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Fertigation of zucchini in greenhouse environments

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Abstract: The objective of this study was to evaluate the effect of nitrogen doses (80, 110, 140 and 170 kg ha^{-1}) applied through fertigation on the yield of two cultivars of *Cucurbita pepo* (Anita F1 and Novita Plus), in a 4 x 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 permit to assume that increasing doses of N lead to a linear increase in yield for cultivar Anita F1 and a quadratic increase for cultivar Novita Plus.

Key words: *Cucurbita pepo* L., drip irrigation, vegetables

Fertigação em abobrinha italiana conduzida em ambiente protegido

Resumo: O objetivo deste trabalho foi avaliar o efeito das doses de nitrogênio (80, 110, 140 e 170 kg ha^{-1}) aplicadas por meio da fertigação na produção de duas cultivares de *Cucurbita pepo* (Anita F1 e Novita Plus) em esquema de arranjo de tratamentos fatorial 4 x 2. O experimento foi conduzido no delineamento inteiramente casualizado com oito repetições. As variáveis medidas foram a soma da biomassa de frutos por planta, número de frutos por planta e biomassa média do fruto. As análises dos dados permitiram inferir que o acréscimo das doses de N resultaram em incremento linear e resposta quadrática da produção das cultivares Anita F1 e Novita Plus, respectivamente.

Palavras-chave: *Cucurbita pepo* L., gotejamento, olerícolas

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Introduction

Vegetable production is an intensely competitive activity. The market demands constancy and production volume, that is difficult to accomplish 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 increase in productivity, since crops are not exposed to environmental variability and disease control is more efficient. Purquerio et al. (2007) related that cultivation in greenhouses results in higher quality and earlier production.

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. Nitrogen is 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 (*Cucurbita pepo* L.) 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 applying nutrients dissolved in water along with 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. In addition, fertigation is the better technique for nitrogen application in *Cucurbita pepo* compared to solid-form application 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 feasibility 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 about *C. pepo* crops grown in greenhouse environments to evaluate growth and yield under fertigation technique. Several studies 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.

Material and Methods

The experiment was carried out from February to June 2012 at the Irrigation Technical Center (CTI) of the Agronomy Department at Maringá State University (UEM), located in Maringá, PR, Brazil, at an elevation of 542 m and coordinates 23º 25' S and 51º 57' W. The greenhouse was 30 m long, 6.9 m wide and 3.5 m high. The experiment was installed in a distroferric red Nitosol area with moderate A horizon, clayey texture, subperennial tropical forest phase (EMBRAPA, 2006).

Climatic data referring to greenhouse (Figure 1) were recorded by means of automatic weather station. Filgueira (2008) reported that the optimum temperature range for zucchini growth includes temperatures between 18 and 25 ºC. It is observed that mean temperatures were within the optimum range for most of the trial period.

The microirrigation system presented a 0.5 m^3 reservoir in which the fertilizers were solubilized

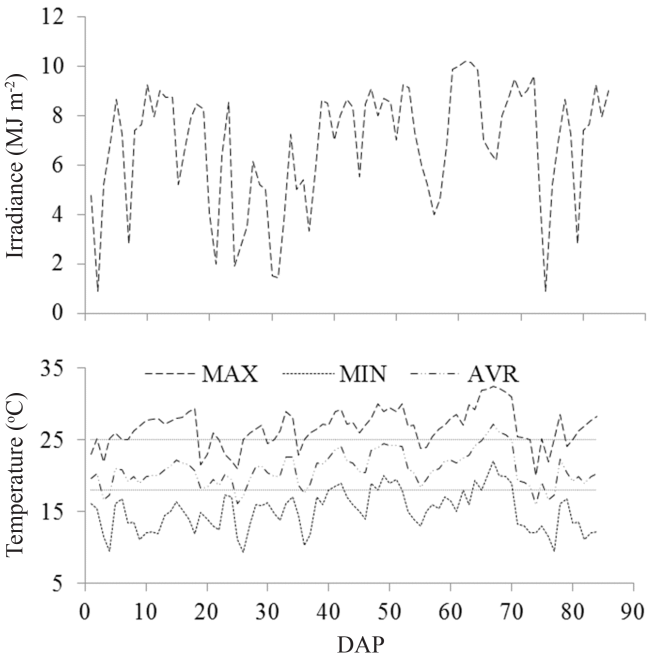


Figure 1. Irradiance, maximum temperatures (MAX), minimum temperatures (MIN) and average temperatures (AVR) inside the greenhouse and optimum temperature range for zucchini growth according to Filgueira (2008)

and a valve that allowed water to enter the SC-30SM motor-pump set, installed below the bottom of the reservoir. Operating pressure of 14 kPa was used, providing mean flow of 0.9 L h^{-1} per emitter. 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 drippers spaced 0.75 m from each other with 0.24 m of micro tube attached at the end of each dripper, with the objective of placing the dripper point 0.03 m from soil level.

