horticultura brasileira

Research

VIDIGAL, SM; MOREIRA, MA. Influence of nitrogen on bell pepper yield in open field conditions during autumn-winter. *Horticultura Brasileira* v.42, 2024. Elocation e285832. DOI: http://dx.doi.org/10.1590/s0102-0536-2024- e285832

Influence of nitrogen on bell pepper yield in open field conditions during autumn-winter

Sanzio M Vidigal[1], Marialva A Moreira[2]

[1]Empresa de Pesquisa Agropecuária de Minas Gerais, Epamig Sudeste, Viçosa-MG, Brasil; sanziomv@epamig.br. [2]Empresa de Pesquisa Agropecuária de Minas Gerais, Epamig Centro Oeste, Sete Lagoas-MG, Brasil; marialvamoreira@yahoo.com.br

ABSTRACT

Nitrogen (N) deserves special attention in the fertilization recommendation for bell peppers, as it is the nutrient absorbed in greater quantity, standing out for the amount required and the functions it performs in the plant. The objective was to evaluate the influence of nitrogen applied as top dressing on bell pepper production in open field during the autumn/winter period. The experiment was conducted in Red-Yellow Argisol. A randomized complete block design with four replications was used. Treatments consisted of nitrogen rates applied as top dressing (0, 75; 150; 300; and 450 kg/ha). Nitrogen increased the number and fresh mass of fruits per plant. The SPAD Reading increased with the increment of nitrogen rates in the three evaluation periods and with the evaluation period. Bell peppers grown during the autumn/winter period showed high productive potential associated with nitrogen rates higher than currently recommended. The yield of marketable fruits increases until 214 kg/ha of N. The critical level for the SPAD reading varied with the age of the plants, with estimated critical values of 53.2, 66.5, and 61.9 at 35, 56, and 154 days after transplanting (DAT).

Keywords: *Capsicum annuum* L. *var. annuum*, cultivation season, SPAD readings, fertilization, yield.

RESUMO

Influência do nitrogênio na produtividade do pimentão em condições de campo aberto no outono-inverno

O nitrogênio (N) merece destaque na recomendação de adubação para o pimentão, uma vez que é o nutriente absorvido em maior quantidade destacando-se pela quantidade exigida e pelas funções que exerce na planta. Objetivou-se avaliar a influência do nitrogênio aplicado em cobertura na produção de pimentão em campo aberto no período de outono/inverno. O experimento foi realizado em Argissolo Vermelho-Amarelo. Utilizou-se o delineamento em blocos ao acaso com quatro repetições. Os tratamentos foram constituídos de doses de N aplicadas em cobertura (0, 75; 150; 300 e 450 kg/ha). O N aumentou o número e a massa fresca de frutos por planta. O Índice SPAD aumentou com o incremento das doses de N nas três épocas de avaliação e com a época de avaliação. O pimentão cultivado no período de outono/inverno apresentou elevado potencial produtivo associado a doses de N superiores a recomendada atualmente. A produtividade de frutos comercializáveis aumenta até a dose de 214 kg/ha de N. O nível crítico para o índice SPAD variou com a idade das plantas, com valores estimados de 53,2; 66,5 e 61,9 aos 35, 56 e 154 dias após o transplante (DAT).

Palavras-chave: *Capsicum annuum* L. var. *annuum*, época de cultivo, leitura SPAD, adubação, produtividade.

Received on May 7, 2024; accepted on July 15, 2024

In Brazil, the average yield of bell peppers is 22 t/ha, occupying an area of 15,000 ha, with a production of 334,615 tons (Goto *et al*., 2016). Traditional bell pepper cultivation is carried out in open fields; however, production in protected environments with fertigation has been increasing (Paulino, 2016). Consequently, research on nitrogen fertilization for bell peppers has been more frequent in this system, while studies for open field environments have become scarcer. Nonetheless, production in open fields still accounts for the largest production area.

The vegetative growth and fruit formation of bell peppers are favored by daytime temperatures between 25 and 27°C and nighttime temperatures between 16 and 20°C, with a temperature range of 8°C (Pinto *et al*., 2019). In the Zona da Mata region of Minas Gerais, Brazil, due to temperature conditions, bell peppers are better adapted to cultivation from August to February (Finger & Silva, 2021). However, in low-altitude regions, they can also be cultivated in winter in the Southeast region of Brazil (Fontes *et al*., 2005). There are few studies on the performance of bell pepper production under adverse conditions caused by environmental phenomena.

Nitrogen (N) deserves prominent consideration in the fertilization recommendation for bell peppers, as it is the nutrient absorbed in the greatest quantity (Fontes *et al*., 2005; Albuquerque *et al*., 2012; Charlo *et al*., 2012), standing out for both the amount required and the functions it serves in the plant. As a component of chlorophyll molecules, N enhances the photosynthetic apparatus and promotes the optimization of photoassimilate production (Kirkby *et al*., 2022). Therefore, managing nitrogen fertilization requires attention to ensure yield and fruit quality in bell peppers, as well as in other vegetables.

The recommended nitrogen application rate for Minas Gerais is between 140 and 180 kg/ha (Pinto *et al*., 2019), while for São Paulo, it ranges from 120 to 200 kg/ha (Villas Bôas *et al*., 2018). Based on daily accumulation rates, Fontes *et al*. (2005) suggest a rate of 190 kg/ha of N for protected environments, while the nitrogen rate for maximum yield has varied from 100 to 350 kg/ha of N (Lorenzoni *et al*., 2016; Costa *et al*., 2018; Silva *et al*., 2020). Conditions in protected environments favor greater growth and development of bell pepper plants compared to open fields, thus the demand for N and other nutrients may be higher in protected environments. In open fields, in the Northeast region of Brazil, Paulino (2016) observed that the maximum bell pepper yield was achieved with a rate of 124.61 kg/ha of N.

