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Effects of top-dressing nitrogen levels on the productivity of cauliflower

Doses de nitrogênio em cobertura sobre a produtividade da couve-flor

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Abstract

Nitrogen (N) is the most used element by plants and its level should be balanced in order to provide a maximum productivity without decreasing plant quality. This study aimed to analyze the effects of nitrogen levels on the cultivation of cauliflower grown in the region of Great Dourados, Mato Grosso do Sul (MS) state. A field experiment was conducted using randomized blocks with four treatments (corresponding to N levels of 0, 150, 300 and 450 kg ha^{-1}) and five replications. The genotype of cauliflower cultivated was hybrid 'Verona'. Inflorescence diameter (ID), inflorescence mass (IM), commercial productivity of the inflorescence (CPI) and percentage of florets per inflorescence (PFI) were evaluated. The parameters were adjusted by quadratic equations. Levels that maximized the diameter, the mass and the inflorescence productivity were 225.0, 252.5 and 252.5 kg ha^{-1} of top-dressing nitrogen, respectively.

Additional keywords: *Brassica oleracea*; mineral nutrition; Parcel fertilization; production of vegetables.

Resumo

O nitrogênio (N) é o elemento mais utilizado pelas plantas, e sua dose deve estar balanceada de forma a proporcionar a máxima produtividade sem causar redução da qualidade das mesmas. Diante do exposto, objetivou-se analisar o efeito de doses de nitrogênio no cultivo da couve-flor cultivada na região da Grande Dourados-MS. Um experimento em campo foi instalado utilizando o delineamento experimental em blocos ao acaso, com quatro tratamentos (correspondentes às doses de N: zero, 150, 300 e 450 kg ha^{-1}) e cinco repetições. O genótipo cultivado foi o híbrido Verona de couve-flor. Foram avaliados o diâmetro de inflorescência (DI), a massa de inflorescência (MI), a produtividade comercial de inflorescência (PCI) e a porcentagem de florete por inflorescência (PFI). Os parâmetros analisados foram ajustados por equações quadráticas. As doses que maximizaram o diâmetro, a massa e a produtividade de inflorescência foram 225,0; 252,5 e 252,5 kg ha^{-1} de nitrogênio em cobertura, respectivamente.

Palavras-chave adicionais: Adubação parcelada; *Brassica oleracea*; nutrição mineral; *p*rodução de hortaliças.

Introduction

The region of Great Dourados, Mato Grosso do Sul (MS) state, Brazil, bases its economic sector on agriculture. However, most vegetables traded are produced in other states. Thus, there is need for a greater dissemination of agronomic knowledge on the cultivation of cauliflowers, especially at a regional level (Matschegewski et al., 2015). Nitrogen fertilization is one of the production factors that may be analyzed aiming to encourage the production of cauliflower in the Great Dourados region.

Cauliflower has become one of the main vegetables grown in Brazil probably due to its recognition as a functional food, acting mainly on cancer prevention (Totušek et al., 2011) due to the presence of antioxidants and high concentrations of vitamins (Soegas et al., 2011). Nitrogen is a precursor of these substances (Schumacher et al., 2012). In addition, nitrogen is the element that contributes the most to the percentage of leaf dry matter and inflorescence of cauliflowers (Avalhães et al., 2009), directly influencing the productivity of the crop (Sánchez et al., 2001).

In general, nitrogen presents the structural functions, it is involved in the processes of ionic absorption, photosynthesis, respiration, multiplication and cellular differentiation. Its deficiency causes yellowing of older leaves and delays flowering (Malavolta, 1980). Nitrogen and phosphorus increases have shown greater responses to increased crop productivity (Avalhães et al., 2009; Kano et al., 2010).

