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Morphological and Productive Correlations of Cutting Pennisetum Varieties Under Conditions of Peruvian Humid Tropics

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ABSTRACT

Livestock farming in the Peruvian tropics is based on the use of grazing forage, but cutting grasses offers greater productivity and seasonality advantages. In this study, the morphological and productive characteristics of King Grass Morado (KGM), Cuba OM-22 (CU), and Maralfalfa (MA) were evaluated and correlated with chlorophyll content under Peruvian humid tropic conditions. Five plots of 1 ha each were installed for the three Pennisetum varieties (2-1-2), with three samples per plot. No significant differences were found in plant height, leaf length, number of nodes, number of leaves/stem, number of stems, stem circumference, length of nodes, leaf, stems, and total weight, chlorophyll index (atLEAF CLOR), performance index (API), and dry matter. KGM stood out in tillering (12.86) (p<0.01), but CU and MA showed greater leaf width (4.16 and 4.42 cm, respectively) (p<0.05). The calculated biomass production was 40.3 t/ha for KGM, 24.5 t/ha for MA, and 76.5 t/ha for CU. MA had higher nitrogen (0.70%) and protein (4.33%) contents (p<0.01). The correlations were significant between stem height with the number of nodes and leaf width, stem circumference with stem, leaf, and total weight (p<0.05), and nitrogen and protein content were estimated with the atLEAF CLOR and API values of the basal leaves with R^2 = 0.548 and R^2 = 0.563, respectively (p<0.05). In conclusion, KGM, CU, and MA differed in some morphological and productive variables and were correlated with others; furthermore, the protein content could be estimated with the atLEAF CLOR and API values in these Pennisetum varieties.

Keywords: chlorophyll; Cuba OM-22; king grass Morado; maralfalfa; regression

INTRODUCTION

In the Peruvian tropics, there is a great diversity of cutting grasses originating from tropical Africa, that have successfully adapted to the environmental conditions of each area and represent a valuable alternative feed for livestock farming (Dixon *et al.*, 2014). Breeding systems in this area are mostly developed extensively and semi-intensively. They are characterized by restricted use of technology in the management of grazing and cutting pastures, resulting in moderate productivity rates (MINAGRI, 2017). In this context, cutting grass cultivation is an alternative to improve the productivity, nutritional quality, and seasonality of grazing pastures in tropical climate regions (Alves *et al.*, 2022).

Among the cutting grasses, varieties of Pennisetum, such as Maralfalfa (*Pennisetum sp.*), King Grass Verde (*Pennisetum purpureum* x *Pennisetum typhoides*), King Grass Morado (*P. purpureum* x *P. typhoides* – Camerún), etc., are important forage resources for livestock feeding due to their high productive potential and tolerance to harsh conditions in the tropics (González-Blanco *et al.*, 2018). Cuba OM-22 is a hybrid of the cross between *P. purpureum* x *P. glaucum*, characterized by its high yield, protein content, and high tolerance to drought due to its deep roots (Clavijo, 2016).

Pennisetum varieties stand out for their high biomass yield and adaptability but variable nutritional quality (Botero-Londoño *et al.*, 2021). The genetic variety, agronomic management (cutting, irrigation, fertilization, etc.), and edaphoclimatic conditions of each area can influence the morphological and nutritional characteristics of Pennisetum (Benabderrahim & Elfalleh, 2021; Ortiz *et al.*, 2017; Uvidia *et al.*, 2015; Alves *et al.*, 2022; Ribeiro *et al.*, 2023). The evaluation of morphological and productive characteristics of grasses and the establishment of correlations based on easily measurable variables can contribute to the identification of Pennisetum varieties with greater productive potential. The selection of varieties for outstanding characteristics is relevant for the development of genetic improvement programs and their establishment in each environment (Calzada-Marín *et al.*, 2014). The study of correlations between some variables to estimate nutritional quality variables of Pennisetum varieties based on rapid and non-destructive measurements can contribute to the selection of the best individuals and varieties. The objective of this study was to evaluate the morphology and correlate the productive characteristics with the estimated chlorophyll content of three Pennisetum varieties (King Grass Morado, Cuba OM-22, and Maralfalfa) under conditions of the Peruvian humid tropics.

MATERIALS AND METHODS

Location

The research was developed in the Estación Experimental Agraria El Porvenir of the Instituto Nacional de Innovación Agraria (INIA), Juan Guerra district, San Martín department, Peru. The area is located between 354872.00 m East Latitude and 9271237.48 m North Latitude, at an altitude of 229 m.a.s.l. The climatic categorization of the zone, according to the Köppen-Geiger classification, corresponds to a Humid Tropical (Af) climate with an average temperature of 26 °C and average annual precipitation of 1337 mm (Weather Station SENAMHI "El Porvenir").

Experimental Design

The study was carried out under an unbalanced completely randomized design with three treatments and six, three, and six repetitions per treatment. The treatments were three varieties of Pennisetum: King Grass Morado or KGM (*P. purpureum* x *P. typhoides* – Camerún), Cuba OM-22 or CU (*P. purpureum* x *P. glaucum*), and Maralfalfa or MA (*Pennisetum sp.*). For this, five plots of 1 ha each were installed for the three varieties of Pennisetum (2 plots for KGM, 1 plot for CU, and 2 plots for MA), with 3 subplots per variety, making a total of 15 subplots of 0.33 ha each. The stem cuttings (vegetative seeds) of KGM and MA were obtained from the plots of the Instituto Superior Tecnológico Nor-Oriental de la Selva, Tarapoto, Department of San Martín, Peru, and the stem cuttings of CU were obtained from the experimental plots of the Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas, Department of Amazonas, Peru; who acquired them from Colombia. For sowing, stem cuttings of KGM were sown at a distance of 0.80 m between lines, MA at 0.90 m between lines, and CU at 0.80 m between lines. Fertilization with nitrogen, phosphorus, and potassium was applied at doses of 200 kg, 50 kg, and 150 kg/ha/year, respectively. The evaluation and cutting for analysis were carried out in the summer of 2023.

