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Grass size and butterfly pea inclusion modify the nutritional value of elephant grass silage

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Abstract – The objective of this work was to evaluate the nutritional value of silages from tall-sized and dwarf elephant grass (*Pennisetum purpureum*) genotypes, intercropped or not with butterfly pea (*Clitoria ternatea*). The experiment was performed in randomized complete blocks, in a 4x2 factorial arrangement (four genotypes × two cropping systems). The genotypes intercropped or not with butterfly pea were: IRI-381 and Elephant B, tall sized; and Taiwan A-146 2.37 and Mott, dwarf. Forage was harvested 60 days after regrowth. In the silage from Mott grass intercropped with butterfly pea, lower contents of lignin (78.1 g kg^{-1}), neutral detergent fiber (636.0 g kg^{-1}), and neutral detergent insoluble protein (13.15 g kg^{-1}), besides a greater dry matter recovery (873.3 g kg^{-1}), were observed. The silage from Taiwan A-146 2.37 intercropped with the legume showed a greater crude protein content (136.1 g kg^{-1}). In both silages, the ammonia nitrogen contents were quite reduced (26.4 g kg^{-1}). However, greater residual water-soluble carbohydrate contents were observed in the silages from the intercrop (1.85 mg g^{-1}) and from the Mott grass monocrop (1.51 mg g^{-1}). Moreover, there was a lower in vitro dry matter digestibility (676.7 g kg^{-1}) for the silage from the intercrop. Dwarf genotypes increase the nutritional value of elephant grass silage, compared with the tall-sized ones. Intercropping with butterfly pea improves silage fermentation characteristics, despite reducing its digestibility. Therefore, the ensilage of dwarf Mott elephant grass intercropped with butterfly pea shows more promising results.

Index terms: *Clitoria ternatea*, *Pennisetum purpureum*, intercropping.

Porte da gramínea e inclusão da cunhã modificam o valor nutritivo da silagem de capim-elefante

Resumo – O objetivo deste trabalho foi avaliar o valor nutritivo de silagens de genótipos anões e altos de capim-elefante (*Pennisetum purpureum*), consorciados ou não à cunhã (*Clitoria ternatea*). O experimento foi realizado em delineamento de blocos ao acaso, em arranjo fatorial 4x2 (quatro genótipos × dois sistemas de plantio). Os genótipos consorciados ou não à cunhã foram: IRI-381 e Elefante B, de porte alto; e Taiwan A-146 2.37 e Mott, anões. A forragem foi colhida após 60 dias de rebrota. Na silagem do capim Mott consorciado à cunhã, foram observados menores teores de lignina (78,1 g kg^{-1}), fibra em detergente neutro (636,0 g kg^{-1}) e proteína insolúvel em detergente neutro (13,15 g kg^{-1}), além de maior recuperação da matéria seca (873,3 g kg^{-1}). A silagem de Taiwan A-146 2.37 cultivado em consórcio com a leguminosa apresentou maior teor de proteína bruta (136,1 g kg^{-1}). Em ambas as silagens, os teores de nitrogênio amoniacal foram bastante reduzidos (26,4 g kg^{-1}). No entanto, maiores teores residuais de carboidratos solúveis em água foram observados nas silagens do consórcio (1,85 mg g^{-1}) e do capim Mott em monocultivo (1,51 mg g^{-1}). Além disso, houve menor digestibilidade in vitro da matéria seca (676,7 g kg^{-1}) na silagem do consórcio. Os genótipos anões aumentam o valor nutricional da silagem de capim-elefante, comparados aos de porte alto. O consórcio com a cunhã melhora as características fermentativas da silagem, apesar de reduzir a sua digestibilidade. Portanto, a ensilagem do capim anão Mott consorciado à cunhã apresenta resultados mais promissores.

Termos para indexação: *Clitoria ternatea*, *Pennisetum purpureum*, consórcio.

Introduction

Irregular rainfall distribution throughout the year leads many farmers to adopt forage conservation practices in their properties to prevent animal weight loss or maintain herd performance during the dry season (Furtado et al., 2019). Silage is one of the alternatives for forage conservation, which is done through anaerobic fermentation (Veriato et al., 2018).

