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Nitrogen fertilization and different crop management practices in pickling cucumber (*Cucumis sativus* L.)

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Abstract

The use of nitrogen (N) fertilization has been shown to increase the quality and production of cucumber. Thus, the goal of this work was to evaluate crop management practices with and without shoot pruning and the application of N in a pickling cucumber crop under greenhouse conditions. The experiment was conducted in a greenhouse at the Goiano Federal Institute, Urutaí Campus. The experimental design involved randomized blocks in a 2×5 factorial arrangement, with two different management treatments (with and without pruning) and five doses of N (0, 50, 100, 150 and 200 kg ha^{-1} N), with four replicates. The doses of N were split among three applications at 15, 30 and 45 days after plant emergence. Each plot contained ten plants with a 0.2-m spacing between plants and a 0.8-m spacing between rows. The four central plants in each plot were evaluated, and the following assessments were performed: leaf N content, relative chlorophyll index, stem diameter, fruit length, fruit diameter, number of fruits, fruit fresh mass, fruit dry mass, shoot fresh mass, production per plant and total yield. The data were subjected to analysis of variance (F test) at the 5% probability level, and when significant effects were observed for the N doses, regression analyses were performed. Management with and without pruning directly influenced the production of pickling cucumber. The doses of N influenced the development and yield of cucumber under greenhouse conditions.

Keywords: Production, Nitrogen, Greenhouse.
Abbreviations: N_nitrogen; LNC_leaf N content; RCI_relative chlorophyll index; SD_stem diameter; FL_fruit length; FD_fruit diameter; NF_number of fruits; FFM_fruit fresh mass; FDM_fruit dry mass; SFM_shoot fresh mass; PRODP_production per plant; YIELD_total yield.

Introduction

Cucumbers (*Cucumis sativus* L.) are a common component in the diet of the global population and are consumed in both fresh and pickled forms, as well as in a wide variety of dishes.

Cucumber is an herbaceous, annual plant with large stems and an indeterminate growth habit and features berry-type fruit, which are supported by tendrils along the branches (Filgueira, 2012).

The cucumber crop is of great social importance and requires direct and indirect labour because of the cultural practices required throughout the crop cycle. In addition, cucumber has been gaining prominence in the vegetable market for its use in the pickling industry, which provides greater added value and increases revenue, especially for family agricultural operations.

Producers in the state of Goiás represent a large proportion of the domestic production of multiple crops, and the success of the cucumber crop is largely due to the high level of production technology used by the producers. In this sense, the efficient use of nitrogen (N) fertilization and crop management in greenhouses can contribute to both the financial and environmental success of the crop in the state.

The use of cultivation techniques for various crops has been increasingly studied, especially at the time of the cultural practices. The removal of branches from the lower part of the cucumber plant is a strategy for improving cucumber development, quality and production.

Studies on plant management and pruning systems are important for understanding the physiological factors associated with the production performance of the crop and for the adoption of more appropriate production systems to meet the demands of the produce sector and the market (Sediyama et al., 2014).

The management of production and distribution of photoassimilates consists of pruning the plant population and maximizing the fruit production, which are related to the need to achieve the potential production of assimilates throughout the entire plant and to allocate the assimilates with the greatest possible quality for fruit production (Schvambach et al., 2002; Resende and Flori, 2004).

N is a nutrient that influences processes involved in plant growth, development and yield, and it changes the source-

sink relationship and, consequently, the ratio of assimilates between vegetative and reproductive organs (Queiroga et al., 2007).

N is important throughout the entire cucumber crop cycle, as it crucial to the formation of amino acids, proteins, nucleic acids and other cell constituents needed for plant and fruit growth. The leaves play a large role in the N metabolism (Tanemura et al., 2008).

However, the excessive application of N can harm plant development and production and can cause damage to the environment. Therefore, the rational use of N-based fertilizers, with the aim of increasing the efficiency of N use by plants, is essential for the sustainable development of agriculture (Xu et al., 2012).

Therefore, the goal of the present work was to evaluate the management of a pickling cucumber crop with and without shoot pruning and the application of doses of N under greenhouse conditions.

