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Cucurbita pepo nitrogen fertigation in greenhouse environments

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Greenhouse crops afford higher quality and competitiveness. The objective of this work was to evaluate the effect of nitrogen doses (80, 110, 140 and 170 kg ha^{-1}) applied through fertigation in the yield of two cultivars of *Cucurbita pepo* (Anita F1 and Novita Plus), in a 4 × 2 factorial design. The experiment was carried out in an entirely randomized design with eight replications. The study evaluated the sum of the fresh biomass of fruits per plant, number of fruits per plant and mean fruit biomass. Analysis of the collected data made it possible to assume that increasing doses of N led to a linear yield increase for cultivar Anita F1 and a quadratic increase for cultivar Novita Plus.

Key words: *Cucurbita pepo*, nitrogen, drip fertigation, vegetables.

INTRODUCTION

Vegetable production is an intensely competitive activity. The market demands constancy and production volume, which vegetable farmers cannot meet due to lack of investment in technology for production systems. In this context, greenhouse crops emerge as an alternative for the seasonality of production and increased productivity, as crops are not exposed to environmental variability and disease control is more efficient. Moreover, greenhouse crops afford higher quality, such as with leafy vegetables, and earlier production (Purquerio et al., 2007).

Nitrogen is linked to photosynthesis, respiration, root development and activity, cellular growth and differentiation. It is among the nutrients that promote the most significant morphological changes in the plant, capable of altering the number and mass of fruits. On the other hand, excessive doses of nitrogen promote vegetative growth in detriment of reproductive growth (Marschner, 1995). Nitrogen fertilization of squash promotes plant growth from the seedling stage (Higuti et al., 2010), which may lead in the future to larger leaf area and greater supply of photoassimilates for fruits. To obtain high yields, it is essential to avoid excess or deficient nitrogen fertilization.

Fertigation is the technique of adding solubilized nutrients to irrigation water. The success of fertigation depends on a combination of factors, including the uniformity of water application, which reflect directly on the uniformity of nutrient distribution in the area. For this

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Table 1. Physical and chemical properties of the soil of the experimental sites before planting.

Parameter	Results
Physical properties (%)	
Coarse sand	5.0
Fine sand	8.3
Silt	12.0
Clay	74.7
Textural class	Clay
Chemical properties	
pH in Water	6.80
pH in $CaCl_2$	6.10
Organic matter (g dm^{-3})	26.08
Total Carbon (g dm^{-3})	15.13
Available P (mg dm^{-3})	4.27
Exchangeable K (cmol $dm^{-3)}$	0.27
Exchangeable Ca (cmol $dm^{-3)}$	5.07
Exchangeable Mg (cmol $dm^{-3)}$	1.45
Cation exchange capacity (cmol dm^{-3})	9.53

reason, fertigation combined with a drip irrigation system shows higher efficiency compared to other irrigation methods. In addition, fertigation is the better technique for nitrogen application in *Cucurbita pepo* compared to solid-form application followed by irrigation, as it increases the efficiency of nitrogen and water use (Mohammad, 2004). Improper technique leads to several problems, such as soil salinization and fertilizer waste, which can decrease productivity, increase the incidence of disease (Zatarim et al., 2005) and reduce the viability of the production system. This reinforces the need for more information on nitrogen fertilization in greenhouse environments, in order to support proper handling and obtain maximum yield per unit of nitrogen applied.

The adequate dose of nitrogen varies according to the technology of the production system, edaphoclimatic conditions and crop characteristics. Currently there is scarce information on *C. pepo* crops grown in greenhouse environments to evaluate growth and yield by using the fertigation technique. Several works can be found in the literature on nitrogen fertigation of other cucurbitaceous species, such as watermelon, melon and cucumber. However, extrapolating the results of other crops may not be adequate. The objective of this work was to evaluate the production of two cultivars of *C. pepo* (Anita F1 and Novita Plus) by applying different nitrogen doses (80, 110, 140 and 170 kg ha^{-1}) through fertigation in a greenhouse.

