

Effect of nitrogen rates on the forage yield of maize genotypes under superadhesion

ABSTRACT (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

Maize production is directly linked to the genetic potential of the variety and management practices, among them, sowing density and soil fertility. The objective of this work was to analyze the effect of the application of nitrogen doses and its efficiency and use in maize genotypes grown under over - densification conditions, in the city of Rio Largo, Alagoas. The experiment was carried out from November 2015 to March 2016, and a randomized complete block design was used in the 3 x 4 factorial scheme (three maize genotypes: Branca, Viçosense and Nordestino, and four nitrogen doses: 80, 160, 240 and 320 kg ha⁻¹) with three replications, at seeding density of 167 thousand plants per hectare. The dry matter production of the forage and its qualitative characteristics were evaluated: dry matter, mineral matter, crude protein, neutral detergent fiber, acid detergent fiber and hemicellulose. Under the conditions of over-counting, it is concluded: (a) the corn genotypes Viçosense, Branca and Nordestino, for the productive and qualitative characteristics of the forage, presented similar and satisfactory behavior, except for the variable HC, where the genotype Branca stood out in relation to the others, presenting the highest levels of hemicelluloses, which gives it the highest concentrations of energy and digestibility of its forage; (b) the dose 80 kg ha⁻¹ of nitrogen was the most satisfactory for the productive and qualitative characteristics of maize fodder, since its effect was similar to increasing nitrogen dosages, in addition to providing a higher percentage of NDF.

Keywords: Zea mays; cultivars; nitrogen fertilization; high density.

1. INTRODUCTION (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

Maize (*Zea mays* L.) is one of the most produced crops in Brazil, with a crop area of 15.9 million hectares, comprising grain and forage production [1]. Considering that it is possible to manipulate the crop, the main destination of the crop is for human and animal feeding, and industrial use [2,3].

The production of this crop is directly linked to the entire production system, involving the genetic potential of the variety, the conditions of the production environment and the management practices adopted [4]. Among the existing management practices in maize producing areas, sowing density and soil fertility are important to reach higher yields for this crop. The sowing density is determinant in the management of the plant arrangement, being one of the cultural practices that most interferes in the corn production [5]. Productivity increases as the density increases, but in spite of providing these gains the production components are adversely affected because the crop does not have a mechanism of efficient space compensation and, therefore, competing minimally for nutrients, light and others [3,6].

Already the fertilization provides the plant with enough nutrients for it to express its full productive potential. For maize and most crops, nitrogen is the most required nutrient and is of great importance for the development of the plant. However, nitrogen fertilizers are one of the inputs that most cost production costs, so they must be applied in sufficient quantity and

in an adequate way in order to avoid economic losses [7,8,9]. In Brazil, there are practically no maize cultivars developed for fodder production, since the genotypes available on the market have not been genetically improved for this purpose, making forage a co-product in the maize production chain, which implies an increase in production costs and low forage yield [10].

With the need of storage of dry mass for animal feed, there is a greater interest in obtaining highly productive genotypes for fodder, besides presenting high nutritional quality. Thus, the objective of this research was to determine the most efficient nitrogen dose and the use of this nutrient in three maize genotypes, grown under superadhesive conditions for quality forage production in the municipality of Rio Largo - AL.

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

The experiment was conducted at the Agricultural Sciences Center of the Federal University of Alagoas (CECA-UFAL), located at 9° 27' south latitude and 35° 27' west longitude and 127m altitude, with Koppen type wet season with dry seasons from spring-summer to rainy from autumn-winter) during the months of November 2015 to March 2016. The experiment was carried out from November 2015 to March 2016, with a randomized complete block design in the 3 x 4 factorial scheme (three maize genotypes and four nitrogen doses) with three replicates. Three experimental maize genotypes were evaluated: Viçosense, Branca and Northeast; improved and adapted to the state of Alagoas. The four nitrogen rates evaluated were: 80; 160; 240; and 320 kg ha⁻¹, being used as source urea, with 45% N.

The area was divided into three blocks, with a total of 36 experimental plots, consisting of three lines of 6 m in length, with 60 plants per line and 180 plants per plot, totaling an area of 10.8 m² per plot. The spacing used was 0.6 m between rows and 0.2 m between plants within the row, with two plants per hole, thus presenting a planting density of approximately 167 thousand plants.ha⁻¹. The useful area of the parcel destined to evaluate the forage production and its qualitative characteristics was constituted by the central line, discarding the first two pits of each end, corresponding to an area of 3.36 m².

Soil preparation was carried out mechanically, with a plowing and two harrows. According to the results of the chemical analysis of the soil (Table 1), there was no need to correct it, since maize presents good development in soils whose pH index is between 5.5 and 7.5 and also not has aluminum present [11].

