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Effect of Nitrogen and Potassium Fertilization Doses on Elephant-Grass Genotypes for Energy Purposes

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Abstract

In view of the current global energy landscape, to develop alternative energy mechanisms to the oil has become essential. For that, biomass as well as the use of elephant-grass present themselves as attractive choices for energy purposes. That culture has a high growth prospect, as it contains characteristics such as high production, biomass quality, and high photosynthetic capacity. The purpose of this work was to assess the response of eight elephant-grass genotypes to nitrogen and potassium fertilization from the evaluation of morpho-agronomic traits. It was used a randomized block experimental design with three replications in the factorial scheme within a subdivided plot composed of principal factor (plots): genotypes and secondary components (subplots): potassium (2 levels) × nitrogen (3 levels)—200 × 400, 200 × 1000, 200 × 1600, 500 × 400, 500 × 1000, and 500 × 1600 kg ha^{-1}. There was an adjustment of first degree linear model of the regression for all traits in at least one genotype. For DMP, the Capim Cana D'África, CPAC, and IJ 7139 genotypes indicated an inversely proportional response to the increasing of N in the fertilization. The response according to the N increasing in the fertilization was directly proportional for the CPAC genotype in relation to the NP, and for the Cana D'África, CPAC, and IJ 7139 genotypes in relation to the ALT. For SD, the CPAC and Vruckwona genotypes showed a positive effect on the increasing doses of N, and the IJ 7139 genotype, a negative correlation. The results are quite promising and ensure the use of the eight elephant-grass genotypes as an alternative source for biomass production.

Keywords: bioenergy, linear regression, morpho-agronomic traits, *Pennisetum purpureum* Schum.

1. Introduction

The use of vegetal biomass to produce energy has been of great interest to the researchers, as it is an excellent alternative to the excessive burning of fossil fuels, to combat climate changes and environmental imbalances generated by the high rate of greenhouse gas emissions during the burning. Given that, the elephant-grass has stood out as one of the main species to produce biomass for energy purposes (Morais, Quesada, Reis, Urquiaga, Alves, & Boddey, 2011), as it produces large amount of biomass and quality to turn it into bioenergy. Those traits when associated to others, such as fiber contents, lignin, and to the relation C:N make this culture an excellent alternative energy source (Mohammed et al., 2015).

For the past years, the elephant-grass biomass has been subject of study, focusing on its utilization as solid fuel, due to its high potential to produce renewable energy and the possibility to be used as an energy renewable source. That is because of its shorter development cycle and its capacity to produce double tones of dry biomass per hectare yearly, when compared to the Eucalyptus, which is the main source used to generate energy by direct combustion (Mckendry, 2002; Marafon, Camara, Santiago, & Rangel, 2010).

By contrast, together with its high productive potential, the elephant-grass culture has a high nutrient extraction from the soil, such as N, K, Ca, and S due to its high dry matter production (Santos et al., 2012).

Nitrogen is an essential constituent of proteins, which participates in the photosynthetic process and plant development concerning height and tiller number; consequently, it contributes to the increasing of the dry matter production of the culture (Bonfim-da-Silva & Monteiro, 2006). According to Oliveira et al. (2015), the elephant grass crop presents high potential to produce biomass, according to the nitrogen fertilization, in order to meet the growing demand for energy.

Potassium is the cation with the highest concentration in plants and shows relevant physiologic and metabolic functions, such as enzyme activation, photosynthesis, assimilate translocation, nitrogen absorption, and protein synthesis, thus, becoming limiting in systems with intensive use of cultivated soils (Andrade, Fonseca, Queiroz, Salgado, & Cecon, 2003). This way, nitrogen and potassium play a fundamental role for an adequate fertilization program for the elephant-grass culture.

The nitrogen fertilization is one of the components that most demand energy in agriculture and cattle production, able to achieve up to 50% of all energy consumed in the agriculture steps of a production system. Thus, the ideal is to produce biomass with high fiber, lignin and cellulose contents, high dry matter production, and low consume of nitrogen fertilizers to this plant provides quality biomass for energy purposes and its energy yield is significantly positive (Borges, Aquino, & Evangelista, 2016). There are numerous reports in literature about the effects of nitrogen fertilization in elephant-grass; also, strong effects increasing diverse traits, such as dry matter, crude protein, leaf/stem relation, number of tillers, plant height, among others have been shown (Cruz et al., 2010; Santos et al., 2014; Oliveira et al., 2015; Almeida et al., 2016; Novo et al., 2016). However, in order that those effects are evident, there is the need that other factors are not limiting the plant growth, such as climate, soil, vegetation, and others.

