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Effect of nitrogen and potassium fertilizations on elephant grass genotypes used for energy purposes in Northern Rio de Janeiro State, Brazil

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Similar to many other human activities, the energy sector has a global concern with environmental issues. The use of renewable energy sources such as biomass is an alternative to the use of fossil fuels. Eight elephant grass genotypes showing energy production potential were herein assessed. The genotypes were grown from February 2014 to March 2016 in Campos dos Goytacazes County – Rio de Janeiro State, Brazil. They were fertilized with three different nitrogen doses (400, 1000 and 1600 kg N ha^{-1}) and two potassium doses (200 and 500 kg K_2O ha^{-1}). The experiment followed a randomized block design, with three repetitions, using a split-plot factorial scheme. The aim of the current study was to assess the effect of different nitrogen and potassium doses in fertilizing different genotypes of elephant grass by analyzing the morphoagronomic traits. The lowest K dose (200 kg ha^{-1}) was enough to generate the best outcomes in characteristics presenting significant effects. The N increase in the fertilization process did not promote dry matter production gains. The lowest N dose (400 kg ha^{-1}) was enough to promote the highest values. As for the other traits assessed in the current study, although there was a genotype that showed statistically significant difference from any other genotype at a particular dose, the increasing N doses in the fertilization did not influence the performance of the genotypes.

Key words: Renewable energy, biomass, mineral nutrients, *Pennisetum purpureum* Schum.

INTRODUCTION

Fossil fuels such as coal, oil and natural gas are non-renewable, as well as environmentally damaging energy sources due to their formation (millions of years), consumption rates and polluting potential. They release CO_2 in the atmosphere during their extraction process. The price raise and the negative environmental impacts of the use of fossil fuels have reinforced the interest in using renewable forms of alternative energy. Extensive studies on bioenergy indicate that biomass conversion into energy is an important alternative, since it is a renewable source. Biomass is considered a CO_2 neutralizer because the carbon dioxide released during its combustion is recaptured by the new biomass growth. Thus, biomass is the only alternative energy source able to produce liquid, solid and gaseous fuels to replace the fossil ones (Simacek, 2008; Ohimain et al., 2014; Oliveira, et al., 2015b).

Elephant grass is a perennial C4-metabolism poaceae acknowledged as energy crop due to its advantages: fast growth, disease resistance, adaptability, little handling and easy propagation (Tsai, 2009). In addition, it is highly efficient in fixing the CO_2 from the atmosphere and has the potential to be used in biofuel production or in direct combustion (Rossi et al., 2014).

Nitrogen (N) and potassium (K) stand out among the macronutrients because of the key role they play in plant nutrition. Nitrogen is an essential constituent of proteins and it directly interferes in the photosynthetic process due to its participation in the chlorophyll molecule. Potassium is the cation showing the highest concentration in plants; this nutrient has relevant physiological and metabolic functions such as enzyme activation, photosynthesis and translocation of assimilates, as well as nitrogen uptake and protein synthesis. Thus, nitrogen and potassium are limiting factors for systems that make intensive use of cultivated soils (Taiz and Zeiger, 2012).

Nitrogen fertilization is the main N addition vehicle and one of the most important inputs in agricultural systems due to its increased performance in plant productivity (Lopes, 2007). Since elephant grass is a high productivity species, it is worth considering that its nutrient requirements are related to the production potential of cutting-system crops. According to Mistura et al. (2006), elephant grass responds to increasing nitrogen levels. The authors also highlight that potassium fertilization is of great importance, mainly when the plant is grown in cutting systems. Potassium removal due to plant cutting and transportation to other areas, other than the production site, often results in major nutritional imbalance issues in the soil.

The aim of the current study is to assess eight genotypes of elephant grass (Cubano Pinda, Vruckwona, IAC-Campinas, Capim Cana D'África, Cameroon, CPAC, IJ 7139 and BAG-86) with energy potential subjected to three nitrogen doses (N1= 400, N2 = 1000 and N3 = 1600 kg N ha^{-1}) and to two potassium doses (K1 = 200 and K2 = 500 kg K_2O ha^{-1}), under the soil and climate conditions of Campos dos Gotacazes in the Northern region of Rio de Janeiro State, by analyzing the morphoagronomic traits.