Thus, our hypothesis is that bell peppers can express their productive potential in autumn/winter cultivation in low-altitude locations associated with the most appropriate nitrogen rate. The objective of this study was to investigate the influence of nitrogen applied as top dressing on bell pepper production during the autumn/winter period in open field conditions at a low-altitude location in the Zona da Mata region of Minas Gerais.

MATERIAL AND METHODS

The experiment was conducted at the experimental farm of Empresa de Pesquisa Agropecuária de Minas Gerais (EPAMIG) (20°24'S; 42°49'W; 450 m altitude), Oratórios, from April to September 2015. The region's climate varies from Cwa, humid tropical to Aw, semi-humid with hot summers, according to Köppen and Geiger (Vidigal *et al*., 2023). The maximum and minimum average annual temperatures are respectively 21.6 and 19.5°C; the average precipitation is 1,162 mm. During the experiment period, the mean maximum, minimum, and average temperatures were 24.9, 14.0, and 19.5°C, respectively. The accumulated rainfall was 175.9 mm, distributed throughout the cycle as follows: 74.7 mm from 0 to 64 days after transplanting (DAT), 27.1 mm from 64 to 92 DAT, 8.9 mm from 92 to 127 DAT, and 65.2 mm from 127 to 159 DAT (Figure 1).

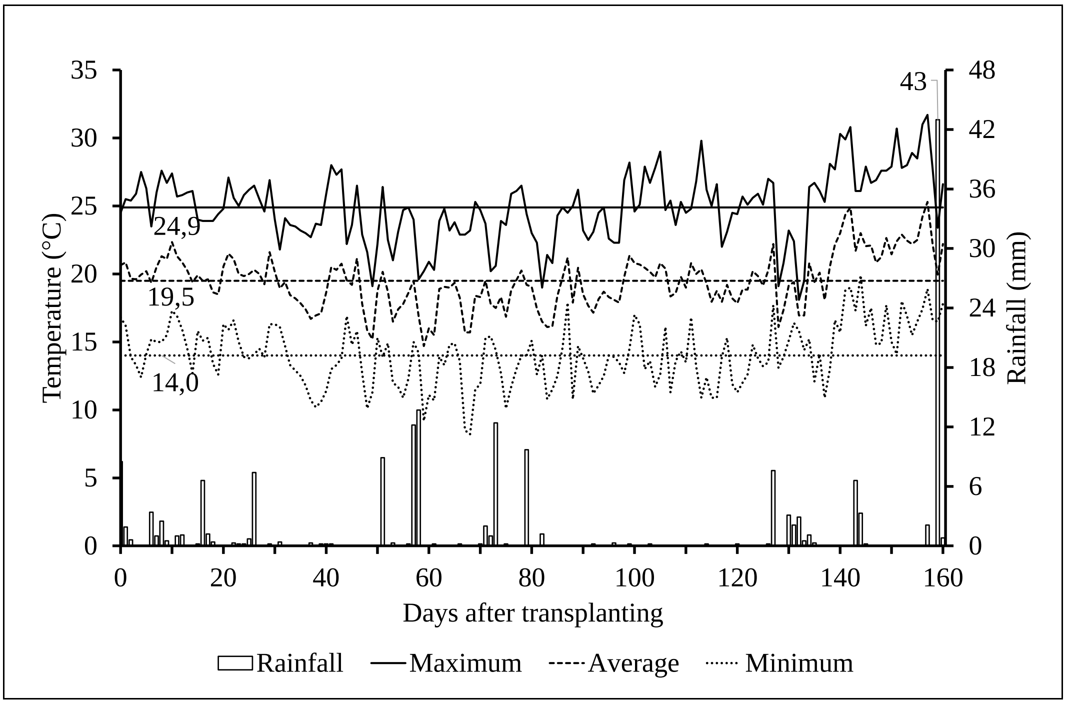

Figure 1. Maximum, average and minimum daily air temperature, and rainfall during the experiment period. Oratórios, EPAMIG, 2015.

The treatments consisted of five N rates (0; 75; 150; 300; and 450 kg/ha), defined according to the recommended rate of 140 to 180 kg/ha for Minas Gerais (Pinto *et al*., 2019). These rates were applied in top dressing, in four plots, 20%; 20%; 30%; and 30% of the applied rate at 21, 44, 65, and 84 days after transplanting (DAT). The N source used was urea (45% of N). The treatments were arranged in a randomized complete block design, with four replicates. Each experimental unit consisted of five rows, with 10 plants each.

The soil in the cultivation area, classified as Red-Yellow Argisol, had the following chemical characteristics in the 0-20 cm depth layer of samples taken before the experiments were conducted in two years of planting: pH (water) = 5.6; Ca = 1.50 cmolc/dm³; Mg = 0.7 cmolc/dm³; Al = 0.0 cmolc/dm³; H+Al = 3.47 cmolc/dm³; P = 21.1 mg/dm³ (Mehlich 1); K = 89 mg/dm³; organic matter = 14.0 g/kg; B = 0.3 mg/dm³; Cu = 1.3 mg/dm³; Fe = 91.3 mg/dm³; Mn = 99.6 mg/dm³ and Zn = 5.2 mg/dm³.