Results and Discussion

Development and production components

The results revealed no significant differences between treatments with and without pruning in terms of leaf N content, relative chlorophyll index at 20 and 35 days after emergence (DAE) of the plants, stem diameter, fruit length and fruit diameter (Table 1). Additionally, no differences in terms of fruit length and diameter were present because size and diameter were standardized to meet the pickling standards (Table 1).

Management practices only affected the relative chlorophyll index at 50 DAE (Table 1). Pruning resulted in better apical growth because the plant did not need to allocate part of its nutrients to the lower branches. This result is related to the fact that N is a mobile nutrient in the plant (Malavolta et al., 1997), and it is involved in plant growth and development and may change the source-sink relationship, thus leading to changes in the distribution of the assimilates between vegetative and reproductive organs (Queiroga et al., 2007). In the family Cucurbitaceae, N fertilization can result in an increase in the leaf area of the plant and can consequently affect the production of photoassimilates and fruits.

The interaction between management practices and N doses had a significant effect (Fig 1A). However, this effect was only observed for management without pruning. The N doses influenced the leaf N content of cucumber, exhibiting a quadratic trend with a peak at 137 kg ha^{-1} N corresponding to a leaf N content of 46.2 g kg^{-1}. According to Trani and Raij (1996), the N content was within the range ideal for a cucumber crop, i.e., between 45 and 60 g kg^{-1} (leaf dry mass), indicating that the plants had an appropriate amount of N. The values found in this work are close to those reported by Pôrto et al. (2014) for a cucumber crop and Azambuja et al. (2015) and Pôrto et al. (2011) for a zucchini crop.

The N doses significantly influenced the relative chlorophyll index of the cucumber plants at 35 DAE, resulting in a value of 35 (Fig 1B). A quadratic trend was observed, with a peak at 121.37 kg ha^{-1} and a SPAD index value of 39.8 (Fig 2). The results corroborate the findings of other authors for pumpkin (Swader and Moore, 2002), muskmelon (Azia and Stewart 2001), cucumber (Pôrto et al., 2014), zucchini (Pôrto et al., 2011), radish (Caetano et al., 2015) and cabbage (Nascimento et al., (2017), which also exhibited increased relative chlorophyll index values in their leaves with increased doses of N. According to Fontes and Araujo (2007), N is a macronutrient involved in the synthesis and the structure of the chlorophyll molecules; thus, to a certain level, the increase in the N supply available to plants promotes an increase in the relative chlorophyll index and produces a more intense green colour in the plant's leaves.

The interactions between management with and without pruning and the N doses had significant effects on the relative chlorophyll index at 50 days (Fig 1C). The values associated with the management treatment with pruning followed an increasing linear trend, with SPAD index values between 40.5 and 49.9. The values associated with the management treatment without pruning exhibited a quadratic trend, with a peak at 143.87 kg ha^{-1} N and a SPAD index value of 45.00. Güler and Büyük (2007) concluded that the maximum yield in a cucumber crop corresponded to a critical SPAD index level of 44.93.

The interaction between management without pruning and the N doses had a significant effect on stem diameter (Fig 1D). The values fit a quadratic regression, with a peak at 99.5 kg ha^{-1} N and a stem diameter of 10.13 mm. Silva et al. (2011), who studied N levels and cucumber plants, observed that, in conjunction with a complete nutrient solution, the stem diameter was 8.61 mm at 28 days after transplanting. N fertilization was reported to have significant effects on stem diameter by Costa et al. (2015), who evaluated the application of different doses of N (0, 90, 180 and 270 kg ha^{-1}) and the resulting impacts on the stem diameter of spaghetti squash, specifically the cultivar Novita Plus. Those authors concluded that the largest stem diameter was obtained with a dose of 145 kg ha^{-1} N. Silva et al. (2011) found that N levels limited the cucumber plant growth in terms of stem diameter: the application of 30% of the N amount recommended for the crop resulted in a stem diameter of 7.05 mm, whereas the application of the recommended dose resulted in a diameter of 8.61 mm.