MATERIALS AND METHODS

Location and experimental design

The experiment was conducted at the Agro-Energy and Waste Utilization State Research Center of PESAGRO located in Campos dos Goytacazes County-RJ, Brazil (latitude 21° 44' 43'' S; longitude 41° 18' 29'' W; 10 m altitude; datum WGS84). The climate in the region is hot and humid, and the mean annual temperature is 22.7°C. The results of the soil analysis conducted in the experimental site on January 8th, 2014, were: water pH = 5.7; P = 7 mg dm^{-3}; K = 121 mg dm^{-3}; Ca, Mg, Al, H + Al and Na = 3.8, 2.5, 3.6 and 0.1 cmol dm^{-3}; CEC = 10.2; and organic matter = 26.5 g dm^{-3}.

The experiment was arranged in a randomized block design with three repetitions, according to a split-plot factorial scheme comprising three factors: Factor 1 (plots): genotypes - 8 clones; Factor 2: N - three doses (400, 1000 and 1600 kg N ha^{-1}); and Factor 3: K - two doses (200 and 500 kg K_2O ha^{-1}) (sub-plots). Each block comprised of 8 plots. The plots corresponded to parallel rows (12 m-long) spaced 1.5 m from each other. Each row was planted with one of the eight genotypes. The plot was divided into 6 sub-plots (2 m each) wherein the treatments corresponding to six N and K doses (400 x 200, 1000 x 200, 1600 x 200, 400 x 500, 1000 x 500 and 1600 x 500 kg ha^{-1} of N x K) combinations were applied. An area of 1.5 m² was used to collect the samples to be analyzed through laboratory procedures, the central length (1.0 m) of each sub-plot was taken into account.

The experiment was conducted on February 12th, 2014. The soil was conventionally prepared using a harrowing grid and cultivation furrows (10 cm-deep) were opened. Culm fragments were arranged with 100 kg ha^{-1} of simple superphosphate (P_2O_5) within the furrows, in a single row. Thirty days after the planting, 25 kg ha^{-1} of urea (CH_4N_2O) and potassium chloride (KCl) were applied to the furrows.

The genotypes used in the experiment came from the Active Elephant Grass Germplasm Bank (AEG GB) of Norte Fluminense Darcy Ribeiro State University, located in Campos do Goytacazes County – RJ, Brazil. The genotypes were selected through visual analysis based on late flowering. Such property is desirable for long-term elephant grass cultivation aiming at dry matter production. The following genotypes were selected: Cubano Pinda (G1), Vruckwona (G2), IAC-Campinas (G3), Capim Cana D'África (G4), Cameroon (G5), CPAC (G6), IJ 7139 (G7) and BAG-86 (G8).

The standadized cut was performed in the culm base on March 29th, 2014 (45 days after planting) in order to enable the uniform growth of the shoots. Two assessment cycles were held (two cuts after a year of growth). The fertilization was split in 6 applications in each assessment cycle, according to the rainfall. The first

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assessment cut took place on March 10th, 2015 and the second one, on March 15th, 2016. The experiment was conducted under natural conditions, without irrigation.

The following morphoagronomic traits were assessed before each cut: number of tillers per meter (NT), which were found by counting the number of tillers in the 1.5 m² area of the sub-plot; mean plant height (H), based on the mean height of the plants in the sub-plot, expressed in m and measured using a graduated scale; mean culm diameter (CD), expressed in cm and measured 10 cm from the ground level, using a digital caliper; mean leaf blade width (LBW), expressed in cm, based on the mean width of the center of three leaves.

