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EFFECT OF NITROGEN FERTILIZATION ON YIELD AND QUALITY OF WATERMELON, CV. TOP GUN[1]

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ABSTRACT – Nitrogen (N) is the second most important nutrient required by watermelons that can limit their growth and affect fruit quality when deficient. We evaluated the soil (N-nitrate) and foliar N contents and soluble-solid content of the watermelon 'Top Gun' in Brazil at six rates of N fertilization (0, 50, 100, 150, 200 and 250 kg ha^{-1}). N-nitrate and foliar N levels increased linearly with rate. Number of total and marketable fruit, weight of total and marketable fruit and total and marketable yields varied quadratically with rate. N rates of 187 and 184 kg ha^{-1} produced the highest total and marketable yields, respectively. The rate of N fertilization did not significantly affect total-solid content.

Keywords: *Citrullus lanatus.* Performance. Fresh weight. Nitrogen fertilization. Soil nitrate.

EFEITO DA FERTILIZAÇÃO NITROGENADA NA PRODUTIVIDADE E QUALIDADE DO FRUTO DA MELANCIA, CV. TOP GUN

RESUMO - O nitrogênio (N) é o segundo nutriente mais demandado pela melancia e o que mais limita o seu crescimento e afeta a qualidade quando em deficiência. Foi avaliada a concentração de N no solo (N-nitrato), o teor de N na planta e sólidos solúveis da melancia 'Top Gun' no Brasil, com seis doses de N (0, 50, 100, 150, 200 e 250 kg ha^{-1}). Os valores de N-nitrato e N foliar aumentaram linearmente com as doses de N. Número de frutos total e comercial, massa de frutos total e comercial e produtividade total e comercial apresentaram efeito quadrático. A maior produtividade total e comercial foram obtidas com 187 e 184 kg ha^{-1} de N, respectivamente. As doses de N não influenciaram no teor de sólidos solúveis.

Palavras-chave: *Citrullus lanatus.* Rendimento. Massa fresca. Fertilização nitrogenada. Nitrato no solo.

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INTRODUCTION

The watermelon (*Citrullus lanatus*) is a socio-economically important vegetable in Brazil, with production estimated at 2.079 million tonnes at an average yield of 21.97 t ha^{-1} (AGROSTAT, 2014), far below its potential of 70 t ha^{-1} (BARROS et al., 2012). Watermelon culture is characterized by high nutrient demand within a short period of time (PAULA et al., 2011), so inadequate fertilization is a main contributor to low yield and fruit quality (BARROS et al., 2012).

Nitrogen (N) is the second most common nutrient absorbed by the plant (GRANGEIRO; CECÍLIO FILHO, 2004; VIDIGAL et al., 2009) and greatly influences its growth. N deficiency causes a gradual chlorosis of older leaves, reducing the growth of young leaves, increasing the distance between sheets and decreasing plant growth, resulting in low yield (PRADO, 2008).

N also affects the quality of the fruit by increasing the amount of soluble solids (SS), an important quality index in several countries (MORAIS et al., 2008; ARAÚJO et al., 2011; BARROS et al., 2012). Excess N can promote vegetative growth at the expense of flowering and fruiting, thereby decreasing the SS content (MOUSINHO et al., 2003), which reduces the resistance to transport and storage (PRADO, 2008). High plant N content also reduces the production of phenolic (fungistatic) compounds and lignin in the leaves, decreasing the resistance to pathogens (SANTOS et al., 2009).

Less than 50% of the N applied is absorbed by the plant (HAWKESFORD et al., 2012). The rest can be lost by leaching, especially in sandy soil (PRASAD; HOCHMUTH, 2015), which can contaminate water sources and the groundwater.

Published recommended rates of N fertilization for watermelon vary widely. Trani et al. (1997a) recommended 80-130 kg N ha^{-1}, and Filgueira, Carrijo and Avelar Filho (1999) recommended 120 kg ha^{-1}. Andrade Júnior et al. (2006) reported that 97.61 kg N ha^{-1} produced maximum yield (60.17 t ha^{-1}) in fertigated watermelon cultures, and Morais et al. (2008) reported an optimal rate of 267 kg N ha^{-1} for a similar yield (68.59 t ha^{-1}). We thus evaluated the effect of the rate of N fertilization on yield and SS content of the watermelon 'Top Gun'.