The data on the number, fresh mass and dry mass of fruits showed no significant differences (Table 2). However, significant effects were observed for shoot fresh mass, yield per plant and total production (Table 2). Sediyama et al. (2014) evaluated different types of pruning in cucumber and observed that pruning resulted in a lower crop yield. The lack of differences in the fruit fresh mass and dry mass between the management treatments with and without pruning is related to the harvest time, which was determined following the commercial standards for pickling cucumber.

A relationship between shoot fresh mass and yield was observed: a greater leaf area corresponded to a greater production of photoassimilates and, consequently, a greater yield. Sediyama et al. (2014), who studied pruning in aodai, Japanese and caipira cucumber plants, observed that the cucumber fruit yield was directly related to the shoot fresh mass. The authors concluded that the increase in fruit yield, number of fruits and fruit mass was attributable to the increased availability of carbohydrates resulting from greater photosynthetic activity in the leaves.

Galvani et al. (2000) reported correlations between the leaf area index and yield of cucumber, specifically the cultivar Hokuho, under greenhouse and field conditions. The authors

Table 1. Leaf N content (LNC), relative chlorophyll index at 20, 35 and 50 DAE (RCI), stem diameter (SD), fruit length (FL) and fruit diameter (FD) as functions of management with and without pruning in pickling cucumber crop. Urutaí-GO, 2016.

Treatment Managements	LNC	RCI 20	RCI 35	RCI 50	SD	FL	FD
	g kg^{-1}	---------- Spad ----------			------- cm -------		mm
without pruning	43.94 a	30.17 a	38.10 a	36.21 b	8.85 a	7.46 a	21.40 a
with pruning	45.08 a	30.01 a	38.04 a	40.59 a	8.52 a	7.51 a	21.41 a
F Value	3.801	0.001	0.016	9.870	2.157	4.430	0.001
CV (%)	4.17	7.16	3.82	4.21	8.15	0.95	2.12

Means followed by the same letter in the column do not differ from each other by the F test at 5% probability.

