Colegio de Postgraduados

Morphological characterization of Elephant grass (*Pennisetum purpureum* Schumach) ecotypes collected in Chiapas, Mexico

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ABSTRACT

Objective: To characterize the morphology of 18 ecotypes of Elephant grass (*Pennisetum purpureum* Schumach) in Chiapas.

Design/Methodology/Approach: The morphological characterization was carried out with 34 quantitative and qualitative descriptors. A principal component analysis and a hierarchical cluster analysis were performed based on the average data.

Results: In the principal component analysis, five of the principal components accounted for 70.7% of the total variability in the 18 ecotypes of Elephant grass. The variables that made the most significant contributions in each CP were: in CP1, internode diameter ($p<0.01$), internode length ($p<0.05$), color of internode without wax ($p<0.01$), number of innovations ($p<0.01$), prophylls ($p<0.01$), number of prophylls ($p<0.01$), external length of the sheath ($p<0.01$), internal length of the sheath at its opening point ($p<0.01$), opening of the auricle ($p<0.01$); for CP2, the number of visible internodes ($p<0.05$), channel width ($p<0.05$), size of innovations ($p<0.05$), adventitious root, number of internodes ($p<0.01$), wax under the sheath ($p<0.05$); and for CP3, number of visible internodes ($p<0.05$), color of the internode with wax ($p<0.001$), channel depth ($p<0.001$), ligule shape ($p<0.05$) and leaflet tip ($p<0.05$). As a result of the hierarchical cluster analysis and the semipartial correlation coefficient, five morphologically distinct groups were determined.

Study Limitations: A more accurate description of the morphological diversity of the grasses requires the characterization of the inflorescence and the spikelet.

Findings/Conclusions: The 18 ecotypes of the Elephant grass (*Pennisetum purpureum* Schumach) collected and characterized were dissimilar with each other; consequently, they are considered a genetic resource with potential importance as forage on the Chiapas coast.

Keywords: tropical grasses, livestock, feeding.

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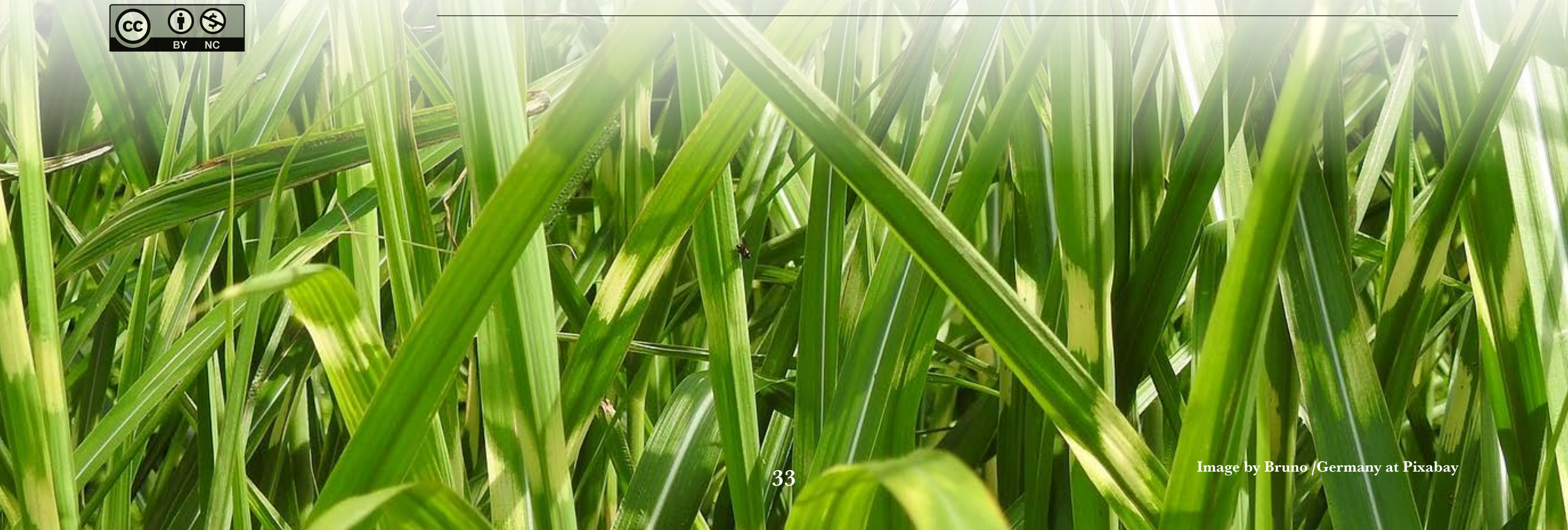

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INTRODUCTION

The Elephant grass [*Pennisetum purpureum* Schumach or *Cenchrus purpureus* Morrone (Schumach)] is native to eastern Africa and has been introduced to the tropics and subtropics of both hemispheres. It is a C_4 grass adapted to environments with high temperatures, high solar radiation, drought, and N or CO_2 limitations (SiB Colombia, 2020). It has a wide dispersion and high genetic diversity (Cavalcante and Lira, 2010). Its morphological characteristics have been researched during the vegetative and reproductive stages (Tcacenco and Lance, 1992). Elephant grass accessions have high genetic diversity, which is distributed in different groups. They have various uses, including the production of biofuels (Silva *et al.*, 2017; Rocha *et al.*, 2017; López *et al.*, 2014) and the production of ethanol (Scholl *et al.*, 2015). Likewise, their lignin, cellulose, and ash contents are suitable for direct combustion (Morais *et al.*, 2009) and they can be used to make paper, due to their amount of lignocellulosic biomass (Madakadze *et al.*, 2010). We also studied the roots and stems of Elephant grass genotypes that benefited from the biological nitrogen fixation in the soil, carried out by a variety of nitrogen-fixing bacteria from the Herbaspirilum, Azospirilum, Gluconacetobacter, Burkholderia, Bradyrhizobium, Klebsiella, Leptotrix, Enterobacter, and Diazotrophic genera (Videira *et al.*, 2012 and 2013).

