduated in centimeters at three representative points in each plot. The CH corresponded to the average height of the curvature of the leaves around the stick from ground level. The PH corresponded to the apical bud of the highest branch.

The cutting height adopted for the grass was close to the ground, while the legume cultivars were 20 cm above the ground. All the material contained in the central rows (5 m²) of the plot was collected and weighed to quantify the green weight. From this, a sub-sample of approximately 1 kg was taken for each cultivar to determine the dry mass and separate it into leaf blade, stem, and senescent material fractions.

After separation, the components were placed in a forced circulation oven at 55 °C for 72 h. Once the dry weight was obtained, the dry matter (DM) content was calculated, and the forage mass (FM, kg ha^{-1}) and botanical components were determined: leaf forage mass (LFM, kg ha^{-1}); stem forage mass (STFM, kg ha^{-1}); dead material forage mass (DMF, kg ha^{-1}); forage mass to stem forage mass ratio (F:ST). During the experimental period, four cuts were made, so at the end of data collection, the four cycles were added together to quantify the production of the systems evaluated (Mg ha^{-1}).

The chemical composition of the forage was assessed on the whole plant obtained by cutting and drying in a forced circulation oven for 72 h. After drying, they were ground in a mill, identified, and submitted for analysis at the Multiuser Animal Nutrition Laboratory at the Jundiaí Agricultural School, Specialized Academic Unit in Agricultural Sciences of the Federal University of Rio Grande do Norte. The samples were evaluated for dry matter (DM), crude protein (CP, g kg^{-1}), ash (g kg^{-1}), neutral detergent fiber (NDF, g kg^{-1}), acid detergent fiber (ADF, g kg^{-1}), and lignin (g kg^{-1}). All the analyses followed the recommendations of Detmann *et al*(11).

The data was analyzed using three models: model I ($Y_{ijk} = \mu + G_i + B_k + e_{ijk}$) was used to analyze the characteristics of the elephant grass; model II ($Y_{ijk} = \mu + L_i + B_k + e_{ijk}$) was used to analyze the characteristics related to the forage legumes; model III ($Y_{ijk} = \mu + A_i + B_k + e_{ijk}$) was used to analyze the production of forage mass during the experimental period.

The model parameters are represented by: Y_{ijk} represents the characteristic evaluated; μ model constant; G_i effect of the cultivation system (Elephant grass + Mandarin, Elephant grass + Fava Larga, Elephant grass + Bela, Elephant grass with fertilizer, Elephant grass without fertilizer); B_k block effect (I, II, III, IV); L_i forage legume effect (Mandarin, Fava Larga, and Bela); A_i represents the cumulative effect of the intercropping and monocultures; e_{ijk} random error observed in each model.

The factors of cropping systems and forage leguminous plants were considered fixed effects, while the block was considered as a random effect. Mixed model analyses were then conducted using the *lme4* package(12). The means were calculated by least squares using the *emmeans* package(13), and when a statistically significant effect was observed (P<0.05), the means were compared using the Tukey test. All analyses were conducted using R software(14).

The condition with fertilizer generated the highest FLL and SER values compared to the other systems evaluated (Table 2). There was no cultivation system effect for the other characteristics. Therefore, for elephant grass, the average values obtained were as follows: LAR of 0.166 leaf tiller d^{-1}, LER of 7.05 cm tiller d^{-1}, Phyl of 6.78 d, LLS of 57.54 d, NLL of 8.65 leaves $tiller^{-1}$ and TPD of 194 m².

Table 2: Morphogenesis and tiller structure of elephant grass in different cropping systems

Cultivation systems	**LAR (leaf tiller d^{-1})**	**LER (cm tiller d^{-1})**	**SER (cm tiller d^{-1})**	**Phyl (days)**	**LLS (days)**	**NLL (leaves $tiller^{-1}$)**	**FLL (cm)**	**TPD (m²)**
Elephant grass + Mandarin	0.168^{a}	6.86^{a}	0.172^{ab}	6.96^{a}	56.20^{a}	8.34^{a}	40.10^{ab}	185.10^{a}
Elephant grass + Fava Larga	0.164^{a}	6.96^{a}	0.149^{b}	6.79^{a}	59.30^{a}	8.88^{a}	40.50^{ab}	184.70^{a}
Elephant grass + Bela	0.159^{a}	6.29^{a}	0.143^{b}	7.03^{a}	58.30^{a}	8.44^{a}	37.40^{b}	196.50^{a}
Elephant grass with fertilizer	0.178^{a}	8.37^{a}	0.206^{a}	6.16^{a}	54.30^{a}	8.92^{a}	44.30^{a}	204.70^{a}
Elephant grass without fertilizer	0.160^{a}	6.76^{a}	0.139^{b}	6.99^{a}	59.60^{a}	8.67^{a}	39.20^{ab}	197.30^{a}
SEM	0.004	0.376	0.011	0.205	1.50	0.099	0.870	7.50
P-value	0.375	0.060	0.001	0.424	0.546	0.209	<0.001	0.292