The level of nitrogen per plant for cauliflower crops should be balanced in order to provide a maximum crop yield without impairing the qualitative characteristics of plants. Variation in nitrogen levels directly affects the physiological activity of plants and may cause an increase in the incidence of physiological disorders such as hollow stems (Hussain et al., 2012; Campagnol et al., 2009; Camargo et al., 2009). Although the productivity of this crop is highly correlated to nitrogen fertilization, a proper N level, allowing a greater productivity with minimum environmental issues, should be determined to prevent the leaching of elements to water sources and a high nitrate accumulation in plant tissues, for it may cause problems to consumers (Donagemma et al., 2008; Čekey et al., 2011; Jadoski et al., 2010).

This crop has an accelerated vegetative stage. The consequences of malnutrition are thus more marked at the reproductive stage, i.e., the commercial product (Camargo et al., 2008). Nitrogen levels recommended by the technical literature differ greatly. Raij et al. (1996) recommended 60 kg ha^{-1} at transplanting and subsequently 150-200 kg ha^{-1} for top-dressing. Van den Boogaard & Thorup-Kristensen (1997) indicated 250 kg ha^{-1} as the most appropriate nitrogen level without recommending application times.

By analyzing the effects of nitrogen and boron on the production of cauliflower and on the incidence of hollow stems, yields ranging from 10.61 to 10.83 t ha^{-1} were obtained using N levels ranging from 100 to 250 kg ha^{-1} (Mello et al., 2009). However, using the same levels, Camargo et al. (2009) obtained higher yields (13.25-18.02 t ha^{-1}).

Crop yield response related to nitrogen increase in cauliflowers can be characterized by linear functions (Camargo et al., 2008; van den Boogaard & Thorup-Kristensen, 1997). However, as the limits of a response function to fertilization are delimited by levels evaluated experimentally, so that productivity do not tend to infinity with the continue increase in nitrogen in the field, it becomes necessary to identify the maximum N levels that the crop may receive without decreasing productivity. Given the above, this study aimed to analyze the effects of nitrogen levels on cauliflower crops grown in the region of Grande Dourados, MS.

Material and methods

The research was conducted at the experimental Irrigation Area of the Faculty of Agricultural Sciences (FCA) of the Federal University of Great Dourados (UFGD), located in Dourados, Mato Grosso do Sul state, during the first half of 2012. The local average altitude is 446 m. The site is located at 22°11'45" S and 54°55'18" N. According to the Köppen classification, the climate of the region is Cwa (humid subtropical), with rainy summers and dry winters, and an average annual temperature of 22 °C. The soil is a Dystroferric Red Latosol with a very clayey texture (EMBRAPA, 2013).

Prior to the experiment, the area was fallow. A soil chemical analysis of the composite samples collected at the 0-20 cm layer was performed (EMBRAPA, 2011). The results obtained were pH $CaCl_2$ = 4.8, P = 17.4 mg dm^{-3}, K = 0.4 $cmol_c\,dm^{-3}$, Ca = 5.41 $cmol_c\,dm^{-3}$, Mg = 1.63 $cmol_c\,dm^{-3}$, Al = 0.28 $cmol_c\,dm^{-3}$, H+Al = 6.31 $cmol_c\,dm^{-3}$; CEC = 13.65 $cmol_c\,dm^{-3}$, V = 54.51 % and OM = 22.94 g dm^{-3}.

The experimental design was randomized blocks with four treatments, corresponding to cover nitrogen levels, and five replications. The N levels were 0, 150, 300 and 450 kg ha^{-1}. The spacing between rows was 1.0 m and between plants was 0.5 m. Each plot contained 20 plants, equivalent to a population of 20,000 plants ha^{-1}. The useful area was formed by two central rows, disregarding the plants from each end, resulting in six plants per experimental unit.