Taking into consideration the forage potential of the Napier grass (Rusdy, 2016; Wangchuk *et al.*, 2015), the ILRI conducted a study of 345 genotypes, in order to analyze and compare genetic diversity between and within world collections. The results provide useful information for the management, conservation, improvement strategy, and improvement of the genetic diversity within the said collections (Muktar *et al.*, 2021). In addition, evaluations of agronomic traits have been carried out (Kebede *et al.*, 2016a) selecting cultivars with high biomass production (Cunha, 2011), as a result of their chemical composition and *in vitro* digestibility (Kebede *et al.*, 2016b). Finally, Nyambati (2010) reported cultivars that produce 6.2 kg per day in grazing systems aimed at milk production.

Given the high potential of Elephant grass, the germplasm bank of the Rosario Izapa experimental field has a genetic improvement program. The first step of the said program was the collection of naturalized ecotypes. The most productive ecotypes, as well as those with the best quality, were selected as forage, both in humid and dry tropical areas. These ecotypes can be used for grazing, haymaking, and silage (mainly during the season when forage is less available), as well as green manure and to control the erosion of the hillsides. Additionally, they improve the feeding of bovines, resulting in a greater production of milk and meat.

The objective of this study was to collect and characterize naturalized clones of the Elephant grass (*Pennisetum purpureum* Schumach) in Chiapas. The collected specimens would be used to develop a genetic base for the selection of outstanding ecotypes with greater production potential and nutritional quality that can be used in grazing.

MATERIALS AND METHODS

The Elephant grass (*Pennisetum purpureum* Schumach) specimens were collected along the Pacific Coastal Plain of the state of Chiapas, from the municipality of Ciudad Hidalgo to the municipality of Tonalá, in a 360-km long and 15-40 km wide area. Table 1 shows the 18 collection sites, where 18 germplasm ecotypes were collected, as well as their respective passport data (Villanueva-Avalos *et al.*, 2012; Morales, 2008). A 1 m^2 sample was obtained and 34 quantitative and qualitative descriptors of 10 randomly selected stems were measured *in situ* (Table 2) (Maldonado-Méndez *et al.*, 2019; Quero-Carrillo *et al.*, 2012; Kretschmer *et al.*, 1979). The quantitative characteristics were measured with a measuring tape, a ruler, and a RoHS™ digital vernier; the qualitative characteristics were evaluated by observation and the color was compared with the Royal Horticultural Society color chart.

Statistical analysis

The mean, the minimum value, the maximum value, the coefficient of variation of the quantitative variables, and the mode of the qualitative data of the 18 ecotypes were determined. A multivariate analysis was used to analyze the data. The principal component analysis (PCA) was carried out using the SAS (2020) PRINCOMP procedure, where the eigenvalues and eigenvectors were considered. The principal components 1, 2, and 3 were plotted on a Cartesian plane to observe the distribution of the characterized ecotypes. In addition, the hierarchical cluster analysis was used, and the groups of the different ecotypes were divided using the squared Euclidean distance and the hierarchical clustering algorithm.

Table 1. Passport data of 18 ecotypes of Elephant grass (*Pennisetum purpureum* Schumach) collected on the Chiapas Coast.

	Ecotype	Location	Latitude (N)	Longitude (O)	Altitude (m)
1	INIFAP Pp-01	Cacahoatán	15° 01’ 53.779”	92° 9’ 44.009”	643
2	INIFAP Pp-02	Tuxtla Chico	14° 56’ 36.956”	92° 10’ 12.730”	318
3	INIFAP Pp-03	Frontera Hidalgo	14° 48’ 15.721”	92° 15’ 21.338”	63
4	INIFAP Pp-04	Ciudad Hidalgo	14° 41’ 33.390”	92° 16’ 55.102”	14
5	INIFAP Pp-05	Metapa	14° 51’ 17.994”	92° 11’ 31866”	77
6	INIFAP Pp-06	Tapachula	14° 54’ 33.405”	92° 16’ 40.399”	173
7	INIFAP Pp-07	Tapachula	14° 54’ 38.875”	92° 16’ 39.372”	161
8	INIFAP Pp-08	Mazatán	14° 51’ 57.620”	92° 25’ 23.917”	27
9	INIFAP Pp-09	Mazatán	14° 49’ 31.841”	92° 28’ 17.311”	7
10	INIFAP Pp-10	Huehuetán	15° 00’ 51.364”	92° 23’ 22.231”	41
11	INIFAP Pp-11	Huehuetán	14° 59’ 27.286”	92° 27’ 06.065”	10
12	INIFAP Pp-12	Huehuetan	14° 59’ 26.833”	92° 27’ 09.548”	17
13	INIFAP Pp-13	Huixtla	15° 05’ 42.492”	92° 28’ 30.359”	34
14	INIFAP Pp-14	Villa Comaltitlán	15° 19’ 54.752”	92° 33’ 48.779”	348
15	INIFAP Pp-15	Mapastepec	15° 25’ 32.689”	92° 00’ 20.872”	29
16	INIFAP Pp-16	Pijijiapan	15° 38’ 23.970”	93° 00’ 20.872”	22
17	INIFAP Pp-17	Tonalá	15° 58’ 27.652”	93° 38’ 11.210”	63
18	INIFAP Pp-18	Pijijiapan	15° 44’ 33.534”	93° 17’ 36.484”	44