Table 1. Chemical analysis of the soil before the execution of the experiment.

pH	P	K	Na	Ca+Mg	Al	H + Al	BS	T	V
in H ₂ O	mg.dm ³			-----	cmolc dm ⁻³	-----			----%---
6,0	35	86	34	4,0	0,0	4,3	4,37	8,67	50,4

Before planting, the main nutrient macronutrients were fertilized: nitrogen (according to the evaluated doses), phosphorus (20kg ha⁻¹) and potassium (40kg ha⁻¹), by means of sources, urea, simple superphosphate and potassium chloride, respectively. Nitrogen was divided in three applications, using one third of the dose in foundation and the remaining two thirds in coverage, at 30 and 45 days after planting (DAP); potassium was applied twice, half on the foundation and the other half at 30 DAP; and the phosphorus only had foundation fertilization. Seeding was done on November 21, 2015, by hand, with five seeds per well planted, and then the thinning was performed at 15 DAP, leaving two plants per hole.

Weed control was performed through manual weeding, with a total of two operations, at 30 and 45 DAP, during the crop cycle. Pest control, especially of the carcass caterpillar (*Spodoptera frugiperda* J. E. Smith), was carried out through two applications, 20 and 30 DAP, at a dose of 0.750 L ha⁻¹ of the insecticide Connect ©, with a manual costal spray. Irrigation was by conventional spraying between two to three times a week, with an average duration of 2 h and a 5 to 7 mm blade, when necessary, to meet the need of the crop.

The evaluations were carried out according to the methodology of [12] at 90 DAP, where at the time the following characteristics were studied: dry matter production (FMAP) in kg.ha⁻¹; while the other characters, dry matter (DM), mineral matter (MM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and hemicellulose (HC) were evaluated based on their percentages

Analyzes of variance were performed by the statistical program Sisvar [13]. The Tukey test was applied in the comparison of averages between maize genotypes within each dose of N only for the variable HC, whose interaction (G) x doses (D) was significant at 5% probability; as well as the polynomial regression and coefficient of determination in the evaluation of the means between the different nitrogen doses only for the variable NDF, whose interaction G x D was not significant at 5% of probability.

3. RESULTS AND DISCUSSION

The results of the F test of the analysis of variance of the productive and qualitative characteristics of corn fodder are presented in Table 2. There was no significant difference at 5% probability for the interaction G x D in relation to the characters PFM, MS, MM, PB, NDF and FDA, showing that the behavior of the maize genotypes does not depend on the N rates for forage characteristics, except for the HC character, whose G x D interaction was significant at 5% probability, that is, the behavior of the genotypes for the percentage of HC depends on the dose of N used. There was also no significant difference at 5% probability among maize genotypes in relation to the characters PFMS, MS, MM, PB, FDN and FDA, except for the HC character. However, there was no significant effect at 5% probability for N rates in relation to the PFMS, MS, MM, PB, FDA and HC characters, except for the FDN character, whose second degree equation (quadratic regression) explains the NDF content as a function of the doses of N. The coefficients of variation presented values between 6.02 and 18.89%, constituting excellent experimental precision for the characters MS, MM, FDN and FDA, good experimental precision for PB and HC, and regular experimental precision for PFMS [14].

Table 2. Analysis of variance and coefficients of variation of the productive and qualitative characteristics of the forage of maize genotypes submitted to different doses of nitrogen.

Source of Variation	GL	Medium Squares						
		PFMS (kg ha ⁻¹)	MS (%)	MM (%) ¹	PB (%) ¹	FDN (%) ¹	FDA (%) ¹	HC (%) ¹
Genotypes (G)	2	5035139,6 ^{ns}	9,89 ^{ns}	2,46 ^{ns}	2,25 ^{ns}	3,68 ^{ns}	6,47 ^{ns}	52,41*
Doses of N (D)	(3)	--	--	--	--	--	--	--
Linear Regression	1	18159529,66 ^{ns}	2,16 ^{ns}	0,17 ^{ns}	12,21 ^{ns}	5,20 ^{ns}	1,40 ^{ns}	25,98 ^{ns}
Quadratic Regression	1	28765,29 ^{ns}	0,70 ^{ns}	0,21 ^{ns}	2,21 ^{ns}	71,39*	0,33 ^{ns}	24,07 ^{ns}
Cubic Regression	1	14329811,63 ^{ns}	1,20 ^{ns}	3,28 ^{ns}	1,49 ^{ns}	5,47 ^{ns}	22,84 ^{ns}	5,63 ^{ns}
Interaction (G x D)	6	2646581,66 ^{ns}	0,84 ^{ns}	1,11 ^{ns}	1,28 ^{ns}	17,29 ^{ns}	16,37 ^{ns}	38,03*
Blocks	2	--	--	--	--	--	--	--
Residue	22	6500817,65	4,49	1,13	3,10	10,49	8,08	13,94
Total	35	--	--	--	--	--	--	--
CV (%)		18,89	7,07	8,50	10,77	6,02	7,84	11,09