The cauliflower hybrid 'Verona' was used. Seedlings were grown in trays with 200 cells filled with a commercial substrate (Bioplant®). Seedling transplant took place on March 7, 2012, when the plants reached the transplant index, i.e., five to six definitive leaves. In the experimental area, the base fertilization was made four days before the transplant by applying 140 kg ha^{-1} of N, 40 kg ha^{-1} of P_2O_5 and 80 kg ha^{-1} of K_2O in the form of urea, superphosphate and potassium chloride, respectively (Fontes, 1999). In this same period, 350 g of the commercial substrate Bioplant® were applied to each plant. According to the manufacturer, this substrate is composed of fiber and coconut powder, pine bark, rice husk and vermiculite.

From each treatment totals (150, 300 and 450 kg ha^{-1}), 30%, 40% and 30% were applied at 15, 30 and 45 days after transplanting, respectively. The nitrogen was applied in the form of agricultural urea, containing 45% of N in the composition (Trani et al., 1997).

The cultivation was performed according to the usual needs and recommendations. Throughout the growing season, foliar fertilization was made every 7 days. The composition of the product applied was 11% of N, 11% of P, 11% of K, 2% of Mg, 10% of S, 0.15% of B, 0.30% of Cu, 0.11% of Fe, 0.26% of Mn, 0.04% of Mo and 0.50% of Zn (1.0 g L^{-1}).

The plants were irrigated using a laser-drilled tape (Santeno®) made of linear low-density polyethylene type I. This tape has the following characteristics: internal diameter of 28 mm, wall thickness of 0.24 mm, laser-drilled emitters with a diameter of 0.3 mm and a spacing between emitters of 0.15 m. The tapes were connected to a polyethylene bypass tubing with a nominal diameter of 16 mm and 40 m of operating pressure. The spacing between tapes was 3.0 m, thereby maintaining three rows of plants between two Santeno® tapes. The nominal flow rate for 10 m length is 240 L h^{-1} for an operating pressure of 8 m. The pressure was controlled by a pressure regulating valve inserted into the bypass tube. The bypass tube was connected to the main PVC line with a nominal diameter of 50 mm and 80 m of operating pressure.

The irrigation management was based on the soil water balance considering rainfall and actual irrigation required as inflows, and crop evapotranspiration as an outflow. Meteorological data and reference evapotranspiration (ETo) were obtained from an automatic weather station of the Brazilian Agricultural Research

Corporation (EMBRAPA-CPAO) located in Dourados, MS.

Crop evapotranspiration (ETc) was determined by multiplying the crop coefficient (Kc) by the ETo. The Kc for initial, middle and final stages was 0.65, 1.05 and 0.95, respectively (Souza et al., 2011). The water depth, applied daily, was calculated by the ratio between the water blade required by the crop, which corresponded to the ETc, and the system application efficiency (Ea) previously determined in the field (76%).

The average daily temperature during the experimental period ranged from 12.2 to 27.4 °C (Figure 1). The observed temperatures provided optimal conditions for the germination and development of the crop (Zanuzo et al., 2013). The crop water demand, during the 84 days of cultivation, was 591 mm, supplied by the accumulated rainfall (311 mm) and by the applied irrigation (368 mm) (Figure 2).