The ensilage of tropical forage grasses has been gaining space in relation to that of traditional crops, such as corn (*Zea mays* L.) and sorghum (*Sorghum* spp.), since grasses are perennial, demand less crop management and lower soil fertility, and provide a greater harvest, which can result in an increased yield over the year (Bernardes et al., 2018). Among grasses, elephant grass (*Pennisetum purpureum* Schumach.) stands out for its great dry matter yield and usually greater soluble carbohydrate content, sometimes reaching acceptable values of 111.1 to 154.3 g kg^{-1} for an adequate fermentation process (Souza et al., 2017b).

However, the chemical composition and nutritional value of elephant grass silages may vary, especially due to the size of elephant grass, a trait of the species that has been the focus of several studies (Pereira et al., 2017; Viana et al., 2018). In tall-sized elephant grass, the stem represents a greater proportion of its morphological composition, which reduces the nutritional value of the harvested forage (Souza et al., 2017b). In dwarf elephant grass, however, morphological traits include a high leaf/stem ratio and a large number of leaves per tiller, factors that contribute to a better nutritional value (Andrade et al., 2016).

In addition, tropical grasses have a high moisture content when harvested earlier, which negatively influences fermentation during the process. In this context, legume inclusion has been recommended as an additive for grass-based silages to increase dry matter and water-soluble carbohydrate contents, also increasing forage crude protein content (Copani et al., 2016). Butterfly pea (*Clitoria ternatea* L.) has shown a great cropping potential in regions with tropical, subtropical, and semiarid climates, besides persistence and a greater nutritional value than other legumes (Gomez & Kalamani, 2003; Souza et al., 2017a), with a crude protein content ranging from 140 to 270 g kg^{-1} (Mohammed, 2013; Bishoyi et al., 2014; Oguis et al., 2019).

The objective of this work was to evaluate the nutritional value of silages from tall-sized and dwarf elephant grass genotypes, intercropped or not with butterfly pea.

Materials and Methods

The experiment was carried out at Estação Experimental de Cana-de-Açúcar do Carpina of Universidade Federal Rural de Pernambuco, located in the municipality of Carpina, in the state of Pernambuco, Brazil (07º51'03"S, 35º15'17"W, at 180 m of altitude). The climate of the region is As’, dry tropical, according to Köppen-Geiger, with an average annual rainfall of 1,174 mm and an average temperature of 24.5°C. The soil of region is classified as an Argissolo Amarelo (Santos et al., 2018), i.e., a Yellow Argisol.

Treatments were distributed in a randomized complete block design, under a 4×2 factorial arrangement (four elephant grass genotypes x two cropping systems), with four replicates (experimental silos). The four genotypes assessed were: Elephant B and IRI-381, tall sized, with average heights of 161 and 159 cm, respectively; and Taiwan A-146 2.37 and Mott, dwarf, with average heights of 77 and 98 cm, respectively. All genotypes were grown under monocropping or intercropping with butterfly pea. The experimental site, formed by 32 plots with 25 m^2, was established in 2014, and the elephant grass genotypes were grown in 1 m furrows.

On August 18, 2018, butterfly pea was intercropped between elephant grass rows, 60 days after seeding, in half of the experimental plots. On March 20, 2019, after cutting for uniformity, plots were fertilized according to the following soil chemical properties: pH (water) 5.5, 0.06 $cmol_c$ dm^{-3} Na, 1.60 $cmol_c$ dm^{-3} Ca, 0.80 $cmol_c$ dm^{-3} Mg, 0.00 $cmol_c$ dm^{-3} Al^{+3}, 2.40 $cmol_c$ dm^{-3} H+Al^{+3}, 5.0 mg dm^{-3} P, and 19.5 mg dm^{-3} K. Rates of 100, 60, and 70 kg ha^{-1} N, K_2O, and P_2O_5, respectively, were applied; however, N was not applied on intercropped plots. Sixty days after regrowth, on May 20, 2019, forage was harvested close to the soil for elephant grass and at 20 cm stubble height for the legume. At the moment of harvesting, a 1.0 kg aliquot of fresh forage was sampled in each plot and, then, proportions of each species (elephant grass genotype and butterfly pea) were estimated based on dry matter yield. The proportions of butterfly pea in the intercrops with Elephant B, IRI-381, Mott, and Taiwan A-146 2.37 were 17.7, 25.7, 42.5, and 53.9%, respectively.

