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Nitrogen and potassium fertirrigation on yield characteristics of Italian Zucchini in protected cultivation

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This study aimed to evaluate the effect of different doses of nitrogen and potassium applied through fertirrigation on yield characteristics of Italian Zucchini, Novita Plus cultivar. The experiment was conducted in a greenhouse at the Irrigation Technical Center of the State University of Maringá, Maringá - PR, adopting a completely randomized design in a 4 x 4 factorial scheme, with three replications. Four doses of nitrogen (0, 90, 180 and 270 kg ha^{-1}) and four doses of potassium (0, 90, 180 and 270 kg K_2O ha^{-1}) were tested. The fertirrigation was applied via micro irrigation through drip emitters in a continuous line, operating at a flow rate of 4 L h^{-1}. Number of leaves, number of male and female flowers, average yield and mass of fruits per plant were evaluated. There was an increase in leaf production at the maximum nitrogen dose, as well as an increase in the number of male flowers at the maximum dose of nitrogen and potassium. The number of female flowers was influenced only by nitrogen, with an increase in the number of flowers at the highest nitrogen levels. Regarding the fruit yield, the best obtained doses were 179.19 kg ha^{-1} of N and 171.25 kg ha^{-1} of K_2O. Finally, the doses that expressed maximum fruit mass gain were 136.92 kg ha^{-1} of N and 184.17 kg ha^{-1} of K_2O.

Key words: *Cucurbita pepo* L., cucurbitacea, sexual expression, production, nitrogen metabolism.

INTRODUCTION

The cucurbitaceae family has more than 120 genera and approximately 800 species, and it appears among the main families of vegetables grown by man (Teppner, 2004). The crops of greater economic importance, belonging to this family, are melons, watermelon, cucumbers and pumpkins. In addition to the food value, cucurbits farming in Brazil, in particular pumpkins, have great social importance. It generates direct and indirect jobs since it demands high amount of manual labor from cultivation to marketing (Resende et al., 2013).

The Italian Zucchini is among the ten vegetables of greatest economic value in the country, where the central and southern regions of Brazil stand out for their production and productivity (Carpes et al., 2008). In 2011,

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3,187,953 tonnes of vegetables were produced in the State of Paraná, Brazil, with 1% of the gross value of production, characterized by the production of the Italian Abobrinha, reaching a productivity of 17.8 tons per hectare (Paraná, 2013).

Despite the fact that melon and watermelon are the most grown vegetables in volume from that family, pumpkin is becoming more popular and occupying a significant portion of the agribusiness. In Brazil, its cultivation is traditionally carried out in the field, however, with increasing farming technification, many producers have conducted its cultivation in a protected environment with excellent results (higher yield and quality), especially in less favorable seasons (Pôrto, 2011).

One characteristic of growing vegetables is the intensity of cultivation, that is, resources such as water, nutrients and pesticides are applied in order to exploit the maximum yield potential of plants (Echer et al., 2014). In protected environment farming, this "intensity of cultivation" aims to increase yield and hence achieve greater economic return, given the high cost of the structures. This is due to the adaptation of this culture to the most diverse conditions, its production is possible all year round. The cultivation in a protected environment is gaining space every year due to the specific conditions of Italian Zucchini cultivation, which can be recreated in these environments, guaranteeing better growing conditions, besides accelerating and homogenizing the maturation process of the crop, facilitating its harvesting and commercialization (Lúcio et al., 2008). This cultivation practice has been widely used in the southern region of Brazil, where producers increase their net yields and reduce their losses due to rigorous cold in winter (Couto et al, 2008).

One of the major obstacles to the production of Italian Zucchini in protected environment is the lack of consistent information regarding the nutrition and fertilization of the plants (Pôrto et al., 2012). In addition, another difficulty for the production of pumpkins in protected environment refers to pollination. As pollination is carried out by means of insects, in the protected environment, it is necessary to use labor to carry out the procedure, considering the absence of insects in this environment (Romano et al., 2008).

In general, absorption of nutrients in vegetables follows the pattern of the growth curve (dry matter accumulation). Among the macronutrients, potassium is commonly the nutrient most absorbed by vegetables (Fontes and Lima, 1993). In a study conducted by Vidigal et al. (2007) to evaluate the progress of the absorption of nutrients in pumpkin cultivation, the authors found that K was the nutrient absorbed in larger quantities by the plant, followed by N and Ca, as it was observed for most vegetables. According to these authors, the order of accumulated amounts of macronutrients was K> N> Ca> P> Mg> S.