Table 2. Morphological characteristics used for the characterization study of the ecotypes of the *Pennisetum purpureum* grass collected on the Chiapas coast.

	Character	Acronym	Character state (scale)
	Stem		
1	Number of visible internodes	SNVI	Number
2	Internode diameter (measure the middle internode)	SID	mm
3	Internode length	SIL	mm
4	Presence of wax	SPW	1. Absence, 2. weak, 3. strong
5	Color of the internode with wax	SCIWW1	1. Yellowish, 3. Yellowish green, 5. Black and white, 7. Black
6	Color of the internode without wax	SCIWW2	1. Yellowish, 2. Green, 3. Yellowish green
7	Channel width	SCW	Mm
8	Channel depth	SCD	1. Little deep, 2. intermedium, 3. Deep
9	Innovations	SI	1. Absence, 2. Presence
10	Number of innovations	SIN	Number
11	Size of innovations	SSI	Mm
12	Prophylls	SP	1. Absence, 2. Presence
13	Number of prophylls	SNP	Number
14	Size of prophylls	SSP	Cm
15	Adventitious root	SAR	1. Absence, 2. Presence
16	Number of internodes	SIN	Number
	Leaf		
17	Wax under the leaf sheath	LWULS	1. Absence or very little, 3. Litte, 5. Very little
18	Leaf sheath color	LLSC	1. Green, 2. Yellowish, 3. lime green
19	Leaf sheath hairiness	LSH	1. Absence o very low, 3. low, 5. medium, 7. high, 9. Very high
20	External length of the leaf sheath	LELLS	Cm
21	Internal length of the leaf sheath at the opening point	LILLSOP	Cm
22	Ligule shape	LLS	1. Flat, 2. convex, 3. biconvex
23	Ligule pubescence	LLP	3. low, 5. medium, 7. high
24	Development of the auricle	LDP	1. Rudimentary, 2. developed
25	Opening of the auricle	LOA	Cm
26	Lamina position	LLP	1. Erected, 3. semi-erect, 5. open
27	Lamina lenght	LLL	Cm
28	Lamina width	LLW	Cm
29	Lamina color	LLC	1. Green, 2. Yellowish green, 3. Lime green, 4. Dark green
30	Central veins width	LCVW	Mm
31	Central veins color	LCVC	1. Whitish, 3 Green
32	Hairness in the upper side of the lamina	LHUSL	1. Absence o very low, 3. low, 5. medium, 7. high, 9. Very high
33	Leaflet tip	LLT	1. Absence, 2. Presence
34	Leaf-blade apex length	LLBAL	Cm

RESULTS AND DISCUSSION

Principal Component Analysis (PCA)

Five main components accounted for 70.7 % of the total variability in the 18 ecotypes of the Elephant grass (*Pennisetum purpureum* Schumach): PC1 accounted for 25.4%, PC2 14.2%, PC3 12.3%, PC4 10%, and PC5 8.6% (Table 3).

The variables that made the most significant contributions in each CP were: in CP1, internode diameter (SID), internode length (SIL), color of the internode without wax (SCIWW2), number of innovations (SIN), prophylls (SP), number of prophylls (SNP), external length of the sheath (LELLS), internal length of the leaf sheath at the opening point (LILLSOP), opening of the auricle (LOA); in CP2, number of visible internodes (SNVI), channel width (SCW), size of innovations (SIN), adventitious root (SAR), number of internodes (SIN), wax under the sheath (LWULS); and for CP3, number of visible internodes (SNVI), color of the internode with wax (SCIWW1), channel depth (SCD), ligule shape (LLS), and leaflet tip (LLT) (Table 4).

CP1 is related to stem and leaf variables, while CP2 is related to the stem. Consequently, the distribution on the cartesian coordinates, according to CP1 and CP2 shows the variation found in the ecotypes of the Elephant grass (*P. purpureum* Schumach). In addition, both CPs account for about 40 % of the variation (Figure 1a). The variation in CP1 and CP3 is the result of their relationship with stem and leaf variables (Figure 1b).

Hierarchical Cluster Analysis (HCA)

According to the hierarchical cluster analysis (Kaufman and Rousseuw, 1990), based on 34 stem and leaf morphological variables of the 18 Elephant grass ecotypes, five groups (GI, GII, GIII, GIV, and GV) were determined, using the 0.07 semipartial correlation coefficient (Figure 2).

Table 5 shows the quantitative and qualitative morphological descriptors of stems and leaves, grouped according to the results of the dendrogram.