MATERIALS AND METHODS

The experiment was carried out at the Irrigation Technical Center (CTI) of the Agronomy Department at Maringá State University (UEM), located in Maringá, PR, at an elevation of 542 m and coordinates 23° 25' S and 51° 57' W. The greenhouse structure featured an arch-type cover, was 30 m long, 6.9 m wide and 3.5 m tall. The experiment was installed in a distroferric red Nitosol area with moderate A horizon, clayish texture, subperennial tropical forest phase (EMBRAPA, 2006).

The microirrigation system consisted of a 0.5 m^3 reservoir in which the fertilizers were solubilized, and a valve that allowed water to enter the SC-30SM motor-pump set, installed below the bottom of the reservoir. A total of 14 kPa of operating pressure was used, providing mean flow of 0.9 L h^{-1} per drip feeder. A slide valve and manometer adaptation were installed at the pump output, enabling control of pressure in the system. The main line consisted of PVC tubes, 0.032 m in diameter. The main line had a return to the reservoir, characterizing a closed system and making it possible to clean the main line after each fertigation process. Seven irrigation lines were installed with high-density polyethylene pipes, 0.016 m in diameter, and 19 IRRITEC drips with 0.24 m of micro tube attached at the end of each drip, with the objective of placing the drip point 0.03 m from soil level.

To analyze the system and irrigation uniformity, the amount of water emitted by all drips individually was collected, for a period of 0.46 h. Data collection was performed with the aid of plastic containers, labeled and with a defined tare. The water mass collected in each drip was quantified using a GEHAKA BG8000 digital scale, accurate to 0.1 g. Given specific water mass equal to 1 kg L^{-1}, the flow of each drip was calculated in L h^{-1}. The distribution uniformity coefficient (CUD) was calculated according to Bralts (1986) and was equal to 91.3%.

The treatments were the result of the combination of four nitrogen doses (80, 110, 140 and 170 kg ha^{-1}) and two cultivars of *C. pepo* (Anita F1 and Novita Plus), totaling eight treatments arranged in an entirely randomized design in a 4 × 2 factorial treatment arrangement. Eight replications were used per treatment, totaling 64 plots.

To prepare the experimental area, the 0 to 0.15 m layer of soil was tilled with a rotary hoe over the full area. Holes were prepared

Table 2. Mean effect of nitrogen doses on yield attibutes of the varieties.

Variety	FFB	NF	AFB
Anita F1	538.80	2.67	200.62
Novita Plus	707.17	3.53	202.84
CV (%)	3.72	11.75	1.56
F test (P <0.01)	0.0029	0.0035	ns

FFB, Fruit fresh biomass; NF, number of fruits; AFB, average fruit biomass.

manually, at a depth of 0.20 m. The soil was analyzed at the Maringá Rural Laboratory. According to the results of the soil analysis (Table 1), Trani and Raij (1996) recommend increasing base saturation to 80% and providing 400 kg ha^{-1} of P. Dolomite with 84% relative efficiency and monoammonium phosphate (MAP) were used to prepare the holes. In addition, 2.1 g of urea were added to each hole, equivalent to 19.5% of the dose in the lowest treatment, so that the soil solution showed an adequate concentration of nutrients for early crop development (CARRIJO et al., 2004).

Sowing took place on March 17, 2012 in 72-cell Styrofoam trays previously filled with substrate. Transplantation took place 19 days after sowing (DAS), at a spacing of 0.80 m between rows and 0.75 m between plants. Acephate was sprayed at 14 and 19 DAS, Metamidophos at 32 DAS, Thiophanate-methyl and Chlorothalonil at 35 DAS, and Mancozeb at 35 and 47 DAS. Female flowers were manually pollinized every morning.

Potassium fertilization was equally distributed in six fertigations during the cycle, considering a crop extraction of 247.52 kg ha^{-1} of K and expected yield of 13600 kg ha^{-1} (Furlani et al., 1978; Carrijo et al., 2004). Nitrogen doses were equally distributed in five weekly fertigations starting 27 days after sowing (DAS) and on different days than potassium fertilizations. According to Vidigal et al (2007) , nitrogen and potassium have to be apllied in several doses throughout the cycle.

