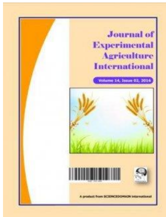

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Study of Nitrogen Efficiency of Three Corn Cultivars in Green Ears Production

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Authors' contributions

This work was carried out in collaboration between all authors. Author CFS participated in the idea and management of the experiment, besides writing the article. Author LCG participated in the elaboration of the research project, conduction of experiments and writing of the article. Author VFLS was responsible for collecting, tabulating and analyzing the data. Authors JVC, JLAS and LPG participated in the management of the experiment from the implantation to the data collection. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The objective of this study was to evaluate the efficiency of nitrogen utilization by corn cultivars for the production of green ears.

Study Design: Treatments were constituted by the combination of two nitrogen doses (0 and 90 kg ha^{-1} N) and three corn cultivars (Cruzeta, Truck and AG 1051). The experimental design was the randomized block design, in a 2 x 3 factor scheme, with five replications.

Place and Duration of Study: The experiment was conducted at a garden of the Department of Plant Science of Federal Rural University of the Semi-arid, Mossoró, Rio Grande Norte state, Brazil, from February to May 2015.

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Methodology: The following parameters were evaluated: plant height, insertion of the first ear, stalk diameter, number and the productivity of marketable husked/not husked green ears , and the indices of efficiency agronomic efficiency, physiological efficiency, ear production efficiency, recovery efficiency and use efficiency.

Results: It was observed that application of nitrogen increased the plant height, insertion of the first ear, dry matter, number and the productivity of green ears. Cultivars differed in terms of stem diameter, plant dry matter and prolificacy. The cultivar Truck exceeded others regarding the ear number (husked, non-husked and total). However, as for productivity, the cultivars differed significantly only in the production of marketable husked ears. There was a significant difference among the cultivars, regarding agronomic efficiency and recovery efficiency.

Conclusion: Based on the values of the nutritional efficiency indices, Cultivar AG 1051, was more effective in using nitrogen to produce green ears as compared to Cruzeta and Truck. The dose of 90 kg ha^{-1} N recorded the higher yield of green corn than no nitrogen application.

Keywords: Zea mays; productivity; efficiency indices; mineral nutrition.

1. INTRODUCTION

Corn (*Zea mays* L.) is the most cultivated cereal in the world, with the largest producers being the United States, China, and Brazil. It has significant economic importance, due to its high production potential and the various forms of use in human and animal food, *in natura* and the high-tech industry. It also contributes to social development, due to its capacity to generate employment and income [1]. It is commercialized mainly in the form of grains. However, in the northeastern region of Brazil, due to higher financial returns, the production of green ears has become a promising activity, and is cultivated throughout the year [2].

Nitrogen fertilization plays a very important role; it is one of the most influential factors in corn crop productivity. On the other hand, for the production of green ears, N has been responsible for a yield increase; its effect was also influenced by other factors, such as genotypic and environmental ones [3].

The identification of genotypes that can absorb and use nitrogen effectively is a way to increase the efficiency of using nitrogen fertilizer in corn cultivations, to increase production, minimize losses and reduce environmental contamination [4]. In this context, the importance of genetic improvement is evident, aiming not only at genotypes that are responsive to nitrogen fertilization, but also at the study of effective genotypes in the use of nitrogen [5].

The objective of this study was to evaluate the efficiency of nitrogen utilization by corn cultivars for the production of green ears.

2. MATERIALS AND METHODS

2.1 Site Location and Characterization

The experiment was conducted at a garden in the Plant Science Department of Federal Rural University Semi-arid, Mossoró, Rio Grande do Norte State, in Brazil, (5º11″ southern latitude and 37º20″ western longitude, with 18 m altitude), from February to May 2015. The soil of the experimental area is classified as Eutroferric Yellow - Red Argisol [6]. The chemical analysis conducted on soil samples from the experimental area, at a depth between 0 and 20 cm, presented the following results: pH in H_2O (1:2.5) = 6.5; $P_{(mehlich^{-1})}$ = 0.21 g kg^{-1}; K = 0.20 g kg^{-1}; Ca = 1.20 g kg^{-1}; Mg = 0.49 g kg^{-1}; Al = 0.04 g kg^{-1}; H + Al = 0.39 g kg^{-1} and Organic matter = 12.80 g kg^{-1}.