MATERIAL AND METHODS

Location and characterization of the area

The experiment was conducted in the field from 29 August to 22 November 2012 at São Paulo State University (UNESP), Jaboticabal, SP, Brazil (21°14'05"S, 48°17'09"W; 614 m a.s.l.). The average, maximum and minimum temperatures during the experiment were 24.2, 31.8 and 17.6 °C, respectively. Relative humidity ranged from 33 to 91%, and solar radiation ranged from 3.7 to 27.9 MJ m^{-2} d^{-1}. The cumulative rainfall for the period was 226 mm, distributed over 14 rainy days.

The soil of the experimental area was classified as a Eutrophic Oxisol of the EMBRAPA (2006) taxonomic system. The chemical and physical properties of the soil prior to the experiment were: pH ($CaCl_2$) 5.3; organic matter, 22 g dm^{-3}; P(resin), 90 mg dm^{-3}; S-SO_4^{2-}, 8 mg dm^{-3}; K^+, 3.2 $mmol_c$ dm^{-3}; Ca^{2+}, 19 $mmol_c$ dm^{-3}; Mg^{2+}, 6 $mmol_c$ dm^{-3}; H+Al, 25 $mmol_c$ dm^{-3}; Al^{3+}, 0 $mmol_c$ dm^{-3}; SB, 28 $mmol_c$ dm^{-3}; cation exchange capacity, 53 $mmol_c$ dm^{-3}; soil base saturation, 53%; clay content, 565 g kg^{-1}; silt content, 200 g kg^{-1}; fine-sand content,104 g kg^{-1} and coarse-sand content, 131 g kg^{-1}.

Treatments and experimental design

The experimental design was randomized blocks with six N rates (0, 50, 100, 150, 200 and 250 kg ha^{-1}) and four replicates. Each experimental plot consisted of three rows 2.5 m apart with 12 plants each and 1.0 m between plants in an area of 90 m^2. Data were collected from the eight central plants of the central row (20 m^2).

Field preparation and fertilization

The soil was plowed and disked 60 days before planting, and lime (PRNT, 125%; 48% CaO and 16% MgO) was incorporated in the entire field to increase the saturation of the soil to 70% (TRANI et al., 1997a).

Fertilization in furrows approximately 0.30 m in depth consisted of 120 kg P_2O_5 ha^{-1} and 30 kg K_2O ha^{-1} (TRANI et al., 1997a) using simple superphosphate and potassium chloride. Two seeds of the watermelon 'Top Gun', the main hybrid used by farmers in São Paulo, were sown per hole, 3-4 cm deep. The plants were thinned seven days after emergence (DAE) to one plant per hole.

All N was applied manually as a continuous bead beside the rows of plants five times in equal amounts, seven days apart and beginning after 13 DAE using potassium nitrate (13% N-NO_3^- and 36.5% K^+) and ammonium nitrate (16.5% N-NO_3^- and 16.5% N-NH_4^+). From early flowering, 30 DAE, N was supplied as calcium nitrate (1% N-NH_4^+, 14.5% N- NO_3^- and 19% Ca^{2+}) at a rate equivalent to 36 kg Ca ha^{-1}. Only K as potassium chloride (58% K_2O) was applied to the control treatment. At the same times as the N fertilizations, 15 kg K_2O ha^{-1} were applied as potassium chloride and/or potassium nitrate. All treatments received the same amounts of

K and Ca.

The plants were irrigated by drip irrigation using self and anti-draining drippers 0.5 m apart, at a nominal flow rate of 1.4 L h^{-1}. Irrigation was managed using daily estimates of crop evapotranspiration. Reference evapotranspiration for the climate (FARIA et al., 2002) was calculated using daily data from the UNESP meteorological station in Jaboticabal, and the crop coefficients were those used by Grangeiro, Medeiros and Negreiros (2006).

