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Canonical correlations among morpho-agronomic and chemical traits in hybrids between elephant grass and millet

Rogério Figueiredo Daher[1], Antônio Vander Pereira[2], Bruna Rafaela da Silva Menezes[3], Sabrina Cassaro[1], Antônio Alonso Cecon Novo[4], Eduardo Peres Furlani[5], Antônio Teixeira do Amaral Júnior[1], Messias Gonzaga Pereira[1]

[1]Universidade Estadual do Norte Fluminense. Postal Code: 28013-600, Campos dos Goytacazes, RJ, Brazil
[2]Embrapa Gado de Leite. Postal Code: 36038-330, Juiz de Fora, MG, Brazil
[3]Universidade Federal Rural do Rio de Janeiro. Postal Code: 23.897-000, Seropédica, RJ, Brazil
[4]Instituto Federal Fluminense. Postal Code: 28360-000, Campus Bom Jesus do Itapapoana, RJ, Brazil
[5]Universidade Federal de Juíz de Fora. Postal Code: 36100-040, Juíz de Fora, MG, Brazil

***Corresponding author: brunarafamenezes@hotmail.com**

Abstract

Studies involving the canonical correlation analysis in forage plants for interspecific hybrids between elephant grass (*Pennisetum purpureum*) and millet (*Pennisetum glaucum*) are scarce. The objectives of this study were to obtain estimates of coefficients of phenotypic, genotypic, and residual correlation and evaluate the degree of association between morpho-agronomic and chemical traits in 132 interspecific hybrids between elephant grass and millet. The experiment was conducted in the city of Coronel Pacheco-MG (Brazil). The experimental design was randomized complete blocks with 132 treatments and three replicates. Morpho-agronomic and bromatological characteristics were analyzed. The correlation analysis indicated that plants with elevated dry matter yield considering the whole plant, leaf or stem in taller plants and plants with intense tillering have lower crude protein contents, while plants with a greater diameter show lower percentages of fiber and cellulose and greater dry matter digestibility *in vitro*. By canonical correlations, the chi-squared test at 1% probability by was found that the hybrids showing morpho-agronomic and chemical patterns with taller plants and high dry stem matter yield have increased percentage of cellulose. In contrast, in the same canonical pair, plants with reduced leaf dry matter yield showed lower contents of silica and organic matter and reduced digestibility *in vitro*. The effect on the improvement of forage quality in hybrids of *Pennisetum* and millet was evidenced by the better performance of the plants for high dry matter yield of the stem, showing the potential of the same for inclusion in breeding programs.

Keywords: Coefficient of genotypic correlation, dry matter yield, forage quality, plant breeding, percentage of cellulose.

Introduction

Elephant grass and millet are species grown in almost all tropical and subtropical regions of the world. Elephant grass is an alotetraploid species with 2n = 4x = 28 chromosomes (genomes A'A'BB) and millet is a diploid species with 2n = 2x = 14 chromosomes (AA genomes). Because they are closely related, they present an appropriate genetic combining ability. In the hybrids obtained by the crossing of elephant grass and millet, elephant grass contributes to the rusticity, aggressiveness, perenniality and high yield of dry matter. On the other side, millet contributes to vigor, forage quality, seed size, resistance to drought and disease tolerance (Leão et al., 2012). Thus, with this cross, we obtain sterile triploid hybrids with 2n = 3x = 21 chromosomes (genomes AA'B), vegetatively propagated, but with great forage potential, in view of being productive more than the elephant grass (Diz, 1994).

The crossing of elephant grass (*Pennisetum purpureum* Schum.) with millet (*Pennisetum glaucum* (L.) R. Br.) is an alternative to generate superior cultivars (Boddorff and Occumpaugh, 1986; Hanna & Monson, 1980; Schank and Chynoweth, 1993). In addition to better forage quality, hexaploid hybrids display high production of large, viable seeds, which makes them recommended for propagation by seed (Diz et al., 1994; Schank et al., 1993). According to Souza Sobrinho et al. (2005), the crossing between *P. purpureum* and *P. glaucum* has potential to generate improved forage cultivars because of the superiority of some hybrids as compared with control varieties Pioneiro and Cameroon.