Among the nutrients of higher demand by plants, nitrogen is one of the most important. This nutrient influences the processes involved in the growth and development of plants by altering the source-sink relation and hence the distribution of assimilates between vegetative and reproductive organs (Pôrto et al., 2014). In cucurbits, the increase in N dose, to a limited extent, provides increment in plant leaf area, having an effect on the production of photoassimilates and consequently the production of fruits (Queiroga et al., 2007).

Nitrogen fertilization is very important to obtain adequate yield, and the proper dosage varies according to the desired productivity, cultivar, management techniques, nutrient source and edaphoclimatic conditions (Pôrto et al., 2012). When applied in excess, nitrogen fertilization can result in reduced quality and nutritional security due to nitrate concentration and, when applied in small amounts, can cause nutritional deficiency with chlorosis and subsequent necrosis of leaves (Pôrto et al., 2014).

Potassium has a key role in the activation of enzymes and transport of carbohydrates, as well as being part of the photosynthesis processes, respiration, cell growth and elimination of active oxygen. Potassium deficiency symptoms in the plant are expressed through reduced growth, reduced resistance to pathogens and degradation of indole-3-acetic acid (IAA) (Malavolta, 2006).

The objective of this study was to evaluate the performance of the Italian Zucchini crop using different doses of nitrogen and potassium via fertirrigation.

MATERIALS AND METHODS

The experiment was conducted in a protected environment at the Irrigation Technical Center of the State University of Maringá - UEM, located in Maringá - PR (23°23'56.50 " S and 51°57'7.53 " W, 542 m of altitude). According to Koppen, the local climate is classified as Cfa, subtropical, with the occurrence of average temperatures below 18°C in the coldest month and temperatures above 22°C in the hottest month, with annual rainfall ranging from 1400 to 1600 mm (Caviglione et al., 2000).

The experimental design adopted was completely randomized (CRD) in a factorial 4 × 4 with three replications. The first factor consisted of four nitrogen doses (0, 90, 180, 270 kg ha^{-1}) and the second factor of four potassium doses (0, 90, 180 and 270 kg ha^{-1}). The environment of cultivation is 30 m long, 5.7 m wide and has a ceiling height of 2.5 m. The environmental structure has arch type roof, covered with 150 µm thick polyethylene film, with anti-UV treatment and anti-aphid screen on the sides. Inside the environment, it was installed a meteorological station, scheduled to record daily temperature data.

The soil is classified as Distroferric Red Nitosol, presenting moderate A horizon with clay texture (Embrapa, 2013). Its chemical characterization showed pH in $CaCl_2$ = 4.9; P = 3.19 mg dm^{-3}; K^+= 0.16 $cmol_c$ dm^{-3}; Ca^{2+}= 2.00 $cmol_c$ dm^{-3}; Mg^{2+}= 0.60 $cmol_c$ dm^{-3}; Al^{3+}= 0.62 $cmol_c$ dm^{-3}; $H^+ + Al^{3+}$= 3.74 $cmol_c$ dm^{-3}; organic matter = 17.97 g dm^{-3}; CEC = 6.50 $cmol_c$ dm^{-3} and base saturation (V%) = 42.46%. Lime application was performed (0.29 t ha^{-1}) to increase the base saturation up to 80%, according to the recommendation for the crop, developed by Trani (2007). The seedlings were grown

Table 1. Summary of the analysis of variance for the results of leaf number (LN), number of male flowers (NMF) number of female flowers (NFF), average number of fruits per plant (ANF) and average fruit mass (AFM).

Source of variation	Pr>Fc				
	LN	NMF	NFF	ANF	MMF (g fruit^{-1})
Doses of N (A)	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*
Doses of K (B)	0.7391^{NS}	0.0000*	0.0155*	0.0249*	0.0008*
A*B	0.1422^{NS}	0.0668^{NS}	0.0906^{NS}	0.1367^{NS}	0.0720^{NS}
Overall average	28.33	51.13	16.02	7.15	225.16
CV (%)	7.69	5.49	6.11	8.08	10.84

*Significant at 5%; NS- non significant; DF- degrees of freedom; CV- coefficient of variation.

in 72 cells polystyrene trays, containing commercial substrate and remained in a protected environment until the time of transplanting, when they had three true leaves.