In order to distribute the blade during the weekly cycle of irrigation, the culture was irrigated three times a week by applying 2/3 of the total water demand week before the first and second irrigation. The amount of the third application was applied to the difference between the blades and the amount required for the current week. Tensiometers were installed in the plots for treatments with 50 and 150 kg N ha^{-1} at a depth of 0.30 m and 0.05 m from a plant for monitoring soil moisture.

The plants were protected from whiteflies by a covering of a white polypropylene fabric, Agrotêxtil®, with a weight of 25 g m^{-2} 0.5 m above the ground up to 33 DAE at the beginning of flowering. Practices during the crop cycle included thinning the plants, hoeing, combing the branches and pest and disease control.

Harvest began at 81 DAE when the tendrils near the fruit of the peduncle dried. We evaluated the concentration of N-nitrate in the soil solution (mg dm^{-3}), foliar N concentration (g kg^{-1}), number of total and marketable fruit (units ha^{-1}), fresh weight of total and marketable fruits (kg), total and marketable fruit yield (kg ha^{-1}) and SS (ºBrix).

The N-nitrate concentration in the soil solution was measured by a portable meter with a selective microelectrode (Cardy Meter, Horiba Inc.). For this, we used two extractors with microporous ceramic capsules installed in front of the central plant of the evaluated row, at a of depth 0.30 m and 0.10 m from the dripline, which was 0.10 m from the plant row. Soil-solution extracts were obtained at the beginning of flowering, at 33 DAE. The soil solutions were extracted at a vacuum pressure of 60 kPa using a hand vacuum pump. The soil solutions were collected after 24 h at vacuum pressure and prior to irrigation using a suction syringe coupled to a plastic tube. The samples were transferred to polypropylene vials.

Foliar N content was determined at the appearance of the female flowers (35 DAE). The sixth leaves were sampled from the tip of the branch, following Malavolta, Vitti and Oliveira (1997), for the eight plants per plot. The leaves were washed in deionized water and then oven-dried with forced air circulation at 65 °C to a constant weight. The dried leaves were ground and digested and the total N content was determined as described by Bataglia et al. (1983).

The total number of fruit, the total weight of the fruits and the number of marketable fruit with weights ≥8 kg with no cracks or rot were determined for each plot. The total and marketable yield of fruit were estimated. The SS content was evaluated for two randomly chosen fruits of each plot. The fruits were cut in half and a small amount of pulp was collected from the central region of the fruit. The SS content of the juice extracted from the pulp, in the center of the fruit, was determined using a portable refractometer model Modelo ATC-S/Mill-E.

An analysis of variance, *F* test and polynomial regression were conducted using ASSISTAT (version 7.6) (SILVA; AZEVEDO, 2009).

RESULTS AND DISCUSSION

The N-nitrate concentration of the soil solution was significantly influenced by N rate. The concentration ranged from 33.75 mg dm^{-3} in the control to 191.63 mg dm^{-3} at the highest N rate applied (Figure 1). These values are higher than the 6.34 mg nitrate dm^{-3} reported by Feltrim (2010) for fertigated watermelon in a Yellow Red Argisol. The amounts were also above the range considered optimal by Heckman (2003), between 25 and 30 mg dm^{-3}. A soil N-nitrate concentration of 91.22 mg dm^{-3} was needed in our study to reach 90% of the maximum marketable yield. The variation in published soil nitrate contents may be due to differences in sampling depth, tillage practices, soil type and the form of application of nitrogenous fertilizers (SANGOI et al., 2003; RAMBO et al., 2004). The synchronization of the availability (supply) of N in the soil with stages with the highest demand, however, is very important for maximizing the efficiency of N fertilization.

Foliar N content (FN) increased linearly with N rate (Figure 1). The lowest and highest contents were 38.8 and 46.3 g N kg^{-1}, respectively, within the range (25-50 g N kg^{-1}) considered suitable for watermelon (TRANI; RAIJ, 1997b). N-deficient plants have levels < 10 g kg^{-1}, and levels > 50 g kg^{-1} are considered toxic (MALAVOLTA; VITTI; OLIVEIRA, 1997). Feltrim et al. (2011) observed different values obtained in this study and without significant effect on the increase of N, whose average grade was 29.5 g kg^{-1} N, probably due to the organic matter content.