In the development of a breeding program, the selection of superior hybrids should be performed as efficiently as possible. The existence of significant correlations is indicative of the viability of indirect selection to obtain gains in the trait of more economic importance. However, because the quantitative traits are under the control of several genes with diverse interactions, linkages and pleiotropic effects, the selection of a trait may trigger a number of alterations in the populations, some of which are not desired by the breeder (Cruz et al., 2012).

The path analysis, whose initial theory was proposed by Wright (1921 and 1923), has a great importance in the partition of the coefficient of correlation into direct and indirect effects of independent explicatory traits. It works on a principal basic dependent variable, enabling the study of specific forces that produce a correlation between correlated variables. But, it has the limitation of considering only one dependent variable. Menezes et al. (2014), in an experiment conducted in two cuts under the soil-climatic conditions of Northern Rio de Janeiro State, concluded that the traits such as plant height and tiller diameter best explain the dry matter yield potential of elephant grass. Silva et al. (2008), evaluated five clones of elephant grass in Itambé-PE and concluded that there was a high correlation among almost all explanatory variables and the primary variable. However, number of leaf blades per tiller best explained the dry matter yield and worked directly and indirectly on the explicatory variables.

On the other hand, the canonical correlation analysis enabled the evaluation of interrelationships involving two distinct complexes determined by at least two variables. In breeding programs, this methodology has been used to evaluate the relationship between primary and secondary components of production (Carvalho et al., 1998; Tavares et al., 1999; Lorencetti et al., 2006), agronomic versus morpho-physiological traits (Amaral et al., 1997; Santos et al., 1994) and morpho-agronomic versus root-quality traits (Vidigal et al. 1997). This technique has been utilized widely in the breeding of various crop species; however, currently there are still few studies of this nature involving forage plants (Rossi et al., 2014; Nave et al, 2009; Cunha et al., 2011), especially interspecific hybrids between elephant grass (*Pennisetum purpureum* Schum.) and millet (*Pennisetum glaucum* (L.) R. Br.).

The objectives of this study were to obtain estimates of coefficients of phenotypic, genotypic, and residual correlation and to evaluate the degree of association between morpho-agronomic and chemical traits in 132 triploid interspecific hybrids between elephant grass (*Pennisetum purpureum* Schum.) and millet (*Pennisetum glaucum* (L.) R. Br.) from a cut made in the soil-climatic conditions of the city of Coronel Pacheco-MG, Brazil.

Results and discussion

Morpho-agronomic and bromatological evaluation

The estimates of the phenotypic, genotypic, and environmental correlations involving the morpho-agronomic, chemical, and simultaneously both sets of traits are presented in Tables 1, 2, and 3, respectively. A slight predominance of the estimates of genotypic correlation relative to the estimates of phenotypic and environmental correlations (52 and 57%, respectively) was observed for the situations involving the morpho-agronomic and chemical traits separately (Tables 1 and 3). An expressive dominance of the estimates of genotypic correlation as compared with the phenotypic and environmental ones (87%) was also detected when evaluated together (Table 3), indicating lower influence of the environmental component working on the relationship of these two sets of traits. However, Silva et al. (2014) evaluated hybrids of elephant grass in a partial diallel cross and observed that they had different performances in the two evaluated cuts, i.e., the management at the time of the cut affects the performance of the harvested forage because of the genotype × environment interaction. Considering the significance of the estimates of genotypic correlations, it is observed that in a total of 91 obtained estimates (Tables 1, 2, and 3), only 14 did not differ from zero by the t-test (P>0.05), demonstrating great reliability in the obtained estimates due to the high number of pairs of combinations. The existence of significant correlations is indicative of the viability of indirect selection to obtain gains in the trait(s) of greater economic importance (Cruz et al., 2012).