After transplanting the seedlings, aiming at the establishment of the crop, daily irrigations were performed, keeping the soil at field capacity for ten days. Thereafter, irrigations and fertirrigations were performed according to the reading of tension values recorded in six tensiometers installed in the experimental area, three at the depth of 10 cm and three at the depth of 20 cm.

Nitrogen and potassium applications were performed when the tensiometers recorded tensions of 20 KPa, and this value was considered as critical, indicating the need to carry out a new irrigation according to the methodology suggested by Marouelli (2008). Irrigation management was performed based on the estimate of crop evapotranspiration (ETc), which corresponds to the reference evapotranspiration (ET0), obtained using the evaporimeter of Piché, and multiplied by the crop coefficient (Kc). For the Italian Zucchini, Kc values of 0.15; 0.95 and 0.70 at the initial, intermediate and final cycle were used, respectively, according to Allen et al. (2006).

The irrigation system used was drip micro irrigation. The system operated at a flow rate of 4 L h^{-1}, monitored by means of a glycerine manometer with 10 mwc operating pressure. The uniformity of water distribution in the irrigation system was evaluated through Christiansen coefficient (CUC) according to the methodology described by Keller and Karmeli (1974) and a value exceeding 90% was obtained which is considered "excellent" according to Bernardo (2008).

Nitrogen and potassium levels were established based on the total need of nutrients along the zucchini crop cycle, cultivar Novita Plus, according to Trani (2007). The nitrogen was applied using the calcium nitrate fertilizer, while potassium was provided by the application of potassium chloride. Doses of N and K were injected into the main irrigation system line before the filtration system. A 0.5 hp centrifugal pump was used as injector equipment, installed with suction, which repressed the solution of water + fertilizer from a 500 L capacity tank where the mixture was performed. The system was initialized and concluded with the application of water, in order to stabilize the flow of the drippers and avoid the occurrence of clogging.

The first male and female flowers began to appear 22 days after transplanting. Manual pollination process was started, according Romano et al. (2008), removing the petals from the male flowers and smoothly rubbing them on the female flowers, which then were tied with waxed paper bags in its peduncle. Around two days after pollination, the waxed paper bags were removed.

Harvests began 30 days after transplanting and were performed daily until the depletion of the productive capacity of the plants. For comparison study of growth of Italian Zucchini plants under the different treatments, the following parameters were evaluated: number of leaves emitted per plant, number of male flowers, number of female flowers, average fruit mass (g fruit^{-1}) and yield (t ha^{-1}).

With the acquisition of data, analysis of variance was performed and on the occurrence of significant differences at the level of 5% for the variables doses of nitrogen and doses of potassium, regression analyzes were applied using the SISVAR statistical software, version 5.4 (Ferreira, 2014).

RESULTS AND DISCUSSION

Analysis of variance of the studied variables is presented in Table 1. There was no interaction between nitrogen and potassium for any of the variables. The nitrogen dose factor had a significant effect on the number of leaves, number of male flowers, number of female flowers, average number of fruits per plant and average fruit mass. Significant effect was observed for the dose of potassium factor for number of male flowers, number of female flowers, average number of fruits per plant and average fruit mass.

Regarding the nitrogen doses, it was possible to observe an increase in the number of leaves of Italian Zucchini, by means of an increasing linear function, as shown in Figure 1. It is noted that increasing levels of N provided higher number of leaves. Each 1 kg ha^{-1} of N promoted the increase of 0.0744 leaves per plant. On average, the application of 270 kg ha^{-1} of N represented an increment of 110% as compared to the control treatment.

Possibly, the application of N doses increased the lifespan of the leaves (Garcez neto et al., 2002), allowing them to be able to perform photosynthetic activity for a longer time interval. Consequently, photoassimilates production in each leaf occurred over a longer period, thus favoring the increase of biomass production and *Cantalupensis* melon under protected environment. The authors verified that there was an increase in the number