The climatic conditions during the experiment were characterized by a mean temperature of 34.8°C with a minimum of 22.3°C and a maximum of 28.5°C. A mean relative humidity of 64.9% and accumulated rainfall during the period of 127.8 mm were recorded.

2.2 Treatments and Experimental Design

Treatments were constituted by the combination of two nitrogen doses (0 and 90 kg ha^{-1}) and three corn cultivars (Cruzeta, Truck and AG 1051). The experiment was set under the randomized block design, in a 2 x 3 factor scheme, with five replications. Each experimental plot consisted of three rows measuring 3 m in length, spaced 0.8 m apart, containing 10 plants in each row. The central row was considered as the usable area, discarding one plant at each end.

Nitrogen doses were used to evaluate the efficiency of N use in corn cultivars, where the dose "0" corresponded to the N content in the soil (D0) and the 90 kg ha^{-1} N (D90), was the recommended dose for corn production [7]. The commonly used corn cultivars in the region viz. Cruzeta (Open pollination), Truck (modified triple hybrid) and AG 1051 (double hybrid) were studied.

2.3 Field Establishment

Soil preparation was performed by ploughing and harrowing, followed by opening furrows with an approximate 0.20 m depth for planting. The fertilization was based on soil analysis and recommendation for corn [7], using 30 kg ha^{-1} of N (treatment with N); 40 kg ha^{-1} of P_2O_5, 40 kg ha^{-1} of K_2O; 1.0 kg ha^{-1} of B and 3.0 kg ha^{-1} of Zn. In covering, in the N treatment, 30 kg ha^{-1} of N was applied on 15 days after sowing (DAS) and 30 kg ha^{-1} of N was applied when the plant presented eight definitive leaves. The used nutrient sources were urea, triple superphosphate, potassium chloride, boric acid and zinc sulfate.

Sowing was done with three seeds per hole, at a spacing of 0.8 x 0.3 m and, when the plants had four definitive leaves (9 DAS), thinning was performed, leaving one plant per hole. The irrigation was done by dripping, with tips spaced of 0.3 m apart and a flow of 1.4 L h^{-1}. Weed control, when necessary, was performed by manual weeding. Four sprayings were performed using the insecticides Decis® (deltamethrin) and Premio® (chlorantraniliprole) at doses of 200 and 100 mL ha^{-1}, respectively, for the control of carpiaceous caterpillars (*Spodoptera frugiperda*).

2.4 Harvesting and Parameters Evaluated

The height of the plants, the insertion of the first ear and the stalk diameter were measured for all plants from the usable area of the plot before harvesting (68 DAS).

The harvesting of green ears was done manually at the phenological stage R3 (milky grains), on 70 DAS; on the occasion, the number and the productivity of marketable green ears that were not husked (damage-free ears, well wrapped, ≥ 22 cm long) and husked (ears with good grains and ≥ 18 cm long). Two plants per plot were cut at the stem region, separated in leaves, stalk and ears, washed and dried in a forced air circulation oven (65°C) until reaching a constant mass, to obtain the dry matter of the plant. Subsequently, the content of N in said parts was then determined. The analysis of N was carried out in the extract obtained by sulfuric digestion (N) and quantified by the semi-micro method of Kjeldahl [8].

Nitrogen accumulation values were obtained through the product between N content and dry matter. With the data of dry matter and N accumulation, the following indices were calculated [9]: Agronomic efficiency (AE); Physiological efficiency (PE); Ear production efficiency (CPE); Recovery efficiency (RE) and Use efficiency (UE), using the following equations:

$$AE\ (kg\ kg^{-1}) = (PV_{cN} - PV_{sN})/(QN_a) \quad (1)$$
$$PE\ (kg\ kg^{-1}) = (MST_{cN} - MST_{sN})/(AN_{cN} - AN_{sN}) \quad (2)$$
$$CPE\ (kg\ kg^{-1}) = (PV_{cN} - PV_{sN})/(AN_{cN} - AN_{sN}) \quad (3)$$
$$RE\ (kg\ kg^{-1}) = (AN_{cN} - AN_{sN})/ (QN_a) \quad (4)$$
$$UEN\ (kg\ kg^{-1}) = PE \times RE \quad (5)$$