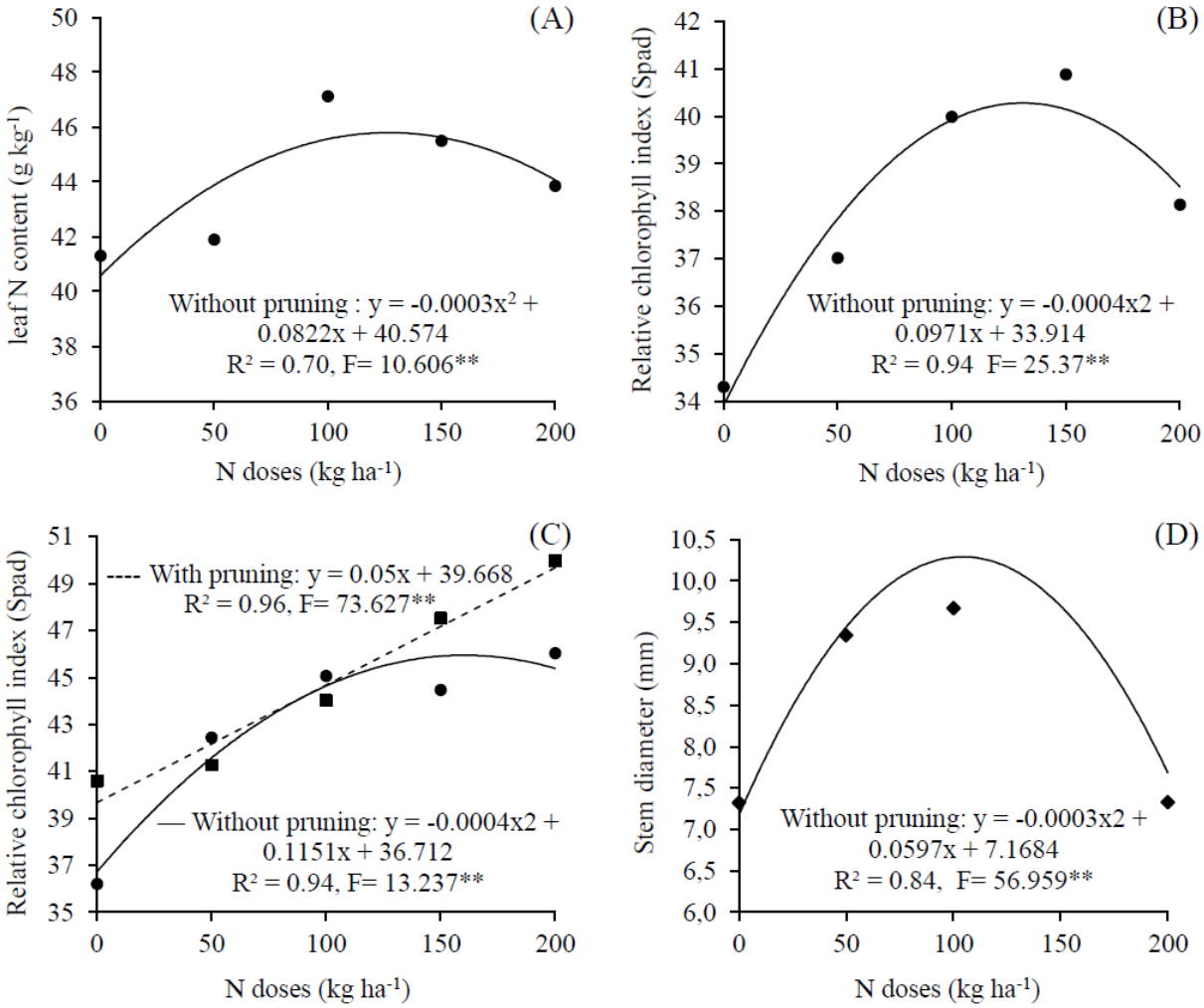

Fig 1. Values of leaf N content (A) and relative chlorophyll index at 35 DAE (B) as a function of N dose, interaction between N dose and management for the relative chlorophyll index at 50 DAE (C) and stem diameter as a function of N dose (D) in a pickling cucumber crop. Urutaí-GO, 2016. ** = significant at a 1% probability.

Table 2. Number of fruits (NF), fruit fresh mass (FFM), fruit dry mass (FDM), shoot fresh mass (SFM), production per plant (PRODP) and total yield (YIELD) as a function of management with and without pruning in a pickling cucumber crop. Urutaí-GO, 2016.

Treatment Managements	NF	FFM	FDM	SFM	PRODP	YIELD
	fruits ha^{-1}	---------- g plant^{-1} ----------				kg ha^{-1}
without pruning	35800 a	33.35 a	1.50 a	536.15 a	1013.00 a	56293 a
with pruning	30216 a	31.35 a	1.40 a	380.71 b	833.81 b	46322 b
F Value	5.048	1.915	2.247	32.202	6.529	6.529
CV (%)	23.80	14.12	14.11	18.89	24.05	24.05

Means followed by the same letter in the column do not differ from each other by the F test at 5% probability.