The purpose of this work is to assess the effect of different doses of nitrogen and potassium fertilization in morpho-agronomic traits of elephant-grass genotypes in edaphoclimatic conditions in Campos dos Goytacazes city, Rio de Janeiro state, Brazil.

2. Material and Methods

The experiment was conducted in an agreement area between the Centro Estadual de Pesquisas em Agroenergia e Aproveitamento de Resíduos, PESAGRO, Rio (Agroenergy and Waste Management State Research Center) and the Universidade Estadual do Norte Fluminense Darcy Ribeiro, UENF (State University of North Fluminense Darcy Ribeiro) located in Campos dos Goytacazes city. The climate is classified as Aw type, tropical hot and humid, with dry season in winter, rainy season in summer and annual precipitation around 1,152 mm (Köppen, 1948).

The soil is characterized as a yellow latosol soil (Brazilian public agricultural research corporation [Embrapa], 2013) by the following chemical composition: pH 5.7; phosphorus 7.0 mg dm^{-3}; potassium 121 mg dm^{-3}; calcium 3.8 cmol$_c$ dm^{-3}; magnesium 2.5 cmol$_c$ dm^{-3}; aluminum 0.0 cmol$_c$ dm^{-3}; hydrogen + aluminum 3.6 cmol$_c$ dm^{-3}.

The accessions used in the experiment were selected for presenting superior traits in terms of biomass generations. Genotypes Cubano Pinda (G1), Vruckwona (G2), IAC-Campinas (G3), Capim Cana D'África (G4), Cameroon (G5), CPAC (G6), IJ 7139 (G7), and BAG-86 (G8) were used.

The experiment used randomized block design with three replications (blocks), in a split-plot arrangement consisting of two factors: Factor 1 (plots): genotypes—eight clones; Factor 2 (sub-plots): potassium (two levels) × nitrogen (five levels)—200 ×400, 200 × 1000, 200 × 1600, 500 × 400, 500 × 1000, and 500 × 1600 kg ha^{-1} of K × N (six combinations).

Each block was composed of eight lines of 12 m length and spacing 1.5 mm between lines. The plot was composed of one line, each one divided into subplots of 2 m, with a total of six subplots, which received the treatments (six combinations). It was considered 1.5 m^2 within the subplot to remove the samples that would be assessed.

The experiment was conducted on February 12, 2014. The planting chemical fertilization was performed according to the nutritional recommendation for the species and based on the results of the chemical analysis of the soil obtained. During each evaluation cycle, the fertilization was divided into six applications depending on the rainfall. Manual weeding with a hand hoe was chosen to weed between the lines and in the cultivation lines to control invasive plants (Freire et al., 2013).

The plot-leveling cut was made on 03/29/2014 (45 days after planting), the first cut for evaluation was on

03/10/2015 and the second one, on 03/15/2016.

The following morpho-agronomic traits were evaluated:

a) Dry matter production (DMP), estimated by the product of the dry matter production of the whole plant multiplied by the percentage of the green matter of the plant, and the value obtained converted to t ha^{-1};

b) Number of tillers per linear meter (NT) obtained by counting the tillers with height greater than 70 cm contained within the useful area of the sub-subplot just before the evaluation cut;

c) Mean height of the plants (HEI) in m, measured by graduated scale, based on the medium height of the plants in the plot, measured from the soil up to the apex of the upright leaves, just before the evaluation cut;

d) Mean diameter of the stem at the base of plant (DS)—in mm, measured at 10 cm from ground level by means of a digital caliper just before the evaluation cut.

Statistical analyses were performed with the Genes programs (Cruz, 2013).

3. Results and Discussion

With a view to finding a regression model (first degree or Lack of Regression), it was carried out an analysis taking as independent variable the increasing doses of N and, as dependent variables, the morpho-agronomic traits evaluated.

3.1 Dry Matter Yield (DMY)

Regarding Table 1, it could be seen that, only in the second year, there were genotypes that showed statistical significance of regression based on the estimates of mean squares for the regression and deviations of regression applied to DMP. It could also be noted a significant linear effect of first degree in the regression analysis due to the doses of N within K2 (500 kg ha^{-1} of K_2O) for IAC-Campinas (G3), CPAC (G6), and IJ7139 (G7) genotypes with their respective coefficients of determination: 98.26%; 91.58%, and 84.34%.