Where;

PV_{cN} is the production of green ears with nitrogen fertilization (kg);
PV_{sN} is the production of green ears without nitrogen fertilization (kg);
QN_a is the quantity of applied N (kg);
MST_{cN} is the total production of dry matter with nitrogen fertilization (kg);
MST_{sN} is the total production of dry matter without nitrogen fertilization (kg);
AN_{cN} is the total N accumulation with nitrogen fertilization (kg);
AN_{sN} is the total N accumulation without nitrogen fertilization (kg).

2.5 Statistical Analysis

The obtained data were submitted to analysis of variance and the averages were compared by Tukey's test at 5% probability, using the statistic software SISVAR [10].

3. RESULTS AND DISCUSSION

There was a significant effect (P=0.05) in the cultivar and N dose interaction regarding the plant height and insertion of the first ear. Stem diameter, plant dry matter, total ear number, number of marketable-husked ears and productivity of marketable-husked ears were significant to isolated factors (cultivar and dose).

As for prolificacy, the factor cultivar was the only significant one. The N dose factor significantly affected the total ear productivity and the marketable non-husked ears.

3.1 Plant Height, Insertion of the First Ear, Stalk Diameter and Dry Matter

Except for the cultivar Truck, the application of nitrogen increased the plant height and insertion of the first ear. In the absence of N, cultivars did not differ significantly as for these characteristics. With the application of N (D_{90}), 'Cruzeta' had the highest plant height and ear insertion, even if it did not differ from AG 1051 as for plant height (Table 1). In this cultivar, increments in the plant height and ear insertion with N application were 18 and 24%, respectively, as compared to the treatment with no N application.

The increase in plant height and ear insertion, caused by N application, is mainly due to the role that N plays in the vegetative development, thereby influencing the height of plants and the accumulation of phytomass, since higher plants tend to provide a higher ear insertion [11]. This characteristic of higher ear insertion is desirable from the operational point of view, since it provides significant advantages during harvesting.

Cultivars differed in terms of stem diameter, plant dry matter and prolificacy (Table 2). As for stem diameter, AG 1051 exceeded the others, which did not differ from one another. On the other hand, Cruzeta and Truck presented greater plant dry matter and prolificacy as compared to AG 1051. The increase in the stem diameter is an important physiological factor, since the stem does not only have a leaf and inflorescence support function, but it mainly works as a structure for the storage of soluble solids that are used during grain formation [12]. The application of N provided greater stem diameter and plant dry matter. As for prolificacy, there was no significant difference.

3.2 Number and the Productivity of Green Ears

The cultivar Truck exceeded the others concerning the ear number (husked, non-husked and total). However, as for productivity, the cultivars differed significantly only in the production of marketable husked ears (PMHE); Truck was superior but it did not differ from AG 1051 (Table 3). The percentage of non-husked marketable ears in relation to the total ear number was high in all the cultivars and it was 94, 95 and 97%, respectively for Cruzeta, Truck and AG 1051.

Table 1. Plant height and insertion of the first ear, in corn cultivars, without the application of N (D_0) and with the application of 90 kg ha^{-1} of N (D_{90})

Cultivars	Plant height (cm)		Insertion of ear (cm)	
	D_0	D_{90}	D_0	D_{90}
Cruzeta	209.0 aB	247.0 aA	110.0 aB	137.0 aA
Truck	205.0 aA	212.0 bA	99.0 aA	103.0 cA
AG 1051	204.0 aB	226.0 aA	106.0 aB	122.0 bA
CV (%)	5.86		7.91	

Means followed by the same lowercase letter in the column and upper case in the line, within each variable do not differ by Tukey test, at 0.05 of probability

Table 2. Stem diameter, plant dry matter and prolificacy according to corn cultivar and N dose

Cultivars	Stem diameter (mm)	Dry matter (g planta^{-1})	Prolificacy
Cruzeta	21.85 b	159.86 a	1.05 ab
TrucK	20.98 b	140.80 ab	1.20 a
AG 1051	24.38 a	134.41 b	1.03 b
Dose N(Kg ha^{-1})			
0	20.67 b	126.25 b	1.07 a
90	24.21 a	163.38 a	1.12 a
CV (%)	7.69	12.66	13.35