The collected samples were fractionated, packed in paper bags and weighed after cutting. Subsequently, they were dried in a forced air circulation oven at 65°C. Seventy-two (72) hours later, the samples were removed in order to be weighed and to obtain air-dried samples (ADS). The ADSs were ground in Wiley mill (2 mm sieve). Two grams (2 g) of it were dried in an oven at 105°C, for 16 h, and then weighed in order to obtain the oven-dried samples (ODS). The dry matter rate DMR was estimated through the ratio between the ADS and ODS values. The dry matter production (DMP) resulted from the product between fresh matter production and DMR, and it was converted to t ha^{-1}.

Statistical analysis

The statistical analyses were performed in the Genes software (Cruz, 2013). The variance analysis of the traits assessed in the statistical randomized block design used the following statistical model, according to a split-plot factorial design:

$$Y_{ijkl} = \mu + B_l + G_i + \varepsilon_a + N_j + G_iN_j + K_k + G_iK_k + N_jK_k + G_iN_jK_k + \varepsilon_b$$

Where, Y_{ijkl} = value of the i^{th} genotype, at the j^{th} nitrogen dose, at the k^{th} potassium dose and in the l^{th} block; μ = overall mean of the experiment; G_i = effect of the i^{th} genotype; B_l = effect of the l^{th} block; ε_a = effect of the error a, associated with the i^{th} genotype in the $l\text{-}^{th}$ block; N_j = effect of the $j\text{-}^{th}$ nitrogen dose; G_iN_j = effect of the interaction between the i^{th} genotype and the j^{th} nitrogen dose; K_k = effect of the k^{th} potassium dose; G_iK_k = effect of the interaction between the i^{th} genotype and the k^{th} potassium dose; N_jK_k = effect of the interaction between the j^{th} nitrogen dose and the k^{th} potassium dose; $G_iN_jK_k$ = effect of the interaction between the i^{th} genotype and the j^{th} nitrogen dose and the k^{th} potassium dose; ε_b = effect of the error b, associated with the i^{th} genotype, with the j^{th} nitrogen dose and with the k^{th} potassium dose in the l^{th} block.

A multiple comparison test was conducted in order to study the contrasts between the means of the N factor within the K factor after the individual variance analysis, according to Tukey's method, at 5% significance level.

RESULTS AND DISCUSSION

The G factor had no effect ($P > 0.05$) on any of the traits assessed in the two cuts. Only the N factor had effect on the DMP trait in the first year of the experiment, whereas all factors (except for the G factor) and interactions had effect on the DMP trait in the second year of the experiment. Only the N factor had statistically significant effect on the DMR trait in the first year of experiment. Only the interaction between K and N had effect on the NT trait, in the second cut. Only the N factor had effect on the H trait, in the first cut; and on the CD trait, in the second year of experiment. Only the interaction between K and G had significant effect on the LBW trait, in the first year of experiment.

High coefficients of variation (CV) were found in most variables. According to Pimentel-Gomes (2000), the CV values cannot be standardized for all cultures since each culture has its own peculiarities, depending on the assessed traits. Thus, these values may be acceptable since the studied traits are ruled by many genes, as well as strongly influenced by the environment.

There was also the option of conducting a study focused on the effects of the N levels within K as it is a tipical procedure in experiments based on the factorial scheme. According to such scheme, a factor must be assessed in constrast to the other one. However, with regard to the characteristic wherein K has presented significant effect, either alone or in interaction, it was observed that the lowest K dose (200 kg ha^{-1}) was enough to genetrate the best outcomes.

Table 1 shows that, according to the Tukey's test ($P < 0.05$), there was statistically significant difference between at least two genotypes in traits such as DMP, DMR and CD at doses N3, N1 and N3, respectively, in the second cut; and between genotypes of the LBW trait, at doses N1 and N3, in the first cut. There was no statistically significant difference between genotypes in the other traits, in their respective cuts.