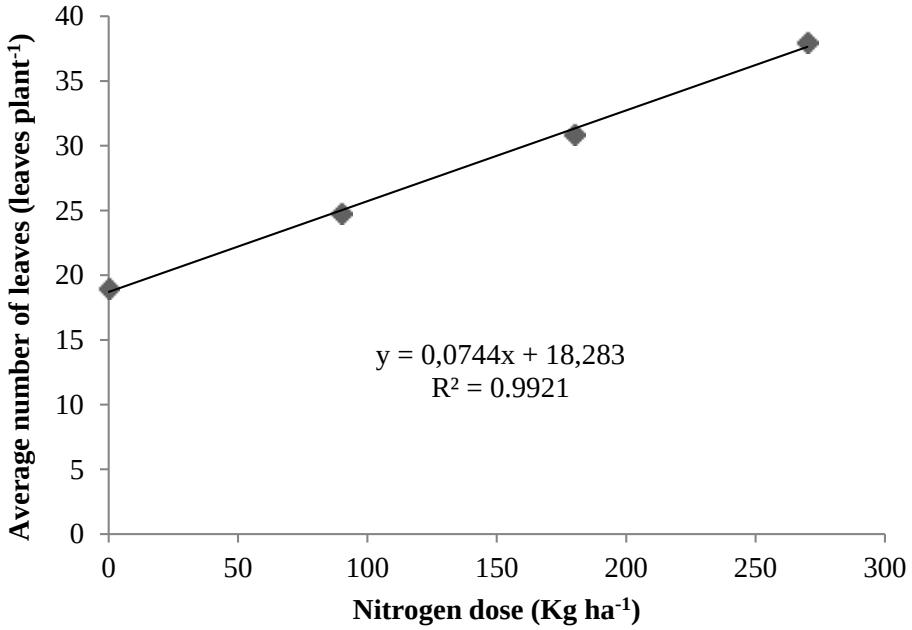

Figure 1. Average number of leaves of Italian Zucchini plants, Novita Plus cultivar, due to the application of different nitrogen doses.

of leaves per plant up to the dose of 180 kg ha^{-1}. Corroborating with the results obtained in this study, Higuti et al. (2010) evaluated the yield of pumpkin seedlings with different doses of potassium and found no significant difference for the number of leaves. The number of male flowers of Italian Zucchini plants showed a significant difference for the N dose factor as well as for the K dose factor (Table 1).

An increase in the number of male flowers is observed through the linear function with the application of nitrogen and potassium, as outlined in Figure 2. It is noted that the highest number of male flowers was 69.8, obtained at the dose of 270 kg ha^{-1} of N. Ng'etich et al. (2013) assessed the number of flowers according to the levels of nitrogen and obtained 67.5 flowers at the dose of 160 kg ha^{-1} of N. According to these authors, the role of nitrogen in increasing the number of male flowers per plant is clear, being the highest number obtained with higher doses. The Italian Zucchini plants possibly absorbed nitrogen in adequate amounts, a fact that reflected in the production of male flowers. Kano et al. (2010) stated that the nutrient stimulates the production of flower buds. The flower buds pass through the cellular differentiation process, which also has the involvement of nitrogen (Cabello, 1996).

Regarding potassium levels, it was observed that the dose of 270 kg ha^{-1} of K_2O allowed obtaining of 53.5 male flowers per plant. Representing a 10% increase as compared to the control treatment. According Shabala (2003), the nitrogen is involved in protein synthesis, which in conjunct composes amino acids, which have a specific function. The potassium acts as ionic regulator being involved in processes such as the activation of transport enzymes of various types of solutes and opening and closing of stomata. Thus, these two major nutrients are concentrated in vegetable organs of intense metabolic activity, such as flower buds. The nitrogen doses and potassium doses presented a significant difference in the number of female flowers (Table 1). Increase in the number of female flowers of Italian Zucchini was observed with the application of increasing doses of N, and it was possible to adjust a crescent linear regression model. Regarding the potassium doses, a quadratic regression model was adjusted, as shown in Figure 3.

The highest number of female flowers (20.17 female flowers $plant^{-1}$) was obtained with the application of the dose of 270 kg ha^{-1} of N. The number of female flowers in the dose of 270 kg ha^{-1} was 51% higher than what was obtained with the application of 0 kg ha^{-1} of nitrogen. Ng'etich et al. (2013) assessed the number of Italian Zucchini flowers and obtained 24 flowers per plant. According to these authors, the maximum number of flowers occurred at the dose of 120 kg ha^{-1} and was 63.5% higher than the number of flowers at the dose of 0 kg ha^{-1}. According to these authors, doses above 120 kg ha^{-1} did not result in increase in the number of flowers. This result differs from that obtained in this experiment, where it is apparent that the number of flowers has a linear increase as a function of nitrogen. No reduction in the number of flowers was observed in doses greater than 120 kg ha^{-1}.