Total number of fruits (TNF) varied quadratically with rate of fertilization, with maximum TNF (5534 fruit ha^{-1}) at 193 kg N ha^{-1} (Figure 2). The control treatment produced 2326 fruit ha^{-1}, or 58% fewer fruit, demonstrating the high response of watermelon to the supply of N. Barros et al. (2012) observed a decreasing linear effect on the number of fruits with increasing N, with 5468 ha^{-1} at 50 kg N ha^{-1} to 3367 ha^{-1} at 250 kg N ha^{-1}. Feltrim et al. (2011) reported no difference in the number of fruits when evaluated N and K rates, which was attributed to the high density of the plants.

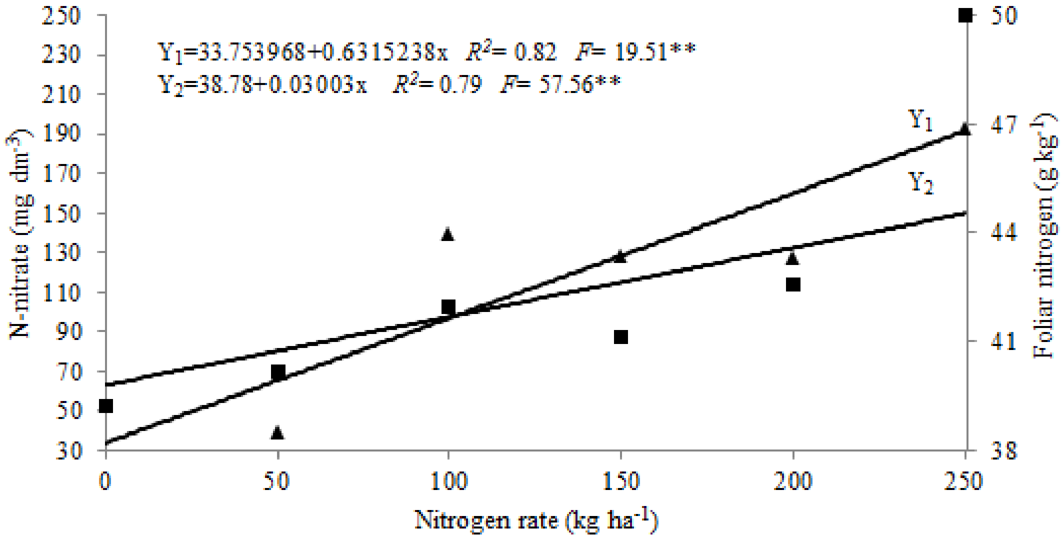

Figure 1. N-nitrate content in the soil solution (Y_1) and foliar nitrogen content of watermelon 'Top Gun' (Y_2) as functions of the rate of nitrogen fertilization at the beginning of flowering (33 DAE) and the beginning of female flowering (35 DAE), respectively.