Group I include the following ecotypes: INIFAP Pp-01, INIFAP Pp-03, INIFAP Pp-10, INIFAP Pp-14, and INIFAP Pp-15. According to its characteristics, the stem grows rapidly by producing more internodes (26) than the other groups; however, its diameter is smaller (20.51 mm) and it is 14.9 cm long. The internode with wax is black and white, while the internode without wax is yellowish green. The highest channel is 4.78 mm wide, which

Table 3. Eigenvalues and ratio of the total variance per principal component, based on the morphological characteristics of 18 ecotypes of the Elephant grass (*Pennisetum purpureum* Schumach).

PC	Eigenvalues	Difference	Proportion	Acumulate
1	6.627	2.934	0.254	0.254
2	3.692	0.479	0.142	0.396
3	3.213	0.609	0.123	0.520
4	2.604	0.351	0.100	0.620
5	2.252	0.514	0.086	0.707

PC=Main component.

Table 4. Values of the principal components and the correlation coefficient of each morphological variable of 18 ecotypes of Elephant grass (*Pennisetum purpureum* Schumach).

Variable	Eigenvectors			Pearson's coefficient correlation		
	PC1	PC2	PC3	PC1	PC2	PC3
SNVI	0.110	0.346	0.264	0.283ns	0.664*	0.472*
SID	0.339	0.178	−0.055	0.873**	0.342ns	−0.097ns
SIL	−0.200	0.163	−0.093	−0.515*	0.312ns	−0.167ns
SPW	−0.058	0.176	−0.013	−0.150ns	0.337ns	−0.022ns
SCIWW1	0.000	−0.274	0.381	0.000ns	−0.525*	0.683**
SCIWW2	−0.248	−0.092	0.143	−0.639**	−0.176ns	0.255ns
SCW	0.118	0.255	−0.076	0.302ns	0.490*	−0.135ns
SCD	−0.184	0.009	−0.351	−0.472*	0.017ns	−0.629**
SI	0.130	0.177	0.164	0.335ns	0.340ns	0.293ns
SIN	0.235	0.190	0.075	0.604**	0.364ns	0.135ns
SSI	0.110	0.230	−0.017	0.284ns	0.442*	−0.030ns
SP	−0.320	0.170	0.044	−0.822**	0.326ns	0.078ns
SNP	−0.261	0.263	0.152	−0.671**	0.504*	0.271ns
SSP	−0.254	0.190	0.212	−0.654*	0.366ns	0.379ns
SAR	−0.125	0.223	−0.076	−0.322ns	0.428ns	−0.135ns
SIN	0.000	0.330	0.316	−0.001ns	0.634**	0.565*
LWULS	−0.077	−0.279	0.287	−0.198ns	−0.536*	0.515*
LLSC	−0.051	0.195	−0.004	−0.130ns	0.375ns	−0.007ns
LSH	0.173	−0.144	−0.226	0.445ns	−0.276ns	−0.405ns
LELLS	0.312	0.027	−0.037	0.802**	0.052ns	−0.065ns
LILLSOP	0.323	−0.001	0.015	0.832**	−0.002ns	0.026ns
LLS	−0.079	0.007	−0.385	−0.202ns	0.013ns	−0.689*
HPLI	0.055	−0.209	0.097	0.142ns	−0.401ns	0.174ns
LLP	−0.106	0.096	−0.232	−0.273ns	0.184ns	−0.416ns
LOA	0.351	0.059	0.075	0.903**	0.113ns	0.133ns
LLP	0.032	0.191	−0.253	0.081ns	0.366ns	−0.452*

SNVI, SID, SIL, SPW, SCIWW2, SCW, SCD, SI, SIN, SSI, SP, SNP, SSP, SAR, SIN, LWULS, LLSC, LSH, LILLSOP, LLP, LDP, LOA, LLP; ** Statistically highly significant with alpha=0.001, *=significant with alpha=0.05, and ns=Not statistically significant.

means it is not deep. It tends to form a larger number of innovations (10), bigger prophylls (10.6), and more internodes with adventitious roots (10) and consequently it quickly enters the reproductive phase. Under the sheath, it has scarce wax. It has an external length of 17.7 cm; at the opening point, the internal length measures 8.6 cm. Its ligule is convex, its auricle measures 1.7 cm, and the tip on the leaflet measures 2.7 cm.

Group II was made up of five ecotypes: INIFAP Pp-04, INIFAP Pp-08, INIFAP Pp-12, INIFAP Pp-17, and INIFAP Pp-13. Its stems are 20.78 mm wide and 14.7 cm long, with less internodes (22) than the previous group. The internodes with wax and without wax are both yellowish green. The channel is 4.37 mm wide, and it is deep. It presents

