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ORIGINAL RESEARCH ARTICLE

Increase in okra production with the addition of nitrogen

Valdilene Coutinho-Miranda*, Irais Dolores Pascual-Reyes, Aline Torquato-Tavares, João Victor Gonçalves-Carline, Kássio Abel Silva-Sousa, Ildon Rodrigues-do-Nascimento

Universidade Federal do Tocantins, Brazil. E-mail: dilene.223@hotmail.com

ABSTRACT

Introduction: Growth, yield and quality of okra (*Abelmoschus esculentus* (L.) Moench) are related to fertilizer application, being nitrogen (N) the most outstanding, due to its direct relationship with photosynthesis and vegetative growth of the plant. **Objective:** The objective was to evaluate the agronomic and productivity characteristics of okra as a function of N dose. **Materials and methods:** The study was conducted at the experimental area of Campus Gurupi, the Universidad Federal de Tocantins (UFT), Brazil, in two planting periods (autumn/winter and spring/summer). The experimental design used was randomized block design (RBD) with six treatments (50, 100, 150, 150, 200 and 250 kg N ha^{-1}) and four replications. Urea was used as a source of N. The characteristics evaluated were: productivity, average fruit mass, height and plant chlorophyll index. **Results:** Productivity and plant height were superior in the fall/winter crop. Mean fruit mass and chlorophyll index were not influenced by planting time. For productivity, a linear response was obtained with increasing dose up to the limit of the N dose used (250 kg ha^{-1}), with a mean value higher than 14 t of fruit. Mean mass and plant height responded linearly to increasing N dose. Nitrogen affected the chlorophyll index, with maximum values of 45.96 and 47.19, observed in the two evaluation periods. **Conclusion:** Planting time and N content in the soil interacted with plant height, being favorable in the period without precipitation. N influenced all the characteristics, demonstrating the importance of nitrogen fertilization in the development of okra plants.

Keywords: *Abelmoschus Esculentus*; Sowing; Nitrogen Fertilization; Linear Response

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1. Introduction

Okra (*Abelmoschus esculentus* (L.) Moench) is a vegetable of the malvaceae family, a popular food of high nutritional value, originally from Africa and introduced to Brazil by slaves from this continent[1]. They are heat-tolerant plants, presenting desirable characteristics such as fast cycle, economically viable production and resistance to pests and diseases. In hot climate regions it can be produced throughout the year[1].

Okra is demanding in nitrogen (N), required in large quantities by plants because it is present in the composition of the production of new cells and tissues, such as in ATP, NADH, NADPH, chlorophyll molecules, alkaloids, amino acids, proteins, innumerable enzymes and vitamins, hormones and in several compounds of plant metabolism[2].

In okra, nitrogen fertilization plays a fundamental role in the productivity of marketable fruits. N in okra cultivation is an essential element, as it promotes an increase in leaf area index, which favors vegetative growth and increases the number of vegetative and floral buds[3]. N also provides an increase in height as the dose of nitrogen fertilizer increases[4].

N fertilizer dosage recommendations for okra are variable, ranging from 60 kg ha^{-1} for the Amazon region to 180 kg ha^{-1} for soils with medium or low fertility[5].

Plants grown with inadequate amounts of N do not fully express their genetic potential, because a series of morphological alterations occur, more energetically in the physiological processes in the plant, from absorption to complete assimilation and transformation of N into organic molecules. With high doses of N there is a negative effect on growth, cells develop slower protoplasm, do not build sufficient support material for cell walls, which becomes fragile plants and may be vulnerable to mechanical damage, so that their productivity is reduced[6]. In addition, N deficiency reduces growth, compromising the partitioning of assimilates between the different parts of the plant, generally causing an increase in the ratio between the dry mass of the roots and the aerial part[4].

In spite of the great importance of nitrogen fertilization in okra cultivation, little is known about the best doses to use that allow good vegetative development and satisfactory yields, so there is a need to define a dose of N capable of providing maximum yield, in addition to the other benefits that this practice provides to the crop.