LAR= leaf appearance rate; LER= leaf elongation rate; SER: Stem elongation rate; Phyl= Phyllochron; LLS= leaf lifespan; NLL= number of live leaves; FLL= final leaf length; TPD= tiller population density. *P*-value= probability of significant effect. SEM= Standard error of the mean.

^{ab} Means followed by distinct lowercase letters in the column differ by the Tukey test.

When checking the CH, FM, LFM, STFM, and DMF of elephant grass, the scenario with fertilization generated the highest values (Table 3). The cultivation systems had no effect on F:ST, with an average value of 2.98.

Table 3: Structural and botanical characteristics of elephant grass in different cultivation systems

Cultivation systems	CH (cm)	FM (kg ha^{-1})	LFM (kg ha^{-1})	STFM (kg ha^{-1})	DMF (kg ha^{-1})	F:ST
Elephant grass + Mandarin	39.10^{b}	1238^{c}	832^{c}	355^{b}	51.10^{b}	2.94^{a}
Elephant grass + Fava Larga	37.50^{b}	1333^{bc}	901^{bc}	380^{b}	51.60^{b}	2.97^{a}
Elephant grass + Bela	40.30^{b}	1227^{c}	828^{c}	345^{b}	53.90^{b}	3.16^{a}
Elephant grass with fertilizer	45.50^{a}	2209^{a}	1475^{a}	651^{a}	83.30^{a}	2.79^{a}
Elephant grass without fertilizer	40.20^{b}	1681^{b}	1125^{b}	484^{ab}	71.80^{ab}	3.03^{a}
SEM	0.757	80.93	46.08	35.02	4.94	0.136
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	0.452

CH= canopy height; FM= forage mass; LFM= leaf forage mass; STFM= stem forage mass; DMF= forage mass of dead material; F:ST= ratio of forage mass to stem forage mass. *P*-value: probability of significant effect. SEM: Standard error of the mean.

[abc] Means followed by distinct lowercase letters in the column differ by the Tukey test.

The Mandarin and Fava Larga cultivars had the highest PH values, while the Bela cultivars had high LFM, PD, and FSM values (Table 4). The cropping systems did not affect LFM, with an average value of 1,041 kg ha^{-1}.

Table 4: Structural and botanical characteristics of forage legumes intercropped with elephant grass

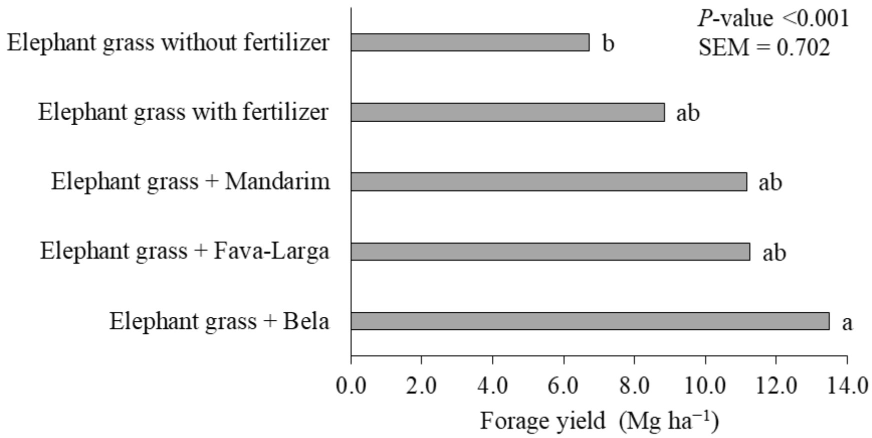
Cultivation systems	PH (cm)	PD (m²)	FM (kg ha^{-1})	LFM (kg ha^{-1})	FSM (kg ha^{-1})
Elephant grass + Mandarim	104.90^{a}	6.99^{b}	1551^{b}	987^{a}	564^{b}
Elephant grass + Fava Larga	98.90^{a}	6.87^{b}	1482^{b}	983^{a}	499^{b}
Elephant grass + Bela	55.00^{b}	59.77^{a}	2145^{a}	1153^{a}	991^{a}
SEM	4.27	0.279	121.56	56.42	3,70
P-value	<0.001	<0.001	0.008	0.268	<0.001

PH= plant height; PD= plant density; FM= forage mass; LFM= leaf forage mass; FSM= forage stem mass. *P*-value: probability of significant effect. SEM: Standard error of the mean.

ab Means followed by distinct lowercase letters in the column differ by the Tukey test.