When assessing the DMP in function of the nitrogen fertilization, Santos et al. (2014) noticed an adjustment of second degree linear model at 5% level significance by means of the F test to show the increasing trend in the dry matter production of the elephant-grass, according to the increasing doses of nitrogen. Likewise, Oliveira et al. (2015), when studying the effect of increasing doses of N in the fertilization of six elephant-grass genotypes, observed an adjustment of second degree linear model for the Cameroon-Piracicaba genotype, which presented maximum production of 57.95 t ha^{-1} for a dosage of 1600 kg ha^{-1} of N.

On the other hand, Figure 1 shows that, for the genotypes in which adjusted regression model was obtained (G4, G6, G7), their highest dry matter production (51.94; 50.70; and 55.10 t ha^{-1}) occurred when applying the lowest dose of N. That is, in general, concerning the dry matter production, it was observed there was a trend for the genotype to respond, in an inversely proportional way, to the increment of N in the fertilization. By performing an analysis of the DMP mean values of the eight genotypes at each dose of N (400, 1000, and 1600 kg ha^{-1}) during the two evaluation years, it was possible to notice the decreasing response of genotypes, which DMP values for N1, N2, and N3 are 34.87; 32.15, and 28.62 t ha^{-1} for the first cut, and 44.15; 40.07, and 38.45 t ha^{-1} for the second cut.

The biomass production capacity is one of the most relevant traits to be assessed in the elephant-grass culture. However, by the results obtained, it could be seen that the goal to achieve higher dry matter production was accomplished when applying the smallest dose of N for fertilization (400 kg ha^{-1}). Those results confirm the ones found by Novo et al. (2016). When working with increasing doses of N and K, they observed that as the nitrogen dose associated with the potassium doses was increased, the production was not increased but suppressed.

Table 1. Estimates of mean squares for the sources of variation due to the regression and the deviation of regression for the first degree linear models for dry matter production (DMP), covering eight elephant-grass genotypes under different nitrogen (N1 = 400, N2 = 1000, N3 = 1600 kg ha^{-1} of N) and potassium doses (K1 = 200 and K2 = 500 kg ha^{-1} of K_2O) throughout two-year cultivation for energy purposes

Genotypes	K doses		PMS							
			First cut				Second cut			
			DF	1st Degree	R² (%)	Model	DF	1st Degree	R² (%)	Model
Cubano de Pinda	K1	Reg	1	21.91			1	356.30		
		Dev	1	6.74	78.48	-	1	89.94	79.85	-
	K2	Reg	1	347.90			1	149.10		
		Dev	1	14.01	96.12	-	1	325.50	31.42	-
Vruckwona	K1	Reg	1	65.66			1	305.50		
		Dev	1	294.20*	18.24	-	1	323.20	48.59	-
	K2	Reg	1	226.20			1	32.83		
		Dev	1	331.70	40.54	-	1	897.10*	3.53	-
IAC-Campinas	K1	Reg	1	31.43			1	156.60		
		Dev	1	192.80	14.02	-	1	7.04	95.7	-
	K2	Reg	1	31.85			1	301.70		
		Dev	1	57.34	35.71	-	1	161.90	65.07	-
Capim Cana D'África	K1	Reg	1	55.25			1	0.10		
		Dev	1	50.97	52.01	-	1	260.80	0.04	-
	K2	Reg	1	0.53			1	429.20*		
		Dev	1	70.68	0.74	-	1	7.56	98.26	1
Cameroon	K1	Reg	1	18.88			1	312.20		
		Dev	1	21.23	47.06	-	1	180.80	63.33	-
	K2	Reg	1	352.40			1	263.30		
		Dev	1	186.50	65.38	-	1	77.73	77.20	-
CPAC	K1	Reg	1	173.10			1	217.3		
		Dev	1	3.96	97.76	-	1	97.45	69.03	-
	K2	Reg	1	110.30			1	654.80*		
		Dev	1	222.90	33.10	-	1	60.18	91.58	1
IJ 7139	K1	Reg	1	181.80			1	109.20		
		Dev	1	2.82	98.47	-	1	628.80	14.80	-
	K2	Reg	1	87.60			1	1268.00*		
		Dev	1	104.50	45.60	-	1	325.50	84.33	1
BAG-86	K1	Reg	1	0.31			1	532.60		
		Dev	1	194.10	0.16	-	1	322.60	62.27	-
	K2	Reg	1	32.81			1	8.29		
		Dev	1	363.45	8.25	-	1	128.80	6.04	-

Note. * = Significant at 5% level probability by F test. Overall mean for the DMP—31.89 t ha^{-1} trait (first cut) and 40.89 t ha^{-1} (second cut).