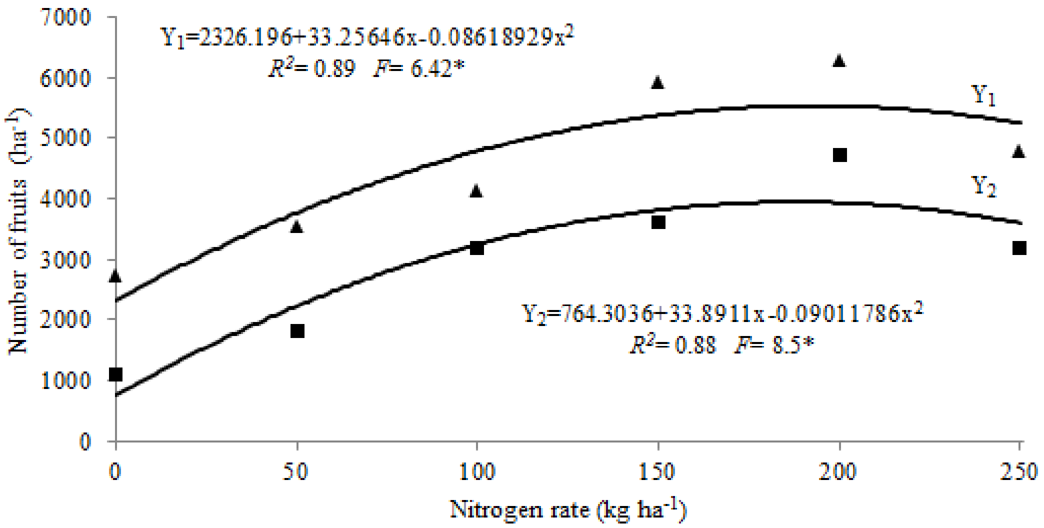

Figure 2. Total number of fruits (Y_1) and number of marketable (Y_2) 'Top Gun' watermelon as functions of the rate of nitrogen fertilization.

The number of marketable fruits (NMF), 3950.7 fruit ha^{-1}, was highest at 188 kg N ha^{-1}, corresponding to 71% of TNF (Figure 2). The rates that maximized TNF and NMF were similar, and higher rates began to have a negative effect on fruiting, in agreement with the results obtained by Araújo et al. (2011) and Barros et al. (2012). The shading caused by excessive foliar growth due to high rates of N fertilization can decrease net photosynthesis (PRADO , 2008). The interception of solar radiation by the foliage, in many parts of plants, cannot maintain a positive carbon balance, and production decreases (SILVA et al., 2011).

The total fresh weight (TFW) and weight of marketable fruits (MFW) were highest at 153 and 128 kg N ha^{-1}, respectively (Figure 3). Mean MFW was 7.97 kg in the control but was only 19% of the maximum NMF. MFW in this study was similar to the 8 kg obtained by Barros et al. (2012) at 128 kg N ha^{-1}.

TNF, NMF, TWF and MFW responded similarly to N fertilization and were consistent with those reported by Andrade Júnior et al. (2006). The increase in the number of fruits per plant increase competition for assimilates, which decreases NMF and CMF. Valantin-Morinson et al. (2006) also reported that increasing the number of fixed melons increased the competition for photoassimilates between fruits and decreased individual fruit weight. Andrade Júnior et al. (2006) obtained a total fruit weight of 8.98 kg, close to that in our study, at 103 kg N ha^{-1}.

Total yield (TY) was highest (44800 kg ha^{-1}) at 187 kg N ha^{-1}, and marketable yield (MY) ^{1} was highest (34960 kg ha^{-1}) at 184 kg N ha^{-1} (Figure 4). TY and MY were 14 205.94 and 6206.5 kg ha^{-1}, respectively, in the control, 68 and 82.25% lower than the highest TY and MY, respectively.

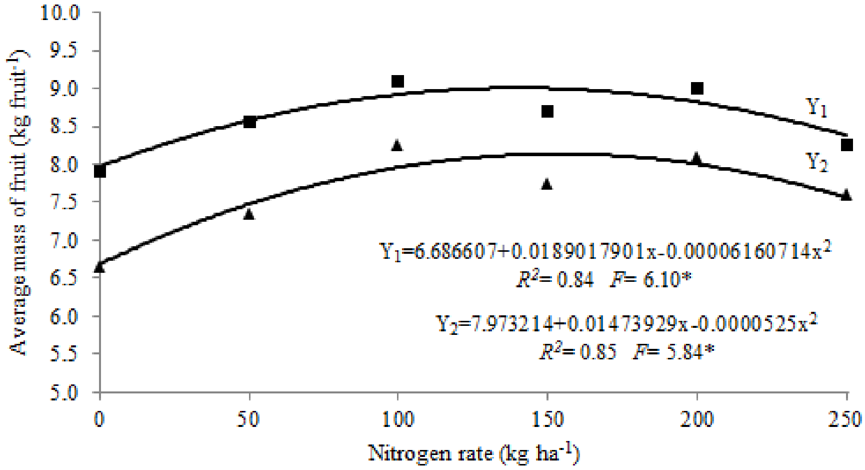

Figure 3. Total fresh weight (Y_1) and marketable weight (Y_2) of watermelon 'Top Gun' as functions of the rate of nitrogen fertilization.