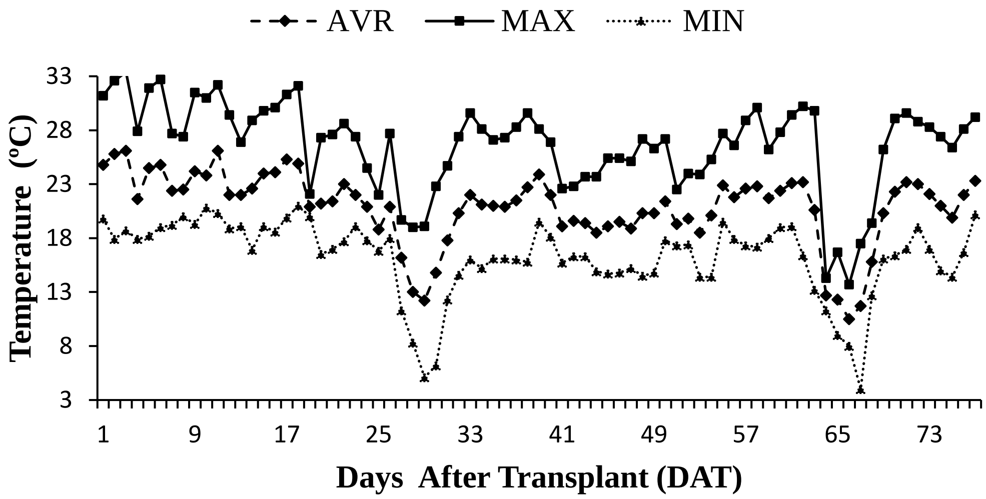

Figure 1 - Average (AVR), maximum (MAX) and minimum (MIN) daily air temperatures during the cultivation period.

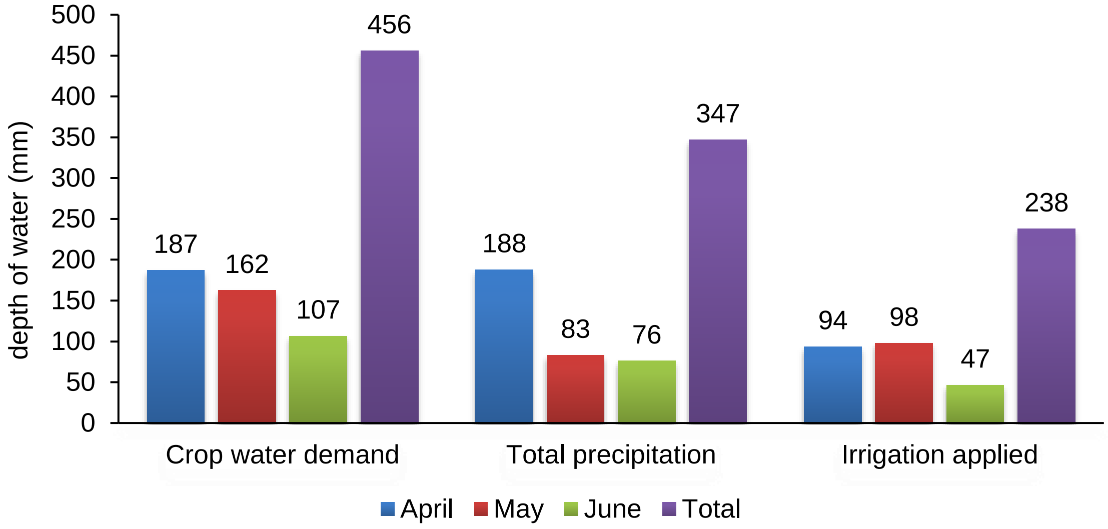

Figure 2 - Crop water demand, total precipitation and irrigation applied for each month of cultivation.

The harvest of the experiment was made 84 days after transplanting (May 30, 2012). Six useful plants of each plot were collected to perform the following evaluations: inflorescence diameter (cm), inflorescence mass (g), commercial productivity of the inflorescence (t ha^{-1}) and percentage of florets per inflorescence (%).

To obtain the inflorescence diameter (ID), the circumference of inflorescences collected was initially measured with a tape measure. Then, by the ratio between the circumference and the π value, the diameter of the inflorescence was obtained. To obtain the inflorescence mass (IM), all leaves were removed and a cut was made at the point where the stems become only one stem. Then, the inflorescence (floret and stem) was weighed with a digital scale. The commercial productivity of the inflorescence (CPI) was obtained based on the extrapolation of the productivity achieved in the useful area to the population of plants per hectare. Plants did not show injuries or malformation. Thus, all harvested plants were considered commercial. The percentage of florets per plant (PFI) was obtained by the ratio between the mass of the florets and the mass of the inflorescence.

Data were submitted to analysis of variance using F test. When significant, a regression analysis was performed using the software SISVAR (Ferreira, 2011).