The environment becomes a cause of correlations when two traits are influenced by the same differences of environmental conditions. Negative values for environmental correlation indicate that the environment benefits a trait over another, and positive values indicate that both traits are benefited or impaired by the same causes of environmental variation (Cruz et al., 2012). Overall, the estimates of positive values prevailed, except for those involving the chemical traits solely (Table 2), wherein the negative values of environmental correlation surpassed the positive ones, anticipating a complex relationship caused by favoring and/or disfavoring of the environmental conditions.

Genotype x environment relationship

Differences in sign involving genotypic and environmental correlations indicate that the causes of genetic variation influence the traits through mechanisms different from the cause of the environmental variation (Falconer, 1987). The trait CP illustrates this situation well, as it showed negative estimates of genotypic correlations with the traits related to dry matter yield (from the whole plant, PDMI; of the leaves, LDMY; and of the stem, SDMY), HGT, and NT, indicating that more productive plants, taller plants, and plants with intense tillering will have lower CP contents. Contrastingly, the positive sign of the estimates of environmental correlation determines that environmental causes such as temperature and humidity influence CP and the traits such as PDMY, LDMY, SDMY, HGT, and NT positively.

Conversely, the trait SD also showed differences in sign, involving genotypic correlations (negative) and environment (positive) with the set of traits NDF, ADF, CEL, and DMDIV, the latter having positive genotypic correlation and negative environmental correlation. Thus, plants with a greater diameter showed lower percentages of fiber and cellulose and greater DMDIV. According to Pereira et al. (2014), the *in vitro* digestibility is lower in the whole plant (stem + leaf) compared with the leaves because of the high concentration of lignified material. That means when the concentration of stems decreases, DMDIV increases as a result of the greater lignin content.

Table 1. Estimates of the coefficients of phenotypic (r_F), genotypic (r_G), and environmental (r_A) correlation among seven morpho-agronomic traits evaluated in 132 intraspecific hybrids between elephant grass and millet in Coronel Pacheco-MG, Brazil.

	r	LDMY[2/]	SDMY[3/]	LSR[4/]	HGT[5/]	NT[6/]	SD[7/]
PDMY[1/]	F	0.8605	0.9641	-0.1211	0.4540	0.6689	0.1634
	G	0.8023**	0.9441**	-0.1173ns	0.3387**	0.7896**	-0.0065ns
	A	0.8919	0.9735	-0.1448	0.5371	0.6086	0.2770
LDMY	F		0.6944	0.3266	0.2323	0.5110	0.3574
	G		0.5608**	0.4847**	-0.0847ns	0.4842**	0.5080**
	A		0.7649	0.1891	0.4601	0.5394	0.2529
SDMY	F			-0.3414	0.5202	0.6785	0.0446
	G			-0.4304**	0.5166**	0.8279**	-0.2895**
	A			-0.3020	0.5325	0.5942	0.2667
LSR	F				-0.4185	-0.2040	0.4363
	G				-0.6199**	-0.2917**	0.7708**
	A				-0.1603	-0.0834	-0.0186
HGT	F					0.1275	-0.1222
	G					-0.0599ns	-0.4606**
	A					0.3032	0.1833
NT	F						-0.1682
	G						-0.3893**
	A						0.0426

** - significantly different from zero (P<0.01); ns - not significant (P>0.05) by the t test (DF = 131), applied only to genotypic correlations.
[1/]PDMY - whole-plant dry matter yield; [2/] LDMY - leaf dry matter yield; [3/] SDMY - stem dry matter yield; [4/]LSR - leaf:stem ratio; [5/]HGT - average plant height; [6/]NT - number of tillers per linear meter; [7/]SD - average diameter of stem at the base of the plant.