Forage was chopped to 2.0 to 3.0 cm, with the aid of a stationary forage machine, and compacted in experimental silos composed of cylindrical PVC tubes (20 cm diameter and 60 cm height), until reaching an average density of 600 kg m^{-3} based on fresh matter. In the bottom of each silo, 3.5 kg washed sand were added, being kept separated from the silage by a screen in order to absorb and quantify effluents. The silos were sealed with lids equipped with Bunsen-type valves for gas escape and remained closed for 45 days. During the opening of the silos, silage samples were separated for pH measurement (Silva & Queiroz, 2002) and ammonia nitrogen (NH_3-N) quantification (Bolsen et al., 1992). For aerobic stability estimation, about 3 kg of each silage were placed in lidless plastic buckets, without being compacted, and kept at room temperature. Silages and room temperatures were recorded daily at 7:00 a.m., 1:00 p.m., and 7:00 p.m. Four A-DIV-0090 digital thermometers (Incoterm Ltd., Porto Alegre, RS, Brazil) were placed at different points of the laboratory to record room temperature. To record silage temperature, TP101 electronic digital thermometers (Elecrow, Limassol, Cyprus), ranging from -10 to 150ºC, were positioned in the geometric center, within the silage mass. Aerobic stability break-off was based on the necessary time (in hours) to increase temperature in 2ºC in relation to room temperature (Kung Jr et al., 2018).

The contents of dry matter (DM), ash, crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, lignin (Horwitz, 2005; Detmann et al., 2012), neutral detergent insoluble protein (NDIP), acid detergent insoluble protein (ADIP) (Licitra et al., 1996), and in vitro dry matter digestibility (IVDMD) (Tilley & Terry, 1963) were analyzed for both fresh forage and silages (Table 1). The residual water-soluble carbohydrate content (WSCr) (Yemm & Willis, 1954) and pH and NH_3-N (Silva & Queiroz, 2002) were evaluated only for silages. Moreover, the fermentation coefficient (FC) of

Table 1. Nutritional value and buffer capacity (BC) of elephant grass (*Pennisetum purpureum*) genotypes and butterfly pea (*Clitorea ternatea*) before ensilage in 2019, in the municipality of Carpina, in the state of Pernambuco, Brazil.

Variable	Elephant grass genotype				Butterfly pea
	Mott	Taiwan A-146 2.37	Elephant B	IRI-381	
DM (g kg^{-1} FM)	208.9	202.1	254.2	248.4	351.2
Ash(1) (g kg^{-1})	20.5	18.9	17.9	17.8	55.0
NDF(1) (g kg^{-1})	649.0	651.7	696.8	683.5	617.0
ADF(1) (g kg^{-1})	346.0	343.6	381.3	376.3	382.5
Hemicellulose(1) (g kg^{-1})	301.7	313.1	314.7	307.6	167.3
Cellulose(1) (g kg^{-1})	304.6	301.5	331.1	322.6	348.9
Lignin(1) (g kg^{-1})	41.0	37.2	48.0	52.4	51.7
CP(1) (g kg^{-1})	102.3	110.9	84.5	87.8	162.3
NDIP(2) (g kg^{-1})	47.5	49.7	47.4	45.0	251.8
ADIP(2) (g kg^{-1})	17.7	21.4	17.0	20.2	146.5
IVDMD(1) (g kg^{-1})	551.8	548.9	527.1	514.7	657.1
WSC(1) (mg g^{-1})	1.9	1.1	1.2	0.7	3.81
BC (n.e.mg 100 g^{-1})	43.2	51.8	42.5	43.4	57.25

(1)Results based on dry matter content. (2)Results based on crude protein content. DM, dry matter; FM, fresh matter; NDF, neutral detergent fiber; ADF, acid detergent fiber; CP, crude protein; NDIP, neutral detergent insoluble protein; ADIP, acid detergent insoluble protein; IVDMD, in vitro dry matter digestibility; and WSC, water-soluble carbohydrate.

fresh forage was calculated as described by Weissbach & Honig (1996), considering three variables: WSC, buffer capacity (BC), and DM contents, according to the equation: FC = DM (g kg^{-1}) + 8 × WSC (mg g^{-1}) / BC (n.e. mg 100 g^{-1} DM).