Urea dilutions for the treatments took place in the reservoir filled to the 150 L inner mark of water. 50 L of solution was used to stabilize the system, in which 26 L was used to fill the inner volume of the pipes and 24 L were used as a safety margin. During stabilization, the entire pool applied was collected in containers located under the drips. After stabilization, the motor-pump set was turned off, the containers below the drips corresponding to treatment were removed, and the motor-pump set was turned on again, applying 50 L. The remaining volume of solution in the reservoir was discarded. The applications of nitrogen doses in solid form were carried out near the drip point.

Soil moisture control was carried out with the aid of three tensiometers with Bourdon vacuum gauge, installed 0.20 m deep throughout the experimental area. The objective was to maintain soil water tension between 10 and 30 kPa, applying the same pool in all plots throughout the experiment.

Harvest began 52 DAS, lasting until 84 DAS. Fruits longer than 0.15 m were collected every morning. Immediately after harvest, the fruits were taken to the laboratory for analysis. The measurements of fruit fresh biomass were obtained using a GEHAKA BG8000 digital scale, accurate to 0.1 g.

Data on the sum of fruit fresh biomass (SFFB) per plant, number of fruits per plant (NF) and mean fruit biomass (MFB) were converted through a base 10 logarithm, so that residues would stand near normal distribution and feature homoscedasticity. They were later subjected to analysis of variance. The quantitative variables were subjected to regression analysis and tested by the test t (P <0.01).

RESULTS AND DISCUSSION

Table 2 shows the mean values for SFFB, NF and MFB of the cultivars in the average doses. Although cultivar Novita Plus showed higher yield per plant, mean fruit size did not show significant differences. Higher yields depending on N dose can be explained by the greater supply of photoassimilates to the fruits due to increased leaf area and liquid photosynthesis. N is absorbed by the mass flow and transported to the leaves, where approximately 70% of this nutrient is found in the chloroplasts, taking part in the synthesis and structure of chlorophyll molecules (Marenco and Lopes, 2005). Strassburguer et al. (2011) affirm that *C. pepo* shows higher harvesting rate if grown during spring-summer, when the availability of solar radiation is greater than during summer-fall, which suggests the importance of leaf area in capturing solar energy, producing photo-assimilates and supplies for fruits, resulting in higher yields.

Figure 1 shows the graphs of production as a function of tested doses. For cultivar Anita F1, the data fit the linear regression, which suggests that the dose corresponding to maximum yield is greater than 170 kg N ha^{-1}. For cultivar Novita Plus, variables SFFB and NF, data fit more adequately a polynomial regression, with maximum yield per plant of 942.4 g and 4.6 fruits corresponding to doses 142.1 and 133.3 kg N ha^{-1} (8.52 and 8.00 g of N per plant, respectively). For MFB, the increase was linear in response to application of the doses. The increase in the variables can be explained by the favoring towards formation of the vegetative canopy and extraction of N to form fruits (Carrijo et al., 2004). This result agrees with Zotarelli et al. (2008), who observed that the productivity of *C. pepo* cultivar Wildcat at the dose of 145 kg ha^{-1} of N was statistically superior to the 82 kg ha^{-1} dose. However, it did not show statistical difference to the 217 kg ha^{-1} dose.

The magnitude of the productivity increase in response to doses of N depends on the division of photoassimilates among plant parts. Although the vegetative part is usually responsive to nitrogen most of the time, the reproductive part may not show biomass increase at the same rate (Huett and Belinda, 1991). In melon plants, fruits are a