Soil preparation consisted of plowing and harrowing. Except for N, planting fertilization, based on soil analysis and recommendations for bell pepper (Pinto *et al*., 2019), consisted of 1,500 kg/ha of single superphosphate, 80 kg/ha of potassium chloride, 50 kg/ha of magnesium sulfate, 20 kg/ha of borax, and 20 kg/ha of zinc sulfate. In addition, 320 kg/ha potassium chloride was used, applied in four plots, together with the nitrogen fertilizer applications, in top dressing.

The bell pepper hybrid Laser F1 was used, and seeds were sown in 128 cell expanded polystyrene trays, filled with commercial substrate Plantmax®. Seedlings were transplanted at 61 days after sowing, in 1.00 x 0.60 m spacing (16,667 plants/ha). Plants were irrigated by micro-sprinkler with a flow rate of 52 L/h and arranged at 3.0 m x 3.0 m spacing. The other cultural practices were performed according to the needs and recommendations for the crop (Pinto *et al*., 2019).

At 35, 56, and 154 DAT, the nutritional status evaluation of nitrogen was conducted by determining the green intensity in a fully expanded young leaf, opposite to the developing fruit, at the top of each stem of five randomly obtained plants in the useful area of the plot. Two readings were taken on the leaf blade (right and left edges), with the average of the two readings considered. These readings were conducted between 8:00 and 11:00 hours using the portable chlorophyll meter called SPAD-502 (Soil Plant Analysis Development-502 Konica Minolta®).

The harvest of green fruits, twice a week, began at 64 DAT, and the following characteristics were evaluated: total fruit production, marketable fruits, and non-marketable fruits (malformed, with mechanical damage, damage from pests and diseases).

The marketable fruits were classified based on length for cone-type fruits (Pinto *et al*., 2019), into large fruit (length >120 mm); medium fruit (length >60 and <90 mm); and small fruit (length >50 and <70 mm). The production of marketable fruits was obtained by summing the fruit masses from each harvest after 14 weeks, at 155 DAT. The experiment was concluded due to a wind and rain event, with 43 mm of precipitation occurring at 159 DAT.

The obtained data were submitted to analysis of variance, polynomial regression and correlation. The regression models for the production variables were chosen based on the biological significance, the significance of the regression coefficients, by the t test, and the highest coefficient of determination. The N rates that provided the maximum yield of marketable fruits was obtained by equating to zero the first derivative of the equation of response of marketable fruit yield to the rates of N. The critical level value for the SPAD Reading was estimated with the N rate associated with the maximum yield of marketable fruits, introduced into the previously established model. The software Genes was used to perform the analysis (Cruz, 2016).

RESULTS AND DISCUSSION

The fruit harvest began 64 days after transplanting the seedlings (DAT), and there was no clear definition of the effect of N on fresh fruit yield when 40% of the N rates were applied (Figure 2). Possibly, the nitrogen reserves in the soil allowed for a balance in yield at the beginning of the plant's reproductive phase.

At 71 DAT, after the application of 70% of the N rates, an increase in yield is observed with the growth and development of the plants until the first peak of yield at 92 DAT. However, in the control without N (low N availability) and at the rate of 450 kg/ha of N (high N availability), yield showed lower values than the other rates until the last harvest (Figure 2), which is reflected in the total and marketable yield results at the end of the cycle.

Two complete production cycles were observed with yield peaks at 92 and 127 DAT, followed by the initiation of a new cycle. However, this cycle was not completed due to the termination of the experiment at 159 DAT (Figure 2). The cycles lasted for 35 days and can be characterized by alternating phases of vegetative growth and fruiting. Oliveira et al. (2015), observed on Magali-R bell pepper, three production cycles with intervals of 45 days at 58, 100, and 149 DAT, in an open field during the autumn/winter period in Seropédica-RJ, Brazil.

In this alternation, the plant's drain force is altered by the predominance of the reproductive phase over the vegetative phase, increasing the translocation of photoassimilates from the leaves to the fruits (Kirkby *et al*., 2022). Plants accumulate nutrients and photoassimilates during vegetative growth for later translocation to fruit growth and development, thus resulting in differences in yield throughout the crop cycle. However, the influence of nitrogen (N) on bell pepper fruit yield repeats /ha of N (Figure 2).