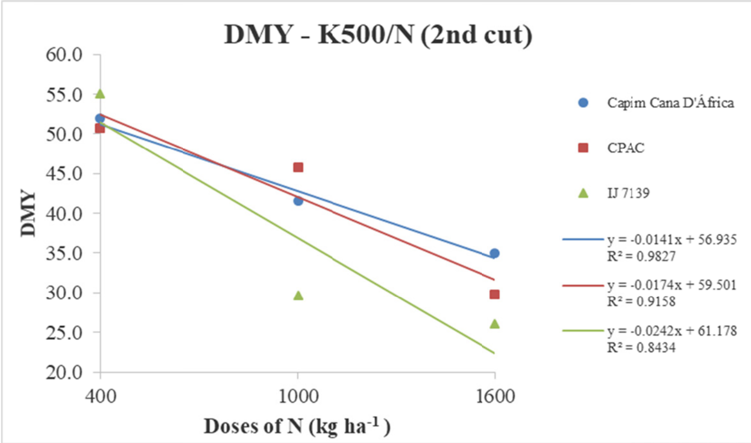

Figure 1. Lines of regression for the DMP trait of the Capim Cana D'África (G4), CPAC (G6), and IJ 7139 (G7) genotypes exposed to fertilization in increasing doses of N (400, 1000, and 1600 kg ha^{-1} of N) within the doses of 500 kg ha^{-1} of K_2O for cut 2

The overall mean for the first and second cuts was 31.89 and 40.89, respectively (Table 1). According to Quesada, Boddey, Reis, and Urquiaga (2004), among the different accessions of the elephant-grass, some of them stand out regarding their high biomass production and high fiber contents. As stated by him, the dry matter production trait achieved values of up to 30 t ha^{-1}in eight months, without applying N-fertilizer. The same way, Botrel, Pereira, and Freitas (2000) found annual mean productivity of 31 t ha^{-1} year^{-1} of dry matter. Those results assert the good selection of elephant-grass varieties that has been performed for high biomass production and the use as an alternative energy source. That provides positive results that ensure the use of the elephant-grass as an alternative energy source by the direct burning of biomass.

In a general comparison between the two cuts, it can be noticed that the dry matter production in the first cut was lower than in the second year of evaluation. In accordance with Table 2, the pluviometric index obtained throughout the experiment was 604.9 and 832.5 mm, in the first and second year, respectively. Tcacenco et al. (1994) state that the elephant-grass culture reaches its optimal development in places where pluviometric precipitation is higher than 1000 mm year^{-1}. When considering a 7-month period (from August 2014 to January 2015), the accumulated precipitation was of only 181.4 mm, that is, plants were more than half first period of cultivation under water deficit.

Therefore, that water limitation, which is an essential factor for production and development of the culture, could have negatively interfere with its development during all experiment and with the traits evaluated throughout both cuts. In the opinion of Barreto, Lira, Santos, and Dubeux Júnior (2001), decreased leaf expansion, acceleration in foliar senescence rate, inhibition of tillering and branches, and delay in growth and development of the plant are aspects affected by the water deficit.

The increase of DMY content with the development of forage plants is due to the structural changes in tissues, metabolism and transformations of photo assimilation of the leaves to the fruits and other organs of the plant (Mendonça & Rocha, 1985).

Table 2. Monthly precipitation recorded between March 2014 and March 2016. Evapotranspirometric Station of Pesagro/Rio, Campos dos Goytacazes, Rio de Janeiro state

Months	Precipitation (mm)		
	2014	2015	2016
January	-	0.0	131.1
February	-	40.3	81.6
March	14.3	110.0	61.6
April	103.1	42.0	
May	25.7	108.8	
June	30.8	49.0	
July	139.6	18.0	
August	14.2	23.8	
September	8.1	81.7	
October	17.7	57.9	
November	69.1	95.7	
December	32.0	81.3	

3.2 Number of Tillers per Linear Meter (NT)

With regard to the NT trait, the CPAC (G6) genotype was the only one among the others to show regression significance due to the doses of N within the K1 dose of 200 kg ha^{-1} of K_2O (Table 3). That genotype also displayed adjustment of first degree linear model ($\hat{y} = 17.2777 + 19.7222 \times 10^{-3}$ N, $R^2 = 98.53\%$) in the second cycle of evaluation (Figure 2).