Means followed by the same lowercase letter in the column, within each variable do not differ by Tukey test, at 0.05 of probability

In spite of the superiority of Truck in terms of the number of marketable non-husked ears (NME), it did not differ from the others in the production of marketable non-husked ears (PME), indicating that, even if the number was higher the ear matter was lower. The PMHE was lower in relation to the PME, in all the cultivars. The reduction was 60, 42 and 43%, respectively for Cruzeta, Truck and AG 1051. This difference occurred since not all non-husked ears have the pattern required by the market for husked ears (ears with good grains and ≥ 18 cm long).

In the green ears production system, non-husked ears are transported in order to avoid the degradation of sugars, the denaturing of the product and to keep the sweet taste. Productivity with husk is an important characteristic for the commercialization of corn green [13].

The application of N, as expected, helped to obtain a greater number of ears and higher productivity (Table 3). This increase is due to the fact that N causes greater effects in the plant growth and development characteristics, which affect the productivity directly or indirectly [14].

3.3 Nutritional Efficiency Indices

Among the evaluated efficiency indices, there was a significant difference among the cultivars, regarding agronomic efficiency and recovery efficiency (Table 4). AG 1051 was more effective in producing ears (AE) and in the quantity of accumulated N (RE), per unit of applied N, however, not differing significantly from the cultivar Truck in terms of RE.

The non-observation of a significant difference in the indices of physiological efficiency (PE), ear production efficiency (EPE) and N usage efficiency (NUE) was probably due to the high variation coefficient. However, AG 1051 was numerically superior in CPE than other cultivars. This indicates that it was also more effective in the production of ears per unit of accumulated N, with a consequent higher NUE. On the other hand, Cruzeta was more effective in the biological production, i.e., it produced a higher quantity of dry matter per applied N unit.

Table 3. Total ear number (TEN), number of marketable non-husked ears (NME) and number of marketable husked ears (NMHE), total ear productivity (TEP), productivity of marketable non-husked ears (PME) and the productivity of marketable husked ears (PMHE), according to corn cultivar and N dose

Cultivars	TEN	NME	NMHE	TEP	PME	PMHE
	-----------ear ha^{-1}------------			--------------- kg ha^{-1}-------------		
Cruzeta	33984,65 b	32031,51 b	18652,49 c	10031,72 a	10008,61 a	4026,07 b
Truck	43055,90 a	41146,17 a	39062,81 a	10707,90 a	10209,20 a	5958,38 a
AG 1051	33333,60 b	32291,93 b	27778,00 b	9798,52 a	9521,95 a	5457,16 ab
Dose N (kg ha^{-1})						
0	34635,70 b	32465,54 b	24356,39 b	8791,30 b	8500,55 b	3999,22 b
90	38947,07 a	37847,53 a	32639,15 a	11567,45 a	11325,96 a	6295,19 a
CV (%)	12,69	15,26	20,71	17,78	18,25	25,74

Means followed by the same lowercase letter in the column, within each variable do not differ by Tukey test, at 0.05 of probability

Table 4. Agronomic efficiency (AE), physiological efficiency (PE), ear production efficiency (EPE), recovery efficiency (RE), N use efficiency (NUE), of corn cultivars for the production of green ears

Cultivars	AE	PE	EPE	RE	NUE
	------------------------------------kg kg^{-1}----------------------------------				
Cruzeta	27,08 b	54,18 a	134,06 a	0,17 b	7,98 a
Truck	19,42 b	42,38 a	56,97 a	0,32 ab	13,74 a
AG 1051	57,67 a	41,97 a	171,12 a	0,36 a	14,04 a
CV (%)	38,84	43,28	64,96	35,61	56,45

Means followed by the same lowercase letter in the column, within each variable do not differ by Tukey test, at 0.05 of probability

4. CONCLUSIONS

The present study revealed that based on the values of the nutritional efficiency indices, cultivar AG 1051 was more effective in using nitrogen to produce green ears corn. The dose of 90 kg ha^{-1} N provided the higher yield of green corn.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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