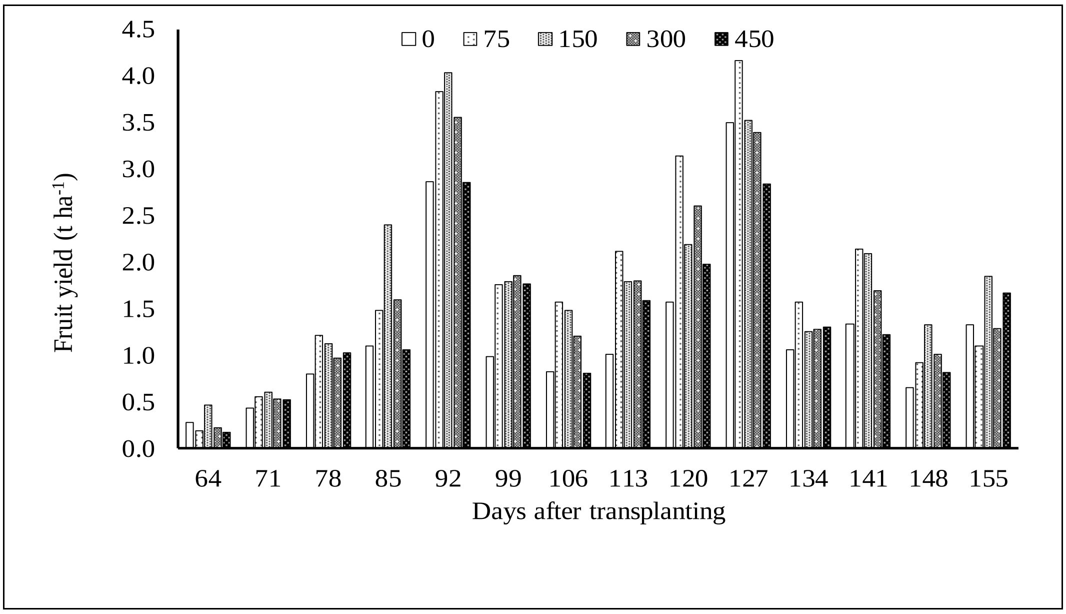

Figure 2. Fruit yield per harvest (days after transplanting) of Laser F1 bell peppers as influenced by rates of N (0, 75, 150, 300 and 450 kg/ha) in Red-Yellow Argisol. Oratórios, EPAMIG, 2015.

Nitrogen increased the number of fruits per plant ($p<0.001$) up to the rate of 212 kg/ha of N, reaching the estimated maximum value of 16.84 fruits/plant, which was 53.0% higher than the control without N and 63.0% higher than the rate of 450 kg/ha of N. There was no difference between the number of fruits in the control without N (11.00 fruits/plant) and the rate of 450 kg/ha of N (10.33 fruits/plant), values lower than the other N rates (Figure 3). Additionally, the fresh fruit mass per plant ($p=0.002$) increased up to the rate of 216 kg/ha of N, reaching the estimated maximum value of 1,731 g/plant. The highest values were observed with the rates of 150 and 300 kg/ha of N, which were 58.5 and 46.4% higher than the control without N and 63.2 and 50.7% higher than the rate of 450 kg/ha^{-1} of N, respectively (Figure 3).

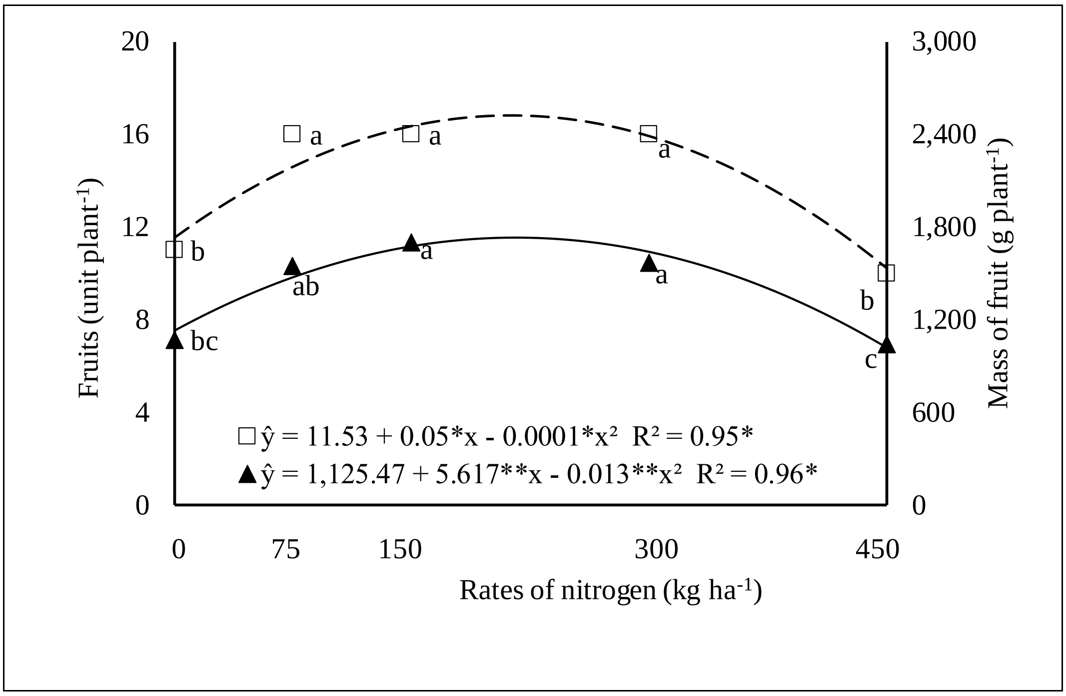

Figure 3. Number and mass of fresh fruit/plant of Laser F1 bell peppers as a function of nitrogen (N) rates in Red-Yellow Argisol. Means with different letters for each variable differ significantly by the Tukey test ($p<0.05$). ** = $p<0.01$. * = $p<0.05$. Oratórios, EPAMIG, 2015.

Nitrogen increased the total number of fruits ($p<0.001$) and the number of marketable fruits ($p<0.001$) up to the rate of 211 kg/ha of N, reaching the maximum values of 288,503 units and 267,778 units, respectively. Marketable fruits represented, on average 92.3%, of the total fruits produced. There was no difference between the total and marketable fruit numbers in the control without N and the rate of 450 kg/ha of N (Figure 4A). However, the number of non-marketable fruits (malformed, with mechanical damage, damage from pests and diseases) was not influenced by N, presenting an average total number of 18,664 units.