Results and discussions

There was a significant difference for inflorescence diameter (ID), inflorescence mass (IM) and commercial productivity of the inflorescence (CPI) in function of nitrogen levels ($p = 0.05$). The variables ID, IM and CPI in function of nitrogen levels better fitted the quadratic model.

The largest inflorescence diameter estimated was 21.52 cm. There was an increase in diameter up to 225.0 kg ha^{-1} of N and a subsequent decrease in diameter as the nitrogen level increased (Figure 3). The treatments with 0 and 450 kg ha -1 of nitrogen showed a very similar inflorescence diameter (17.45 and 17.56 cm, respectively). Then, it can be concluded that high levels of nitrogen may result in a decrease in inflorescence diameter. Such decrease can be compared to the non-application of top-dressing nitrogen to plants.

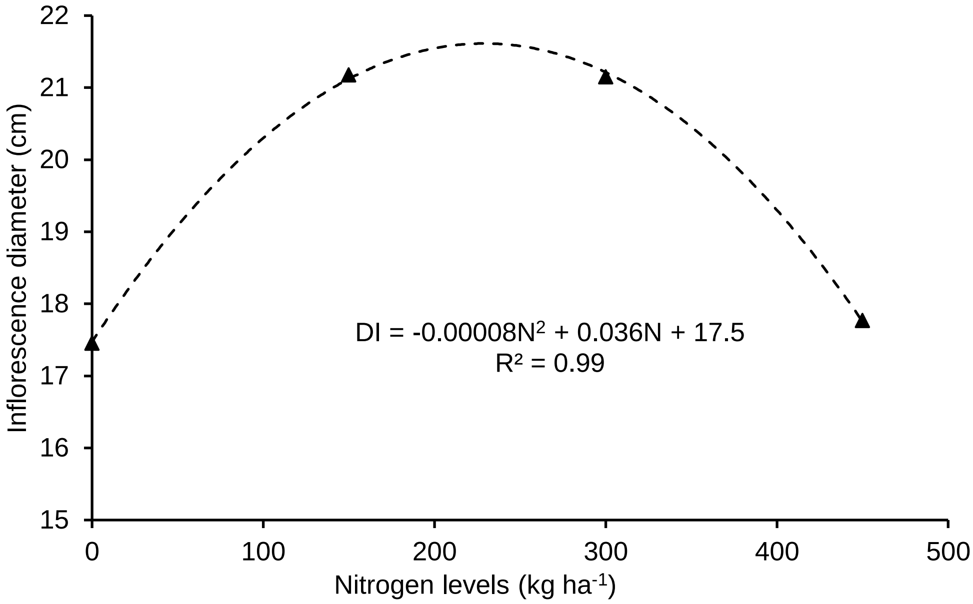

Figure 3 - Response of inflorescence diameter (ID) in function of top-dressing nitrogen levels (0, 150, 300 and 450 kg ha^{-1}) for cauliflower.

Just as the inflorescence diameter, inflorescence mass increased as the nitrogen level increased until the maximum point (252.5 kg ha^{-1} of nitrogen), resulting in a mass of 1,256.6 g. After this level, the mass decreased (Figure 4). Using the highest N level evaluated (450 kg ha^{-1}), an influence mass of 748.8 g was obtained, a result similar to that obtained without the application of nitrogen (715.0 g).

Regarding inflorescence diameter, Camargo et al. (2008) found no significant differences with the increase in nitrogen levels (0-250 kg ha^{-1}). The average diameter ranged between 17.46 and 18.03 cm. Kano et al. (2010) also found no significant differences in diameter with different nitrogen levels. These authors used N levels between 0 and 300 kg ha^{-1} and obtained inflorescence diameter values between 19.2 and 21.8 cm.

However, Camargo et al. (2008) and Kano et al. (2010) recorded a significant response to inflorescence mass with the increase in nitrogen levels, as also reported by this study. Inflorescence diameter can be influenced by plant spacing. However, the two studies mentioned above used the same population density as this study (20,000 plants ha^{-1}). Thus, the increase in mass not proportional to the increase in inflorescence diameter obtained by these studies may be because they used different hybrids.