Morphological and Productive Evaluation

Among the morphological traits, the following were measured: plant height (cm), N° tillers, N° leaves/stems, leaf length (cm), leaf width (cm), N° nodes, and among the productive traits, N° stems, stem circumference (cm), node length (cm), total weight (kg/m^2), leaf weight (kg/m^2), and stem weight (kg/m^2). Biomass production was calculated based on total weight and expressed in t/ha. The measurements were made five months after sowing, the recommended age for establishment before the first cut, and the maximum use of biomass (Calzada-Marín *et al.*, 2014).

Analysis of Nutritional Content and Chlorophyll

The nutritional content of the samples collected was analyzed, considering the dry matter, total nitrogen, and protein content. For dry matter, the samples were subjected to a microwave oven until a constant weight was obtained, according to the method of Rusdy *et al*. (2019). The nitrogen content was determined using the Kjeldahl method (ISO, 1995), and the protein content was estimated from the total nitrogen obtained on a dry matter basis (Buso *et al.*, 2016). In addition, the atLEAF chlorophyll index and atLEAF performance index (API) were determined with a digital chlorophyll meter (CHL PLUS, atLEAF, USA). Three leaf measurements were considered for the regions: basal, middle, and apical of the plant.

Statistic Analysis

The goodness-of-fit assumptions were verified using the Shapiro-Wilk test for normality ($p>0.05$) and the Levene test for homogeneity of variances ($p>0.05$). An ANOVA and Duncan's test were used to compare the means of the variables with a normal distribution (plant height, N° tillers, leaf length, leaf width, N° nodes, atLEAF chlorophyll index, API, dry matter, nitrogen, and protein). The productive characteristics did not fit a normal distribution (N° leaves/stem, N° stems, stem circumference, node length, leaf weight, stem weight, and total weight), so they were subjected to a non-parametric Kruskal-Wallis test ($p<0.05$). To determine correlations, Pearson coefficients were used for variables with a normal distribution and Spearman ranges for variables without a normal distribution ($p<0.05$). The linear regression analysis for the prediction of dry matter, nitrogen, and protein contents based on the atLEAF chlorophyll index and API was carried out using the successive steps method in the SPSS v.15.0 software.

RESULTS

According to Table 1, the morphological characteristics of King Grass Morado (KGM), Cuba OM-22 (CU), and Maralfalfa (MA) did not vary significantly, except for leaf width and N° tillers ($p<0.05$). KGM showed the highest N° tillers (12.83 ± 4.02) but the lowest leaf width (2.76 ± 0.83 cm), and there was no significant difference between CU and MA for both characteristics. No significant differences were found in the productive characteristics among the three Pennisetum varieties. The calculated biomass productions were 40.3 t/ha for KGM, 24.5 t/ha for MA, and 76.5 t/ha for CU.

Table 1. Morphological and productive characteristics of three varieties of Pennisetum

Variables	Varieties of Pennisetum			p-value	K-W test
	King Grass Morado (KGM)	Cuba OM-22 (CU)	Maralfalfa (MA)		
Plant height (cm)	2.91 ± 0.68	3.92 ± 1.10	3.15 ± 0.50	0.17	
N° tillers	12.83 ± 4.02[a]	7.33 ± 4.04[b]	4.00 ± 1.26[b]	<0.01	
Leaf length (cm)	0.98 ± 0.25	1.01 ± 0.12	1.04 ± 0.35	0.94	
Leaf width (cm)	2.76 ± 0.83[b]	4.16 ± 0.63[a]	4.42 ± 0.86[a]	0.01	
N° nodes	13.33 ± 5.65	18.00 ± 6.08	12.00 ± 3.58	0.27	
N° leaves/Stem*	17.50 (10-24)	18.00 (17-58)	18.00 (12-23)		0.68
N° stems*	8.00 (6-17)	8.00 (3-11)	6.00 (5-8)		0.25
Stem circumference (cm)*	4.05 (2.00-6.50)	6.50 (2.04-7.00)	5.70 (2.03-7.50)		0.46
Node length (cm)*	12.08 (11.33-17.17)	18.00 (12.67-18.33)	13.92 (13.00-16.67)		0.21
Leaf weight (kg/m^2)*	1.10 (0.45-1.90)	1.45 (0.35-1.55)	0.62 (0.45-1.10)		0.32
Stem weight (kg/m^2)*	2.93 (1.15-4.70)	6.10 (1.30-7.30)	1.83 (1.10-3.50)		0.24
Total weight (kg/m^2)*	4.03 (1.60-6.90)	7.65 (1.65-9.45)	2.45 (1.55-4.60)		0.22
Biomass production (t/ha)*	40.3 (16.0-69.0)	76.5 (16.5-94.5)	24.5 (15.5-46.0)		

Note: [a,b]Means in the same row with different superscripts differ significantly at the p<0.05 and p<0.01 level. *Variables without normal distribution were analyzed with the Kruskal-Wallis (K-W) test; median (minimum – maximum) is shown.