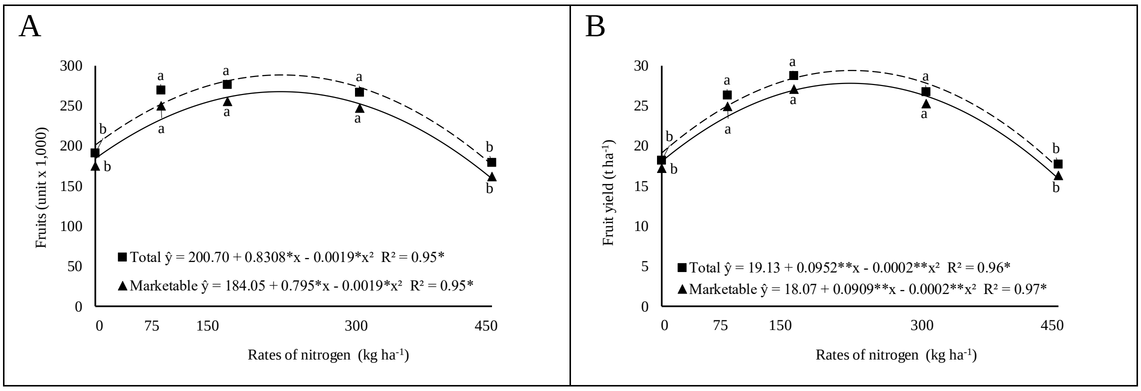

Figure 4. Total and marketable number of fruits (A) and Total and marketable fruit yield (B) of Laser F1 peppers as a function of nitrogen (N) rates in Red-Yellow Argisol. Means with different letters for each variable differ significantly by the Tukey test ($p<0.05$). ** = $p<0.01$. * = $p<0.05$. Oratórios, EPAMIG, 2015.

Nitrogen increased the total fruit yield ($p=0.002$) up to 216 kg/ha of N, reaching a maximum of 29.40 t/ha, while the yield of marketable fruits ($p<0.001$) increased up to 214 kg/ha of N, reaching a maximum of 27.80 t/ha (Figure 4B). Higher yield values could have been achieved if the experiment had not been terminated due to a wind and rain event with 43 mm of precipitation occurring at 159 DAT. Oliveira *et al*. (2015) observed yields of 34.08 and 38.33 t/ha depending on the cultivation system, and a 189-day cycle using the Magali-R bell pepper variety.

The yield obtained in this study exceeded the national average of 22.31 t/ha (Goto *et al*., 2016). A similar result was observed by Paulino (2016) with the Atlantis hybrid grown in open fields, where marketable yield increased up to 125 kg/ha of N, reaching a maximum value of 15.72 t/ha, in Mossoró, Brazil. In protected environment conditions, the growth and development of bell pepper plants are more favored compared to open field cultivation, thus the demand for nitrogen and other nutrients may be higher in this type of cultivation. In various studies conducted in protected cultivation, the rate to achieve maximum yield has varied from 100 to 350 kg/ha of N (Lorenzoni *et al*., 2016; Costa *et al*., 2018; Silva *et al*., 2020). It is observed that the N rate for maximum yield in open field cultivation (Figure 4) falls within the range for protected environment and exceeds the recommendation for Minas Gerais, which is 140 to 180 kg/ha of N (Pinto *et al*., 2019), and for São Paulo, which is 120 to 200 kg/ha of N (Villas Bôas *et al*., 2018). This demonstrates that the productive potential of bell pepper can be better exploited with the application of a higher amount of N.

It is worth noting that variations in soil and climatic conditions, cultivation type, crop cycle, and cultivars can influence yield and fruit number results. Throughout the experiment, maximum temperatures (Tmax) ranged from 18.1 to 30.1°C, up to 30 DAT ranged from 25 to 27°C, from 31 to 100 DAT remained below 25°C, and until 155 DAT, Tmax was close to or above 25°C. Minimum temperatures (Tmin) varied from 8.2 to 19.9°C, until 140 DAT minimum temperatures below 16°C occurred, and subsequently Tmin ranged from 16 to 20°C until 155 DAT (Figure 1). The vegetative growth and fruit formation of bell peppers are favored by daytime temperatures between 25C and 27°C and nighttime temperatures between 16 and 20°C, with a thermal amplitude of 8°C (Pinto *et al*., 2019).

Additionally, the experiment was conducted in the Zona da Mata region of Minas Gerais at an altitude of 450 m. In this region, due to temperature conditions, bell peppers are better adapted to cultivation from August to February (Finger & Silva, 2021). Therefore, lower productivities were expected due to the occurrence of temperatures outside the suitable ranges. However, the maximum yield (27.40 t/ha) was 24.6% higher than the national average of 22.31 t/ha (Goto *et al*., 2016). Thus, bell pepper production in autumn/winter is considered suitable for the Zona da Mata region of Minas Gerais, as it provides higher yields to farmers during this harvest period due to higher prices in the market. Furthermore, it is worth noting that productivities higher than the national average were estimated with rates ranging from 55 to 359 kg/ha of N (Figure 4B).

Nitrogen (N) increased the total number of fruits in the large ($p=0.024$), medium ($p<0.001$), and small ($p=0.043$) classes up to rates of

207, 216, and 117 kg/ha of N, reaching 138,942, 105,392, and 25,831 units, respectively (Figure 5A). With 150 kg/ha of N, the total number of large fruits of 141,142 units was 64.7% higher than the 85,681 units observed with 450 kg/ha of N (Figure 5A). There was no difference in the number of medium-sized fruits between the control without N (64,322 units) and the rate of 450 kg/ha of N (60,502 units) (Figure 5A). With 75 kg/ha of N, the number of small fruits was three times higher than that observed in the control without N; however, it is observed that the increase in N availability resulted in a reduction in the number of small fruits (Figure 5A). The large fruit class represented on average 52.39%, the medium fruit class 38.86%, and the small fruit class 9.08% of the total number of marketable fruits.