Table 2. Estimates of the coefficients of phenotypic (r_F), genotypic (r_G), and environmental (r_A) correlation among seven chemical traits evaluated in 132 interspecific hybrids between elephant grass and millet in Coronel Pacheco-MG, Brazil.

	r	CP[2/]	NDF[3/]	ADF[4/]	DMDIV[5/]	Cel[6/]	SIL[7/]
OM[1/]	F	-0.5047	0.4756	0.4555	-0.6275	0.4905	-0.4650
	G	-0.6953**	0.7424**	0.4373**	-0.6245**	0.4997**	-0.2512**
	A	-0.4734	0.3197	0.4761	-0.6291	0.5004	-0.5506
CP	F		-0.2730	-0.3177	0.4148	-0.3180	0.1609
	G		-0.6038**	-0.2804**	0.6273**	-0.2530**	-0.3164**
	A		-0.1873	-0.3675	0.3747	-0.3914	0.2616
NDF	F			0.8588	-0.7795	0.8402	-0.2505
	G			0.9486**	-0.9716**	0.9542**	-0.4840**
	A			0.7886	-0.6637	0.7472	-0.1509
ADF	F				-0.8342	0.9236	-0.1564
	G				-0.8548**	0.9905**	-0.1293*
	A				-0.8319	0.8591	-0.1788
DMDIV	F					-0.7348	0.2174
	G					-0.8065**	0.0700ns
	A					-0.7007	0.2784
CEL	F						-0.2413
	G						-0.0786ns
	A						-0.3525

** - significantly different from zero (P<0.01); ns - not significant (P>0.05) by the t test (DF = 131), applied only to genotypic correlations. [1/]OM - percentage of organic matter; [2/]CP - percentage of crude protein; [3/]NDF - percentage of neutral detergent fiber; [4/]ADF - percentage of acid detergent fiber; [5/]DMDIV - dry matter digestibility *in vitro*; [6/]CEL - percentage of cellulose; [7/]SIL - percentage of silica.

Table 3. Estimates of the coefficients of phenotypic (r_F), genotypic (r_G), and environmental (r_A) correlations among seven morpho-agronomic traits and seven chemical traits evaluated in 132 interspecific hybrids between elephant grass and millet in Coronel Pacheco-MG, Brazil.

	r	PDMY[1/]	LDMY[2/]	SDMY[3/]	LSR[4/]	HGT[5/]	NT[6/]	SD[7/]
	F	0.0415	-0.1357	0.1294	-0.5193	0.2832	0.0706	-0.3192
OM[8/]	G	-0.0458ns	-0.3155**	0.1106ns	-0.8082**	0.6933**	0.0454ns	-0.8455**
	A	0.0828	-0.0408	0.1386	-0.2930	0.0170	0.0899	0.0283
	F	0.0170	0.1328	-0.0453	0.3034	-0.0915	-0.0323	0.2254
CP[9/]	G	-0.8081**	-0.3756**	-0.9136**	0.9070**	-0.6560**	-0.4847**	0.5775**
	A	0.2298	0.2865	0.1825	0.0651	0.1018	0.1356	0.1226
	F	0.2637	0.0435	0.3498	-0.4920	0.3378	0.3071	-0.2316
NDF[10/]	G	0.5680**	0.0299ns	0.7713**	-0.7684**	0.4959**	0.6043**	-0.6456**
	A	0.0921	0.0524	0.1048	-0.1838	0.2119	0.0573	0.1053
	F	0.3145	0.0220	0.4328	-0.5886	0.4615	0.3285	-0.2745
ADF[11/]	G	0.4746**	-0.1003ns	0.7137**	-0.8131**	0.6901**	0.5487**	-0.8227**
	A	0.2194	0.1099	0.2570	-0.3046	0.2566	0.1203	0.2250
	F	-0.2336	-0.0086	-0.3255	0.4747	-0.3617	-0.2481	0.2435
DMDIV[12/]	G	-0.3187**	0.1316*	-0.5147**	0.6833**	-0.6655**	-0.3588**	0.8425**
	A	-0.1921	-0.0858	-0.2303	0.3116	-0.1576	-0.1728	-0.1716
	F	0.2586	0.0061	0.3621	-0.5621	0.3578	0.3278	-0.3003
CEL[13/]	G	0.4412**	-0.0689ns	0.6500**	-0.8092**	0.5426**	0.5481**	-0.7206**
	A	0.1405	0.0654	0.1671	-0.1970	0.1766	0.0987	0.1202
	F	-0.1525	-0.0741	-0.1768	0.2593	-0.2346	-0.0333	0.0453
SIL[14/]	G	-0.3587**	-0.1184ns	-0.4321**	0.6096**	-0.6181**	0.1267*	0.0606ns
	A	-0.0783	-0.0572	-0.0827	0.0359	-0.0509	-0.1218	0.0398