No significant differences were found in the atLEAF chlorophyll index (atLEAF CLOR) among the three varieties of Pennisetum for a basal (Figure 1A), a middle (Figure 1B), and an apical leaf of the plant (Figure 1C), with averages of 40.87, 45.41, and 47.42, respectively. The atLEAF CLOR value in the apical leaves of KGM was slightly lower than in CU and MA, but not significantly different. Similarly, the API value of the atLEAF CLOR readings did not vary significantly among the three varieties of Pennisetum for a basal (Figure 1D), a middle (Figure 1E), and an apical leaf of the plant (Figure 1F), with averages of 50.17, 60.44, and 63.78, respectively. High variability in dry matter (DM%) content was found among Pennisetum varieties, with averages of 43.25% for KGM, 53.97% for CU, and 38.69% for MA (Figure 1G); however, the differences were not significant. The nitrogen (Figure 1H) and protein contents (Figure 1I) varied significantly among Pennisetum varieties (p<0.01), highlighting MA with 0.70% N and 4.33% protein, without differences between KGM (0.40% N and 2.51% protein) and CU (0.44% N and 2.78% protein).

Table 2 shows the Pearson coefficients for the correlation between the morphological variables of KGM, CU, and MA. Plant height was positively correlated with N° nodes (p<0.01) and leaf width (p<0.05). In Table 3, according to Spearman's ranks for correlation, the total weight was positively correlated with the leaf weight (p<0.01), the stem weight (p<0.01), and the stem circumference (p<0.05). Furthermore, N° leaves/stem is correlated to stem weight (p<0.05), as is stem circumference with leaf weight and stem weight (p<0.05).

API values correlated well with atLEAF CLOR readings in basal, middle, and apical leaves (p<0.01 and p<0.05); additionally, the atLEAF CLOR value of middle leaves was directly correlated with atLEAF CLOR of basal leaves (p<0.01) and apical leaves (p<0.05) (Table 4). The API value of basal leaves was correlated with nitrogen and protein contents (p<0.05), and nitrogen content was positively correlated with protein (p<0.01). Negative correlation values were found between dry matter and nitrogen and protein contents, but they were not significant.

Based on the correlations found, multiple linear regression analyses were carried out. The dry matter content did not have significant correlations; therefore, the contributions of the chlorophyll variables were not significant. On the other hand, the nitrogen content could be predicted by the atLEAF CLOR and API values of basal leaves, with a direct correlation coefficient (R= 0.740) and R^2= 0.548 (p<0.01) using the following equation: y= 0.686 - 0.028 * atLEAF CLOR basal leaves + 0.020 * API basal leaves (Figure 2A). Similarly, the protein content can be predicted by the atLEAF CLOR and API values of basal leaves, with a direct correlation coefficient (R= 0.750) and R^2= 0.563 (p<0.01) using the following equation: y= 4.307 - 0.179 * atLEAF CLOR basal leaves + 0.126 API basal leaves (Figure 2B).

DISCUSSION

Table 1 shows the morphological and productive characteristics of three varieties of Pennisetum (KGM, CU, and MA), where significant differences were obtained in leaf width and number of tillers. KGM was characterized by greater tillering but smaller leaf width, while CU and MA had greater leaf width but less tillering, which could affect their coverage capacity. The highest biomass yield of cutting grasses requires high production of leaves, stems, and tillers to increase the capacity to acquire resources to carry out the photosynthetic processes of the plant (Tubeileh *et al.*, 2016). In tropical pastures with a higher proportion of functional organs, greater interception of light intensity is achieved and CO_2 uptake is enhanced, as well as the synthesis of photoassimilates for the growth and primary production of the grass (Irving, 2015; Calzada-Marín *et al.*, 2014). Furthermore, greater development of tillers contributes to greater coverage of the soil surface, which is necessary for better use of light and a reduction in the development of competing plants. Calzada-Marín *et al.* (2014) found sizes smaller at 150 days (2.3 m) and biomass production of 37297 kg MS/ha. On the other hand, Villanueva-Avalos *et al.* (2022) compared the