It can be verified in this experiment that the doses were

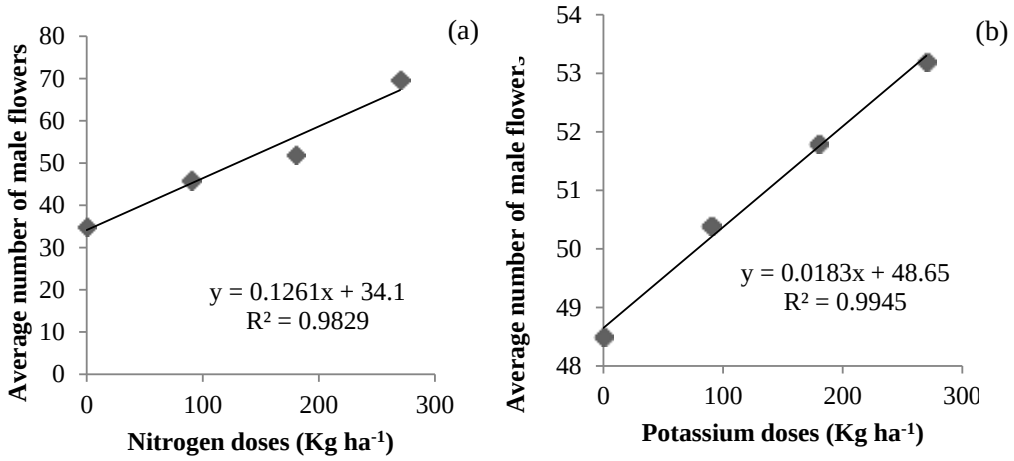

Figure 2. Average number of male flowers of Italian Zucchini plants, Novita Plus cultivar, due to the application of different nitrogen (a) and potassium (b) doses.

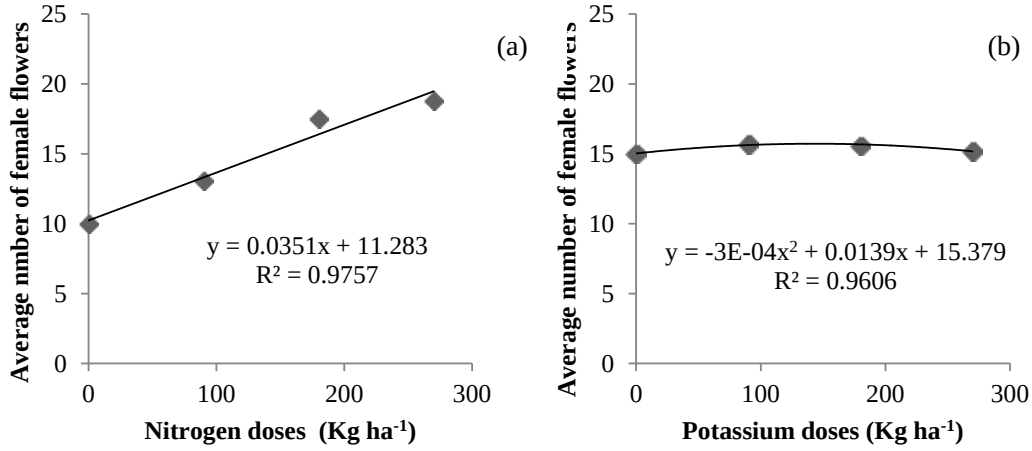

Figure 3. Average number of female flowers of Italian Zucchini plants, Novita Plus cultivar, due to the application of different nitrogen (a) and potassium (b) doses.

adequate, not causing toxicity by excess of the nutrient. Both the deficiency and the excess of nitrogen can reduce the formation of female flowers. Exceeding doses of nitrogen at the flowering stage in vegetable crops, like the Italian Zucchini, favor abortion of female flowers (Silva and Marouelli, 2002).