The two studies mentioned above showed a linear response to inflorescence mass. Camargo et al. (2008), using the highest N level evaluated (250 kg ha^{-1}), obtained a mass of 901.1 g, while Kano et al. (2010), also using the highest N level evaluated (300 kg ha^{-1}), obtained a mass of 1,301.6 g. The maximum mass values were similar to those obtained in this study (1,256.6 g). However, as the highest level applied in this study was higher than the levels reported in the literature, the high level of nitrogen used in last application of the treatment with 450 kg ha^{-1} hindered the development of plants, causing a decrease in mass and inflorescence diameter.

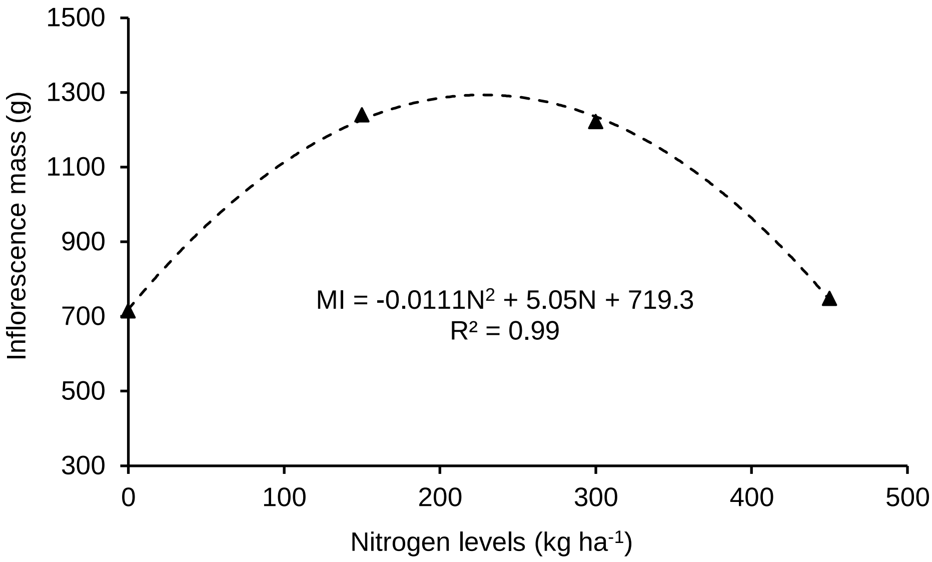

Figure 4 - Response of inflorescence mass (IM) in function of top-dressing nitrogen levels (0, 150, 300 and 450 kg ha^{-1}) for cauliflower.

Nitrogen has a high potential of leaching into the soil, especially in the form of nitrate under high soil humidity conditions (Mendes et al., 2015). The crop was managed aiming to keep the soil always near field capacity, i.e., with appropriate soil moisture conditions for the plants, as well as for leaching. The excess of nitrate may have acted as a charger of ions that were present in the soil solution, such as Ca, Mg, Na and K (Raij, 2011), thus hindering the development of plants in the treatment with 450 kg ha^{-1} of nitrogen. High nitrogen levels also caused a decrease in production parameters for wheat (Teixeira Filho et al., 2010), okra (de Oliveira et al., 2003) and passion fruit crops (Borges et al., 2006).

The resulting commercial productivity of the inflorescence was described by a quadratic function, concave down. The inflection point, in this case, is the nitrogen level that obtained the highest productivity (13.4 t ha^{-1}), i.e., 252.5 kg ha^{-1}. This is the optimal level for crop yield optimization. From the inflection point, there was a decrease in productivity as nitrogen levels increased (Figure 5). Similar results were obtained by Camargo et al. (2008), who used 270 kg ha^{-1} of N and obtained a maximum productivity of 12 t ha^{-1}.