The nutritional status of plants, mainly nitrogen, is directly associated with the quality and quantity of chlorophyll, as it participates in the structural composition of its molecule[7]. When there is N deficiency, a direct effect observed is the reduction of the chlorophyll index[8,9].

N doses affect fruit mass, since the application of adequate N is essential for the development, growth, division, increase, cellular density and photosynthetic expansion, being beneficial for the increase of fruit mass, increasing crop production[10].

A basic aspect of its management is to know the right time to plant this malvaceae. Studies conducted in several countries (Iran, Pakistan, Mexico, Iraq, Bangladesh, Swaziland, India) show that the planting period (combined with other factors) significantly influences crop emergence, growth and yield[11–13].

Studies conducted in Nigeria by Adejoye *et al*.[14] conclude that okra can be planted all year round, as long as water is available, especially during the dry season, to meet its thermal requirements. The increase in temperature causes the reduction of the cycle in days for the opening of the first flower, increases the height of the plant, reduces the number of lateral branches and increases productivity[15].

According to Cerri and Vilella[16] in Buenos Aires, the varieties Colhe Bem and Clemson Spineless, planted in April, produced less than when planted in December, due to the frost that shortened the cycle. In India, in the Calcutta region, summer plantings during the spring/summer season (March to June) resulted in higher yields and better quality fruit than those planted during the rainy season (July to February)[17].

The objective of this work was to evaluate the agronomic and productivity characteristics of okra as a function of N dose.

2. Material and methods

The study was conducted during 2015 in the experimental area of the olericulture sector of the Federal University of Tocantins (UFT—Gurupi Campus), municipality of Gurupi, State of Tocantins, Brazil, located at 11°43′45″ S and 49°04′07″ W and with average altitude of 280 m. According to Koppen's classification[18], the climate of the region is Aw, defined as tropical with a humid summer and dry period in winter. With an average annual temperature of 29 °C and an average annual rainfall of 1600 mm[19].

Temperature, precipitation and relative humidity estimates for the period of the tests are shown in **Figure 1**.

Two experiments were established, the first from April to July (autumn/winter) and the second from September to December (spring/summer). The soil is classified as a dystrophic red-yellow lithosol[20].

Soil analysis was performed at a depth of 0-20 cm, showing: pH in water: 5.78; H + Al: 1.46 cmol dm^{-3}; Ca + Mg: 4 cmol dm^{-3}; K: 0.23 cmol dm^{-3}; P: 26.01 mg dm^{-3}; organic matter: 1.8; V: 74%, total sand: 69.7%, silt: 5.72% and clay: 24.6%.

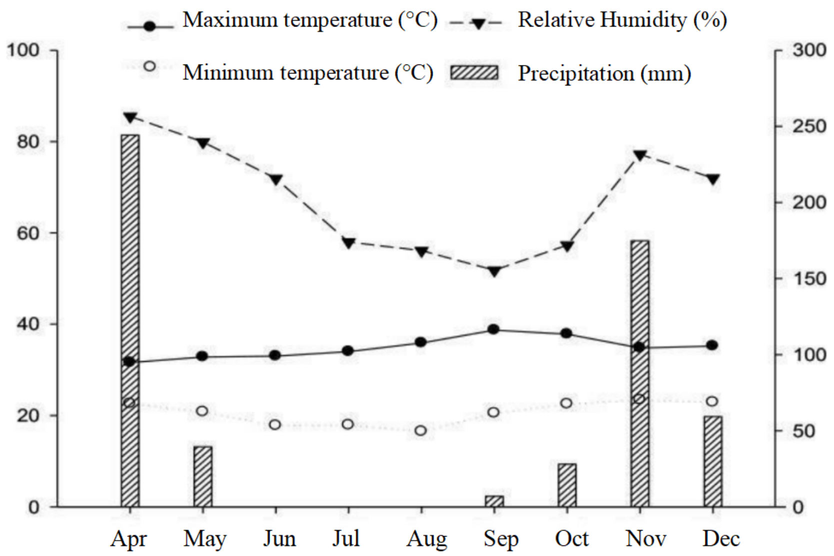

Figure 1. Monthly average values for minimum and maximum air temperature (°C), relative humidity (RH) and precipitation (mm), during the period of conducting the experiments, to evaluate the agronomic and productivity characteristics of okra (*Abelmoschus esculentus* (L.) Moench) as a function of N dose. Gurupi Campus, Federal University of Tocantins, Brazil, 2015.
Source: INMET[19].