Nitrogen, besides favoring vegetative growth and leaf size, also plays a key role in the expression of female flowers. Nitrogen fertilization, especially with the use of nitrate, induces an increase in the number of female flowers on the plant (Menezes, 1994). According to Amer et al. (2009) the growth of pumpkin plants at higher nitrogen doses leads to a significant decrease in the sexual ratio (number of male flowers/number of female flowers), signifying an increase in the number of female flowers. The maximum number of female flowers (16.6 female flowers plant^{-1}) was provided by the application of the dose of 173.75 kg ha^{-1} of K_2O (Figure 3B). Potassium did not have great influence in the production of female flowers. Possibly this is due to the fact that the nutrient has qualitative effect on the fruits, or even contributes to the resistance of shoot to fungal diseases (Filgueira, 2008). However, there is no connection, so far, between the production of female flowers and potassium doses.

Nitrogen and potassium doses significantly influenced the number of fruits per Italian Zucchini plant (Table 1). It was possible to adjust a quadratic regression model for the N dose factor, as well as for the K dose factor, as shown in Figure 4.

The maximum fruit yield was 12.1 fruits per plant,

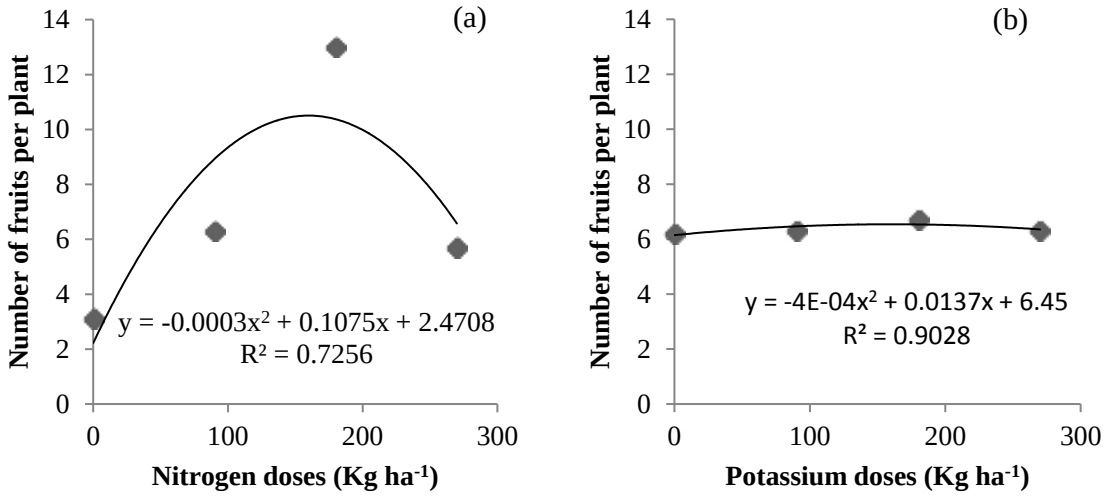

Figure 4. Average number of fruits of Italian Zucchini, Novita Plus cultivar, due to the application of different nitrogen (a) and potassium (b) doses.

obtained with the application of 179.19 kg ha^{-1} of N. As compared to the control, it corresponds to a 363% yield increase. Doses above 179.19 kg of N resulted in decrease of the number of fruits. According to Queiroga et al. (2007), in cucurbits the increase in N doses, to a limited extent, provides increment in plant leaf area, having an effect on the production of photoassimilates and thus in fruit yield. Pôrto et al. (2012) evaluated the effect of different doses of nitrogen (0, 50, 100, 200 and 400 kg ha^{-1} of N) on the number of fruits per plant of zucchini (Caserta cultivar). The authors concluded that the dose of 323 kg ha^{-1} of N provided the maximum number of fruits per plant (7.7 fruits $plant^{-1}$).

Regarding the doses of potassium, the Italian Zucchini plants produced the maximum number of fruits per plant (7.6 fruits $plant^{-1}$) with the application of 171.25 kg per ha of K_2O. The achieved results may be related to the finding of an optimal dose, considering that potassium can contribute to the improvement of chemical and physical characteristics of fruits, due to the optimization in the process of transpiration and formation of carbohydrates (Taiz and Zeiger, 2012). However, if nutritional imbalances take place, caused by excessive applications of potassium doses, physiological disturbances such as drop in yield, fruit quality and increase in osmotic pressure may occur (Marschner, 1995).

Research carried out by Grangeiro and Filho (2004) showed that the highest fruit indexes in watermelon crop were obtained up to the dose of 300 kg ha^{-1} of K_2O. Doses above 300 kg ha^{-1} K_2O caused decrease in fruit indexes for this crop.