¹Data based on dry matter. ns, ** and * Not significant at (P = 0.05) probability, significant at (P = 0.01) probability, significant at (P = 0.05) probability, respectively, by the F-test. PFMS – Fodder Production in Dry Matter; MS – dry matter; MM – Mineral Matter; PB – Crude protein; FDN – Neutral Detergent Fiber; FDA – Fiber in Acid Detergent; HC – Hemicellulose.

Comparing the performance of maize genotypes by the F test for the variables PFMS, MS, MM, PB, FDN and FDA of forage did not show a significant difference at 5% probability, whose general averages were: 13,499.93 kg ha⁻¹, 25.09%, 4.73%, 8.03%, 65.00% and 35.04%, respectively (Table 3).

Regarding the PFMS variable, the corn genotypes Viçosense, Branca and Nordestino reached values of forage production of the dry matter considered low, which reflected in the percentage of dry matter (MS%), partly due to the age at which the plants were harvested (90 DAP), as [15], using a plant density equal to the present work (166,666 plants.ha⁻¹), and studying the same corn genotypes in the same environment, harvested at 95 DAP, obtained 45.93% higher dry matter yield (19,700 kg ha⁻¹). Another factor that contributes to the low forage production of the dry matter of the present study was the lodging of the plants occurred during the conduction of the experiment, since the displacement of the minerals in the conducting pots of the plants was reduced, consequently causing a reduction in the quantity accumulated dry matter. It is worth mentioning that this lodging of the corn plants was due to a very strong wind never occurred in the region.

For mineral matter the average value obtained was 4.73%. The determination of this variable provides an indication of the richness of the sample in mineral elements and / or occurrence of possible contaminations, and is quantified to know the organic matter of the sample. The content of MM does not directly interfere with the forage production capacity.

The importance of the accumulation of minerals is to indicate the amount of nutrients extracted from the soil by the forage plant, because, in grazing systems, the necessary replenishments are necessary, in order to meet the nutritional requirements and to maintain the productivity of the forage plant and the fertility of the soil [16].

The mean crude protein content was 8.02% for the three genotypes, being within the ideal percentage, which should vary between 6 and 9% in forage [17], even with high plant density, 166,000 plants ha⁻¹, indicating that the densification of corn plants, when applied nitrogen fertilization, did not interfere in the protein content of the forage, despite the increase in competition between plants for light and nutrients. [18], using a density of 75,000 ha⁻¹ plants, obtained 7.78% of PB, confirming that the density of plants does not interfere with CP, being more important the characteristic of the genotype and soil fertility.

The mean percentage of FDN was 65%, similar to that found by [17], obtaining results between 59.5 and 64%, and above 60% of FDN value found by [19]. The content of this character is directly related to the cultivar cycle, nocturnal temperatures, soluble carbohydrate content, among others, and FDN is a characteristic that is directly related to the speed of passage of food through the digestive tract.

The FDA had an average content of 35.04% for the evaluated genotypes, and it is related to the digestibility of the forage, containing in its composition cellulose and lignin, which indicates the amount of fiber that is low digestible, thus, the higher the content of FDA, lower forage digestibility [18]. In addition, it also interferes with the energy value of the material, that is, the lower the content, the higher the forage energy value [20].

Table 3 - General averages of corn genotypes for the productive and qualitative characteristics of forag.

Genotypes	PFMS (kg.ha ⁻¹)	MS (%)	MM (%)	PB (%)	FDN (%)	FDA (%)
Viçosense	13.223,72 a	26,64 a	4,40 a	7,58 a	65,68 a	35,93 a
Branca	14.240,01 a	24,56 a	5,10 a	8,30 a	65,31 a	33,71 a

Nordestino	13.036,05 a	24,06 a	4,68 a	8,20 a	64,00 a	35,48 a
Average Overall	13.499,93	25,09	4,73	8,03	65,00	35,04
F _{5%}	0,77 ^{ns}	2,20 ^{ns}	2,18 ^{ns}	0,73 ^{ns}	0,35 ^{ns}	0,80 ^{ns}

Average followed by the same letter in the column do not differ from each other by the Tukey test at (P = 0.05) probability. PFMS – Fodder Production in Dry Matter; MS – dry matter; MM – Mineral Matter; PB – Crude protein; FDN – Neutral Detergent Fiber; FDA – Fiber in Acid Detergent; HC – Hemicellulose.