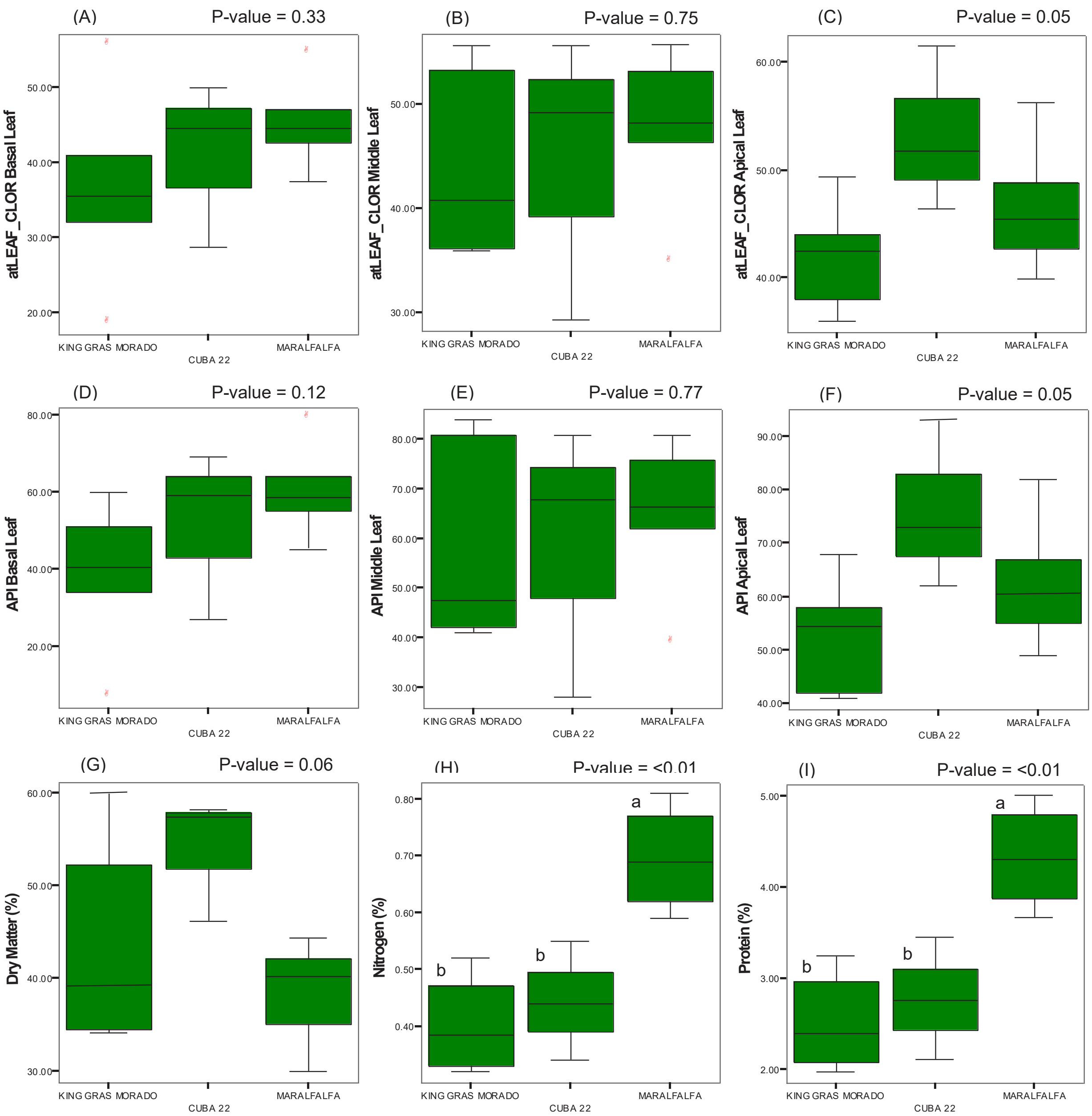

Figure 1. Chlorophyll content index (atLEAF CLOR), atLEAF performance index (API) and forage nutritional values of three varieties of Pennisetum. Different letters in each subdiagram (a, b) represent significant differences at the p<0.01 level. (A) atLEAF CLOR basal leaf, (B) atLEAF CLOR middle leaf, (C) atLEAF CLOR apical leaf, (D) API basal leaf, (E) API middle leaf, (F) API apical leaf, (G) Dry matter, (H) Nitrogen, (I) Protein.

varieties: Elefante, Uruguana, Taiwán, CT-169, Caña Africana, Maralfalfa, Mott, Roxo, King Grass morado, CT-115, Merkerón, Camerún, King Grass verde, Elefante Tamps, Maralfalfa Tamps, and Roxo Tamps; and they found significant differences in plant height, the density of stems per crown, the basal and central diameter of stem, width and length of central leaf, the number of internodes, and length of the central internode. There is variation between reports due to the heterogeneity in the conditions of each experiment, management, and environment. A similar study, but at an altitude of 3000 meters above sea level, reported lower tillering and size in King Grass Morado (5.79 tillers/plant and 0.90 m) and King Grass Verde (5.31 tillers/plant and 0.73 m), but higher in Maralfalfa (8.93 tillers/plant and 0.98 m) (Prudencio-Velásquez *et al.*, 2020), suggesting different modes of adaptability of these Pennisetum varieties.

The biomass production of leaves and stems was correlated to the height and circumference of the stems, which coincides with Calzada-Marín *et al*. (2014), who maintain that in Maralfalfa these variables are directly related to the age of the plant. In this study, a significant correlation was found between plant height with leaf width and plant height with the number of nodes due to the vegetative development of the stem, which promotes the vigorous development of nodes and larger leaves at each node. Likewise, the greater stem circumference related to the greater development of stems and leaves translates into vigorous vegetative growth (Rodrigues *et al.*, 2014; Animasau *et al.*, 2018).

Table 2. Pearson coefficients for correlation between morphological variables of three varieties of Pennisetum

Variables	N° tillers	Leaf length	Leaf width	N° Nodes
Plant height	0.128	0.411	0.539(*)	0.828(**)
	0.648	0.128	0.038	<0.01
N° tillers		0.228	-0.335	0.197
		0.414	0.222	0.482
Leaf length			0.505	0.334
			0.055	0.223
Leaf width				0.396
				0.143

Note: (*) Significant correlation at the p<0.05 level, (**) Significant correlation at the p<0.01 level.

Table 3. Spearman ranks for correlation between morphological and productive variables of three varieties of Pennisetum

Variables	N° Stems	Stem circumference	Node length	Total weight	Leaf weight	Stem weight
N° leaves/stem	0.032	0.417	-0.208	0.485	0.448	0.544(*)
	0.910	0.122	0.457	0.067	0.094	0.036
N° stems		0.149	-0.025	0.352	0.318	0.267
		0.596	0.929	0.198	0.248	0.335
Stem circumference			0.279	0.607(*)	0.589(*)	0.587(*)
			0.314	0.016	0.021	0.021
Node length				0.267	0.200	0.252
				0.337	0.476	0.364
Total weight					0.956(**)	0.989(**)
					<0.01	<0.01
Leaf weight						0.938(**)
						<0.01

Note: (*) Significant correlation at the p<0.05 level, (**) Significant correlation at the p<0.01 level.