Effluent (EL) and gas (GL) losses, besides dry matter recovery (DMR), were estimated by weight difference according to the equations found in Jobim et al. (2007). EL were calculated by: EL (kg Mg^{-1} FM) = {[Wo (kg) × Wen (kg)] / FMef (kg)} × 1,000, where EL is effluent production, Wo is the empty set weight (silo + cover + wet sand + bag) at silo opening, Wen is the empty set weight (silo + cover + dry sand + bag) during ensilage, and FMef is the fresh mass of the ensiled forage. GL were determined using the following equation: GL (g kg^{-1} DM) = {[FWen (kg) - Wen (kg)] × DMen (%DM)} - {[FWo (kg) - Wen (kg)] × DMo (%DM)} × 100 / {[FWen (kg) - Wen (kg)] × DMen (%DM)}, where GL are the gas losses (g kg^{-1} DM), FWen is the full silo weight during ensilage, DMen is forage DM during ensilage, FWo is the full silo weight during opening, and DMo is forage DM content during silo opening. DMR was estimated with the equation: DMR (g kg^{-1} DM) = {[FMf (kg) × DMf (kg)] / [FMi (kg) × DMi (kg)]} × 100, where DMR is dry matter recovery, FMf is forage mass at silo opening, DMf is forage dry matter content at silo opening, FMi is forage mass at silo closure, and DMi is forage dry matter content at silo closure.

Data were subjected to the normality test and analysis of variance. When the F-test was significant, means were compared by Tukey's test, at 5% probability. Data were analyzed with the aid of the R, version 3.0.3, and ExpDes pack, version 1.2.0, software (Ferreira et al., 2018), following the mathematical model: $Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + w_k + \varepsilon_{ijk}$, where Y_{ijk} is the observed value, μ is the population average, α_i is the effect of the elephant grass genotype (1 to 4), β_j is the cropping system effect (1 to 2), $(\alpha\beta)_{ij}$ is the interaction between the elephant grass genotype and cropping system, w_k is the block effect (1 to 4), and ε_{ijk} is the residual error.

Results and Discussion

Compared with the grass genotypes, butterfly pea resulted in a greater BC, but also presented considerably greater DM and WSC contents (Table 1). Greater DM contents were observed in the silage from the grass-legume intercropping, compared with that from elephant grass under monocropping (Table 2). Santos et al. (2013) reported only 190 g kg^{-1} DM content for Elephant B silage without the inclusion of legumes or additives or wilting. According to Borreani et al. (2018), 250 g kg^{-1} DM content guarantees an adequate ensiled mass fermentation, for which legume inclusion was important.

For WSCr contents, there were differences among genotypes and between cropping systems (Table 2), but without any interaction. A greater WSCr content was obtained in silages from grass genotypes intercropped with the legume, compared with exclusive elephant grass silages. This can be justified by the low carbohydrate consumption by the microorganisms of the ensiled mass, since, in silages with a greater moisture content as those from monocrops, there is an increase in this consumption during the fermentation process (Wilkinson & Davies, 2013).

Regardless of the cropping system, the WSCr content was greater in the silage from Mott and lower in that from IRI-381 (Table 2). This result is probably explained by the often lower fibrous carbohydrate content and higher cell content of dwarf genotypes

Table 2. Dry matter (DM) and residual water-soluble carbohydrate (WSCr) contents in silages from tall-sized and dwarf elephant grass (*Pennisetum purpureum*) genotypes grown under monocropping or intercropping with butterfly pea (*Clitoria ternatea*), as well as fermentation coefficient of the harvested fresh forage under both cropping systems, in 2019, in the municipality of Carpina, in the state of Pernambuco, Brazil[(1)].

Cropping system	Fermentation coefficient	CV (%)
Monocropping	24.89B	8.75
Intercropping	27.89B	
	DM (g kg^{-1})	
Monocropping	237.7B	9.21
Intercropping	260.5A	
	WSCr[(2)] (mg g^{-1})	
Monocropping	1.340B	7.20
Intercropping	1.850A	
Genotype	WSCr[(2)] (mg g^{-1})	
Mott	1.233A	7.20
Taiwan A-146 2.37	0.510B	
Elephant B	0.837AB	
IRI-381	0.196C	

[(1)]Means followed by equal letters do not differ by Tukey's test, at 5% probability, considering a same variable under a same experimental factor. [(2)]Results based on dry matter content. CV, coefficient of variation.

(Viana et al., 2018). All WSCr results were lower than 2.0 mg g^{-1} DM, a reference value that characterizes an adequate fermentation process according to Mendieta-Araica et al. (2009). The average value for the silage from the grass-legume intercropping remained about 1.85 mg g^{-1} DM, closer to the reference value of 2.0 mg g^{-1} than that for the silage from the grass monocrop. Santos et al. (2013) found values quite below this limit, ranging from 0.6 to 1.1 mg g^{-1}, for silages from the Elephant B, Mott, and Taiwan A-146 2.37 genotypes, with no additive or legume inclusion.