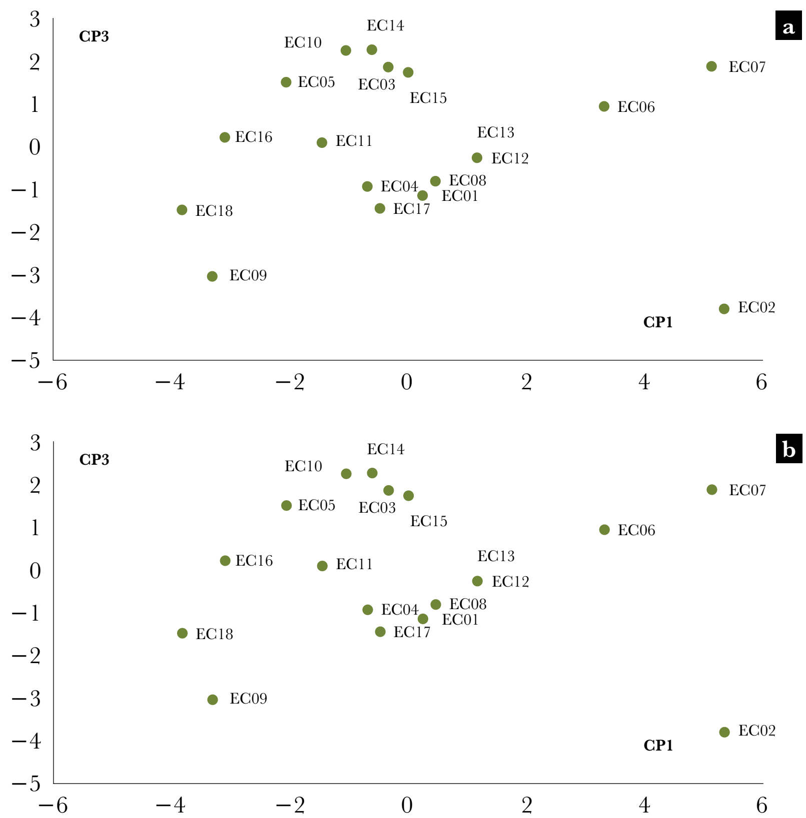

Figure 1. Distribution of 18 Elephant grass (*Pennisetum purpureum* Schumach) ecotypes collected in the state of Chiapas, based on: a) main components 1 and 2 (CP1 and CP2), and b) 1 and 3 (CP1 and CP3).

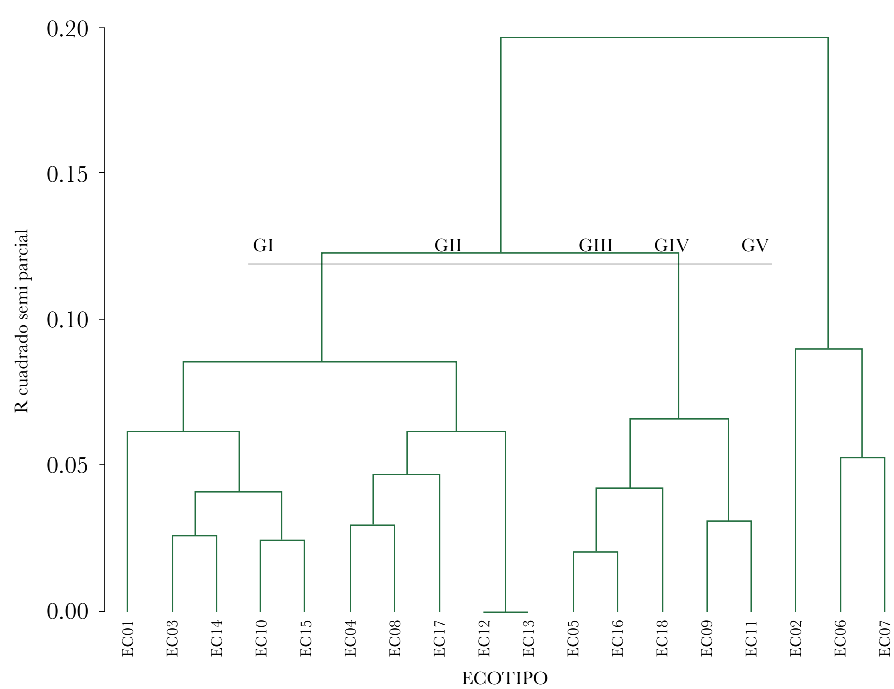

Figure 2. Dendrogram of 34 stem and leaf morphological characteristics of 18 ecotypes of Elephant grass (*Pennisetum purpureum* Schumach) collected in Chiapas, Mexico. GI=Group one, GII=Group two, GIII=Group three, GIV=Group four, and GV=Group five.

Table 5. Quantitative and qualitative morphological descriptors of the stem of 18 ecotypes of the Elephant grass (*Pennisetum purpureum* Schumach) collected in the Chiapas coast.