To analyse the system and irrigation uniformity, the amount of water emitted by all drippers 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 weight. The water mass collected in each dripper was quantified using a digital balance, 0.1 g accuracy. Given specific water mass equal to 1 kg dm^{-3}, the flow of each dripper was calculated in L h^{-1}. The distribution uniformity coefficient (CUD) was equal to 91.3%.

The treatments were the result of a 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 a completely randomized design in a 4 x 2 factorial arrangement. Eight replications were used per treatment, totaling 64 plots.

To prepare the experimental area, the 0 – 0.15 m layer of soil was tilled with a rotary hoe over the full area. Planting holes were dug manually, at a depth of 0.20 m. The soil was analysed at the Maringá Rural Laboratory. According to the results of the soil analysis (Table 1), Trani & Raij (1996) recommend increasing base saturation percentage up to 80% and providing 400 kg ha^{-1} of P. Dolomite with 84% relative efficiency and monoammonium phosphate (MAP) were used to prepare the planting 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).

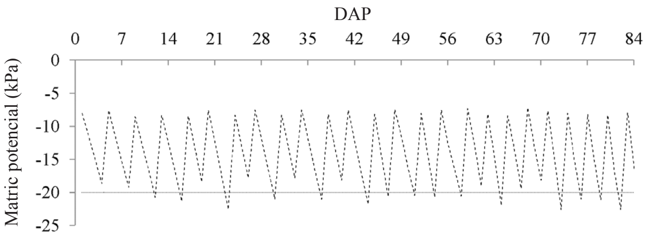
Sowing took place on March 17, 2012 in 72-cell Styro foam trays previously filled with substrate. Transplantation took place 19 days after sowing (DAS), at a spacing of 0.80 m between rows and 0.75 m between plants. Female flowers were manually pollinized every morning.

Table 1. Physical and chemical properties of the soil of the experimental site 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 ($cmol_c$ dm^{-3})	0.27
Exchangeable Ca ($cmol_c$ dm^{-3})	5.07
Exchangeable Mg ($cmol_c$ dm^{-3})	1.45
Cation exchange capacity ($cmol_c$ dm^{-3})	9.53

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 13.600 kg ha^{-1} (Furlani et al., 1978). Nitrogen doses were equally distributed in five weekly fertigations starting 27 DAS and on different days than potassium fertilizations. 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. The motor-pump set was turned on to stabilize the system and the entire pool applied was collected in containers located under the drippers. After stabilization, the motor-pump set was turned off, the containers below the drippers 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.

Soil moisture control was carried out with the aid of three tensiometers with Bourdon vacuum gauge, installed 0.20 m deep in the experimental area. Figure 2 show the soil matric potential throughout the experimental period, calculated by the mean of tree tensiometers readings. The objective was to maintain soil water tension between 8 and 20 kPa, which is considered appropriate for growing zucchini (Marouelli, 2008). The irrigation depth equal to 5 mm was applied in all plots throughout the experiment. Irrigation depth equal to 5 mm was related to the storage capacity of the soil in the 0-0.2 m layer and was calculated by the moisture referring to 8 and 20 kPa soil tension. Soil water retention curve of the experimental area (Blainski, 2007) was



Obs. Matric potential was maintained above -20 kPa, as recommended by Marouelli (2008).

Figure 2 . Soil matric potential troughout the experimental period, measured in days after plantig (DAP)

used to obtain these values of moisture. Different concentrations of nitrogen were applied through irrigation depth equal to 5 mm .