The silage from Elephant B, under intercropping or monocropping, had a greater effluent loss and DMR than that of the other genotypes (Table 3). A lower effluent loss was verified in silages from both the dwarf Mott and tall-sized IRI-381 genotypes in intercropping, compared with those from both genotypes under monocropping. In addition, the silage from Mott showed a greater DMR under intercropping than monocropping. These results are likely associated to the lower DM content of the forage from elephant grass genotypes (Table 1). Likewise, lower effluent loss and gas loss were observed for silages from both Mott and IRI-381 intercropped with butterfly pea (Table 3) due to an increment of 23.2 g kg^{-1} in DM content. This is important since high effluent loss values negatively affect the fermentation process, reduce silage nutritional value, and can cause serious environmental impacts. These results occur because the released effluent is made up of carbohydrates, proteins, minerals, and vitamins; carbohydrates are the main bacteria substrates, including those that synthesize lactic acid, which is important for an adequate silage fermentation (Kung Jr et al., 2018). The positive effect of the grass-legume intercropping was evident on the DMR of the silage from Mott (Table 3), which differed greatly from that of the genotypes under monocropping with 227.1 g kg^{-1} DM. Rigueira et al. (2017) also found a DMR increase from 935.8 to 974.3 g kg^{-1} in 'Marandu' grass [*Urochloa brizantha* (A.Rich.) R.D.Webster] silages when 'Campo Grande' (*Stylosanthes capitata* Vogel with *Stylosanthes macrocephala* M.B.Ferreira & Sousa Costa) was added to the silage mass. The authors concluded that legume inclusion increased DM contents, reduced losses and secondary fermentations, and recovered a greater proportion of ensiled mass. The results obtained in the present study for silage DM content and DMR allow inferring that the intercropping of elephant grass with butterfly pea provided advantages for the ensiling process.

A greater CP content was observed in silages from all genotypes under intercropping, compared with those under monocropping (Table 4). The silage from Taiwan A-146 2.37 intercropped with butterfly pea presented the greatest CP content. Legumes usually have a higher N content in leaf tissues than tropical grasses, which probably explains the increase in the CP of the silages from the intercrops (Table 4). The greater CP content observed in the silages from the Mott and Taiwan A-146 2.37 dwarf genotypes is most likely related to their greater leaf/stem ratio in comparison with that of tall-sized ones (Viana et al., 2018). Santos

Table 3. Effluent losses (EL), gas losses (GL), and dry matter recovery (DMR) of silages from tall-sized and dwarf elephant grass (*Pennisetum purpureum*) genotypes, grown under monocropping or intercropping with butterfly pea (*Clitoria ternatea*) in 2019, in the municipality of Carpina, in the state of Pernambuco, Brazil[(1)].

Cropping system	Elephant grass genotype				CV (%)
	Mott	Taiwan A-146 2.37	Elephant B	IRI-381	
		EL[(2)] (kg Mg^{-1})			
Monocropping	46.34aA	32.00aB	54.38aA	41.00aAB	19.94
Intercropping	9.38bC	26.29aB	57.70aA	12.26bC	
		GL[(2)] (g kg^{-1})			
Monocropping	36.8aB	36.0aB	163.9aA	48.7aB	16.86
Intercropping	21.1aA	22.1aA	27.0bA	25.5aA	
		DMR[(3)] (g kg^{-1})			
Monocropping	646.2bA	789.6aA	778.9aA	747.8aA	10.05
Intercropping	873.3aA	699.6aB	803.8aAB	789.7aAB	

[(1)]Means followed by equal letters, uppercase in the lines and lowercase in the columns, do not differ by Tukey's test, at 5% probability. [(2)]Results based on fresh matter. [(3)]Results based on dry matter. CV, coefficient of variation.

et al. (2013) also found a greater CP content in silages from dwarf elephant grasses compared with those from tall-sized genotypes, with values of 122 and 101 g kg^{-1} for Taiwan A-146 2.37 and Elephant B silages, respectively. When comparing the silages from dwarf genotypes intercropped with butterfly pea, the one from Taiwan A-146 2.37 showed a greater CP content than that from Mott due to the larger legume proportion in the ensiled mass (53.9 vs. 42.5%).