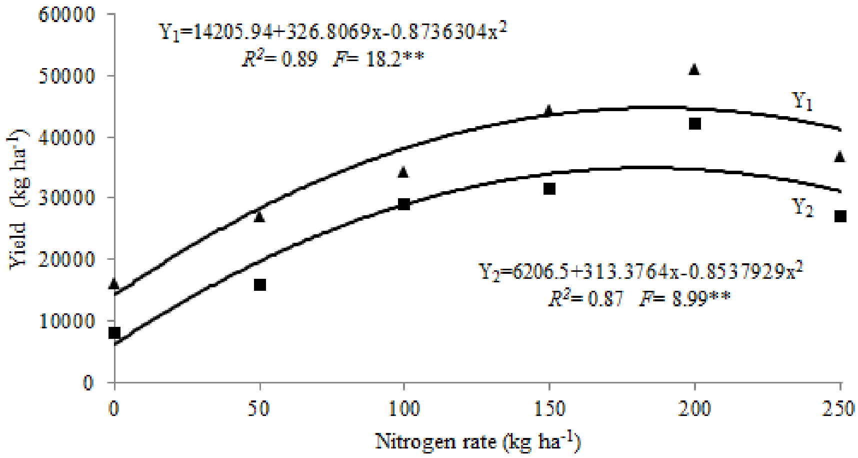

Figure 4. Total yield l (Y_1) and marketable (Y_2) of watermelon 'Top Gun' as functions of the rate of nitrogen fertilization.

MY was higher in our study than the 30.8 t ha^{-1} at 222.1 kg N ha^{-1} reported by Mousinho et al. (2003), also using the conventional fertilization and irrigation system. Barros et al. (2012) reported a similar maximum TY (44 430 kg ha^{-1}), but at 144.76 kg N ha^{-1}. Morais et al. (2008) reported maximum productivity (68 590 kg ha^{-1}) at 267 kg N ha^{-1}.

Andrade Júnior et al. (2006, 2009) obtained a maximal yield at a lower rate of N fertilization using fertigation, demonstrating the greater efficiency of this system in the recovery of the N applied. For example, TY was 66770 kg ha^{-1} at 104480 kg N ha^{-1} and MY was 60170 kg ha^{-1} at only 97.61 kg N ha^{-1} (ANDRADE JÚNIOR et al., 2006). Andrade Júnior et al. (2006), though, defined MY as > 6 kg (> 8 kg in our study).

The discrepancy among the published N rates for maximizing yield is likely due to many factors, including the planting density (FELTRIM et al., 2011), the form of application of fertilizer, soil and climatic conditions and genetics (MOUSINHO et al., 2003; ANDRADE JÚNIOR et al., 2006;. MORAIS et al., 2008).

The relationships between N rate, FN and soil N-nitrate contents and relative yield (RY), which is the ratio of MY estimated for each rate to the maximum MY, are presented in Figure 5.

An increase of 36.59% in the soil N-nitrate content (33.75-79.85 mg dm^{-3}) increased RY from 17.75 to 70%, which is considered a low yield. Increasing the soil N-nitrate content from 79.85 to 109.53 mg dm^{-3} increased RY by 70-90%, which is considered a medium yield, corresponding to an increase of 37.16%. FN for this range of RY varied between 40.97 and 42.38 g kg^{-1}. Soil N-nitrate contents between 109.53 and 149.95 mg dm^{-3} increased RY by 90-100%, but FN content only increased from 42.38 to 44.31 g kg^{-1}. Maximum RY was 10% lower when FN content was >46.16 g kg^{-1}, possibly due to a toxic effect. This value was lower than the 50 g N kg^{-1} observed by Malavolta, Vitti and Oliveira (1997).