** - significantly different from zero (P<0.01); ns - not significant (P>0.05) by the t test (DF = 131), applied only to genotypic correlations.
[1/]PDMY - whole-plant dry matter yield; [2/] LDMY - leaf dry matter yield; [3/] SDMY - stem dry matter yield; [4/]LSR - leaf:stem ratio; [5/]HGT - average plant height; [6/]NT - number of tillers per linear meter; [7/]SD - average diameter of stem at the base of the plant; [8/]OM - percentage of organic matter; [9/]CP - percentage of crude protein; [10/]NDF - percentage of neutral detergent fiber; [11/]ADF - percentage of acid detergent fiber; [12/]DMDIV - dry matter digestibility *in vitro*; [13/]CEL - percentage of cellulose; [14/]SIL - percentage of silica.

Table 4. Correlations and canonical pairs estimated in three morpho-agronomic (Group 1) and four chemical (Group 2) traits evaluated in 132 interspecific hybrids between elephant grass and millet in Coronel Pacheco-MG, Brazil.

Traits	Canonical pairs (C.P.)		
	Canonical coefficients of the Group Variables I		
Morpho-agronomic	1° C.P.	2° C.P.	3° C.P.
LDMY[1/]	-0.4858	-0.5044	1.2379
SDMY[2/]	0.9753	1.2586	-0.4519
HGT[3/]	0.2557	-1.2876	0.4103
Chemical	Canonical coefficients of the Group Variables II		
OM[4/]	-0.2123	-0.9428	-0.7019
DMDIV[5/]	-0.3832	0.3355	-0.4621
CEL[6/]	0.6033	0.9463	-0.5830
SIL[7/]	-0.5279	0.1963	-0.8383
r	0.9509	0.8154	0.3159
χ^2	918.4197**	310.4245**	27.2371**
D.F.	12	6	2

** - significantly different from zero (P<0.01); ns - not significant (P>0.05) by the chi-squared test. [1/]LDMY - leaf dry matter yield; [2/] SDMY - stem dry matter yield; [3/]HGT - average plant height; [4/]OM - percentage of organic matter; [5/]DMDIV - dry matter digestibility *in vitro*; [6/]CEL - percentage of cellulose; [7/]SIL - percentage of silica.

Analysis of genotypic correlations estimates involving traits PDMY, HGT, NT, and SD found in Coronel Pacheco-MG (Table 1), is in close agreement with Daher et al (2004), who evaluated the same traits in 17 intraspecific hybrid of elephant grass in Campos dos Goytacazes-RJ. Among the positive correlations, the following are noteworthy: PDMY with HGT, and PDMY with NT; and among the negative estimates are HGT with SD and SD with NT, indicating that despite the contrasting environmental conditions, the relationships remained stable, corroborating the property of the employed methodology.

Analysis of canonical correlations

Diagnostics of multicollinearity were performed involving all evaluated traits, starting from the strong collinearity to weak collinearity. The final resulting matrix showed a condition number (Max/Min) of 97.532678 and a determinant of 0.002057. The traits were discarded according to the following sequence: CP, NDF, LSR, SD, NT, ADF, and PDMY.
The canonical correlations and the coefficients associated with the canonical pairs of the traits with lack of collinearity suitable to the canonical correlation analysis are shown in Table 4. Traits were divided into two groups: group I consists of morpho-agronomic traits LDMY, SDMY, and HGT, group II corresponds to chemical traits OM, DMDIV, CEL, and SIL.