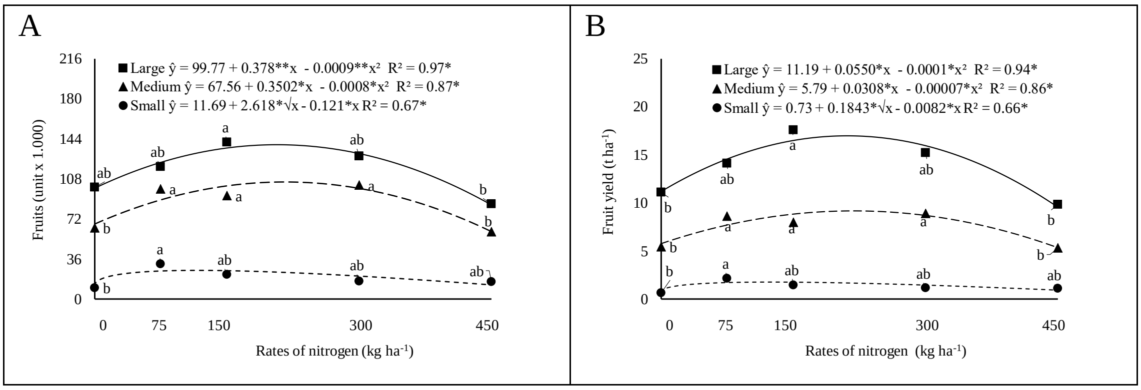

Figure 5. Number of fruits (A) and yield (B) in the Large, Medium and Small classes of Laser F1 peppers as a function of nitrogen (N) rates in Red-Yellow Argisol. Means with different letters for each variable differ significantly by the Tukey test ($p<0.05$). ** = $p<0.01$. * = $p<0.05$. Oratórios, EPAMIG, 2015.

The yield of large fruits ($p=0.014$) increased up to 211 kg/ha of N, reaching a maximum of 17.01 t/ha, and the yield with 150 kg/ha of N was 58.27 and 78.98% higher than the control without N and 450 kg/ha of N, respectively. The yield of medium-sized fruits ($p<0.001$) increased up to 219 kg/ha of N, reaching a maximum of 9.16 t/ha, and there was no difference between the control without N and the rate of 450 kg/ha of N (Figure 5B). Meanwhile, the yield of small fruits ($p=0.050$) increased up to 125 kg/ha of N, reaching a maximum of 1.76 t/ha. With 75 kg/ha of N, the yield was three times higher than that observed in the control without N, and it is observed that the increase in N availability resulted in a reduction in the yield of small fruits (Figure 5B). All characteristics contributing to yield, including number of fruits per plant, fresh fruit weight per plant, and fruit yield per hectare, were found to be higher with the application of 150 kg/ha of N.

The plants that did not receive N (control without N) exhibited the characteristic symptoms of N deficiency, such as yellowing of older leaves and reduced plant growth (Vidigal *et al*., 2019), in addition to showing the lowest values of the SPAD Reading (Figure 6), which indicates the nitrogen nutritional status in various plants (Vidigal *et al*., 2018, 2021). In the case of plants that received an excess of N (450 kg/ha of N), the supernormal vegetative growth, coupled with a delay in the onset of the reproductive stage, resulted in a lower number and size of fruits (Figures 3 and 5), indicating symptoms of excessive N (Vidigal *et al*., 2019).

The SPAD Reading (green color intensity) increased with the increment of N rates in all three evaluation periods (Figure 6). The lowest values were observed at 35 DAT with the maximum estimated value of 53.5 at 279 kg/ha, while at 56 DAT it was 67.5 at 311 kg/ha, and at 154 DAT the highest estimated value was 68.0 at 450 kg/ha of N. The critical SPAD Reading values at 35, 56, and 154 DAT were estimated to be 53.2, 66.5, and 61.9, respectively, with the rate of 214 kg/ha of N.

At 35 DAT, after the application of 20% of the N rates, it is possible to observe that with the increase in N availability compared to the N-deprived control, the plants showed an increase in green color intensity, a consequence of a higher amount of N in the leaves. The same was observed at 56 DAT, after the application of 40% of the N rates, and at the end of the cycle at 154 DAT. The increase in the SPAD Reading indirectly indicates the increase in chlorophyll content, which reflects the N status of the plant (Padilla *et al*., 2018). At 40 DAT, Sediyama *et al*. (2014) observed a linear response of the SPAD Reading to N availability for the Amanda pepper cv., with values ranging from 51.4 to 55.4 with a correlation of r = 0.8394 ($p<0.05$) with the N content in the evaluated leaves, while for the Rubia cv., a mean value of 56.3 was observed. Carvalho *et al*. (2013) noted an increase in the SPAD reading with the increment of N rates in the All Big pepper cv., with the maximum estimated value of 68.8 SPAD units with the rate of 221 mg/dm^3 of N (221 kg/ha), at 80 DAT. Costa *et al*. (2018), working with the All Big, Yolo Wonder, and Red Samurai-Sais cultivars, observed that plants with an SPAD reading of 58.5 during the flowering phase obtained the maximum fruit yield and concluded that the SPAD reading evaluated during the reproductive phase can be used in forecasting pepper production.