The cultivation systems affected the forage yield (Figure 2), where it can be seen that the intercropping involving elephant grass and the Bela cultivar had the highest cumulative production (13.49 Mg ha^{-1}). When no fertilization was applied, the elephant grass in monoculture generated the lowest yield, with a value of 6.72 Mg ha^{-1}.

Figure 2: Forage yield obtained in the cultivation systems during the evaluation period. Lowercase letters in the columns differ by Tukey test



P-value: probability of significant effect. SEM: standard error of the mean.

The highest ash value is observed when elephant grass is intercropped with the Bela cultivar (Table 5). As for the other chemical characteristics of the grass in the different cultivation systems, averages of 73.10 g kg^{-1} of CP, 676.20 g kg^{-1} of NDF, 374.80 g kg^{-1} of ADF, and 62.12 g kg^{-1} of lignin. The Mandarim and Fava Larga cultivars had the highest CP, ADF, and lignin values. On the other hand, there were increases in ash values for the Bela cultivar. The highest concentration of NDF was found in the Mandarim cultivar.

By analyzing the morphogenesis and structure characteristics of elephant grass, such as LAR, LER, Phyl, LLS, and TPD, the cultivar evaluated (Elephant grass - Mott) in the semi-arid region shows remarkable phenotypic plasticity, enabling it to integrate effectively with different forage resources. This adaptability is highly advantageous, as it significantly expands the opportunities for diversification in forage production. In different climatic and soil contexts, as found by Silva *et al* [15] and Seibt *et al* [16], elephant grass has demonstrated its ability to coexist with other forage legumes, such as forage peanuts (*Arachis pintoi*), arrowleaf clover (*Trifolium vesiculosum*), and Asian pigeonwings (*Clitoria ternatea*).

The FLL is one canopy characteristic that reflects leaf area gain[17]. In the case of elephant grass, it was observed that the greatest leaf length was achieved under monoculture conditions and with chemical nitrogen fertilization. In this management, the absence of other forage species that could restrict leaf area dynamics allowed for an increase in leaf size. In addition, the supply of chemical nitrogen fertilizer guarantees the immediate availability of this nutrient, optimizing the dynamics of leaf area[18] and SER[19], justifying the higher values of FM, LFM, and STFM in the monoculture.

As some researchers mentioned[20,21], the NLL is a genetically predetermined trait. Therefore, the tillers maintain a constant number of leaves in ideal conditions without stresses that could inhibit the plant potential. Even in monoculture management without nitrogen fertilization, when the soil has good fertility parameters (Table 1), creating an environment conducive to expressing this constant pattern in the NLL is possible. Likewise, the NLL measurement observed is similar to the results of other authors[22], who obtained a value of 8.58 leaves tiller^{-1} in elephant grass, cultivar Pioneiro (*Pennisetum purpureum* Schum. cv. Pioneiro).

When adding up the FM of elephant grass and legumes, it can be seen that the potential of monoculture is limited, as the intercropping of elephant grass and Bela had the highest forage production (Figure 2). In the literature, it is reported that intercropping between different forage resources promotes increases in the efficiency of utilization of abiotic resources, resulting in increases in plant production (grain and biomass) and soil utilization efficiency[23].

This increase in production can only be achieved by carefully selecting the forage resources that make up the intercropping, so when selecting the forage plants to form this production system, the decision must be based on various agronomic parameters. In the case of the Bela cultivar, despite having the lowest PH, there was a higher PD compared to the guandu bean cultivars, which allowed the stylo cultivar to increase its FM.

This shows that this cultivar can be good option for forage production in the semi-arid region when intercropped with elephant grass. Another advantage of using stylo in intercropping with grasses is the positive residual effect on the soil. Even if this legume disappears from the area, the increase in nitrogen and organic matter ensures forage production in future crops[24].

Grasses from tropical climates naturally exhibit a lower protein fraction in the composition of the FM, and it is common for this group of plants in the vegetative phase to exhibit a CP value ranging from 72.43 g kg^{-1} to 119.30 g kg^{-1}[25,26]. On the other hand, high values of NDF and ADF are observed in the chemical composition of DM from tropical climate pastures[27,28,29].