As for the DMP trait, at dose K2N3, only the G2 genotype (Vruckwona) differed from the lowest mean observed in the second cut. Most genotypes showed DMP values at minimum N dose (600 kg ha^{-1}) higher than those found at the maximum dose (1600 kg ha^{-1}) in both cuts. Similar results were found by Novo (2015), who applied increasing N and K_2O doses to 3 genotypes of elephant grass for two years in Bom Jesus do Itabapoana and found high DMP estimates at minimum N dose (100 kg ha^{-1}). By analyzing both cuts, it was observed that the means ranged from 26.70 to 59.81 t ha^{-1}. These values were similar to those found by Oliveira et al. (2014), who used the same genotypes used in the current study and observed variation from 27.38 to 47.70 t ha^{-1}, in the first cut, and from 25.64 to 51.81 t ha^{-1}, in the second one.

The PMS values found in the present study, which varied from 24 to 48.15 (Cubano Pinda); from 23.63 to 59.81 (Vruckwona); 28.38 to 51.86 (IAC-Campinas); 22.65 to 51.94 (Capim Cana D'África); 26.91 to 46.04 (Cameroon); 22.93 to 50.70 (CPAC); 24.45 to 57.78 (IJ 7139) and 21.22 to 43.48 (BAG-86) kg ha^{-1}, were similar to or higher than the outcomes found by Oliveira et al. (2015a). They worked with 6 elephant grass genotypes grown under increasing N doses (cut at 9 month old) in Campos dos Goytacazes – RJ, Brazil and found mean PMS values varying from 17.61 to 57.65 t ha^{-1}.

Table 1. Mean values of the morphoagronomic traits assessed in eight genotypes of elephant grass grown for energy production purposes for two years and treated with nitrogen (400, 1000 and 1600 kg ha^{-1}) and potassium (200 and 500 kg ha^{-1}) doses; Campos dos Goytacazes – RJ.