Considering the hypothesis of nullity for the canonical variables ($\rho_1=\rho_2=\rho_3=0$), it can be inferred, based on statistic χ^2, that for the three estimated correlations (r_1 = 0.9509 and DF = 12; r_2 = 0.8154 and DF = 6; and r_3 = 0.3159 and DF = 2) there was significance at 1% probability ($P>0.01$), demonstrating the rejection of hypothesis H_0, and agreeing with the significances found by both Nave et al. (2009) and Cunha et al. (2011).

Based on the canonical coefficients of the traits of the first canonical pair, it can be observed that plants with high SDMY and taller plants are determinants of increased CEL in the plant. In contrast, also within this canonical pair, plants with reduced LDMY typically show lower SIL contents as compared with OM, and also lower DM contents, followed by reduced DMDIV. This evolves from the fact that materials with low contents of non-fibrous materials on the cell wall, i.e., with low OM contents, have a low IVDMD (Velásquez et al., 2010).

Analysis of canonical coefficients of the traits of the second canonical pair, whose significance is as high as that in the first canonical pair (Table 4), shows that plants with high SDMY, but small in size and low in LDMY are determinants of the manifestation of reduced OM, but high CEL, and moderate rates of DMDIV and SIL. High SIL, as in the case of low LDMY, is associated with low palatability and intake of forage (Brâncio et al., 2002).

In spite of its significance, the third canonical pair showed a clearly lower canonical correlation as compared with the first two; however, its coefficients made it possible to infer that tall plants, plants with a high LDMY, and those with reduced SDM mostly showed low OM, CEL, and digestibility. These results once again corroborate the fact that a greater concentration of stems in the sample over leaves leads to increased fiber content and reduced *in vitro* digestibility, as also was observed by Cosér et al. (2008).

Materials and methods

Location and experimental conditions

The experiment was conducted at the Experimental Station of Embrapa Dairy Cattle, located in the city of Coronel Pacheco-MG, *Zona da Mata* region of Minas Gerais State, Brazil (426 m altitude, 21°55’50’’ S latitude, and 43°16’15’’ W longitude). According to the Köppen (1948), cited by Ometto (1981), the climatic type in that area is classified as Cwa, with rainy summers and dry winters. The region is of crystalline formation, of Precambrian origin, with relief predominantly mountainous.

Planting was carried out on March (end of the rainy season) using pieces of stem in a single row into 10-cm-deep furrows, along with the application of 100 kg/ha of P_2O_5 at the bottom of the furrow in a hillside soil classified as “dystrophic Yellow Podzolic” (EMBRAPA, 2006) with clayey texture. Liming was performed using 2 t/ha of dolomitic limestone.

The experiment was set in a randomized complete block design with 132 treatments (interspecific hybrids) and three replicates, using at least 20 pieces with three nodes from stems of different plants originating from a same hybrid combination that were seeded into four linear meters, which was the plot. Lines were spaced 1.5 m from each other, resulting in a total plot area of 6 m^2. Weighting, measurements and sampling were performed in two linear meters distributed randomly within the plots, avoiding the flaws, resulting in 3 m^2 of floor area. Two lines planted with cultivar Cameroon around the entire plot were used as borders.

Two plot-leveling cuts were made, and the plots with flaws were replanted. The evaluation cut was made nine weeks after the second plot-leveling cut during the rainy season. After the plot-leveling cut, topsoil fertilization was applied, with 67 kg/ha of the NPK 20-5-20 formulation.