Higher NDF and ADF values generate a forage resource, a potential limiting factor for forage consumption when fed to animals. In addition, increases in fibrous and lignin fractions are associated with forages with high STFM fractions in the forage canopy, impacting a low F:ST ratio[30].

In a study by Lima *et al*[31], different genotypes of elephant grass showed F:ST values ranging from 0.95 to 1.43 when the forage was harvested 56 d after regrowth from the previous cut. In the cutting management adopted for elephant grass intercropped and monocultures in the semi-arid region, a better F:ST ratio was observed when cutting was conducted at the height of 20 cm above the ground, reducing the share of stem in FM. These results indicate that this management strategy was suitable for harvesting elephant grass in the different cropping systems evaluated.

The legumes are expected to have a higher CP content in their composition, making it possible to produce a better-quality feed for animal nutrition. Ligoski *et al*[32] found that the intercropping of pigeon pea (*Cajanus cajan* cv. Super N) with Xaraes palisade grass (*Urochloa brizantha* cv. BRS Xaraés) and maize (*Zea mays*) not only had a higher protein content compared to maize monocropping, but also resulted in a forage that contributes to lower methane emission rates.

The intercropping between the Bela cultivar and elephant grass increased ash fractions for the grass and the legume. Prado *et al*[33] observed that the intercropping of the Bela cultivar with Tamani guinea grass (*Megathyrsus maximus* cv. BRS Tamani) produced FM with higher ash values than monocultures. The introduction of forage legumes through intercropping with other forage resources directly impacts the chemical composition of the soil, where this form of cultivation promotes increases in the bioavailability of essential nutrients. As a result, the grasses in this type of cultivation develop in an environment that enables greater nutrient absorption for the aerial part, which alters the mineral composition of the produced forage[8,34].

It was recommended to intercrop–elephant grass with the cultivar Bela, as it resulted in significant increases in total forage production, which highlights the potential of this cultivation system to optimize forage production in the semi-arid region.

Acknowledgements

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES – Finance Code 001) and National Council for Scientific and Technological Development (CNPq). We thank UNIVASF and UFRN for the support granted for the realization of this research.

Competing interests

The authors declare there are no conflicts of interest.

Table 5: Chemical composition of elephant grass and forage legumes (g kg^{-1})

	*Elephant grass					*Forage legumes				
Cultivation systems	**CP**	**Ash**	**NDF**	**ADF**	**Lignin**	**CP**	**Ash**	**NDF**	**ADF**	**Lignin**
Elephant grass + Mandarin	74.60[a]	124.00[ab]	681[a]	381[a]	61.40[a]	168[a]	45.40[b]	616[a]	434[a]	178.0[a]
Elephant grass + Fava Larga	76.20[a]	124.00[ab]	669[a]	371[a]	58.50[a]	165[a]	38.8[c]	611[ab]	430[a]	178.90[a]
Elephant grass + Bela	72.70[a]	135.00[a]	673[a]	370[a]	62.30[a]	147[b]	77.20[a]	557[b]	357[b]	99.30[b]
Elephant grass with fertilizer	71.10[a]	112.00[b]	683[a]	375[a]	67.60[a]	-	-	-	-	-
Elephant grass without fertilizer	70.90[a]	118.00[ab]	675[a]	377[a]	60.80[a]	-	-	-	-	-
SEM	0.743	2.59	6.40	3.34	1.79	6.58	3.65	10.02	11.95	8.31
P-value	0.108	0.010	0.894	0.250	0.371	<0.001	<0.001	0.006	<0.001	<0.001

* Values expressed concerning dry matter. CP= crude protein, NDF= neutral detergent fiber; ADF= acid detergent fiber. *P*-value: probability of significant effect. SEM: Standard error of the mean.

[abc] Means followed by distinct lowercase letters in the column differ by the Tukey test.

Literature cited:

1. Pereira GF, Emerenciano Neto JV, Difante GS, Assis LCS, Lima PO. Morphogenic and structural characteristics of tropical forage grasses managed under different regrowth periods in the Brazilian semi-arid region. Semina: Ciênc Agrár 2019;40(1):283.

2. Costa ABG, Difante GS, Campelo BAM, Gurgel ALC, Costa CM, Theodoro GF, *et al*. Morphogenetic, structural and production traits of Marandu grass under nitrogen rates in Neo soil. Arq Bras Med Vet Zootec 2021;73:658-664.