Group	Ecotype	1	2	3	5	6	7	8	10	12	13	16	17	20	21	22	25	33
		SNVI	SID	SIL	SCIWW1	SCIWW2	SCW	SCD	SIN	SP	SNP	SIN	LWULS	LELLS	LILLSOP	LLS	LOA	LLT
GI	INIFAP Pp-01	26	21.63	13.2	1	1	5.42	2	7	2	13.1	5	3	16.7	9.1	2	1.9	0.1
GI	INIFAP Pp-03	23	20.42	18.3	5	3	4.01	1	4	2	13.4	10	3	21.0	12.0	2	1.8	4.0
GI	INIFAP Pp-14	28	19.76	18.8	5	3	4.80	2	15	2	7.3	15	5	18.2	7.2	2	1.8	3.6
GI	INIFAP Pp-10	29	18.53	12.6	5	3	4.69	1	12	2	12.6	11	3	15.2	8.3	2	1.7	2.7
GI	INIFAP Pp-15	26	22.23	11.6	5	3	4.97	1	10	2	6.7	10	5	17.5	6.3	2	1.6	2.9
MEAN		26	20.51	14.9	5	3	4.78	1	10	2	10.6	10	3	17.7	8.6	2	1.7	2.7
GII	INIFAP Pp-04	21	19.10	18.6	3	3	4.32	3	7	2	12.4	7	3	17.2	9.5	2	1.7	0.1
GII	INIFAP Pp-08	22	20.02	13.7	3	3	4.29	3	10	2	3.5	3	3	16.7	11.3	2	1.7	1.9
GII	INIFAP Pp-17	27	19.45	15.5	3	3	4.79	3	12	2	4.7	2	5	17.9	7.0	3	1.6	3.2
GII	INIFAP Pp-12	20	22.66	13.0	5	3	4.23	1	15	2	5.4	4	3	18.3	8.0	3	2.0	2.7
GII	INIFAP Pp-13	20	22.66	13.0	5	3	4.23	1	15	2	5.4	4	3	18.3	8.0	3	2.0	2.7
MEAN		22	20.78	14.7	3	3	4.4	3	12	2	6.3	4	3	17.7	8.8	3	1.8	3.2
GIII	INIFAP Pp-05	23	17.25	13.9	3	3	3.24	2	10	2	13.8	8	5	13.1	8.1	2	1.4	5.1
GIII	INIFAP Pp-16	20	15.28	16.0	5	3	3.98	2	5	2	12.4	2	3	14.7	5.5	2	1.3	2.7
GIII	INIFAP Pp-18	14	12.59	16.3	5	3	2.97	3	3	2	7.4	3	5	14.0	5.0	3	0.9	2.3
GIII	INIFAP Pp-09	14	17.11	15.8	3	3	5.16	3	1	2	6.6	1	3	15.2	5.3	3	1.4	1.9
GIII	INIFAP Pp-11	18	17.38	15.1	5	3	3.98	2	1	2	6.0	2	5	18.5	9.8	2	1.8	3.0
MEAN		18	15.92	15.4	5	3	3.87	2	4	2	9.2	2	5	15.1	7	2	1.4	3.0
GIV	INIFAP Pp-02	23	27.78	14.5	1	1	4.67	2	16	1	0.1	6	1	22.9	14.5	3	2.2	3.3
GV	INIFAP Pp-06	21	20.48	10.4	5	3	4.11	1	12	1	0.6	0	5	18.8	12.3	2	2.0	2.7
GV	INIFAP Pp-07	22	22.94	11.0	7	1	4.63	1	10	1	0.1	5	5	20.5	13.8	1	2.5	3.2
MEAN		21	21.71	10.7	7	3	4.37	1	11	1	0.3	5	5	19.7	13.0	2	2.2	2.9

SNVI=Number of visible internodes; SID=Internode diameter (measure the middle internode); SIL=Internode length; SCIWW1=Color of the internode with wax; SCIWW2=Color of the internode without wax; SCW=Channel width; SCD=Channel depth; SIN=Number of innovations; SP=Prophylls; SNP=Number of prophylls; SIN=Number of internodes; LWULS=Wax under the leaf sheath; LELLS=External length of the leaf sheath; LILLSOP=Internal length of the leaf sheath at the opening point; LLS=Ligule shape; LOA=Opening of the auricle; LLT=Leaflet tip.

10 innovations, 5 prophylls, and 4 internodes with adventitious root; therefore, like the previous group, it quickly enters the reproductive phase. The external length of the sheath is 17.7 cm: at the opening point, the internal length measures 8.8 cm. The opening of the auricle measures 1.8 cm and the tip of the leaflet measures 3.2 cm.

Group III was made up of five ecotypes: INIFAP Pp-05, INIFAP Pp-16, INIFAP Pp-18, INIFAP Pp-09, and INIFAP Pp-11. It has thinner and longer stems (with a 19.92 mm diameter and a 15.4 cm length) and fewer internodes (18). The internodes with a lot of wax are black and white, while the internodes without wax are yellowish green. The channel is 3.87 mm wide and has an intermediate depth. It has a lower number of innovations (4), a high number of prophylls (9), and few internodes with adventitious roots (2). Like the previous groups, it quickly enters the reproductive phase. The sheath measures 15.1 cm (external length) and 6.7cm at the opening point (internal length). A scarce amount of wax can be found underneath. The ligule is biconvex. The auricle measures 2.2 cm (opening) and the tip of the leaflet measures 3.0 cm.

Group IV consisted of a single ecotype: INIFAP Pp-02. It stands out for having the maximum averages in descriptors of high forage value (Wouw *et al.*, 1999). Its stem has the following characteristics: the number of internodes is one of the highest (23), their thickness is greater (27.78 mm), and the internodes are of medium length (14.5 cm). The internodes with and without wax are both yellowish. The channel is less wide than the highest specimen (4.67 mm) and it is of intermediate depth. It has the highest number of innovations (16). The absence of prophylls sets this group apart from the others, because it does not enter the reproductive stage. It has 6 internodes with adventitious roots. It has scarce wax under the sheath. The external length of the sheath measures 22.9 cm and, at the opening point, the internal length of the sheath measures 14.6 cm. The ligule is convex, the auricle measures 1.7 cm, and the tip of the leaflet measures 3.3 cm.