The HC variable presented a significant difference for the dose of 80 kg ha⁻¹ of N, with the genotype Branca presenting a higher percentage. For the other doses, there was no statistical difference between the genotypes (Table 4). This higher proportion of hemicellulose in the White genotype gives it a higher digestibility, since the degradability of hemicellulose is inversely related to the lignification rate [21], and hemicellulose, more digestible than cellulose, integrates the FDN [12].

Table 4. Means of corn genotypes within each nitrogen dose for the hemicellulose (HC) character.

Genotypes	Variable1 HC (%)			
	Doses of Nitrogen (kg ha ⁻¹)			
	80	160	240	320
Viçosense	34,15 ab	29,73 a	28,92 a	26,19 a
Branca	45,45 a	32,62 a	30,60 a	30,56 a
Nordestino	24,00 b	26,14 a	29,79 a	34,16 a
Average Overall (%)	--	29,50	29,77	30,30
Δ (5%)	11,68	11,68	11,68	11,68

¹Average followed by the same letter in the column do not differ from each other by the Tukey test at (P = 0.05) probability. HC – Hemicellulose.

Table 5 shows the averages observed for the productive and qualitative characteristics of the forage as a function of the nitrogen doses. There was no significant effect among the nitrogen rates for these characters, where the lowest nitrogen dose (80 kg ha⁻¹) had the same effect in these characters.

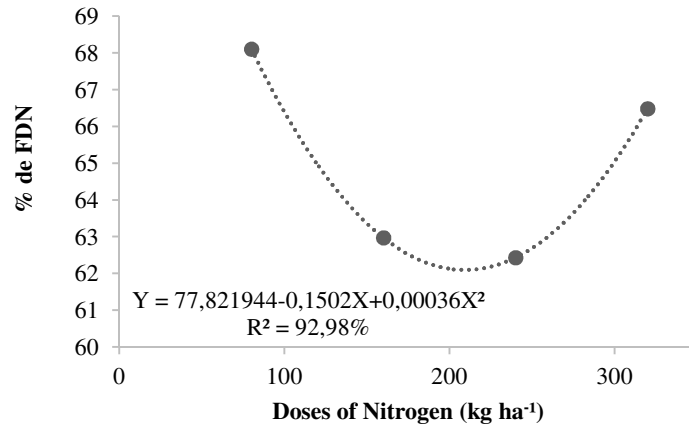
Table 5. Observed means for the productive and qualitative characteristics of the forage as a function of the nitrogen doses.

Nitrogen doses (kg.ha ⁻¹)	PFMS (kg.ha ⁻¹)	MS (%)	MM (%)	PB (%)	FDA (%)
80	12.236,63	25,42	4,63	7,26	33,86
160	14.057,03	25,01	5,15	7,77	36,88
240	12.999,36	25,49	4,44	8,28	33,53
320	14.706,69	24,23	4,68	8,79	35,90

PFMS – Fodder Production in Dry Matter; MS – dry matter; MM – Mineral Matter; PB – Crude protein; FDA – Fiber in Acid Detergent.

The neutral detergent fiber presented a high-grade equation with high reliability, R² = 92.98% [14], whose dose of 80 kg ha⁻¹ provided a percentage of 68.10% of FDN. The fibers obtained by this method are composed of cellulose, hemicellulose and lignin, which are the main determinants of forage quality and contribute approximately 60% of the dry matter, thus making FDN a very important variable [17].

Figure 1. Trend line of performance of maize genotypes under different nitrogen rates obtained through the regression equation, in relation to the percentage of FDN.



One of the most important characteristics of maize genotypes is forage production, and determining how much the plants respond to the nitrogen doses applied in the soil is a decisive factor in the selection of the genetic material. However, as it can be observed in the present study, not always large doses of nitrogen will guarantee significant increase in production, since there is a limit of the response of the plants to the amount of nitrogen applied.

However, from the productive point of view, the results obtained were satisfactory, which makes feasible the use of the genotypes of this study and the respective ideal doses of nitrogen for each desired characteristic.

4. CONCLUSION

Under the conditions of over-counting, it is concluded: (a) the corn genotypes Viçosense, Branca and Nordestino, for the productive and qualitative characteristics of the forage, presented similar and satisfactory behavior, except for the variable HC, where the genotype Branca stood out, presenting the highest levels of hemicelluloses, which gives it the highest concentrations of energy and digestibility of its forage; (b) the dose 80 kg ha⁻¹ of N was the most satisfactory for the productive and qualitative characteristics of maize fodder, since its effect was similar to increasing nitrogen dosages, in addition to providing a higher percentage of FDN.

COMPETING INTERESTS DISCLAIMER:

Answer: We (authors) have confirmed that there is neither a conflicting interest rate.

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