	GEN	**Cut 1**						**Cut 2**					
		K1			**K2**			**K1**			**K2**		
		N1	**N2**	**N3**	**N1**	**N2**	**N3**	**N1**	**N2**	**N3**	**N1**	**N2**	**N3**
DMP	G1	31.18^{a}	27.43^{a}	27.36^{a}	39.22^{a}	28.96^{a}	23.99^{a}	47.26^{a}	32.85^{a}	31.85^{a}	30.40^{a}	48.15^{a}	40.38^{ab}
	G2	30.80^{a}	39.63^{a}	24.19^{a}	35.91^{a}	42.65^{a}	23.63^{a}	49.55^{a}	55.13^{a}	35.28^{a}	55.13^{a}	36.29^{a}	59.81^{a}
	G3	40.49^{a}	28.38^{a}	35.91^{a}	38.68^{a}	31.02^{a}	34.07^{a}	51.86^{a}	48.63^{a}	41.64^{a}	43.54^{a}	45.45^{a}	29.36^{b}
	G4	28.72^{a}	30.73^{a}	22.65^{a}	33.70^{a}	27.46^{a}	33.11^{a}	41.55^{a}	30.26^{a}	41.80^{a}	51.94^{a}	41.54^{a}	35.02^{ab}
	G5	31.25^{a}	32.73^{a}	27.70^{a}	44.23^{a}	26.91^{a}	28.90^{a}	31.62^{a}	29.32^{a}	46.04^{a}	29.20^{a}	42.05^{a}	42.44^{ab}
	G6	35.05^{a}	31.09^{a}	24.31^{a}	37.77^{a}	22.93^{a}	29.20^{a}	34.70^{a}	47.70^{a}	46.74^{a}	50.70^{a}	45.74^{a}	29.81^{b}
	G7	35.46^{a}	31.14^{a}	24.45^{a}	36.97^{a}	33.56^{a}	44.61^{a}	57.78^{a}	35.78^{a}	49.24^{a}	55.10^{a}	29.70^{a}	26.02^{b}
	G8	26.70^{a}	36.32^{a}	26.24^{a}	39.22^{a}	28.96^{a}	23.99^{a}	40.06^{a}	43.34^{a}	21.22^{a}	36.07^{a}	29.22^{a}	38.43^{ab}
DMR	G1	29.66^{a}	27.98^{a}	26.89^{a}	29.38^{a}	28.80^{a}	23.31^{a}	41.53^{a}	33.39^{a}	32.64^{a}	27.73^{b}	36.09^{a}	35.63^{a}
	G2	31.57^{a}	28.23^{a}	27.23^{a}	29.54^{a}	27.39^{a}	25.83^{a}	41.54^{a}	36.99^{a}	38.05^{a}	36.99^{ab}	30.50^{a}	35.66^{a}
	G3	30.05^{a}	28.29^{a}	29.17^{a}	31.02^{a}	27.76^{a}	29.73^{a}	37.86^{a}	39.02^{a}	35.01^{a}	37.70^{ab}	34.65^{a}	32.55^{a}
	G4	32.68^{a}	23.69^{a}	24.00^{a}	27.50^{a}	27.28^{a}	25.32^{a}	38.75^{a}	31.16^{a}	40.11^{a}	38.66^{ab}	33.42^{a}	35.57^{a}
	G5	28.75^{a}	25.26^{a}	27.30^{a}	33.22^{a}	27.21^{a}	25.07^{a}	33.49^{a}	35.11^{a}	36.06^{a}	30.52^{ab}	37.98^{a}	35.16^{a}
	G6	30.59^{a}	26.85^{a}	26.61^{a}	31.58^{a}	24.14^{a}	24.19^{a}	33.79^{a}	39.22^{a}	37.93^{a}	35.74^{ab}	33.58^{a}	35.61^{a}
	G7	32.30^{a}	24.38^{a}	23.78^{a}	26.27^{a}	27.67^{a}	37.97^{a}	35.28^{a}	35.85^{a}	36.68^{a}	45.59^{a}	29.90^{a}	31.90^{a}
	G8	28.66^{a}	29.81^{a}	29.51^{a}	29.30^{a}	28.78^{a}	28.43^{a}	40.05^{a}	34.19^{a}	30.75^{a}	38.52^{ab}	34.37^{a}	33.58^{a}
NT	G1	27.66^{a}	25.66^{a}	30.66^{a}	34.00^{a}	35.00^{a}	26.66^{a}	35.00^{a}	33.33^{a}	35.33^{a}	38.33^{a}	50.00^{a}	36.66^{a}
	G2	22.33^{a}	40.66^{a}	29.66^{a}	30.00^{a}	40.66^{a}	34.00^{a}	47.66^{a}	48.66^{a}	34.66^{a}	48.66^{a}	42.33^{a}	47.66^{a}
	G3	41.00^{a}	29.66^{a}	39.33^{a}	32.33^{a}	31.33^{a}	28.66^{a}	37.66^{a}	38.66^{a}	43.66^{a}	42.66^{a}	40.33^{a}	29.33^{a}
	G4	23.66^{a}	37.33^{a}	34.00^{a}	32.66^{a}	31.66^{a}	34.66^{a}	39.66^{a}	36.66^{a}	47.33^{a}	47.33^{a}	46.33^{a}	36.00^{a}
	G5	33.00^{a}	37.66^{a}	29.33^{a}	31.66^{a}	30.33^{a}	31.33^{a}	33.66^{a}	29.33^{a}	38.66^{a}	30.00^{a}	44.00^{a}	28.66^{a}
	G6	37.00^{a}	31.33^{a}	23.66^{a}	38.00^{a}	30.66^{a}	40.00^{a}	24.33^{a}	38.66^{a}	48.00^{a}	39.33^{a}	49.00^{a}	35.66^{a}
	G7	27.66^{a}	40.33^{a}	30.66^{a}	33.00^{a}	35.00^{a}	35.66^{a}	40.66^{a}	33.66^{a}	44.33^{a}	42.00^{a}	33.33^{a}	32.00^{a}
	G8	24.66^{a}	42.00^{a}	27.66^{a}	31.33^{a}	46.33^{a}	29.66^{a}	37.33^{a}	38.33^{a}	28.33^{a}	36.00^{a}	37.00^{a}	38.33^{a}
H	G1	3.25^{a}	3.43^{a}	3.35^{a}	3.20^{a}	3.35^{a}	3.43^{a}	3.08^{a}	2.96^{a}	2.98^{a}	3.06^{a}	2.90^{a}	3.06^{a}
	G2	3.40^{a}	3.33^{a}	3.31^{a}	3.35^{a}	3.31^{a}	3.40^{a}	2.96^{a}	3.06^{a}	2.93^{a}	3.06^{a}	3.06^{a}	3.10^{a}
	G3	3.13^{a}	3.23^{a}	3.28^{a}	3.30^{a}	3.43^{a}	3.36^{a}	3.08^{a}	3.05^{a}	3.16^{a}	3.05^{a}	3.06^{a}	3.06^{a}
	G4	3.26^{a}	3.31^{a}	3.35^{a}	2.83^{a}	3.33^{a}	3.41^{a}	3.05^{a}	3.00^{a}	2.86^{a}	3.10^{a}	3.03^{a}	3.05^{a}
	G5	3.30^{a}	3.23^{a}	3.50^{a}	3.33^{a}	3.41^{a}	3.41^{a}	3.06^{a}	3.06^{a}	3.26^{a}	3.15^{a}	3.03^{a}	3.05^{a}
	G6	3.13^{a}	3.43^{a}	3.46^{a}	3.30^{a}	3.23^{a}	3.38^{a}	3.00^{a}	2.96^{a}	2.96^{a}	2.98^{a}	3.06^{a}	2.96^{a}
	G7	3.10^{a}	3.21^{a}	3.40^{a}	3.36^{a}	3.30^{a}	3.38^{a}	3.03^{a}	3.08^{a}	3.06^{a}	3.13^{a}	3.00^{a}	2.96^{a}