Ash value was the lowest in the silage from Elephant B under monocropping, being greater – above 80 g kg^{-1} – in silages both from Taiwan A-146 2.37 and Mott, also under monocropping. No difference was observed for NH_3-N content among the silages from the genotypes under monocropping; however, there was an increase in this content in the silages from the intercropping of Elephant B and the legume (Table 4). All results for NH_3-N contents could be considered reduced, which is adequate for an efficient fermentation process. According to Musco et al. (2016), levels of NH_3-N lower than 100 g kg^{-1} in relation to total N indicate a reduced consumption of soluble carbohydrates for secondary fermentations. This could be attributed to the fact that NH_3-N originates from the proteolysis of protein compounds carried out especially by non-desirable bacteria as *Clostridium* spp. (Furtado et al., 2019). The lack of factor effect on EE contents may be related to the low concentrations of the nutrient in the plant tissues of tropical grasses (Detmann et al., 2012). Although Wahyudi et al. (2019) reported a 24.4 g kg^{-1} DM for EE from Mott grass silages with different additives, the authors did not find any significant difference among ensiled materials.

Greater NDF and hemicellulose contents were observed in the silages from the genotypes under monocropping, while the greatest ADF and lignin contents occurred in the silages from the intercropped genotypes, except from IRI-381 (Table 5). The silage from Taiwan A-146 2.37 grown with butterfly pea presented the greatest ADF and lowest hemicellulose. Moreover, NDIP and ADIP contents were greater in the silages from the grass-legume intercrops and from the monocrops of Elephant B and IRI-381. These results are related to the tall size of the latter genotypes. Tall plants require a greater deposition of supporting tissues (Viana et al., 2018), especially in stems, which leads to an expressive NDF content. In general, legumes and dwarf elephant grasses have a lower NDF content due to morphological, physiological, and productive aspects (Musco et al., 2016; Viana et al., 2018). Regarding ADF and lignin contents, legumes can have greater values than grasses (Borreani et al., 2018). Therefore, greater ADF and lignin contents were found in silages combined with butterfly pea (Table 5), which could be justified by the large legume proportion of 53.9%.

The negative effect of lignin on legumes is usually attributed to its great concentration in the xylem vessels of the plant, often leading to a reduction in IVDMD. Lignin is a highly indigestible fibrous fraction, although its digestibility in legumes is reasonable, precisely because of its concentration in

Table 4. Crude protein (CP), ash, and ammonia nitrogen (NH_3-N) in silages from tall-sized and dwarf elephant grass (*Pennisetum purpureum*) genotypes, grown under monocropping or intercropping with butterfly pea (*Clitoria ternatea*) in 2019, in the municipality of Carpina, in the state of Pernambuco, Brazil[1].

Cropping system	Elephant grass genotype				CV (%)
	Mott	Taiwan A-146 2.37	Elephant B	IRI-381	
		CP[2] (g kg^{-1})			
Monocropping	85.6bA	81.1bAB	67.4bBC	54.7bC	8.31
Intercropping	111.1aB	136.1aA	81.4aC	84.2aC	
		Ash[2] (g kg^{-1})			
Monocropping	85.4aA	87.6aA	49.4bC	66.9aB	9.24
Intercropping	71.2bAB	83.1aA	66.9aB	69.9aAB	
		NH3-N[3] (g kg^{-1})			
Monocropping	23.2aA	29.0aA	24.9bA	24.4aA	24.16
Intercropping	21.1aB	22.8aB	43.9aA	22.2aB	

[1]Means followed by equal letters, uppercase in the lines and lowercase in the columns, do not differ by Tukey's test, at 5% probability. [2]Results based on dry matter content. [3]Results based on total N content. CV, coefficient of variation.

the xylem, a more digestible plant tissue than others such as the phloem and vascular sheath (Musco et al., 2016). However, because of the expressive ADF and lignin contents, NDIP and ADIP contents were also greater in the silages with butterfly pea (Table 5). There was an effect of genotype and cropping system on IVDMD (Table 6). As a consequence of the greater values of ADF, lignin, NDIP, and ADIP in the silages from the genotypes intercropped with butterfly pea, a greater IVDMD coefficient was observed in the silage from the grass monocrop; the silage of Taiwan A-146 2.37 stood out with the greatest value. In general, all IVDMD coefficients obtained can be considered relatively expressive and compatible with tropical

Table 5. Neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose, lignin, neutral detergent insoluble protein (NDIP), and acid detergent insoluble protein (ADIP) in silages from tall-sized and dwarf elephant grass (*Pennisetum purpureum*) genotypes, grown under monocropping or intercropping with butterfly pea (*Clitoria ternatea*) in 2019, in the municipality of Carpina, in the state of Pernambuco, Brazil[(1)].