Harvest began 52 DAS, lasting until 84 DAS. Fruits longer than 0.15 m were collected every morning. Immediately after harvest, fruits were taken to the laboratory for analysis. The measurements of fruit fresh biomass were obtained using a GEHAKA BG8000 digital balance, 0.1 g accuracy. 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. Cultivars yield means were tested by F test ($p < 0.01$). The quantitative variables were subjected to regression analysis and the coefficients were tested by the test t ($p < 0.01$). The SISVAR program (Ferreira, 2008) was used to perform all statistical analysis

Results and Discussion

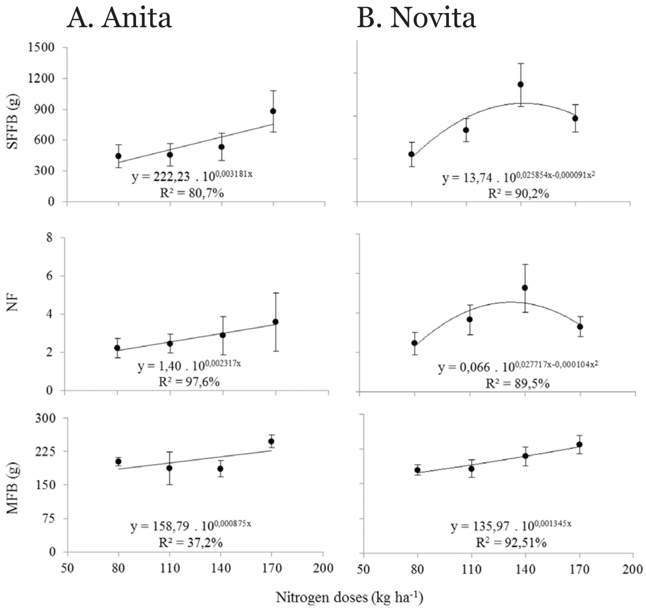
Table 2 shows the mean values for sum of the fresh biomass of fruits per plant (SFFB) and number of fruits per plant (NF) of the cultivars differed significantly ($p < 0,01$) in the mean doses. However, mean fruit size (MFB) did not show significant differences. The yield of Anita F1 and Novita Plus cultivars conducted in greenhouse were respectively 8,980 and 11,786 kg ha^{-1}, while Olinik et al. (2011) obtained 7,650 kg ha^{-1} for Novita Plus cultivar in an experiment conducted under field conditions. These results are in agreement with Filgueira (2008), who claim that protected cultivation results in increased productivity because, among other reasons, protects the crop of inclement weather.

Figure 3 shows the graphs of production as a function of tested doses of N. For Anita F1 cultivar, 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

Table 2. Mean effect of nitrogen doses the sum of fruit fresh biomass (SFFB) per plant, number of fruits per plant (NF) and mean fruit biomass (MFB) of the cultivars

Variety	SFFB	NF	MFB
Anita F1	538.80 a	2.67 a	200.62 a
Novita Plus	707.17 b	3.53 b	202.84 a
CV (%)	3.72	11.75	1.56
F value	10.523	8.003	0.092

Means followed by the same letter in a column do not differ significantly according to the F test ($p < 0.01$)



Vertical bars refer to the standard deviation in the treatment

Figure 3. Anita F1 (A) and Novita Plus (B) yield (SFFB), number of fruits (NF) and mean fruit biomass (MFB) in response to application of nitrogen through fertigation

fit more adequately a polynomial regression, with maximum yield per plant of 942.4 g and 4.6 fruits corresponding to dose of 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 for both cultivars. This result agrees with Zotarelli et al. (2008), who observed that the maximum productivity of *C. pepo* cultivar Wildcat can be obtained at the dose of 145 kg ha^{-1} of N.

The quadratic polynomial model is the most appropriate to describe the variation of crop yield response to nitrogen fertigation (Fageria et al., 1999). One reason of this variation is that the excess of nitrogen applied by fertigation may reduce the absorption of other essential elements, resulting in decreased productivity (Faquin, 1994). Nitrogen applied through fertigation influence the number of fruits and yield of banana (Pinto et al., 2005) and watermelon crop (Anderson Junior et al., 2006) according to the quadratic polynomial model. These mentioned results are in agreement with this work.

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 & Belinda Dettmann, 1991). In melon plants, fruits are a 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*. At suboptimal levels of nitrogen availability, the fruit does not seem to be a strong sink (Huett & Belinda Dettmann, 1991). These authors claim 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

1. Novita Plus cultivar shows higher mean yield compared to Anita F1 cultivar.

2. The application of 170 kg ha^{-1} of nitrogen results in the maximum yield of Anita F1 cultivar.

3. In Novita Plus cultivar, doses of 142.1, 133.3 and 170 kg N ha^{-1} applied through fertigation result in maximum values of the sum of fruit fresh biomass, number of fruits and mean fruit biomass respectively.

Acknowledgements

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