Table 4. Pearson coefficients for correlation between chlorophyll index atLEAF, atLEAF performance index, and nutritional content of the forage of three varieties of Pennisetum

Variables	API basal leaves	atLEAF CLOR middle leaves	API middle leaves	atLEAF CLOR apical leaves	API apical leaves	Dry matter	Nitrogen	Protein
atLEAF CLOR basal leaves	0.96(**)	0.66(**)	0.68(**)	0.51	0.50	0.08	0.43	0.44
	<0.01	0.01	0.01	0.06	0.06	0.78	0.11	0.10
API basal leaves		0.65(**)	0.63(*)	0.58(*)	0.57(*)	0.12	0.58(*)	0.59(*)
		0.01	0.01	0.03	0.03	0.67	0.02	0.02
atLEAF CLOR middle leaves			0.99(**)	0.63(*)	0.64(*)	-0.10	0.44	0.45
			<0.01	0.01	0.01	0.73	0.10	0.10
API middle leaves				0.60(*)	0.61(*)	-0.08	0.38	0.39
				0.02	0.02	0.77	0.16	0.15
atLEAF CLOR Apical leaves					0.99(**)	0.33	0.24	0.24
					<0.01	0.23	0.40	0.39
API apical leaves						0.30	0.25	0.25
						0.28	0.37	0.36
Dry matter							-0.35	-0.34
							0.20	0.21

Note: (*) Significant correlation at the p<0.05 level, (**) Significant correlation at the p<0.01 level.

No differences were found in the dry matter content between the forages evaluated, but MA showed the highest levels of nitrogen and protein. Hermitaño-Osorio *et al*. (2022) found lower levels of dry matter in Maralfalfa in the season of high precipitation at 60 days of cutting (12.59 ± 0.50%) and in the season of lower precipitation at 75 days of cutting (15.65 ± 0.50%). In this study, the cut was carried out five months after sowing, a period considered adequate for the establishment of the pastures before the first cut (Calzada-Marín *et al.*, 2014). In perennial grasses, the morphology and physiological state of the plant at the first cut determine the vigor of subsequent regrowth and the persistence of the crop, due to the energy reserves accumulated for regrowth (Deregibus *et al.*, 2018). The volume of biomass and the dry matter content of grasses are directly related to the age of growth of the plant, since the older the age, the more fibrous and structural components of the plant develop (Tilahun *et al.*, 2017; Jaime *et al.*, 2019).

On the other hand, the protein content in this

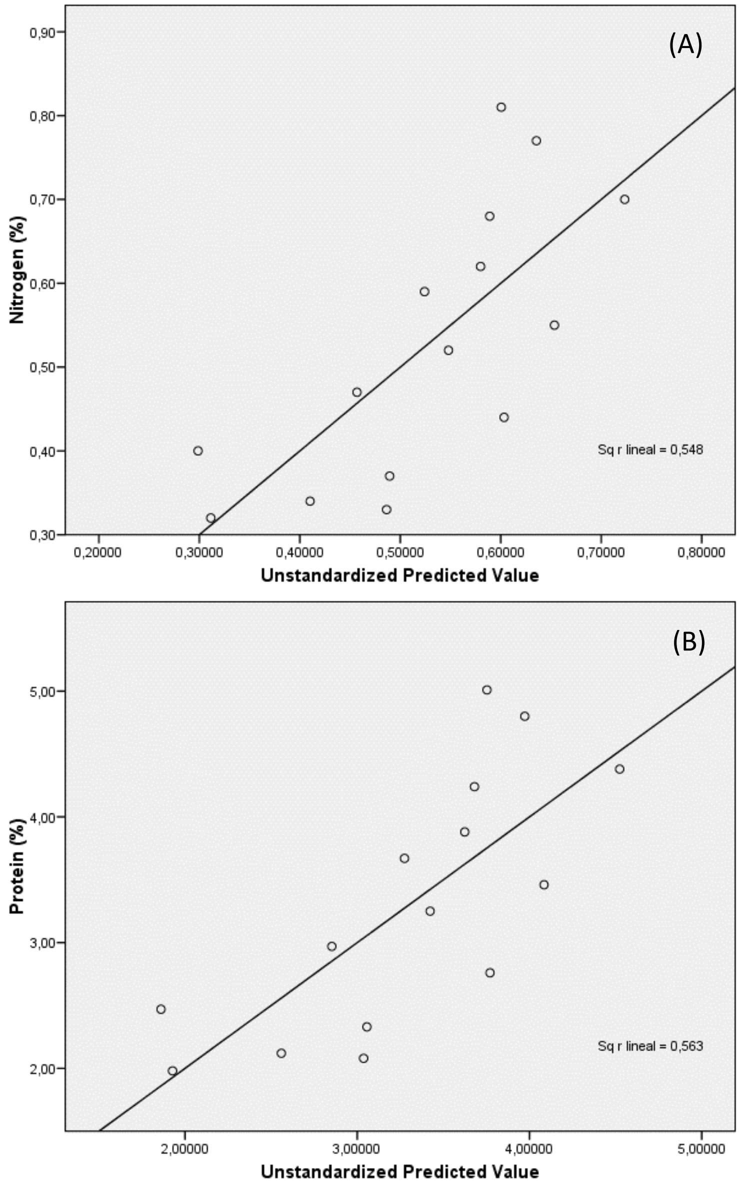

Figure 2. Dispersion of found and predicted values of nitrogen (A) and protein (B) contents in three Pennisetum varieties, based on the atLEAF chlorophyll content index and atLEAF performance index of basal leaves.