Characteristics evaluated

Evaluations were performed with traits divided into morpho-agronomic and chemical. Morpho-agronomic traits: (A) dry matter yield from whole plant (PDMY), leaf (LDMY), and stem (SDMY) — estimated as the product between the weight of the fresh matter of whole plant (kg), leaves, or stems, and the percentage of dry matter of whole plant, leaves, or stems, obtained from the sampling of these plants, with the obtained value (kg/m^2) converted to t/ha; (B) leaf:stem ratio (LSR) — estimated after separation of the sample containing whole plants into leaves and stems, both parts weighed and pre-dried in a forced-ventilation oven at 65 ºC for 72 h, and weighed again, yielding the quotient leaf dry weight:stem dry weight; (C) average plant height (HGT) — expressed in m; (D) number of tillers per linear meter (NT) — obtained by counting the number of tillers taller than 70 cm within two linear meters (plot floor area) moments before the evaluation cut; (E) average diameter of the stem at the base of the plant (SD) — expressed in cm, measured 10 cm above the soil level using a digital caliper moments before the evaluation cut.

Chemical traits: samples of whole plants, leaves, and stems were dried at 60 ºC under air circulation for 72 h. After drying, samples were ground (1 mm) in a Wiley mill and conditioned in glasses. Chemical analyses were performed by the near-infrared spectroscopy method (NIRS) in a ‘Perstorp analytical’, ‘Silver Spring’, MD spectrometer model 5000, attached to a microcomputer equipped with software ISI version 4.1 (‘Infrasoft International University’, Park, PA) from Embrapa Beef Cattle, in Campo Grande-MS. Reading was performed using the wavelengths of 1,100 to 2,500 nanometers. The estimates of the following traits were obtained: a) percentage of organic matter (OM); b) percentage of crude protein (CP); c) percentage of neutral detergent fiber (NDF); d) percentage of acid detergent fiber (ADF); e) dry matter digestibility *in vitro*, in percentage (DMDIV); f) percentage of cellulose (CEL); and g) percentage of silica (SIL).

Statistical analyzes

The analysis of variance was performed based on the average of the plots for each of the traits described above, considering all effects fixed except block and experimental error (fixed model). The following statistical model was adopted: $Y_{ij} = \mu + G_i + B_i + \varepsilon_{ij}$, where: Y_{ij} = observed value of the i-th hybrid combination (or genotype) in the j-th block; μ = overall mean; G_i = effect of the i-th hybrid combination (or genotype); B_i = effect of the j-th block; and ε_{ij} = experimental error.

The associations between the pairs of traits were obtained by the estimates of phenotypic, genotypic, and residual coefficients of correlation. Canonical correlations were utilized based on the genotypic correlations to estimate the maximum correlation between linear combinations of traits distributed in two groups: (I) Morpho-agronomic traits: PDMY, LDMY, SDMY, LSR, HGT, NT, and SD; (II) and chemical traits: OM, CP, NDF, ADF, and DMDIV. The weighting coefficients of the traits in each linear combination were also estimated. A canonical correlation is calculated when the relationship between linear combinations X_1 and Y_1 is maximized, where $X_1 = a_1x_1 + a_2x_2 + ... + a_px_p$; and $Y_1 = b_1y_1 + b_2y_2 + ... + b_qy_q$, (Cruz et al., 2012). It is estimated from the following matrices: R_{11}= p × q, correlation matrix between the traits of group I; R_{22}= p × q, correlation matrix between the traits of group II; and R_{12}= p × q, correlation matrix between the traits of groups I and II. Inferences were made on the canonical pairs associated with significant canonical correlations by statistic χ^2 at 1% probability. All statistical analyses were conducted using the GENES computer software (Cruz, 2013).

Conclusion

The environmental component exerted less influence on the relationship between the two sets of characteristics than on the characteristics within each set, in isolation. Plants with high dry matter yield in whole plant, the leaf or stem and with intense tillering tended to have lower levels of crude protein. Plants of larger diameter tended to present lower percentages of fiber and cellulose and greater *in vitro* dry matter digestibility. In general, triploid interspecific hybrids between elephant grass and millet presented a morpho-agronomic and bromatological pattern characterized by plants with high dry matter yield and with high percentage of cellulose.

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