Table 1. Contd.

	GEN	Cut 1						Cut 2					
		K1			K2			K1			K2		
		N1	N2	N3	N1	N2	N3	N1	N2	N3	N1	N2	N3
	G8	3.25^{a}	3.31^{a}	3.46^{a}	3.26^{a}	3.26^{a}	3.58^{a}	3.00^{a}	2.86^{a}	2.88^{a}	3.01^{a}	2.98^{a}	3.01^{a}
CD	G1	1.57^{a}	1.87^{a}	1.66^{a}	1.70^{a}	1.67^{a}	1.76^{a}	1.76^{a}	1.73^{a}	1.64^{b}	1.80^{a}	1.82^{a}	1.63^{a}
	G2	1.63^{a}	1.91^{a}	1.76^{a}	1.56^{a}	1.53^{a}	1.52^{a}	1.84^{a}	1.86^{a}	2.23^{a}	1.86^{a}	1.98^{a}	1.75^{a}
	G3	1.72^{a}	1.69^{a}	1.73^{a}	1.68^{a}	1.59^{a}	1.65^{a}	1.69^{a}	1.67^{a}	1.69^{b}	1.58^{a}	1.71^{a}	1.68^{a}
	G4	1.61^{a}	1.61^{a}	1.79^{a}	1.65^{a}	1.62^{a}	1.71^{a}	1.73^{a}	1.59^{a}	1.63^{b}	1.70^{a}	1.46^{a}	1.67^{a}
	G5	1.68^{a}	1.67^{a}	1.62^{a}	1.67^{a}	1.68^{a}	1.73^{a}	1.55^{a}	1.63^{a}	1.61^{b}	1.45^{a}	1.62^{a}	1.53^{a}
	G6	1.43^{a}	1.71^{a}	1.80^{a}	1.69^{a}	1.75^{a}	1.71^{a}	1.61^{a}	1.52^{a}	1.79^{b}	1.69^{a}	1.76^{a}	1.49^{a}
	G7	1.61^{a}	1.60^{a}	1.70^{a}	1.59^{a}	1.66^{a}	1.58^{a}	1.67^{a}	1.77^{a}	1.62^{b}	1.90^{a}	1.77^{a}	1.40^{a}
	G8	1.58^{a}	1.71^{a}	1.84^{a}	1.75^{a}	1.63^{a}	1.72^{a}	1.73^{a}	1.56^{a}	1.55^{b}	1.59^{a}	1.70^{a}	1.73^{a}
LBW	G1	6.60^{ab}	6.00^{a}	6.03^{ab}	5.80^{a}	6.20^{a}	6.30^{a}	5.03^{a}	5.26^{a}	5.16^{a}	5.10^{a}	5.00^{a}	5.20^{a}
	G2	6.06^{ab}	5.50^{a}	6.00^{ab}	6.03^{a}	6.50^{a}	6.00^{a}	4.96^{a}	4.93^{a}	5.13^{a}	4.93^{a}	5.16^{a}	5.26^{a}
	G3	7.06^{a}	6.33^{a}	6.13^{ab}	6.33^{a}	5.50^{a}	6.16^{a}	5.30^{a}	5.10^{a}	5.06^{a}	5.20^{a}	5.10^{a}	5.13^{a}
	G4	6.50^{ab}	6.33^{a}	7.00^{a}	6.16^{a}	5.90^{a}	5.83^{a}	5.10^{a}	5.03^{a}	5.03^{a}	4.96^{a}	5.00^{a}	5.06^{a}
	G5	5.96^{ab}	5.66^{a}	5.83^{ab}	6.16^{a}	5.66^{a}	5.83^{a}	5.13^{a}	5.06^{a}	5.13^{a}	5.06^{a}	5.16^{a}	5.00^{a}
	G6	5.83^{b}	6.16^{a}	6.00^{ab}	5.66^{a}	5.66^{a}	6.13^{a}	4.96^{a}	5.13^{a}	5.20^{a}	5.10^{a}	5.10^{a}	5.23^{a}
	G7	5.83^{b}	5.83^{a}	6.00^{ab}	6.10^{a}	6.16^{a}	6.00^{a}	5.06^{a}	5.16^{a}	5.16^{a}	5.10^{a}	5.23^{a}	5.23^{a}
	G8	6.00^{ab}	6.50^{a}	5.66^{b}	5.36^{a}	6.06^{a}	6.33^{a}	5.06^{a}	5.10^{a}	5.23^{a}	4.90^{a}	5.23^{a}	5.30^{a}