study was low (2.51 to 4.33%) due to the advanced age of the initial grass cut (150 days for establishment), which was inverse to the dry matter increase, and also because the protein content in the forage is affected by the nitrogen contribution from the soil and the fertilizers (Delevatti *et al.,* 2019), although we applied 200 kg N/ha at the beginning of the experiment. Related reports support the significant influence of cutting age on the nutritional quality of Pennisetum varieties. In Maralfalfa after 45 days in high and low precipitation, the protein content can reach up to 11.08 ± 0.43% and 16.06 ± 0.43%, respectively (Hermitaño-Osorio *et al.,* 2022); however, in other Pennisetum varieties, the protein content can decrease between 6.11 and 8.77% at 84 days in Napier grass (*P. purpureum*) (Budiman *et al.,* 2012), 9.30% at 135 days (Tilahum *et al.,* 2017), and 7.58% at 150 days (Kefyalew *et al.,* 2020) in *Pennisetum pedicellatum* Trin., 6.36% at 140 days in the entire plant (Araya & Boschini, 2005), and 5.60% at 180 days in the leaves of *P. purpureum* (Ordaz-Contreras *et al.,* 2018). The protein content and non-structural carbohydrates were inversely related to age, the development of fibrous tissues in the stems, and the lignification of the cell walls (Fassio *et al.,* 2018; Prudencio-Velásquez *et al.,* 2020). Although Pennisetum varieties are not characterized by high levels of protein, the content of this nutrient in grasses varies depending on the age and moisture percentage of the plant. Higher protein values of up to 14.81% in Maralfalfa, 12.45% in King Grass Morado, and 16.18% in King Grass Verde were reported in high Andean conditions (Prudencio-Velásquez *et al.,* 2020); in coastal conditions, levels ranging from 6.22% to 16.50% in King Grass Morado, throughout the year up to 70 days of cutting (Jaime *et al.,* 2019); or in Cuba OM-22, where productions of up to 459 kg, 751 kg, 1180 kg, and 1459 kg of protein/ha/cut were found, applying 50, 100, 150, and 200 kg N/ha/cut, respectively (Cerdas-Ramírez *et al.,* 2021). The differences between reports are mainly attributed to the edaphoclimatic conditions and management of the cut-off in each study.

Chlorophyll is one of the most important components for plant function, which indicates the photosynthetic capacity of plants and is related to the production of biomass, nitrogen, and protein content (Ernawati *et al.*, 2023; Pakwan *et al.*, 2020; Croft *et al.*, 2017). There are few reports on the estimation of chlorophyll content in Pennisetum varieties from the tropics. In this study, the values of the chlorophyll content index by a non-destructive method, recorded by an atLEAF device, were used to estimate the nutritional quality of the forage quickly. Although there were no differences between atLEAF CLOR and API values between KGM, CU, and MA in basal, middle, and apical leaves, these were significantly correlated with nitrogen and protein contents. Although the correlation coefficients of the multiple linear regression models were high, to predict the nitrogen and protein contents based on the atLEAF CLOR and API values of basal leaves of the Pennisetum varieties in this study, medium determination coefficients were found (R^2 = 0.548 for nitrogen and R^2 = 0.563 for protein). No reports of estimation of nitrogen content with atLEAF values in forage grasses from the tropics were found; however, in shrubs *Viburnum tinus, Pittosporum tobira,* and *Arbutus unedo,* low coefficients of determination were reported between atLEAF CLOR with the chlorophyll concentration found and the nitrogen content (0.12 and 0.27) (Martín *et al.*, 2007; Mendoza-Tafolla *et al.*, 2022). In other herbaceous plants, higher and more significant correlations (0.96 y 0.99) were reported between atLEAF CLOR values and the nitrogen content in *Eruca sativa* mill., using the equation %N=0.0378 atLEAF CLOR – 0.1298 (Mendoza-Tafolla *et al.*, 2022), *Ociman basilicum* (Ontiveros-Capurata *et al.*, 2022), *Salvia slendens* (Dunn *et al.*, 2018), and *Dianthus chinensis* (Basyouni *et al.*, 2015). It is likely that in plants other than herbaceous plants, such as shrubs and forages in the tropics, the tissue structure makes it difficult to predict nutritional quality with values from the atLEAF device.

CONCLUSION

The present study evaluated the morphological and productive characteristics of King Grass Morado (KGM), Cuba OM-22 (CU), and Maralfalfa (MA) in the Peruvian humid tropics. KGM stood out in tillering, but CU and MA had greater leaf widths. MA had a higher nitrogen and protein content, and biomass volume was positively correlated with most morphological variables. In addition, the chlorophyll content of basal leaves can contribute to estimating protein content through non-destructive measurements.

CONFLICT OF INTEREST

We certify that there is no conflict of interest in any financial, personal, or other relationships with other people or organizations related to the material discussed in the manuscript.

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REFERENCES

Alves, J. P., S. S. Mendes, E. S. Galeano, M. A. P. O. Junior, T. Fernandes, M. Retore, A. C. A. Orrico, & L. D. S. Lopes. 2022. Forage production and quality of BRS capiaçu as a response of cutting age and nitrogen application. Trop. J. Anim. Sci. 45:179-186. https://doi.org/10.5398/tasj.2022.45.2.179

Animasaun, D. A., H. P. Rathod, & R. Krishnamurthy. 2018. Analysis of forage yield and nutritional contents of *Pennisetum glaucum* (pearl millet) and *Pennisetum purpureum* (Napier grass) accessions. Cuban Journal Agricultural Science 52:447-455. https://www.cjascience.com/index.php/CJAS/article/view/832

Araya, M. & C. Boschini. 2005. Producción de forraje y calidad nutricional de variedades de *Pennisetum purpureum* en la Meseta Central de Costa Rica. Agron. Mesoam. 16:37-43. https://doi.org/10.15517/am.v16i1.5180

Basyouni, R., B. Dunn, & C. Goad. 2015. Use of nondestructive sensors to assess nitrogen status in potted poinsettia (*Euphorbia pulcherrima* L. (Willd. Ex Klotzsch)) production. Sci. Hortic. 192:47-53. https://doi.org/10.1016/j.scienta.2015.05.011

Benabderrahim, M. A. & W. Elfalleh. 2021. Forage potential of non-native Guinea grass in north African agroecosystems: Genetic, agronomic, and adaptive traits. Agronomy 11:1071. https://doi.org/10.3390/agronomy11061071