Cropping system	Elephant grass genotype				CV (%)
	Mott	Taiwan A-146	Elephant B	IRI-381	
	NDF[(2)] ($g\ kg^{-1}$)				
Monocropping	683.3aB	711.1aB	757.4aA	743.1aA	2.67
Intercropping	636.0bC	675.8bD	706.9bB	744.6bA	
	ADF[(2)] ($g\ kg^{-1}$)				
Monocropping	391.6bB	431.8bA	386.3bB	424.1aA	2.74
Intercropping	420.4aB	456.4aA	411.2aB	421.5aB	
	Hemicellulose[(2)] ($g\ kg^{-1}$)				
Monocropping	291.6aC	279.3aC	371.0aA	338.9aB	5.50
Intercropping	215.5bB	119.3bC	295.6bA	323.1aA	
	Lignin[(2)] ($g\ kg^{-1}$)				
Monocropping	59.9bB	73.4aB	59.4bB	104.1aA	11.49
Intercropping	78.1aC	83.0aBC	97.8aAB	109.1aA	
	NDIP[(3)] ($g\ kg^{-1}$)				
Monocropping	11.38bA	10.88bA	11.31bA	10.94bA	6.28
Intercropping	13.15aB	14.14aAB	15.80aA	15.90aA	
	ADIP[(3)] ($g\ kg^{-1}$)				
Monocropping	9.11bB	8.14bB	10.75aA	10.73aA	8.68
Intercropping	11.03aA	11.18aA	11.06aA	11.38aA	

[(1)]Means followed by equal letters, uppercase in the lines and lowercase in the columns, do not differ by Tukey's test, at 5% probability. [(2)]Results based on dry matter content. [(3)]Results based on crude protein content. CV, coefficient of variation.

Table 6. In vitro dry matter digestibility (IVDMD) of silages from tall-sized and dwarf elephant grass (*Pennisetum purpureum*) genotypes, grown under monocropping or intercropping with butterfly pea (*Clitoria ternatea*) in 2019, in the municipality of Carpina, in the state of Pernambuco, Brazil[(1)].

Cropping system	IVDMD[(2)] ($g\ kg^{-1}$)	CV (%)
Monocropping	691.0a	2.71
Intercropping	676.7b	
Genotype		
Mott	670.2b	2.71
Taiwan A-146 2.37	701.0a	
Elephant B	676.3b	
IRI-381	678.0b	

[(1)]Means followed by equal letters do not differ by Tukey's test, at 5% probability. [(2)]Results based on dry matter content. CV, coefficient of variation.

grass silages harvested at 60 days after regrowth (Bernardes et al., 2018). Monção et al. (2020) reported a considerably lower IVDMD of 441.7 g kg^{-1} in the silage from 'BRS Capiaçu' elephant grass harvested at 150 days after regrowth and without additives.

Half of the silages showed aerobic stability break-off after being air exposed for 22 hours. Silages from dwarf Mott intercropped with butterfly pea, from Taiwan A-146 2.37 in both cropping systems, and from IRI-381 under monocropping reached 2ºC above room temperature after 36, 42, and 46 hours after silo opening, respectively (Figure 1). Therefore, the greater time of aerobic stability of these silages is likely associated with their lowest WSCr contents (Table 2). According to Kung Jr et al. (2018), silages with greater starch and sugar amounts tend to present aerobic deterioration after silo opening, usually due to the development of larger yeasts and fungi populations, which consume carbohydrates under aerobic conditions. Andrade et al. (2012) reported an aerobic stability break-off from elephant grass silage, with moisture-absorbing additives (soybean husk and cornmeal), only after the first 48 hours of observation. The authors emphasized that the used additives were able to maintain aerobic stability, which did not occur in the present study. Moreover, tropical grass silages are characterized by expressive moisture and are usually exposed to deterioration by aerobic microorganisms. Therefore, soluble sugars can be quickly used by fungi and yeasts after silo opening, a phenomenon that raises temperature and reduces the quality of silages (Kung Jr et al., 2018). In the present study, the rapid changes in temperature for most of the evaluated silages was evident. Lemos et al. (2020) also found a rapid aerobic stability break-off from 'Roxo' elephant grass silage treated with fibrolytic enzymes, with temperatures varying from 27.6 to 30.0°C already in the first hour of evaluation.