The overall means were of 32.74 and 38.85 tillers per linear meter for the first and second cuts, respectively (Table 3). Similarly, Santos et al. (2014) obtained 30.67 tillers to the dose of 1000 kg ha^{-1}of N and 31.75 tillers per linear meter in the dose of 500 kg ha^{-1} of N for genotypes evaluated at 180 days and at 10 months, respectively. On the other hand, Oliveira et al. (2013) noticed mean of 13.24 tiller for 73 elephant-grass genotypes evaluated at six-month age.

According to Novo et al. (2016), the most productive individuals and that produce a high number of tillers tend to have higher levels of dry matter, cellulose and nitrogen.

Table 3. Estimates of mean squares for the sources of variation due to the regression and to the deviations of regression for the first degree linear models for number of tillers (NT) concerning eight elephant-grass genotypes under different nitrogen (N1 = 400, N2 = 1000, N3 = 1600 kg ha^{-1} of N) and potassium doses (K1 = 200 and K2 = 500 kg ha^{-1} of K_2O) throughout two-year cultivation for energy purposes

Genotypes	K doses		NT							
			First cut				Second cut			
			DF	1st Degree	R² (%)	Model	DF	1st Degree	R² (%)	Model
Cubano de Pinda	K1	Reg	1	13.50		-	1	0.17		-
		Dev	1	24.50	35.52	-	1	6.72	2.42	-
	K2	Reg	1	80.66		-	1	4.16		-
		Dev	1	43.55	64.93	-	1	312.50	1.31	-
Vruckwona	K1	Reg	1	80.67		-	1	253.50		-
		Dev	1	430.20	15.79	-	1	112.50	69.26	-
	K2	Reg	1	2.66		-	1	1.50		-
		Dev	1	256.80	1.02	-	1	68.05	2.15	-
IAC-Campinas	K1	Reg	1	4.17		-	1	54.00		-
		Dev	1	220.50	1.85	-	1	8.00	87.09	-
	K2	Reg	1	4.16		-	1	166.60		-
		Dev	1	6.72	38.26	-	1	37.55	87.65	-
Capim Cana D'África	K1	Reg	1	160.20		-	1	88.16		-
		Dev	1	144.50	52.57	-	1	93.38	48.56	-
	K2	Reg	1	6.00		-	1	192.60		-
		Dev	1	8.00	42.86	-	1	43.55	81.56	-
Cameroon	K1	Reg	1	20.17		-	1	37.50		-
		Dev	1	84.50	19.26	-	1	93.38	28.65	-
	K2	Reg	1	0.17		-	1	2.66		-
		Dev	1	2.72	5.76	-	1	430.20*	0.61	-
CPAC	K1	Reg	1	268.70		-	1	840.10*		-
		Dev	1	1.99	99.25	-	1	12.50	98.53	1
	K2	Reg	1	6.00		-	1	20.16		-
		Dev	1	138.80	4.14	-	1	254.50	7.08	-
IJ 7139	K1	Reg	1	13.50		-	1	20.16		-
		Dev	1	249.40	5.13	-	1	156.00	11.44	-
	K2	Reg	1	10.66		-	1	150.00		-
		Dev	1	0.88	92.31	-	1	26.88	84.79	-
BAG-86	K1	Reg	1	13.50		-	1	121.50		-
		Dev	1	501.40*	2.62	-	1	60.50	66.75	-
	K2	Reg	1	4.17		-	1	8.16		-
		Dev	1	501.40*	0.82		1	0.05	99.32	

Note. * = Significant at 5% level probability by F test. Overall mean for the NT—32.74 (first cut) and 38.85 (second cut).

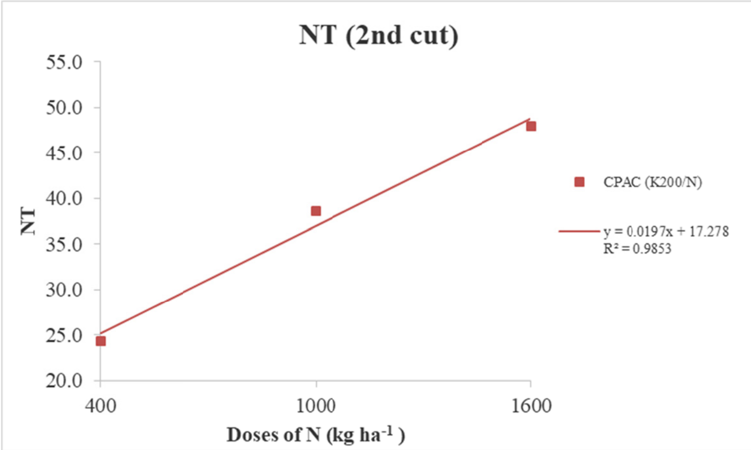

Figure 2. Regression line for the NT trait of G6—CPAC (G6) genotype, exposed to fertilization in increasing doses of N (400, 1000, and 1600 kg ha^{-1} of N) within the dose of 200 kg ha^{-1} of K_2O in the cut 2