Means followed by the same letter in the column do not statistically differ from each other, according to the Tukey's test, at 5% probability. DMP = total plant dry matter production in t ha^{-1}; DMR = total dry matter rate; NT = number of tillers linear m^{-1}; H = mean plant height in meters; CD = mean culm diameter in centimeters; LBW = mean leaf blade width in centimeters.

Only the G7 genotype (IJ7139) at dose K2N1 differed from the lowest mean observed (G1) in the second assessment cut in the DMR trait. The general mean of such trait in the two cuts was 28.13 and 35.67%, respectively, and the values ranged from 23.31 to 37.97% and from 27.73 to 45.59% in the first and second assessment cycles, respectively. The herein observed values were above those reported by Santos et al. (2014), who assessed three genotypes of elephant grass used for energy purposes, 180 days after fertilization with nitrogen (500 and 1000 kg ha^{-1} of N) in Alegre County - ES, Brazil. They found mean DMR 24.8%, values ranging from 23.29 to 25.77%. Oliveira et al. (2015a) found mean values ranging from 25.77 to 35.36%. These values were corroborated by the present study wherein mean values from 26.75 to 36.63% were found between the two assessment cycles.

The general mean of the NT trait was 32.74% in the first cut, and 38.85% in the second one. The lowest mean of the G2 genotype (Vruckwona) at dose K1N1 in the first assessment cycle was 22.33%, and the highest mean of the G1 genotype (Cubano Pinda) at dose K2N2 was 50.00% (Table 1). There was no statistically significant difference between genotypes in the N level assessment within K1 and K2; however, the outcomes were equal to or even higher than those found in studies that have demonstrated the high productive potential of elephant grass. Oliveira et al. (2013) assessed the morpho-agronomic traits of the energy biomass from 73 genotypes of elephant grass in two cuts, after six months of growth in Campos dos Goytacazes - RJ. They found mean NT values of 29.5, 28.5, 26.5, 32 and 23 tillers per linear meter' in genotypes such as Cubano Pinda, Vruckwona, Cameroon, IJ 7139 and Capim Cana D'África, respectively. According to Daher et al. (2004), the NT trait has direct effect on DMP, and it is highly desirable in genotypes used in bioenergy production. Menezes et al. (2014) found direct positive correlation between NT and DMP, and indirect positive correlation between H and DMP. Thus, when the aim is to increase the DMP, as in the case of the elephant grass used to increase biomass energy, it is possible to select high-tillering plants, because they may have increased H and, consequently, high DMP.