3. Oliveira LE, Oliveira FH, Silva GG, Bezerra MGS, Morais ÉG, Bezerra GF, *et al*. Nitrogen and phosphorus fertilizer application to Elephant grass (*Cenchrus purpureus* syn. *Pennisetum purpureum*) cultivar 'Cameroon' in an arenosol in Rio Grande do Norte, Brazil. Trop Grassl Forrajes Trop 2022;10(3):280-287.

4. Figueiredo MRP, Teixeira ACB, Bittencourt LL, Moreira GR, Ribeiro AJ, Silva FSG, *et al*. Elephant grass silage with addition of regional by-products. Acta Sci Anim Sci 2022;44.

5. Islam MR, Garcia SC, Islam MA, Bashar MK, Roy A, Roy BK, Sarker NR, Clark CEF. Ruminant production from napier grass (*Pennisetum purpureum* Schum): A review. Animals (Basel) 2024;14:467.

6. Bueno AM, Andrade AF, Viçosi KA, Flores RA, Sette CR, Cunha TQG, Santos GG. Does nitrogen application improve elephant grass yield and energetic characteristics of biofuels? Bioenerg Res 2021;14:774-784.

7. Boddey RM, Casagrande DR, Homem BGC, Alves BJR. Forage legumes in grass pastures in tropical Brazil and likely impacts on greenhouse gas emissions: A review. Grass Forage Sci 2020;75:1-15.

8. Rezende PR, Rodrigues LM, Backes C, Teodoro AG, Santos AJM, Fernandes PB, Giongo PR, Ribon AA, Bessa SV. Productivity and nutrient extraction by Paiaguás palisadegrass submitted to doses of nitrogen in single cultivation and intercropped with pigeon pea. Arq Bras Med Vet Zootec 2022;74:1151-1160.

9. Epifanio PS, Costa KAP, Severiano EC, Souza WF, Teixeira DAA, Silva JT, Aquino MM. Productive and nutritional characteristics of *Brachiaria brizantha* cultivars intercropped with *Stylosanthes* cv. Campo Grande in different forage systems. Crop Pasture Sci 2019;70:718-729.

10. Santos HG, Jacomine PKT, Anjos LHC, Oliveira VA, Lumbrera JF, Coelho MR, *et al*. Sistema brasileiro de classificação de solos. 5th ed. Brasília: Embrapa CNPS; 2018.

11. Detmann E, Souza MA, Valadares Filho SC. Métodos para análise de alimentos – INCT - Ciência animal. Visconde do Rio Branco: Suprema; 2012.

12. Bates D, Mächler M, Bolker B, Walker S. Fitting linear mixed-Effects models using lme4. J Stat Softw 2015;67:1-48.

13. Lenth R, Singmann H, Love J, Buerkner P, Herve M. Emmeans: estimated marginal means, aka least-squares means. R Package Version 1.4.8. Retrieved from https://CRAN.R-project.org/package=emmeans.

14. R Core Team. R: A Language and Environment for Statistical Computing. Retrieved from https://www.R-project.org/.

15. Silva PH, Santos MV, Mello AC, Silva TBS, Neto DES, da Silva VJ, Dubeux Jr JCB, Coelho JJ, Souza EJO, Cunha MV. Agronomic responses and herbage nutritive value of elephant grass (*Cenchrus purpureus*) genotypes grown as monocrops and mixed with butterfly pea (*Clitoria ternatea*). Crop Pasture Sci 2023;74:1210-1222.

16. Seibt DC, Olivo CJ, Alessio V, Sauter CP, Bratz VF, Aguirre PF. Forage mass and nutritional value of elephant grass intercropped with forage legumes. Rev Ceres 2021;68:429-440.

17. Fernandes PB, Barbosa RA, Morais MG, Medeiros-Neto C, Gurgel ALC, Costa CM, Costa ABG, Santana JCS, Silva MGP, Difante GS. Evaluation and reparametrization of mathematical models for prediction of the leaf area of *Megathyrsus maximus* cv. BRS Zuri. Trop Grassl Forrajes Trop 2020;8:214-219.

18. Euclides VPB, Montagner DB, Araújo AR, Pereira MA, Difante GS, Araújo IMM, Barbosa LF, Barbosa RA, Gurgel ALC. Biological and economic responses to increasing nitrogen rates in Mombaça guinea grass pastures. Sci Rep 2022;12:1937.