Botero-Londoño, J. M., E. M. Celis-Celis, & M. A. Botero-Londoño. 2021. Nutritional quality, nutrient uptake and biomass production of *Pennisetum purpureum* cv. King grass. Sci. Rep. 11:13799. https://doi.org/10.1038/s41598-021-93301-w

Budiman, B., R. D. Soetrisno, S. P. S. Budhi, & A. Indrianto. 2012. Morphological characteristics, productivity and quality of three Napier grass (*Pennisetum purpureum* Schum) cultivars harvested at different age. J. Indones. Trop. Anim. Agric. 37:294-301. https://doi.org/10.14710/jitaa.37.4.294-301

Buso, W., A. França, E. Miyagi, R. Ferreira, & D. Corrêa. 2016. Effects of nitrogen fertilizer on carbohydrate and protein fractions in pearl millet (*Pennisetum glaucum*) cultivars. Tropical Grasslands Forrajes Tropicales 4:47-53. https://doi.org/10.17138/TGFT(4)47-53

Calzada-Marín, J. M., J. F. Enríquez-Quiroz, A. Hernández-Garay, E. Ortega-Jiménez, & S. L. Mendoza-Pedroza. 2014. Growth analysis of maralfalfa grass (*Pennisetum* sp.) in a warm humid climate. Rev. Mex. Cienc. Pecu. 5:247-260. https://doi.org/10.22319/rmcp.v5i2.3664

Cerdas-Ramírez, R., E. Vidal-Veja, & J. C. Vargas-Rojas. 2021. Productivity of Cuba OM-22 grass (*Pennisetum purpureum x Pennisetum glaucum*) with different levels of nitrogen fertilizer. InterSedes 22:136-161. https://doi.org/10.15517/isucr.v22i45.47069

Clavijo, O. 2016. Manual del forraje *Pennisetum* sp. Cuba OM-22 (*Pennisetum purpureum* x *Pennisetum glaucum*) la Plata (Huila): SENA Regional Huila, Edit. Surcolombiana.

Croft, H., J. M. Chen, X. Luo, P. Bartlett, B. Chen, & R. M. Staebler. 2017. Leaf chlorophyll content as a proxy for leaf photosynthetic capacity. Glob. Chang. Biol. 23:3513-3524. https://doi.org/10.1111/gcb.13599

Deregibus, V. A., M. J. Trlica, & D. A. Jameson. 2018. Organic Reserves in Herbage Plants: their Relationship to Grassland Management. In: Rechcigl (Ed). Handbook of Agricultural Productivity. Volumen I: Plant Productivity. 1st Edition. CRC Press, Boca Raton. p. 30.

Delevatti, L. M., A. S. Cardoso, R. P. Barbero, R. G. Leite, E. P. Romanzini, A. C. Ruggieri, & R. A. Reis. 2019. Effect of nitrogen application rate on yield, forage quality, and animal performance in a tropical pasture. Sci. Rep. 9:7596. https://doi.org/10.1038/s41598-019-44138-x

Dixon, A. P., D. Faber-Langendoen, C. Josse, J. Morrison, & C. J. Loucks. 2014. Distribution mapping of world grassland types. J. Biogeogr. 41:2003-2019. https://doi.org/10.1111/jbi.12381

Dunn, B. L., H. Singh, M. Payton, & S. Kincheloe. 2018. Effects of nitrogen, phosphorus, and potassium on SPAD-502 and atLEAF sensor readings of Salvia. J. Plant Nutr. 41:1674-1683. https://doi.org/10.1080/01904167.2018.1458874

Ernawati, A., L. Abdullah, I. G. Permana, & P. D. Karti. 2023. Morphological responses, biomass production and nutrient of *Pennisetum purpureum* cv. Pakchong under different planting patterns and harvesting ages. Biodiversitas 24:3439-3447. https://doi.org/10.13057/biodiv/d240640

Fassio, A., W. Ibañez, E. Fernández, D. Cozzolino, O. Pérez, **E. Restaino, A. Pascal, C. Rabaza, & G. Vergara.** 2018. El Cultivo de Maíz Para la Producción de Forraje y Grano y la Influencia del Agua. Serie Técnica 239. INIA. Unidad de Comunicación y Transferencia de Tecnología del INIA (Eds). Montevideo, Uruguay. p. 59.

González-Blanco, J. L., O. González-Paneque, A. Puertas-Arias, J. Machado-Castillo, & I. Miranda-Cabrera. 2018. Performance in two cultivars of *Pennisetum purpureum* Schumach at different doses of organic and mineral fertilization. Rev. Arbit. Inter. Koinonía 3:96-108.

Hermitaño-Osorio, F. M., A. R. Bernal-Marcelo, F. C. Tantahuillca-Landeo, F. Trillo-Zárate, M. Calderón-Montes, P. Quiroga-Espilco, J. Nuñez-Delgado, & A. R. Rodríguez-Vargas. 2022. Growth dynamics and nutritional value of *Pennisetum* spp (cv. *Maralfalfa*) in three cutting ages and two seasons in the Peruvian tropics. Rev. Investig. Vet. Perú 33:e23337. https://doi.org/10.15381/rivep.v33i4.23337

Irving, L. J. 2015. Carbon assimilation, biomass partitioning and productivity in grasses. Agriculture 5:1116-1134. https://doi.org/10.3390/agriculture5041116

ISO. 1995. ISO 11261: Soil Quality. Determination of total nitrogen. Modified Kjeldahl Method. First Edition. International Organization for Standarization (ISO), Geneva.