The experimental design used was a randomized block design with six treatments 0, 50, 100, 150, 200 and 250 kg ha^{-1} of N and four replications. Urea (46-00-00) was used as the N source. The N doses studied were distributed in two applications, 50% was applied in the furrow at sowing and the remaining 50% was added in the cover crop (30 days after sowing (dds)).

Fertilization was carried out according to the soil analysis. A total of 80 kg ha^{-1} of K_2O was applied, distributed in two applications, 50% at sowing and 50% in the cover crop (30 dds). As a source of phosphorus, 60 kg ha^{-1} of P_2O_5 were applied at sowing, in the form of simple superphosphate.

The plots consisted of forty plants, distributed in four 5.0 m long furrows, with a spacing of 0.50 m between plants and 0.80 m between rows; the twenty central plants were considered as the useful plot. The Santa Cruz 47® variety was used in direct sowing, and four seeds were planted per plant. Ten days after emergence, thinning was carried out at one plant per bush.

Soil preparation was conventional. In the first period (autumn/winter), sprinkler irrigation was carried out in two-day periods until 30 dds (totaling fifteen irrigations) and with a three-day period after that period until harvest (totaling thirteen irrigations).

Weed control was manual. During crop management, pest and disease control was carried out according to the recommendation for the crop[21].

Harvesting began at 45 days and was followed by harvesting every two days, when the fruits were tender, fiber-free, deep green in color and over 10 cm in length. Harvest duration was 45 days. The characteristics evaluated were: 1) commercial fruit yield: obtained by the weight of the commercial fruit harvested from the useful plot on a digital scale and the data converted into Mg ha^{-1}; 2) average mass of the commercial fruit (g): obtained from the weight of the commercial fruit harvested from the useful plot on a digital balance; 3) plant height (cm): evaluated at flowering with a tape measure graduated in centimeters; 4) total chlorophyll index: determined with the use of a portable chlorophyllometer model CFL 1030.

In each period the mean values of each plot were subjected to individual and pooled analysis of variance (after comparison of the ratio of the mean squares of the residual), Tukey's test[22] was applied ($p \leq 0.05$) and a regression analysis. The variables that had a response were fitted to mathematical models to explain the variation in the observed data. Graphs were produced in the Zigma Plot program. Statistical analyses were performed with SISVAR software version 5.3[23].

3. Results

Between evaluation periods, significant differences were found for productivity and plant height, but not for chlorophyll index and mean fruit mass (**Table 1**).

Table 1. Overall mean for productivity, plant height, chlorophyll, mean mass, length, fruit diameter of okra (*Abelmoschus esculentus* L.) in two sowing periods. Gurupi Campus, Federal University of Tocantins, Brazil, 2015.

Features	**Period**	
	Autumn/winter	**Spring/Summer**
Production (Mg ha^{-1})	13.86 a	9.95 b
Mass of fruit (g)	20.00 a	20.00 a
Plant height (cm)	92.46 a	71.06 b
Chlorophyll (ICF)	44.04 a	44.48 a

Means followed by the same lowercase letter on the line indicate that they do not differ statistically from each other by Tukey's test ($p \leq 0.05$).

Although insects and pathogens are more likely to appear during the rainy season, no incidence was observed, since insecticide and fungicide applications were made to control them. In addition to fertilization, local climatic conditions are pre-harvest factors that affected yield.

Okra productivity responded to N doses in an increasing linear fashion (**Figure 2**), where the 250 kg h^{-1} dose in the two periods was the maximum production with 16.83 Mg ha^{-1} (autumn/winter) and 13.50 Mg ha^{-1} (spring/summer).