Finally, group V is made up of two ecotypes, which are distinguished by a low number of internodes (21), with a medium diameter (21.75) and of short length (10.7). The internodes with wax are deep black, while the internodes without wax are yellowish green. The channel is 4.37mm wide and it is not deep. It has an average number of innovations (11) and adventitious root in five internodes. It does not present prophylls. Its sheath shows scarce wax underneath and has an external length of 19.7 cm. The ligule is convex, the auricle measures 1.7 cm, and the tip of the leaflet measures 2.9 cm. Xavier *et al.* (1995) observed that Napier grass has 15.60 internodes, with an 18.0 mm diameter and a 9.80 cm length. It has prophylls and adventitious roots. Its sheath is 21.30 cm long and the ligule measures 3.80 mm. These data match the range of the characterized ecotypes. For their part, Wouw *et al.* (1999) characterized 53 accessions of *Pennisetum purpureum* and *P. purpureum* × *P. glaucum*, based on their agronomic and morphological characteristics, and obtained five groups. The separation was the result of the following characteristics: the length of the internodes, the thickness of the stem, the hairiness, the length and width of the leaf, how they grow, and the rhizomes or roots in the internodes. In the present work, these characteristics were used. Five groups were also obtained, which have been described in the previous paragraph.

CONCLUSIONS

The 18 ecotypes of the Elephant grass (*Pennisetum purpureum* Schumach) collected and characterized show dissimilarities between them. Therefore, they are considered a genetic resource with potential forage importance on the Chiapas coast.

REFERENCES

Cavalcante, M., Lira, M. A. (2010). Variabilidade genética em *Pennisetum purpureum* Schumacher. *Revista Caatinga, 23*(2), 153-163. https://www.redalyc.org/articulo.oa?id=237116915020.

Cunha, M. V., Andrade Lira, M. de, Dos Santos, M. V. F., Freitas, E. V. de, Junior, J. C. B. D., Mello, A. C. L. de, Martins, K. G. R. (2011). Association between the morphological and productive characteristics in the selection of elephant grass clones. *Revista Brasileira De Zootecnia, 40*(3), 482–488. Doi.org/10.1590/S1516-35982011000300004.

Kaufman, L. Rousseeuw, P. J. (1990). Finding groups in data: An introduction to cluster analysis. Wiley – Interscience. 1ª Edición. Estados Unidos de America. 342 p.

Kebede, G., Feyissa, F., Assefa, G., Alemayehu, M., Mengistu, A., Kehaliew, A., Melese, K., Mengistu, S., Tadesse, E., Wolde, S., Abera, M. (2016). Evaluation of Napier Grass (*Pennisetum purpureum* L.) Schumach) Accessions for Agronomic Traits Under Different Environmental Conditions of Ethiopia. *International Journal of Advanced Research, 4*(4), 1029-1035.

Kebede, G., Feyissa, F., Assefa, G., Alemayehu, M., Mengistu, A., Kehaliew, A., Melese, K., Mengistu, S., Tadesse, E., Wolde, S., Abera, M. (2016). Chemical Composition and In-vitro Organic Matter Digestibility of Napier Grass (*Pennisetum purpureum* (L.) Schumach) Accessions in the Mid and Highland Areas of Ethiopia. *International Journal of Livestock Research, 6*(4), 41-59. Doi:10.5455/ijlr.20160317124016.

Kretschmer, A. E. (1979). Caracterización y evaluación preliminar. En: Mott, G.O. (Ed.). Manual para la colección, preservación y caracterización de recursos forrajeros tropicales. Cali, Colombia. CIAT. 37-49 pp.

López, Y., Seib, J., Woodard, K., Chamusco, K., Sollenberger, L., Gallo, M., Flory, S.L., Chase, C. (2014). Genetic diversity of biofuel and naturalized napiergrass (*Pennisetum purpureum*). *Invasive Plant Science and Management, 7*(2), 229-236. Doi:10.1614/IPSM-D-13-00085.1

Madakadze, I. C., Masamvu, T. M., Radiotis, T., Li, J., Smith, D. L. (2010). Evaluation of pulp and paper making characteristics of elephant grass (*Pennisetum purpureum* Schum) and switchgrass (*Panicum virgatum* L.). *African Journal of Environmental Science and Technology, 4*(7), 465-470. DOI: 10.5897/AJEST10.097.

Maldonado-Méndez, J. J., Guerra-Medina, C. E., Ovando-Cruz, M. E., Valle-Mora, F. J., Ovando-Barroso, E., Gálvez-Marroquín, L. A. (2019). Caracterización morfológica de 15 pastos de la especie *Pennisetum purpureum*. *Agro Productividad, 12*(12), 39-46. Doi.org/10.32854/agrop.vi0.1484.

Morais, R. F., Souza, B. J., Leite, J. M., Soares, L. H.B., Alves, B. J. R., Boddey, R. M., Urquiaga, S. (2009). Elephant grass genotypes forbioenergy production by direct biomass combustion. *Pesquisa Agropecuária Brasileira, 44*(2), 133-140. Doi.org/10.1590/S0100-204X2009000200004.

Morales, N. C. R. (2008). Metodología para la recolecta y conservación de germoplasma de plantas forrajeras en las zonas áridas y semiáridas de México. INIFAP-Sitio Experimental "La Campana". *Folleto Técnico No. 21*. Chihuahua, Chihuahua. 21 p.