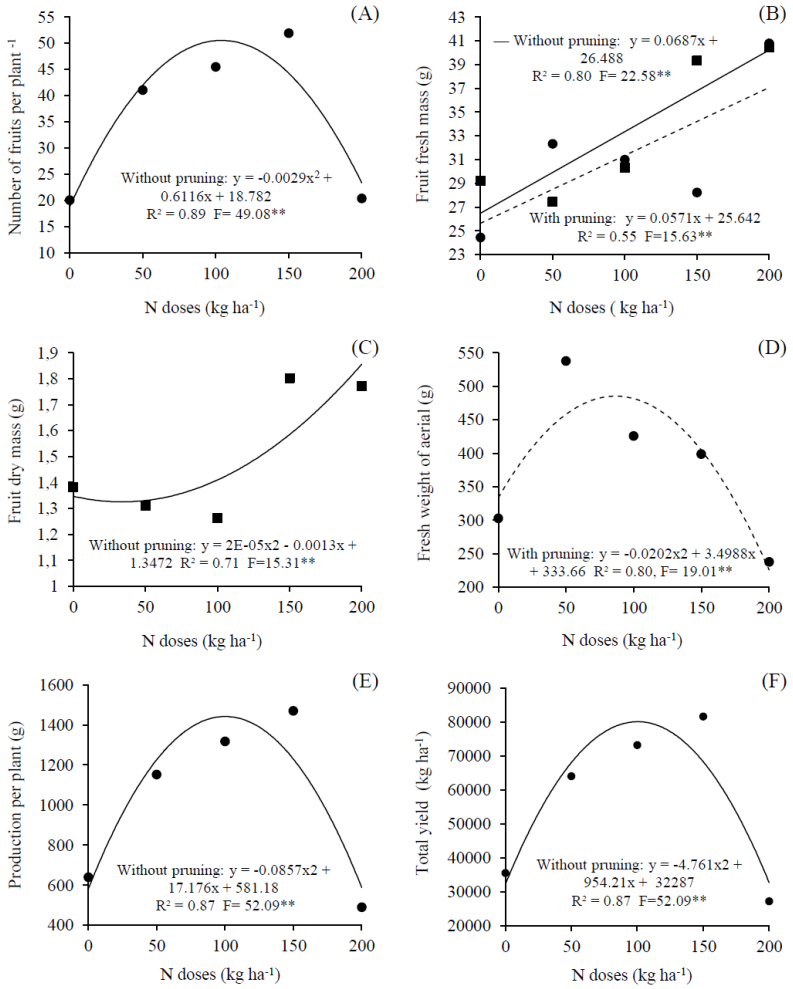

Fig 2. Number of fruits per plant in management without pruning (A), fruit fresh mass in management with pruning (B), fruit dry mass in management without pruning (C), fresh weight of aerial in management with pruning (D) and production per plant (E) and total yield (F) in management without pruning in a pickling cucumber crop. Urutaí-GO, 2016. ** = significant at a 1% probability.

found that the maximum yield occurred in areas with the highest leaf area index values in the crops under both conditions. Sediyama et al. (2014) found that management treatments with pruning did not result in increases in fruit yield for cucumbers from the groups aodai, Japanese and caipira in the Minas Gerais forest zone (Zona da Mata Mineira).

The number of fruits per plant was significantly affected by the combination of management without pruning and N doses (Fig 2A). The values fit a quadratic regression with a maximum production of 51.0 fruits per plant at a N dose of 105.45 kg ha^{-1}. These results are higher than those obtained by Silva et al. (1988), i.e., 10.8 fruits per pickling cucumber plant, and higher than those reported by Resende and Flori (2003), i.e., 9.01 to 14.81 fruits per pickling cucumber plant.

In terms of fruit fresh mass, significant effects were observed between management treatments with and without pruning and doses of N (Fig 2B). In the management treatments with and without pruning, the values fit a positive linear regression with the doses of N. Resende et al. (2003) assessed cultivars of pickling cucumber and obtained values of fruit fresh mass between 39.77 and 47.07. Antunes et al. (2014) analysed African horned cucumber yield in response to N fertilization (0, 40, 80, 120, 160 and 200 kg ha^{-1}) and observed a quadratic relationship between the characteristic production of fruit fresh mass per plant and the N dose, with an estimated production of 516.41 g per plant at a N dose of 154.44 kg ha^{-1}.

In terms of fruit dry mass (Fig 2C), there was an interaction between the management practices and doses of N, but significant effects were only observed for the management treatment without pruning. The values fit a quadratic regression with a minimum value of 33.7 kg N. For shoot fresh mass, the values of the interaction fit a quadratic regression with a peak at 86.60 kg N (Fig 2D). The results obtained for the production per plant and yield revealed that the interaction between management treatment without pruning and N doses had significant effects (Fig 2E and 2F), resulting in quadratic regressions with peaks at 100.2 kg N for both analysed variables, corresponding to a maximum production per plant of 1441.7 g per plant and a yield of 80,098 kg ha^{-1}. The results obtained in this work show that the observed yield was higher than those reported by Resende et al. (2003) and Resende and Flori (2003), who evaluated the agricultural performance of pickling cucumber cultivars and obtained maximum yields of 39.780 and 34.540 kg ha^{-1}, respectively. Therefore, these results show that the yields obtained in this work are above

the expected yields for pickling cucumber under greenhouse conditions.