19. Rodrigues LF, Santos AC, Junior OS, Santos JGD, Faria AFG, Coelho BPL. Morphogenic and structural characteristics of Marandu grass cultivated under grazing management and nitrogen fertilization. Semina: Ciênc Agrár 2019;40(5Supl1):2331-2340.

20. Lemaire G, Agnusdei M. Leaf tissue turn-over and efficiency of herbage utilization. In: Lemaire G, Hodgson J, Moraes A, et al. editors. Grassland ecophysiology and grazing ecology. Wallingford: CAB International; 2000:265-288.

21. Difante GS, Nascimento Junior DD, Da Silva SC, Euclides VPB, Montagner DB, Silveira MCT, Pena KS. Características morfogênicas e estruturais do capim-marandu submetido a combinações de alturas e intervalos de corte. Rev Bras Zootec 2011;40:955-963.

22. Sales ECJ, Saraiva CRS, Reis ST, Rocha Júnior VR, Pires DAA, Vitor CMT. Morphogenesis and productivity of Pioneiro elephant grass under different residual heights and light interceptions. Acta Sci Anim Sci 2014;36:137-143.

23. Chapagain T, Riseman A. Intercropping wheat and beans: effects on agronomic performance and land productivity. Crop Sci 2014;54:2285-2293.

24. Menezes RC, Alves EB, Casagrande DR, Lara MAS, Evangelista AR, Bernardes TF. Xaraés palisadegrass remains productive after the disappearance of stylo in tropical legume-grass pasture. Sci Agric 2015;72(6):484-488.

25. Ferreira EA, Abreu JG, Martinez JC, Braz TGS, Ferreira DP. Cutting ages of elephant grass for chopped hay production. Pesqui Agropecu Trop 2018;48(3):245-253.

26. Coca FOCG, Gomes ENO, Junges L, Itavo LCV, Nonato LM, Gomes FK, Itavo CCBF, Difante GS, Dias AM. Protodioscin content, degradation kinetics, and *in vitro* digestibility of Marandu palisadegrass hay as were affected by cutting interval of the canopy. Trop Anim Sci J 2022;45:299-307.

27. Euclides VPB, Macedo MCM, Valle CBD, Difante GDS, Barbosa RA, Cacere ER. Valor nutritivo da forragem e produção animal em pastagens de *Brachiaria brizantha*. Pesqui Agropecu Bras 2009;44:98-106.

28. Rodrigues JG, Difante GS, Ítavo LCV, Pereira MG, Gurgel ALC, Costa ABG, Véras ELL, Monteiro GOA, Dias AM, Ítavo CCBF. Forage Accumulation and Nutritional Characteristics of *Brachiaria* Cultivars Grown in a Semi-arid Environment. Trop Anim Sci J 2023;46:85-96.

29. Costa RRGF, Costa KAP, Souza WF, Epifanio PS, Santos CB, Silva JT, Oliveira SS. Production and quality of silages pearl millet and paiaguas palisadegrass in monocropping and intercropping in different forage systems. Biosci J 2018;34:957-967.

30. Brâncio PA, Euclides VPB, Nascimento Júnior D, Fonseca DM, Almeida RG, Macedo MCM, Barbosa RA. Avaliação de três cultivares de *Panicum maximum* Jacq. sob pastejo: disponibilidade de forragem, altura do resíduo pós-pastejo e participação de folhas, colmos e material morto. Rev Bras Zootec 2003;32:55-63.

31. Lima ES, Silva JFC, Vásquez HM, Araújo SAC, Lista FN, Costa DPB. Produção de matéria seca e proteína bruta e relação folha/colmo de genótipos de capim-elefante aos 56 dias de rebrota. Rev Bras Zootec 2007;36:1518-1523.

32. Ligoski B, Gonçalves LF, Claudio FL, Alves EM, Krüger AM, Bizzuti BE, Lima PMT, Abdalla AL, Paim TP. Silage of intercropping corn, palisade grass, and pigeon pea increases protein content and reduces *in vitro* methane production. Agronomy 2020;10:1784.

33. Prado LG, Costa KAP, Silva LM, Costa AC, Severiano EC, Costa JVCP, Habermann E, Silva JAG. Silages of sorghum, Tamani guinea grass, and *Stylosanthes* in an integrated system: production and quality. Front Sustain Food Syst 2023;7:1-15.

34. Silva LM, Costa KAP, Oliveira KJ, Costa AC, Silva JAG, Costa JVCP, *et al*. Fermentation dynamics and quality of maize silage with Pigeon pea. Sem Ci Agr 2023;44:567-584.