The level that provided the highest productivity was above the recommended by Raij et al. (1996) for the state of São Paulo (150-200 kg ha^{-1} of cover nitrogen). However, productivities are within the satisfactory range for the culture (8.0-16 t ha^{-1}). Possibly, this range of recommended N levels may not be ideal for all growing conditions. During the conduction of this study, there was a wide temperature range. The maximum temperature reached 34.7°C and the minimum 5.1 °C. The hybrid used is recommended for mild temperatures (approximately 20 °C). Such wide variation, common in the Great Dourados region, may have provided an adverse condition to the development of plants, causing an increased nutrient demand and a higher nitrogen volatilization at high temperature peaks, causing an increased demand for the application of the fertilizer.

Through the analysis of inflorescence diameter, mass and productivity, it is possible to make a decision regarding the most appropriate level of top-dressing nitrogen to be applied to cauliflower crops (225.0, 252.5 and 252.5 kg ha^{-1}), depending on the parameter considered. However, these parameters should not be the only features to be considered in order to identify the most suitable level for the cultivation of cauliflower. Whenever possible, the determination of the most adequate N level should involve productive (ID, IM and CPI) and qualitative parameters, such as the percentage of florets per inflorescence (PFI). The percentage of florets is considered a qualitative parameter for cauliflower plants because it quantifies the portion of the inflorescence which is generally valued for consumption, i.e., the florets.

The percentage of florets per inflorescence was not significant in relation to the increase in nitrogen levels ($p \leq 0.05$). The values obtained for the levels 0, 150, 300 and 450 kg ha^{-1} of cover nitrogen were 89.2%, 85.1%, 90.2% and 88.9%, respectively. During the 85 days of cultivation, plants showed no physiological disorders or other abnormalities that damaged their marketing. This can be proven by the values obtained for commercial productivity, as they are within the standard value considered satisfactory for the culture (Raij et al., 1996) and similar to those reported by Camargo et al. (2008).

Conclusion

The most appropriate N levels may also be chosen according to relevant production parameters. To obtain a maximization of inflorescence diameter, mass and productivity, the recommended levels are 225.0, 252.5 and 252.5 kg ha^{-1} of top-dressing nitrogen, respectively.

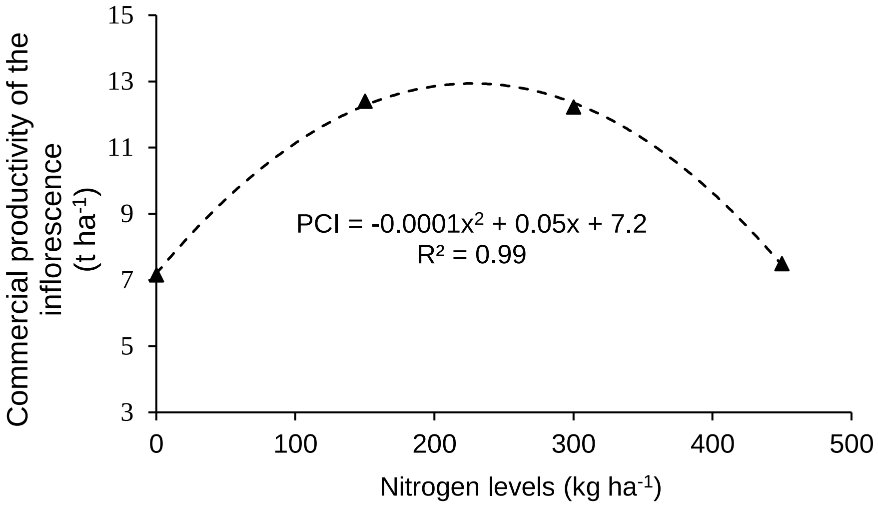

Figure 5 - Response of commercial productivity of the inflorescence (CPI) in function of top-dressing nitrogen levels (0, 150, 300 and 450 kg ha^{-1}) for cauliflower.

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