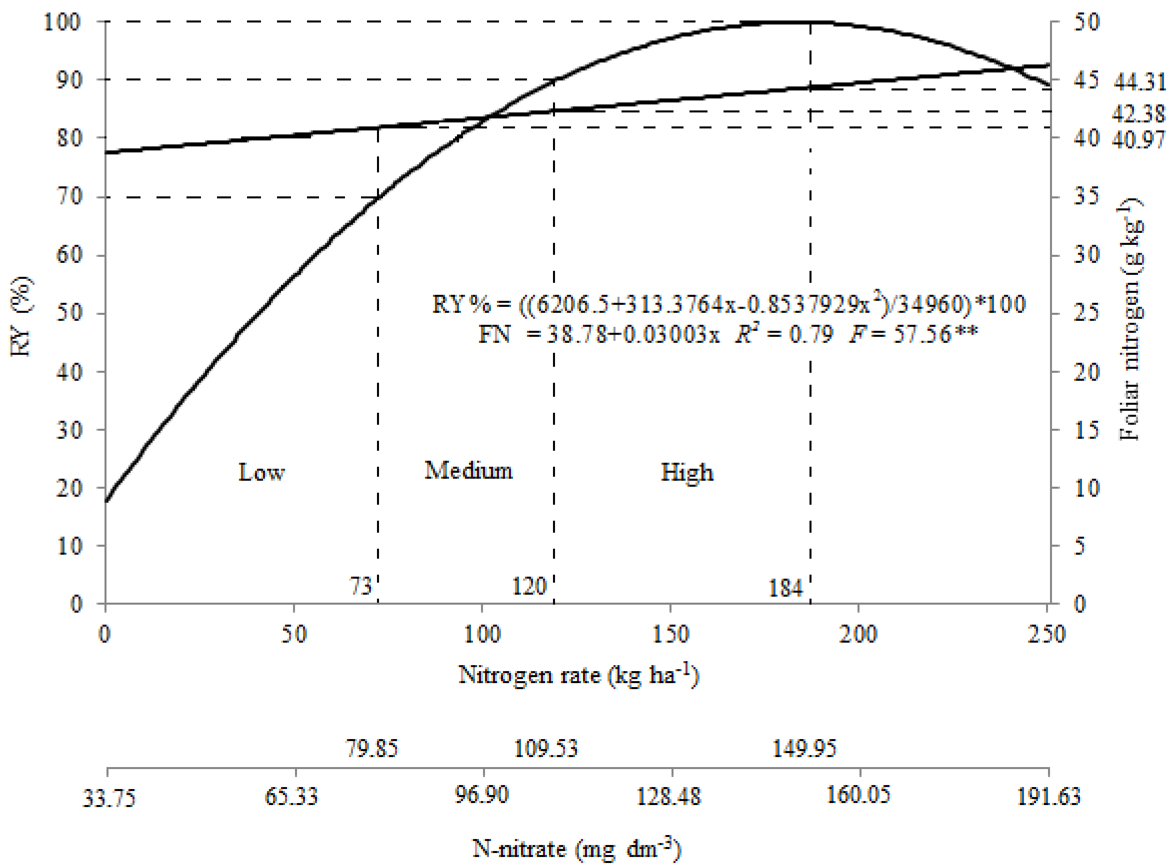

Figure 5. Relative yield (RY), foliar nitrogen (FN) and N-nitrate content in the soil solution as functions of the rate of nitrogen fertilization.

The rate of N fertilization did not affect the SS content. Mean SS was 10.7 °Brix, higher than the minimum of 10 °Brix recommended for commercialization (ARAÚJO et al., 2011; BARROS et al., 2012). The lack of significant effect of N on the SS content may have been due to the large increases in TNF and MNF, which increased the number of fruits of the plant and equalized the assimilates partition. Other studies evaluating the rate of N fertilization have also reported no effect on SS, with averages from 9.8 to 10.7 °Brix (ANDRADE JÚNIOR et al., 2006; MORAIS et al., 2008). Araújo et al. (2011) and Barros et al. (2012), evaluating the cultivar Crimson Sweet, however, reported a positive response.

CONCLUSIONS

N fertilization increased the nitrate content of the soil, foliar N content and the number and weight of total and marketable fruits. Total and marketable yields of 'Top Gun' were highest at 187 and 184 kg N ha^{-1}, respectively. Foliar N content between 42.3 and 44.3 g kg^{-1} and soil nitrate content between 109 and 150 mg dm^{-3} provided 90-100% of the maximum marketable yield. Applications up to 250 kg N ha^{-1} did not affect the SS content of the fruit.

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