The average fruits mass was influenced by the application of nitrogen and potassium doses (Table 1), and it was possible to adjust quadratic regression models for both factors, as shown in Figure 5.

The application the dose of 270 kg ha^{-1} of N caused a drop in average fruit mass. The yield obtained with this dose is lower than that achieved with the control, indicating that the excess of nitrogen is equally or more harmful than the nutrient deficiency. The maximum average fruit mass (240.17 grams $fruit^{-1}$) was obtained with the application of the dose of 136.92 kg ha^{-1} of N. This represents approximately 11.5% increased as compared to the control. According to Ng'etich et al. (2013), the increment in vegetative and reproductive characteristics due to the increase in the supply of nitrogen could be attributed to the increase in nitrogen uptake and its role in chlorophyll synthesis and consequently in the process of photosynthesis and carbon assimilation.

Pôrto et al. (2012) studied the effect of different doses of nitrogen (0, 50, 100, 200, 400 kg ha^{-1} of N) and found significant differences in average fruit mass of zucchini, Caserta cultivar. These authors found quadratic responses with the application of the maximum estimated dose of 265 kg ha^{-1} of N, which provided the production of fruits with the maximum average fruit mass of 240 g per fruit. This result represents an increase of 54% as compared to the control, being higher than the values obtained in the present work.

The application of 184.17 kg ha^{-1} of K_2O provided fruit mass of 227.71 grams $fruct^{-1}$. Higher doses resulted in the drop of the fruit mass, because the excess potassium ends up inhibiting the absorption of calcium, an essential element for fruit formation.

Esmaielpour and Hokmalipour (2014) verified that 150 kg ha^{-1} of potassium allowed maximum yield. According to these authors, potassium increases the transport of assimilates to the fruit, increasing the "sink" power of the fruit.

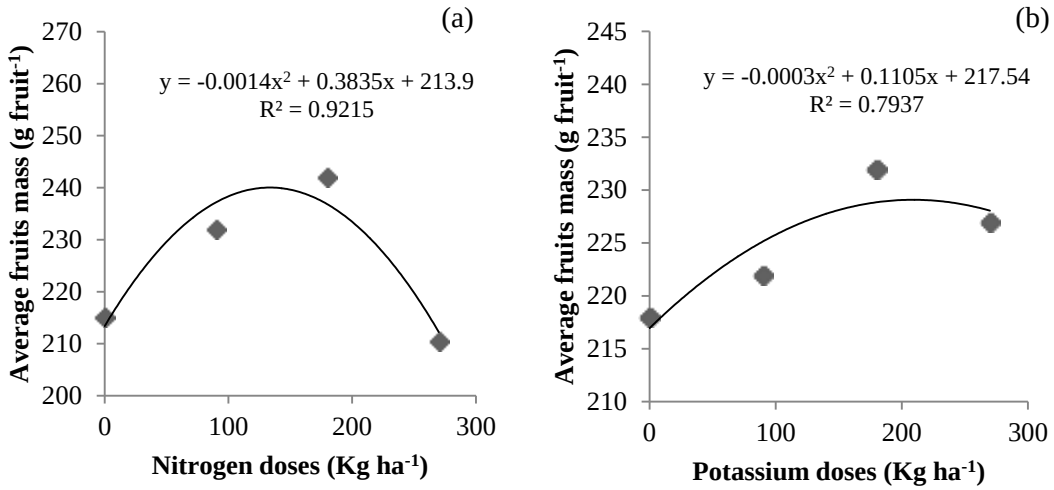

Figure 5. Average fruits mass of Italian Zucchini, Novita Plus cultivar, due to the application of different nitrogen (a) and potassium (b) doses.

Conclusions

The number of leaves of Italian Zucchini crop has a direct relationship with increasing nitrogen doses, unlike potassium doses that did not exert any effect.

Regarding floral crop production, the studied nutrients had significant effect on the production of male and female flowers, giving more emphasis to the nitrogen that allowed maximum sexual expression of the crop in male flowers through the maximum nitrogen dose.

The maximum doses of the studied nutrients resulted in losses in average number of fruits and average fruit mass, due to the inhibition of absorption of other nutrients as well as cause physiological disturbances to the plant.

Conflict of interests

The authors have not declared any conflict of interests.

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