Materials and Methods

Location and installation of experiment

The experiment was conducted in a greenhouse at the Goiano Federal Institute (Instituto Federal Goiano - IF Goiano) - Urutaí Campus, located on Highway Geraldo Silva Nascimento, km 2.5, in a rural zone in the municipality of Urutaí in Goiás state (GO), Brazil. The site has an average elevation of 744 m and is located at latitude 17° 27' 49'' S and longitude 48° 12' 06'' W. The climate of the region is Cwa, according to the Koppen classification, which is characterized as a warm temperate climate, with summer rains and an average air temperature greater than 22 °C (Cardoso et al., 2014). The soil of the area is classified as Red Latosol according to Santos et al. (2013). The chemical characteristics of the soil in the experimental area were determined before performing the experiment according to the methodology proposed by Ribeiro et al. (1999), and the following chemical features were obtained in the 0.0-0.20 m layer: 920 mg dm^{-3} of P (Melich); 23 g dm^{-3} of organic matter; pH 5.7 ($CaCl_2$); K, Ca, Mg and H+Al = 8.0; 89.0; 23.0 and 16.0 mmolc dm^{-3}, respectively, and a base saturation of 88.5%.

Statistical design and plant materials

The experimental design used in this study involved randomized blocks in a 2x5 factorial arrangement, with two crop management treatments (with and without pruning) and five doses of N (0, 50, 100, 150 and 200 kg ha^{-1} of N), with four replicates. The doses of N were split among three applications at 15, 30 and 45 DAE of the plants. Each plot was composed of ten plants, with a 0.2-m spacing between plants and a 0.8-m spacing between rows. The four central plants of each plot were evaluated.

The greenhouse used in this study was a plant nursery, with dimensions of 6.4 m x 18.0 m and a height of 4.00 m under the gutter and 6.00 m at the peak of the arched cover. The structure was built with galvanized steel arches and was covered with 150-µm reflective polyethylene film.

Seeds of the pickling cucumber (*Cucumis sativus* L.) hybrid Kybria F1 were used, and sowing was performed on 01/19/2016 by placing two seeds directly into the planting furrow. Thinning was performed, leaving only one plant per furrow after their emergence. Irrigation was performed using a drip irrigation system, and the soil was kept near field capacity, i.e., 15 kPa potential, as monitored by a mercury tensiometer placed 0.10 m from the crop at a depth of 0.15-0.30 m in the experimental area. Pruning was performed at the heights of 0.20 and 0.10 m, when 50% of the plants reached heights of 0.5 and 1.0 m, respectively. Manual weeding and plant health control were performed as needed to control weeds and pests.

Evaluated characteristics

The harvests were performed daily, starting at 37 days after sowing and lasting for a period of 36 days. The following plant-related parameters were assessed: leaf N content, relative chlorophyll index, stem diameter, fruit length, fruit diameter, number of fruits, fruit fresh mass, fruit dry mass, shoot fresh mass, production per plant and total yield. At 20, 35 and 50 DAE, the relative chlorophyll index was determined in the fourth fully expanded leaf counted from the apex in each of the four plants per plot using a portable chlorophyll meter. To measure the N concentration in the leaves, the fourth fully expanded leaf with petiole, as counted from the apex, was collected from each of the four plants per plot at 51 DAE and was dried in a forced air oven at 65 °C for approximately 48 hours. After drying, the material was ground in a Wiley mill equipped with a 1-mm mesh sieve and was stored in paper bags until analysis, according to the methods described in Malavolta et al. (1997).

The length and diameter of the fruits were measured in millimetres using a graduated ruler. The fresh and dry masses of the fruits were obtained by weighing the material using a 0.001-g precision scale before and after drying in a forced air oven at 65 °C. For the shoot fresh mass, all four plants in each plot were collected and weighted, and the average weight was used to represent the treatment. The number of fruits and the production per plant were obtained by counting and weighing all fruits harvested during the experiment.

Statistical analysis

The data were subjected to analysis of variance (F test) at the 5% probability level, and when significant effects were observed for the N doses, regression analysis was performed. All statistical analyses were performed using R 3.1.2 software (R Core Team, 2015).

Conclusion

Management with and without pruning directly influenced the production of pickling cucumber.

The doses of N influenced the development and yield of cucumber under greenhouse conditions.

Conflict of interests

The authors have not declared any conflict of interests.

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