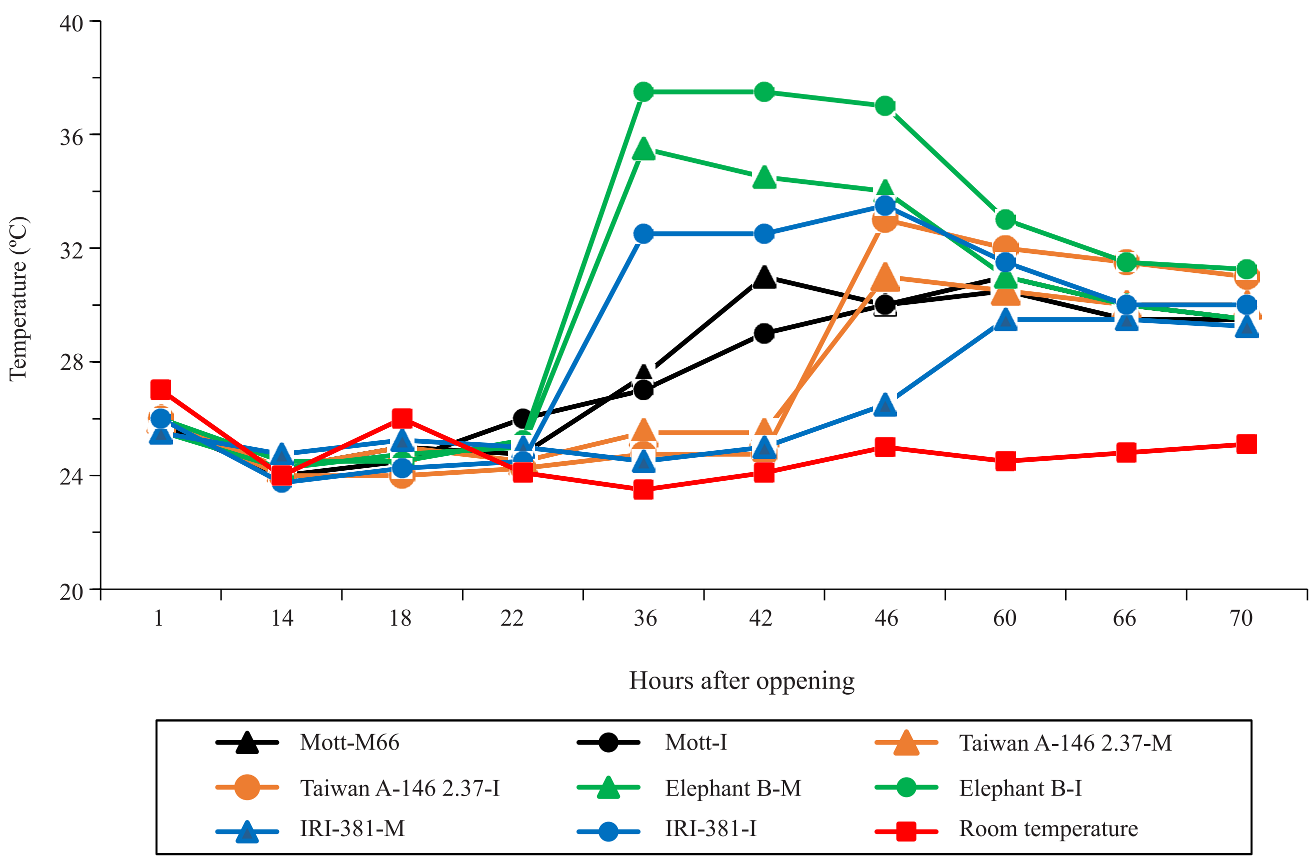

Figure 1. Temperature of silages from tall-sized and dwarf elephant grass (*Pennisetum purpureum*) genotypes, grown under monocropping or intercropping with butterfly pea (*Clitoria ternatea*), in relation to room temperature. M, monocropping; and I, intercropping with butterfly pea.

Conclusions

1. The silages from the Mott and Taiwan A-146 2.37 dwarf elephant grass (*Pennisetum purpureum*) genotypes have a greater nutritional value than those from tall-sized ones.

2. Intercropping with butterfly pea (*Clitoria ternatea*) improves the fermentative characteristics of elephant grass silages, despite reducing their digestibility.

3. The silage from the Mott dwarf genotype intercropped with butterfly pea stands out compared with the others, due to its fermentation characteristics, losses, and nutritional value.

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