3.3 Mean Height of the Plants (HEI)

For the HEI trait, it was noted by the estimates of the mean squares due to regression that, in the first-year evaluation, there was significance of first degree models (Table 4) adjusted to the mean values of the genotypes in function of the doses of N within K for the Capim Cana D'África ($\hat{y} = 2.7083 + 4.8611 \times 10^{-4}$ N, R^2 = 85.46%), CPAC ($\hat{y} = 3.0666 + 2.7778 \times 10^{-4}$ N, R^2 = 82.42%), and IJ7139 ($\hat{y} = 2.9888 + 2.5 \times 10^{-4}$ N, R^2 = 98.38%) genotypes (Figure 3).

The overall mean for the first and second cuts was of 3.32 and 3.03 m, respectively (Table 4). In accordance with Santos, Silva, and Queiroz Filho (2001), a greater elongation of the stem, as a defense mechanism of the plants, was seen during a period of water stress probably in function of the leaf area reduction (Table 2). In Figure 3, the Capim Cana D'África (G4), CPAC (G6), and IJ 7139 (G7) genotypes responded positively to the increasing of N in the fertilization at the first-year evaluation. Despite observing that the HEI of the genotypes was not influenced by the doses of N for five genotypes, the values are close to the ones found by other authors. When noticing six genotypes exposed to nitrogen fertilization in increasing doses of N (100, 200, 400, 800, and 1600 kg ha^{-1}), Oliveira et al. (2015) noticed an overall mean of 3.54 m.

Table 4. Estimates of mean squares for the sources of variation due to the regression and the deviation of regression for the first degree linear models for height (HEI) concerning eight elephant-grass genotypes under different nitrogen (N1 = 400, N2 = 1000, N3 = 1600 kg ha^{-1} of N) and potassium doses (K1 = 200 and K2 = 500 kg ha^{-1} of K_2O) throughout two-year cultivation for energy purposes

Genotypes	K doses		HEI							
			First cut				Second cut			
			DF	1st Degree	R^2 (%)	Model	DF	1st Degree	R^2 (%)	Model
Cubano de Pinda	K1	Reg	1	0.015		-	1	0.015		-
		Dev	1	0.035	29.67	-	1	0.009	62.79	-
	K2	Reg	1	0.081		-	1	0.000		-
		Dev	1	0.002	97.35	-	1	0.055	0.00	-
Vruckwona	K1	Reg	1	0.010		-	1	0.002		-
		Dev	1	0.001	89.28	-	1	0.027	5.77	-
	K2	Reg	1	0.003		-	1	0.001		-
		Dev	1	0.007	35.52	-	1	0.000	74.99	-
IAC-Campinas	K1	Reg	1	0.030		-	1	0.010		-
		Dev	1	0.001	96.43	-	1	0.010	48.07	-
	K2	Reg	1	0.006		-	1	0.000		-
		Dev	1	0.020	25.00	-	1	0.000	74.99	-
Capim Cana D'África	K1	Reg	1	0.010		-	1	0.050		-
		Dev	1	0.0001	98.68	-	1	0.003	93.55	-
	K2	Reg	1	0.510*		-	1	0.003		-
		Dev	1	0.080	85.46	1	1	0.003	51.92	-
Cameroon	K1	Reg	1	0.060		-	1	0.060		-
		Dev	1	0.050	51.92	-	1	0.020	75.00	-
	K2	Reg	1	0.010		-	1	0.015		-
		Dev	1	0.003	74.99	-	1	0.008	62.79	-
CPAC	K1	Reg	1	0.167*		-	1	0.001		-
		Dev	1	0.035	82.42	1	1	0.000	74.99	-
	K2	Reg	1	0.010		-	1	0.000		-
		Dev	1	0.023	30.73	-	1	0.016	2.41	-
IJ 7139	K1	Reg	1	0.135*		-	1	0.001		-
		Dev	1	0.002	98.38	1	1	0.002	42.85	-
	K2	Reg	1	0.0004		-	1	0.041		-
		Dev	1	0.0112	3.57	-	1	0.005	89.28	-
BAG-86	K1	Reg	1	0.070		-	1	0.020		-
		Dev	1	0.003	95.30	-	1	0.011	64.47	-
	K2	Reg	1	0.150		-	1	0.000		-
		Dev	1	0.050	75.00	-	1	0.002	0.00	-

Note. * = Significant at 5% level probability by F test. Overall mean for the HEI—3.32 m (first cut) and 3.02 m (second cut).