The minimum values of fruit production could be observed in the 0 N dose (control) in the two sowing periods (with 9.79 Mg ha^{-1} in autumn/winter and 6.00 Mg ha^{-1} in spring/summer). Comparing the control with the 250 kg ha^{-1}, there was a difference of 7.04 and 7.5 Mg ha^{-1} for fall/winter and spring/summer, respectively, indicating that fertilization resulted in significant yields with N applications.

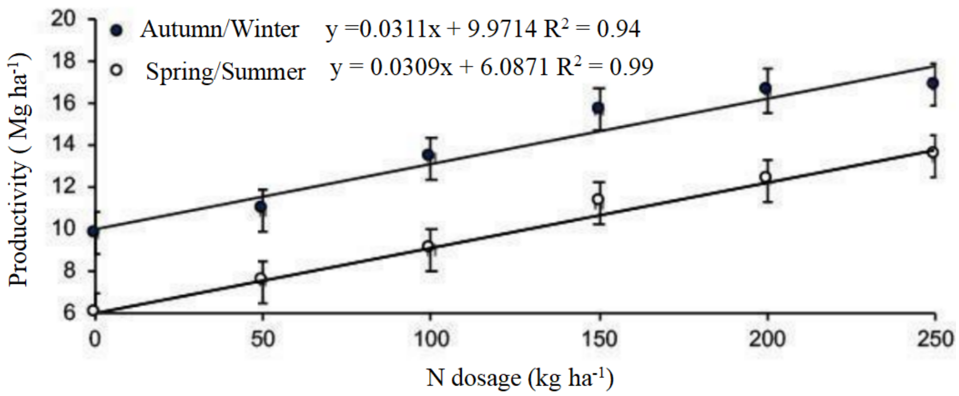

Figure 2. Fruit productivity of okra (*Abelmoschus esculentus* L.), as a function of N doses in two sowing periods. Gurupi Campus, Federal University of Tocantins, Brazil, 2015.

Although okra is considered a rustic plant, a growing and satisfactory effect is perceived with increases up to a dose of 250 kg ha^{-1} of N, and it behaved as a plant with a high response to this nutrient, which positively affects the fruiting of the plant and contributes to the development of the root system, production and quality of the fruits.

The treatment without N fertilization showed lower productivity than those with fertilization.

Fruit mass ranged from 16 to 20 g, with the 250 kg ha^{-1} showing the highest values (20 g) in the two planting periods (**Figure 3**).

The control had the lowest mean fruit mass with 16 g and 18 g in the autumn/winter and spring/summer periods, respectively. For plant height, significant differences were observed between planting periods and between N treatments. In the autumn/winter crop the mean was 92.46 cm and for spring/summer it was 71.06 cm.

Plant height increased with increasing N doses, however, this increase was not reflected in the average fruit mass in the fall/winter period, as can be seen in **Figure 3**. It was observed that plant growth was related to productivity and in this sense was dependent on N availability. At 250 kg ha^{-1} the highest plant heights were obtained with 97.95 (fall/winter) and 84.65 cm (spring/summer) (**Figure 4**).

The chlorophyll index between planting periods did not differ. However, the index increased in relation to N doses (**Figure 5**).

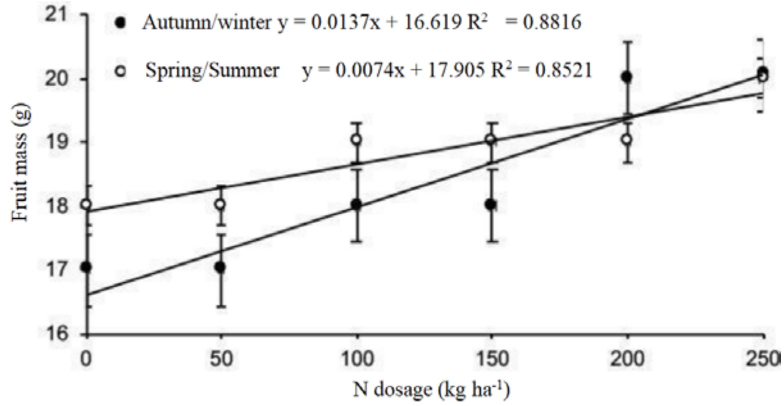

Figure 3. Mass of okra (*Abelmoschus esculentus* L.) fruit as a function of N. Campus Gurupi, Federal University of Tocantins, Brazil. 2015.