Jaime, A., M. Rosemberg, & M. Echevarría. 2019. Effect of age and season on the yield and nutritive value of Morado elephant grass (*Pennisetum purpureum* x *Pennisetum americanum*) in the central coast. Sci. Agropecu. 10:137-141. https://doi.org/10.17268/sci.agropecu.2019.01.15

Kefyalew, A., B. Alemu, & A. Tsegaye. 2020. Effects of fertilization and harvesting age on yield and quality of Desho (*Pennisetum pedicellatum*) grass under irrigation, in Dehana district, Wag Hemra Zone, Ethiopia. Agriculture Forestry Ficheries 9:113-121. https://doi.org/10.11648/j.aff.20200904.13

Martín, I., N. Alonso, M. López, M. Prieto, C. Cadahía, & E. Eymar. 2007. Estimation of leaf, root, and sap nitrogen status using the SPAD-502 chlorophyll meter for ornamental shrubs. Commun. Soil Sci. Plant Anal. 38:1785-1803. https://doi.org/10.1080/00103620701435555

Mendoza-Tafolla, R. O., P. Juárez-López, R. E. Ontiveros-Capurata, I. Alia-Tejacal, D. Guillén-Sánchez, O. G. Villegas-Torres, & A. T. Chávez-Bárcenas. 2022. Estimation of concentration of chlorophyll, N, and biomass using non-destructive measurements in arugula (*Eruca sativa*). Bioagro 34:151-162. https://doi.org/10.51372/bioagro342.5

MINAGRI. 2017. Ministerio de Agricultura y Riego. Diagnóstico de crianzas priorizadas para el plan ganadero 2017-2021. May 30, 2020. Available on http://repositorio.minagri.gob.pe/jspui/bitstream/MINAGRI/328/1/plan-ganadero-2017-2021.pdf [May 30, 2023].

Ontiveros-Capurata, R. E., P. Juárez-López, R. O. Mendoza-Tafolla, I. Alia-Tejacal, O. G. Villegas-Torres, D. Guillén-Sánchez, & A. D. Cartmill. 2022. Relationship between chlorophyll and nitrogen concentration, and fresh matter production in basil 'Nufar' (*Ocimum basilicum*) with three handheld chlorophyll meter readings: SPAD, atLEAF and MC-100. Rev. Chapingo, Ser. Hortic. 28:189-202. https://doi.org/10.5154/r.rchsh.2021.09.018

Ordaz-Contreras, R., E. Sosa-Montes, S. I. Mendoza-Pedroza, R. D. Améndola-Massiotti, S. Reyes-Castro, E. Ortega-Jiménez, S. Joaquín-Cancino, & A. Hernández-Garay. 2018. Chemical composition of the King Grass (*Pennisetum purpureum* Schumach) at different cutting interval. Agro Productividad 11:134-139.

Ortiz, F., O. Reyes, F. O. Carrete, J. F. Sánchez, E. Herrera, M. Murillo, & R. Rosales. 2017. Nutritional and fermentative quality of maralfalfa (*Pennisetum* sp.) silages at different cutting ages and ground corn levels. Rev. Fac. Cienc. Agrar. 49:345-353.

Pakwan, C., A. Jampeetong, & H. Brix. 2020. Interactive effects of N form and P concentration on growth and tissue composition of hybrid napier grass (*Pennisetum purpureum* × *Pennisetum americanum*). Plants 9:1003. https://doi.org/10.3390/plants9081003

Prudencio-Velásquez, D. M., Y. N. Hidalgo-Vásquez, N. H. Chagray-Ameri, F. E. Airahuacho-Bautista, & R. M. Maguiña-Maza. 2020. Forage production and quality of three species of the genus *Pennisetum* in the high Andean zone of Ancash. Rev. Invest. Innov. Agropec. Rec. Nat. 7:21-29.

Ribeiro, R. E., A. C. Mello, M. V. Cunha, M. V. Santos, S. B. Costa, J. J. Coelho, R. O. Carvalho, & V. J. Silva. 2023. Water use efficiency and yield responses of *Cenchrus purpureus* genotypes under irrigation. J. Agric. Sci. 161:572-580. https://doi.org/10.1017/S0021859623000461

Rodrigues, R. C., T. V. Sousa, M. A. Melo, J. S. Araújo, R. P. Lana, C. S. Costa, M. E. Oliveira, M. O. Parente, & I. B. Sampaio. 2014. Agronomic, morphogenic and structural characteristics of tropical forage grasses in northeast Brazil. Tropical Grasslands Forrajes Tropicales 2:214-222. https://doi.org/10.17138/TGFT(2)214-222

Rusdy, M., S. Baba, S. Garantjang, & I. Syarif. 2019. Effects of supplementation with Gliricidia sepium leaves on performance of Bali cattle fed elephant grass. Livest. Res. Rural. Dev. 31:84.

Tilahun, G., B. Asmare, & Y. Mekuriaw. 2017. Effects of harvesting age and spacing on plant characteristics, chemical composition and yield of desho grass (*Pennisetum pedicellatum* Trin.) in the highlands of Ethiopia. Tropical Grasslands Forrajes Tropicales 5:77-84. https://doi.org/10.17138/TGFT(5)77-84

Tubeileh, A., T. J. Rennie, & M. J. Goss. 2016. A review on biomass production from C4 grasses: Yield and quality for end-use. Curr. Opin. Plant Biol. 31:172-180. https://doi.org/10.1016/j.pbi.2016.05.001

Uvidia, H., J. Ramírez, J. Vargas, I. Leonard, & J. Sucoshañay. 2015. Yield and quality of the *Pennisetum purpureum* vc Maralfalfa in the Amazonía Ecuatoriana. Rev. Electron. de Vet. 16:1-11.

Villanueva-Avalos, J., A. Vázquez-González, & A. Quero-Carrillo. 2022. Agronomic attributes and forage production in ecotypes of *Cenchrus purpureus* under subhumid tropical conditions. Rev. Mex. Cienc. Agric. 13:1-9.