With respect to H, the genotypes did not differ from each other when they were subjected to different N levels within K. The general mean height was 3.32 and 3.03 m in the first and second assessment cycles, respectively. The lowest height (2.86 m) was found in the G8 genotype (BAG-86) at dose K1N2 in the second cut. The highest height (3.50 m) was found in the G5 genotype (Cameroon) at dose K1N3 in the first cut. The H trait was important because it was directly correlated with dry matter production (Xia et al., 2010; Menezes et al. 2014). These values are different from those found by Oliveira et al. (2015a), who found mean H 3.54 m when they assessed six genotypes of elephant grass grown under increasing N doses and cut at 9 months of age in Campos dos Goytacazes – RJ.

However, these results are similar to those found by Novo (2015), who obtained general mean H 3.04 m, and individual H means ranging from 2.79 to 3.19 m in elephant grass genotypes subjected to fertilization using increasing N and K_2O doses.

With respect to the CD trait, the G2 genotype (Vruckwona) at dose K1N3 differed from the other genotypes in the second cut, and presented 2.23 cm CD. The general means were 1.68 and 1.69 cm in the first and second cuts, respectively. These values corroborate those found by Rossi et al, (2014), who assessed the morphoagronomic traits of 40 genotypes of elephant grass in Campos dos Goytacazes - RJ. The authors found general CD genotype mean of 1.72 cm in 11-month-old plants, in the third cut. However, Santos et al. (2014) reported higher CD values in the second assessment cut in 300 day-old plants. They found means of 1.80 and 1.78 cm in genotypes subjected to N doses of 500 and 1000 kg ha^{-1}, respectively. On the other hand, the CD outcomes in the present study are above those found by Oliveira et al. (2015a), who found mean value of 1.59 cm, ranging from 1.27 to 1.83 cm for the herein described characteristic in 6 genotypes of elephant grass assessed for energy purposes at the age of 9 months. The culm diameter showed positive correlation with dry matter production (Xia et al., 2010) and it had direct effect on such trait (Daher et al., 2004).

The LBW trait is concerned the leaf area used to capture sunlight and, consequently, its photosynthetic capacity. The general LBW means observed in the first and second cuts were 6.06 and 5.11 cm, respectively. Two genotypes shown values above the average. The G3 genotype (IAC-Campinas) has shown mean LBW 7.06 cm at dose K1N1. The G4 genotype (Capim Cana D'África) has shown mean LBW 7.00 cm at dose N3K1. These values are different from those found by Rossi et al. (2014), who reported mean LBW 3.95 cm in 11-month-old genotypes; and also from those observed by Oliveira et al. (2015a), who reported mean LBW 4.71 cm in genotypes fertilized with increasing N doses.

Conclusions

Overall, the genotypes did not differ from each other when they were assessed for biomass production potential. The lowest K dose (200 kg ha^{-1}) was enough to generate the best results in characteristics that presented significant effect. The fertilization with increased N amounts did not promote DMP gains, and the lowest N dose (400 kg ha^{-1}) was sufficient to promote the highest values.

Likewise, as for the other traits assessed in the current study, although there was a genotype that showed statistically significant difference from any other genotype at a particular dose, the increasing N doses in the fertilization did not influence the performance of the genotypes. However, the results were consistent and met the expectations of energy production potential, since they assured the use of eight elephant grass genotypes as alternative biomass production sources.

Conflict of Interests

The authors have not declared any conflict of interests.

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