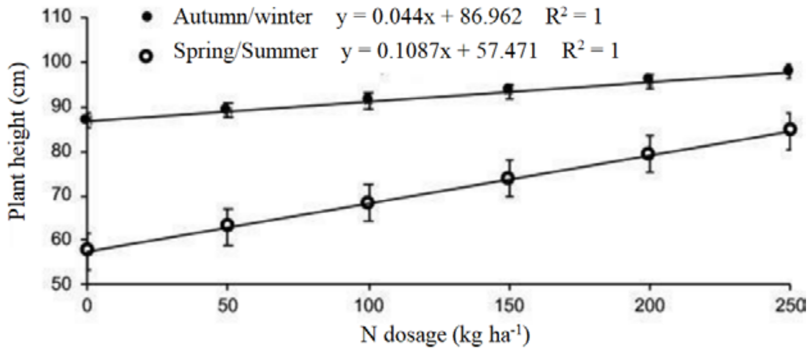

Figure 4. Height of okra (*Abelmoschus esculentus* L.) plants as a function of N dose. Gurupi Campus, Federal University of Tocantins, Brazil, 2015.

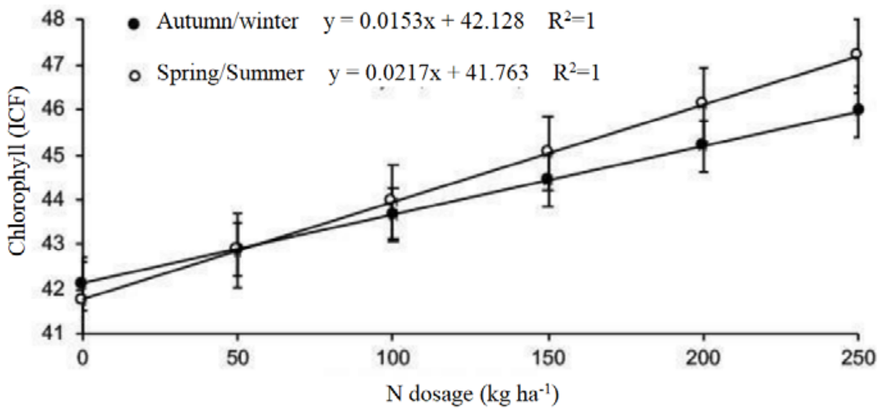

Figure 5. Total chlorophyll index in okra (*Abelmoschus esculentus* L.) crop as a function of N dose. Gurupi Campus, Federal University of Tocantins, Brazil, 2015.

The highest chlorophyll indices were 45.96 and 47.19 with 250 kg N ha^{-1} for the autumn/winter and spring/summer periods, respectively. The lowest indices were for the control with 42.13 in the first period and 41.76 in the second.

The chlorophyll index increased linearly with increasing N doses. At the 250 kg ha^{-1} the chlorophyll index was higher.

4. Discussion

The highest fruit production occurred in autumn/winter (13.86 Mg ha^{-1}) (**Table 1**), these results can be attributed to the climatic conditions of each period.

Meteorological data in the region during the periods of the experiments (**Figure 1**) recorded a maximum temperature in autumn/winter between 31.6 to 34 ℃ and relative humidity ranging from 58.0 to 85.5%, while in the spring/summer period the maximum temperature ranged from 34.8 to

38.7 °C with relative humidity between 51.8 to 77.2%, which possibly promoted a negative effect on the development and production in the okra crop.