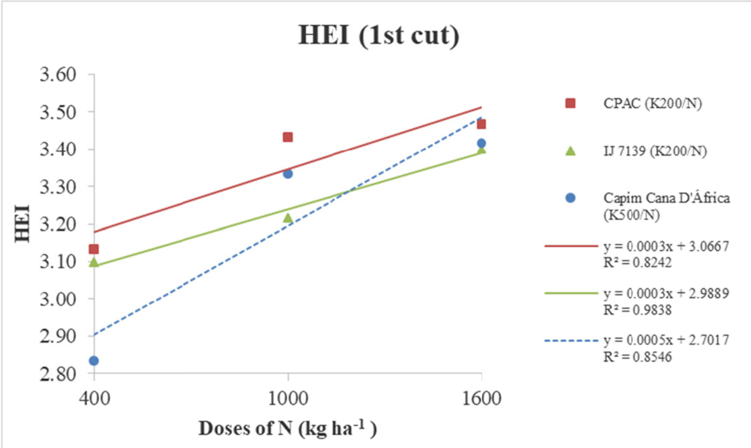

Figure 3. Regression lines for the HEI trait of genotypes that displayed adjustment of first degree linear model according to study of the increasing doses of N (400, 1000, and 1600 kg ha^{-1} of N) within the dose 200 kg ha^{-1} of K_2O (G6—CPAC and G7—IJ7139) and within the dose 500 kg ha^{-1} of K_2O (G4—Capim Cana D'África) in the cut 1

3.4 Mean Diameter of the Stem at the Base of Plant (DS)

Regarding the DS trait, there was significance of first degree models adjusted to the mean values of the genotypes according to the doses of N within K in the first cut for the CPAC ($\hat{y} = 1.34661 + 3.0694 \times 10^{-4}$ N, $R^2 = 91.82\%$) genotype within the K1 dose and in the second cut for the Vruckwona ($\hat{y} = 1.6588 + 3.2222 \times 10^{-4}$ N, $R^2 = 78.22\%$) genotypes in the K1 dose and IJ 7139 ($\hat{y} = 1.6588 + 3.2222 \times 10^{-4}$ N, $R^2 = 92,86\%$) in K2 dose (Table 5 and Figure 4).

As stated by Daher et al. (2004), the traits number of tillers per linear meter and diameter of tillers, could explain the potential of dry matter production acting on the basic variable in a direct and inversely proportional way, alternating themselves according to the environmental conditions occurred during the growth. Similarly, Mello et al. (2006) reported that the diameter of the stem directly relates itself to the tolerance of the plant to dry season, that is, stems with higher diameter are also more resistant to drought, probably because of the highest content of reserve compounds in those materials. Menezes et al. (2014) noted differentiated, direct and positive effect of the NS on the DMP between cuts performed.

The overall means of 1.68 and 1.69 cm for the first and second cuts confirm in this study (Table 6) the results stated by Oliveira et al. (2015), who observed a mean of 1.60 cm for the six elephant-grass genotypes fertilized with increasing doses of N, which showed significant adjustments of first and second degrees linear models ($P < 0.05$). They reported that, this way, the diameter of the stem can be influenced by the nitrogen fertilization, since four of the six genotypes achieved regression to first degree level; this showed that when increasing the fertilization dose, the diameter of the stem will proportionally increase. On the contrary, it can be verified, in this work, that the DS was not influenced by the increasing of N in the fertilization, as most of the genotypes showed lack of regression; that explains the trait behavior in function of the doses of N applied.

Table 5. Estimates of mean squares for the sources of variation due to the regression and the deviation of regression for the first degree linear models for diameter of stem (DS), concerning eight elephant-grass genotypes under different nitrogen (N1 = 400, N2 = 1000, N3 = 1600 kg ha^{-1} of N) and potassium doses (K1 = 200 and K2 = 500 kg ha^{-1} of K_2O) throughout two-year cultivation for energy purposes.