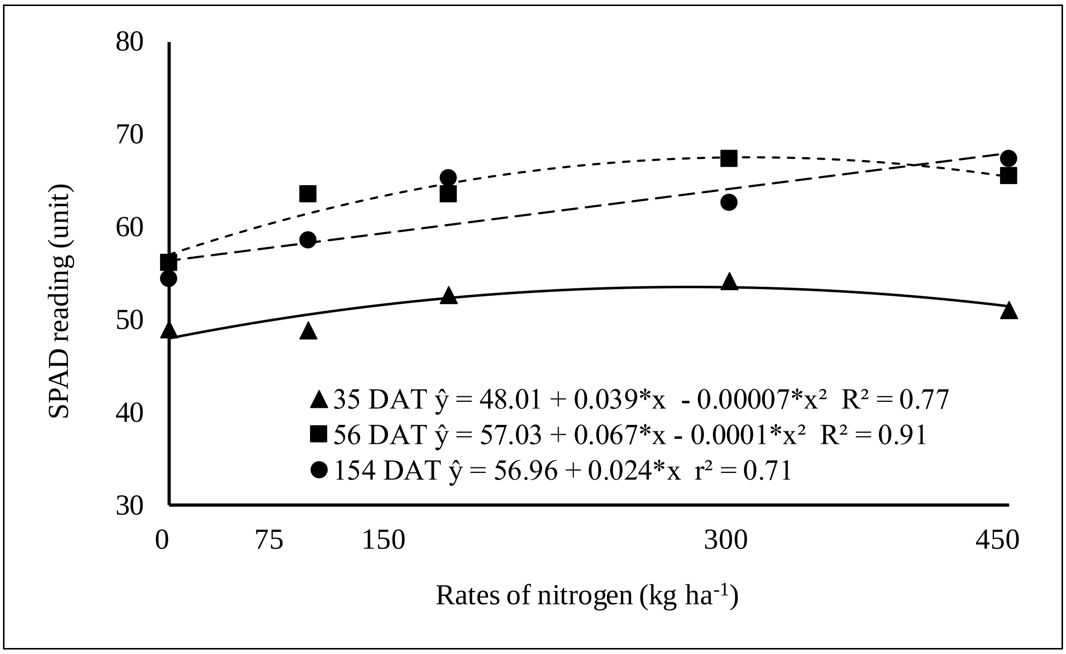

Figure 6. SPAD reading of Laser F1 bell pepper leaves at 35, 56 and 154 days after transplanting (DAT) as a function of nitrogen (N) rates in Red-Yellow Argisol. * = $p<0.05$. Oratórios, EPAMIG, 2015.

The increase in the SPAD Reading due to nitrogen fertilization shows the relationship between N and the green color intensity of the plant, with higher chlorophyll synthesis and greater photosynthetic activity, resulting in increased production (Taiz *et al*., 2021). Moreover, the SPAD chlorophyll meter has the ability to detect the onset of N deficiency before it is visible to the human eye and early enough to correct this deficiency without reducing yield (Samborski *et al*., 2009), provided that there is no unwanted interruption of the cycle and other factors do not become limiting.

The applied nitrogen increased the amount of chlorophyll (estimated by the SPAD Reading) in the leaves, which directly reflects on the photosynthetic rate and production of photoassimilates and other structural compounds, such as amino acids, carbohydrates, and fats (Prado, 2021), resulting in a greater mass of reproductive organs, such as fruits, which are the commercialized part of the pepper.

However, variations in SPAD readings can occur due to various factors, besides nutrient deficiency, such as environmental conditions, variety, and growth stage of the crop. Thus, models need to be adjusted for each situation. The SPAD reading has shown a positive correlation with pepper yield (Felisberto *et al*., 2016) and for various species (Milagres *et al*., 2018; Vidigal *et al*., 2018, 2021) and has been used in forecasting production, however, under the conditions of this study, there was no significant positive correlation of SPAD readings with pepper yield.

The results allow us to conclude that bell peppers grown during the autumn/winter period showed high productive potential associated with nitrogen rates higher than currently recommended. The yield of marketable fruits increases until 214 kg/ha N, and that the critical level for the SPAD reading varied with the age of the plants, with estimated critical values at 154 DAT.

ACKNOWLEDGEMENTS

To the Research Support Foundation of Minas Gerais State (FAPEMIG) for the financial support to the project.

REFERENCES

ALBUQUERQUE, FS; SILVA, EFF; BEZERRA NETO, E; SOUZA, ERA; SANTOS, NA. 2012. Nutrientes minerais em pimentão fertirrigado sob lâminas de irrigação e doses de potássio. *Horticultura Brasileira* 30: 681-687.

CARVALHO, K; KOETZ, M; SILVA, TJ; CABRAL, CE; NUNES, JÂ. 2013. Adubação nitrogenada na cultura do pimentão em ambiente protegido. *Enciclopédia Biosfera* 9: 49-58.

CHARLO, HCO; OLIVEIRA, SF; VARGAS, PF; CASTOLDI, R; BARBOSA, JC; BRAZ, LT. 2012. Accumulation of nutrients in sweet peppers cultivated in coconut fiber. *Horticultura Brasileira* 30: 125-131.

COSTA, FS; LIMA, AS; MAGALHÃES, ID; CHAVES, LHG; GUERRA, C. 2018. Fruit production and SPAD index of pepper (*Capsicum annuum* L.) under nitrogen fertilizer doses. *Australian Journal of Crop Science* 12: 11-15.

CRUZ, CD. 2016. Genes Software-extended and integrated with the R, Matlab and

Selegen. *Acta Scientiarum. Agronomy* 38: 547-552.

FELISBERTO, PAC; GODOY, LJG; FELISBERTO, G. 2016. Índices de cor da folha para monitoramento nutricional de nitrogênio em plantas de pimentão. *Científica* 44: 207-216.