Meteorological factors can influence development and production, because they act directly on plant metabolism[6]. The most appropriate average temperature for okra cultivation is between 21.1 to 29.4 °C, with an average maximum at 35 °C and a minimum of 18.3 °C[15]. Relative humidity for okra production is also important, since most fungal diseases occur due to high humidity, for okra culture, the amount of water in the soil should not be less than 65% of field capacity[24]. In rainy months, losses of applied N can be accentuated to the detriment of the agronomic performance of vegetables. At the same time, the volatilization of NH_3 from urea increases with temperature, so the hydrolysis rate provides a greater amount of volatile NH_3[25,26].

The okra production obtained was found within the range of the Brazilian average which is estimated around 15 and 20 Mg ha^{-1}, with a vegetative cycle varying between 150 and 400 days, and 12 Mg ha^{-1} when the cycle is 120 days[1,27]. Similar results were found by Oliveira *et al*.[28], when studying okra production in the city of Areia in the state of Paraíba as a function of N dose (0, 50, 100, 150 and 200 kg ha^{-1}), where they observed a maximum production of 16.7 Mg ha^{-1} at the N dose of 150 kg ha^{-1} , and at the 0 dose (control) a maximum productivity of 6 Mg ha^{-1}.

The increase in production occurs because okra demands higher amounts of N, being this nutrient limiting in its production, mainly in tropical soils, where its content is low, which implies the practice of nitrogen fertilization. The work of Oliveira *et al*.[29] also reported positive effects of N on fruit mass (18 g), number of fruits per plant (34 fruits plant^{-1}) and production (22 Mg ha^{-1}) of okra. The maximum fruit mass obtained in this work was similar to that of Zucchi *et al*.[30] of 20 g. By omitting N in the nutrient solution in okra, a reduction in plant height and intense fall of flower buds was observed, which reduced its fruiting[31].

The maximum dose of N compared to the absence of nitrogen fertilization resulted in higher fruit mass, leading to a greater efficiency of use of the factors of the environment that resulted in fruits with higher mass[32].

A low or lack of N in the plant would cause a decrease in assimilates, consequently, a decrease in the number of fruits per plant, a reduction in mass and other changes in fruit characteristics, such as length, width, color and texture[33].

N deficiency in the crop affects and limits vegetative growth and development, reduces leaf size due to lack of chlorophyll, low formation of proteins and structural genetic materials, which reduces the photosynthesis process[34].

The maximum plant height was 98 cm at the highest N dose, other authors such as Nascimento et al.[2] reported lower values when using different levels of salinity in irrigation and four doses of N(50, 75, 100 and 125 kg ha^{-1}) in Cruz de las Almas—BA with a maximum height of 75.16 cm; in the same sense Costa[35], in Santa Helena de Goiás—GO, observed a maximum height of 73.82 cm.

In relation to the chlorophyll index, Sediyama *et al*.[36] obtained results similar to those of the present research, when evaluating the productivity of okra as a function of porcine biofertilizer doses in Oratórios—MG, where they found a linear increase as the biofertilizer dose increased, they observed with the maximum dose a chlorophyll index of 46.87. The higher index occurred due to a higher amount of pigment present in the leaf, since this is positively correlated with the N content in plants, mainly due to the fact that between 50 and 70 % of the total N in the leaves are an integral part of enzymes that are associated with chloroplasts. The chlorophyll index can be indicative of N concentration in leaves, helping in the management of nitrogen fertilization of crops[37].

Just as production increased linearly with increasing N doses, the chlorophyll index responded in the same way, since N concentration has a direct relationship with photosynthetic efficiency. This occurs because chlorophyll is responsible for the conversion of light energy to chemical energy by specific photoreceptors[38]. The process occurs in leaves by the dependence of enzymes, basically constituted of proteins, which depend on N[38,39].

5. Conclusions

Planting time and soil nitrogen content interacted with okra plant height, being favorable in the period when precipitation did not occur.

N can influence all characteristics, which demonstrates the importance of nitrogen fertilization on plant development in okra cultivation.

Conflict of interest

The authors declared no conflict of interest.

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