Muktar, M.S., Bizuneh, T., Wolde, B., Assefa, Y., Jones, C.S. (2021). Genetic diversity in Napier grass (Cenchrus purpureus) collections and progeny plants: Potential duplicates and unique genotypes. Poster prepared for Tropentag 2021 - Towards shifting paradigms in agriculture for a healthy and sustainable future. Nairobi, Kenya: ILRI.

Nyambati, E. M., Muyekho, F. N., Onginjo, E., Lusweti, C. M. (2010). Production, characterization and nutritional quality of Napier grass [*Pennisetum purpureum* (Schum.)] cultivars in Western Kenya. *African Journal of Plant Science, 4*(12), 496-502.

Quero-Carrillo, A. R., Villanueva-Avalos, J. F., Enríquez-Quiroz, J. F., Morales-Nieto, C. R., Bolaños-Aguilar, E. D., Castillo-Huchim, J., Maldonado-Méndez, J. J., Herrera-Cedano, F. (2012). Manual de Evaluación de Recursos Genéticos de Gramíneas y Leguminosas Forrajeras. INIFAP – CIRPAC. Campo Experimental Santiago Ixcuintla. *Folleto Técnico Núm. 22*. Santiago Ixcuintla, Nayarit, México. 41 p.

Rocha, J. R. A., Machado, S. C., Carneiro, J. C., Carneiro, S. P. C., Resende, C. J., V. M. D., S. F. J. Ledo, and S. J. E.Carneiro. (2017). Bioenergetic potential and genetic diversity of elephant grass via morpho-agronomic and biomass quality traits. *Industrial Crops and Products*, 95, 485-492.

Rusdy, M. (2016). Elephant grass as forage for ruminant animals. *Livestock Research for Rural Development, 28*(4), 1-6.

SAS, System for Windows. (2020). SAS User's Guide Statistics, SAS Inst. Inc. Cary North Carolina USA.

Scholl, A.L., Menegol, D., Pitarelo, A. P., Fontana, R. C., Filho, A. Z., Ramos, L. P, Dillon, A. J. P., Camassola, M. (2015). Ethanol production from sugars obtained during enzymatic hydrolysis of elephant grass (*Pennisetum purpureum*, Schum.) pretreated by steam explosion. *Bioresource Technology*, 192, 228–237. Doi.org/10.1016/j.biortech.2015.05.065

SiB Colombia (2020). Catálogo de la Biodiversidad de Colombia, Sistema de Información sobre Biodiversidad de Colombia. Recuperado de: https://catalogo.biodiversidad.co/file/56e7788183c45700544e4021/summary.

Silva, V., Daher, R., Araújo, M., Souza, Y., Cassaro, S., Menezes, B., Gravina, L., Novo, A., Tardin, F., Júnior, A. (2017). Prediction of genetic gains by selection indices using mixed models in elephant grass for energy purposes. *Genet. Mol. Res., 16*(3), gmr16039781. Doi: 10.4238/gmr16039781.

Tcacenco, F. A., Lance, G. N. (1992). Selection of morphological traits for characterization of elephant grass accessions. *Tropical Grasslands*, 26, 145-155.

Videira, S. S., Oliveira, D. M., Morais, R. F., Borges, W. L., Baldani, V.L. D., Baldani, J. I. (2012). Genetic diversity and plant growth promoting traits of diazotrophic bacteria isolated from two *Pennisetum purpureum* Schum. genotypes grown in the field. *Plant Soil*, 356, 51–66. Doi: 10.1007/s11104-011-1082-6.

Videira, S. S., Silva, M. D. C. P., de Souza Galisa, P., Dias, A. C. F., Nissinen, R., Divan, V. L. B., Elsas, J. D. V., Baldani, J. I., Salles, J. F. (2013). Culture-independent molecular approachesreveal a mostly unknown high diversity of active nitrogen-fixing bacteria associated with *Pennisetum purpureum*—a bioenergy crop. *Plant soil*, 373, 737–754. Doi: 10.1007/s11104-013-1828-4.

Villanueva-Ávalos, J.F., Morales-Nieto, C.R., Enríquez-Quiroz, J. F., Quero-Carrillo, A. R., Herrera-Cedano, F. Jiménez-Guillen, R., Silva-Luna, M. (2012). Manual para la recolección y conservación de germoplasma forrajero en México. INIFAP – CIRPAC. Campo Experimental Santiago Ixcuintla. *Folleto Técnico Núm. 20.* Santiago Ixcuintla, Nayarit, México. 46 p.

Wangchuk, K., Rai, K., Nirola, H., Thukten, Dendup, C., Mongar, D. (2015). Forage growth, yield and quality responses of Napier hybrid grass cultivars to three cutting intervals in the Himalayan foothills. *Tropical Grasslands-Forrajes Tropicales*, 3, 142-150.

Wouw, M. V, Hanson, J., Luethi, S. (1999). Morphological and agronomic characterisation of a collection of napier grass (*Pennisetum purpureum*) and *P. purpureum* × *P. glaucum*. *Tropical Grasslands*, 33, 150-158.

Xavier, D. F., Botrel, M. de A., Daher. R. F., Gomes, F. T., Pereira, A. V. (1995). Caractetizacao morfológica e agronômica de algumas cultivares de capim-etefante (*Pennisetum purpureum*, Schum.). Coronel Pacheco: EMBRAPA-CNPGL. 24 p.