FINGER, FL; SILVA, DJH. 2021. Cultura do pimentão e pimentas. In: FONTES, PCR; NICK, C (eds). *Olericultura: teoria e prática*. 2nd ed. Universidade Federal de Viçosa Brasil: 567-574.

FONTES, PCR; DIAS, EM; GRAÇA, RN. 2005. Acúmulo de nutrientes e método para estimar doses de nitrogênio e de potássio na fertirrigação do pimentão. *Horticultura Brasileira* 23: 275-280.

GOTO, R; CUNHA, A; SANDRI, MA; ONO, EO. 2016. Exigências climáticas e ecofisiologia. In: NICK, C; BORÉM, A (org). *Pimentão: do plantio à colheita*. Viçosa, Brasil: UFV, p.17-33.

KIRKBY, E; NIKOLIC, M; WHITE, PJ; XU, G. 2022. Mineral nutrition, yield and source-sink relationships. In: RENGEL, Z; CAKMAK, I; WHITE, PJ (eds). 2022. *Marschner's mineral nutrition of plants*. Academic Press p.131-200.

LORENZONI, MZ; REZENDE, R; SOUZA, AHC; SERON, CDC; HACHMANN, TL. 2016. Response of bell pepper crop fertigated with nitrogen and potassium doses in protected environment. *Agrotechnology* 5: 1-5.

MILAGRES, CC; FONTES, PCR; SILVEIRA, MV; MOREIRA, MA; LOPES, IPC. 2018. Índices de nitrogênio e modelo para prognosticar a produção de tubérculos de batata. *Revista Ceres* 65: 261-270.

OLIVEIRA, AD; CARVALHO, DF; PEREIRA, JBA; PEREIRA, VDC. 2015. Crescimento e produtividade do pimentão em dois sistemas de cultivo. *Revista Caatinga* 28: 78-89.

PADILLA, FM; SOUZA, R; PEÑA-FLEITAS, MT; CARMEN GIMÉNEZ, MG; THOMPSON, RB. 2018. Different responses of various chlorophyll meters to increasing nitrogen supply in sweet pepper. *Frontiers in Plant Science* 9: 1752.

PAULINO, RDC. 2016. Acúmulo de matéria seca e de nutrientes em pimentão adubado com doses de nitrogênio e fósforo. UFERSA, Mossoró, Brasil. 52p. Available at https://repositorio.ufersa.edu.br/server/api/core/bitstreams/b6865698-0aa6-48be-b597-74507c85415e/content, Accessed February 2, 2023.

PINTO, CMF; VIDIGAL, SM; MOREIRA, GR; CALIMAN, FRB; VENZON, M; PICANÇO, MC; NEVES, WS. 2019. Pimentão (*Capsicum annuum* L.). In: PAULA JUNIOR, TJ; VENZON, M (coords). *101 Culturas: manual de tecnologias agrícolas*. EPAMIG Belo Horizonte, Brasil:748-757.

PRADO, RM. 2021. Mineral nutrition of tropical plants. Austria, Springer Cham. 339p.

SAMBORSKI, SM; TREMBLAY, N; FALLONE, E. 2009. Strategies to make use of plant sensors-based diagnostic information for nitrogen recommendations. *Agronomy Journal* 101: 800-816.

SEDIYAMA, MAN; SANTOS, MRD; VIDIGAL, SM; PINTO, CLDO; JACOB, LL. 2014. Nutrição e produtividade de plantas de pimentão colorido, adubadas com biofertilizante de suíno. *Revista Brasileira de Engenharia Agrícola e Ambiental* 18: 588-594.

SILVA, JM; FONTES, PCR; MILAGRES, CDC; ABREU, JAA. 2020. Yield and nitrogen use efficiency of bell pepper grown in SLAB fertigated with different nitrogen rates. *Journal of Plant Nutrition* 43: 2833-2843.

TAIZ, L; ZEIGER, E; MOLLER, IM; MURPHY, A. 2021. *Fundamentos de fisiologia vegetal*. Artmed, Editora Ltda. Porto Alegre, Brasil: 584p.

VIDIGAL, SM; CECÍLIO FILHO, AB; CORTEZ, JWM; PEREIRA, PRG. 2019. Diagnóstico visual na avaliação do estado nutricional das hortaliças. *Informe Agropecuário* 40: 41-54.

VIDIGAL, SM; LOPES, IPC; PUIATTI, M; RIBEIRO, MRF; SEDIYAMA, MAN. 2018. SPAD index in the diagnosis of nitrogen status in cauliflower as a function of nitrogen fertilization. *Científica* 46: 307-314.

VIDIGAL, SM; MOREIRA, MA; PAES, JM; PEDROSA, MW. 2023. Does high onion plant density increase nitrogen demand? *Revista Caatinga* 36: 381-389.

VIDIGAL, SM; PUIATTI, M; LOPES, IPC; SEDIYAMA, MAN. 2021. Nitrogen content, SPAD index and production of single head broccoli. *Horticultura Brasileira* 39: 52-57.

VILLAS BÔAS, RL; TRANI, PE; MELO, AMT; LEITE, D; KARIYA, EA. 2018. Pimentão e pimenta-hortícola. In: TRANI, PE; RAIJ, B; CANTARELLA, H; FIGUEIREDO, GJB. *Hortaliças: Recomendações de calagem e adubação para o estado de São Paulo*. Coordenadoria de Assistência Técnica Integral (CATI), São Paulo, Brasil: 66-69.

Author's ORCID:

Sanzio Mollica Vidigal – ORCID: 0000-0003-2895-0203
Marialva Alvarenga Moreira – ORCID: 0000-0003-4697-5594