Genotypes	K doses		DS							
			First cut				Second cut			
			DF	1st Degree	R^2 (%)	Model	DF	1st Degree	R^2 (%)	Model
Cubano de Pinda	K1	Reg	1	1.200		-	1	0.023		-
		Dev	1	13.410*	8.19	-	1	0.002	91.92	-
	K2	Reg	1	0.500		-	1	0.042		-
		Dev	1	0.610	44.88	-	1	0.023	64.67	-
Vruckwona	K1	Reg	1	2.780		-	1	0.224*		-
		Dev	1	9.640	22.44	-	1	0.062	78.22	1
	K2	Reg	1	0.190		-	1	0.017		-
		Dev	1	0.029	86.56	-	1	0.058	22.79	-
IAC-Campinas	K1	Reg	1	0.032		-	1	0.000		-
		Dev	1	0.240	12.04	-	1	0.000	10.71	-
	K2	Reg	1	0.091		-	1	0.015		-
		Dev	1	1.060	7.89	-	1	0.010	58.23	-
Capim Cana D'África	K1	Reg	1	4.950		-	1	0.015		-
		Dev	1	1.650	75.00	-	1	0.017	46.26	-
	K2	Reg	1	0.576		-	1	0.000		-
		Dev	1	0.768	42.86	-	1	0.098	0.82	-
Cameroon	K1	Reg	1	0.580		-	1	0.004		-
		Dev	1	0.080	87.75	-	1	0.005	46.04	-
	K2	Reg	1	0.540		-	1	0.009		-
		Dev	1	0.131	80.38	-	1	0.033	22.11	-
CPAC	K1	Reg	1	20.350*		-	1	0.046		-
		Dev	1	1.810	91.82	1	1	0.063	42.39	-
	K2	Reg	1	0.060		-	1	0.064		-
		Dev	1	0.440	11.96	-	1	0.060	51.60	-
IJ 7139	K1	Reg	1	1.090		-	1	0.005		-
		Dev	1	0.530	67.16	-	1	0.033	12.75	-
	K2	Reg	1	0.017		-	1	0.375*		-
		Dev	1	1.017	1.65	-	1	0.028	92.86	1
BAG-86	K1	Reg	1	0.160		-	1	0.048		-
		Dev	1	0.880*	15.78	-	1	0.013	79.15	-
	K2	Reg	1	0.170		-	1	0.028		-
		Dev	1	2.470	6.67	-	1	0.002	91.95	-

Note. * = Significant at 5% level probability by F test. Overall mean for the DS—1.68 mm (first cut) and 1.69 mm (second cut).

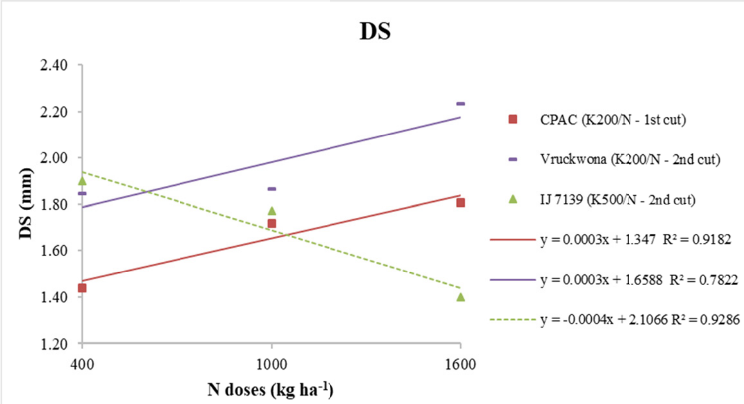

Figure 4. Regression lines for the DS trait of genotypes that showed adjustment of first line linear model according to study of the increasing doses of N (400, 1000, and 1600 kg ha^{-1} of N) within the dose 200 kg ha^{-1} of K_2O in the cut 1 (G6—CPAC) and cut 2 (G2—Vruckwona) and within the dose 500 kg ha^{-1} of K_2O (G7—IJ 7139) in the cut 2

4. Conclusions

For the Capim Cana D'África (G4), CPAC (G6), and IJ 7139 (G7) genotypes, the adjustment of first degree linear model of the regression indicates that the increasing of N in fertilization had a negative influence on the DMP.

Concerning the NT and HEI traits, the regression analysis revealed that, for the CPAC (G6) genotype, with respect to the NT, and for the Cana D'Africa (G4) and CPAC (G6) genotypes, in relation to the HEI, the response according to the increase of N in the fertilization was directly proportional.

For the DS, the CPAC (G6) and Vruckwona (G2) genotypes indicated a directly proportional response to the increasing of the doses of N, and the IJ 7139 (G7) genotype confirmed an inversely proportional response.

The results are very promising and confirm the use of the eight elephant-grass genotypes as an alternative source for biomass production.

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