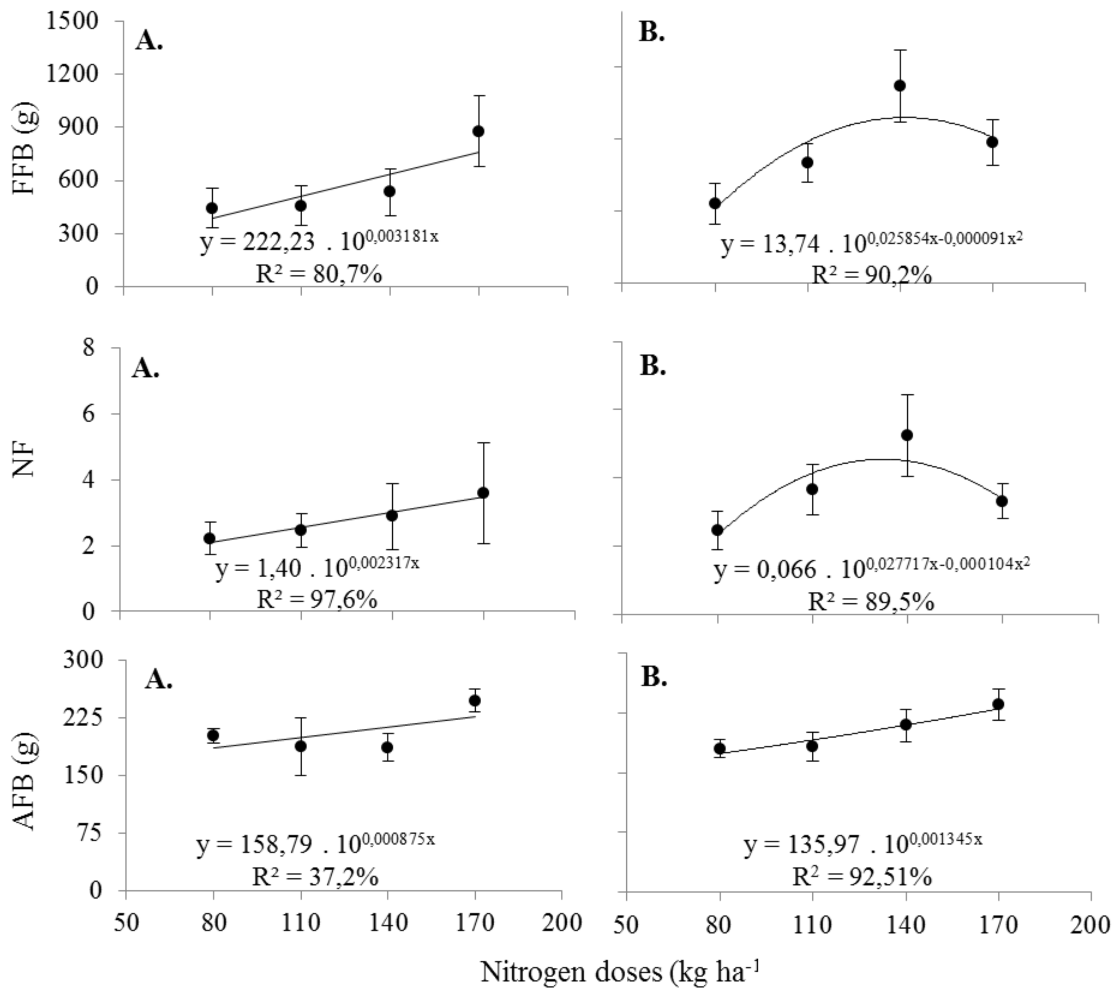

Figure 1. Anita F1 (A) and Novita Plus (B) yield in response to application of nitrogen through fertigation. Vertical bars refer to the standard deviation in the treatment. FFB, Fresh fruit biomass; NF, number of fruits; AFB, average fruit biomass.

powerful sink of photoassimilates to the plant (Duarte et al., 2008), which may represent a reduction in the rate of increase for vegetative biomass during the reproductive period. However, Strassburguer et al. (2011) did not detect this characteristic for *C. pepo*, which suggests a positive interaction between N doses, rate of leaf area increase and yield. At suboptimal levels of nitrogen availability, the fruit does not seem to be a strong sink (Huett and Belinda, 1991). The same authors affirm that at low level of N availability, a decrease is observed in the reproductive period and delayed fruit set, which results in smaller and less plentiful fruits.

Conclusions

Cultivar Novita Plus shows higher average yield compared to cultivar Anita F1. Cultivar Anita F1 shows a linear increase in productivity, number of fruits and da mean biomass per fruit when N doses were raised up to 170 kg ha^{-1}. In cultivar Novita Plus, the increase in productivity and number of fruits is quadratic, and doses of 142.1 and 133.3 kg N ha^{-1} applied via fertigation correspond to the maximum respective values. Higher N doses provide a linear increase in mean fruit biomass in the tested dose interval.

Conflict of Interests

The authors have not declared any conflict of interests.

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