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Lettuce production in a greenhouse under fertigation with nitrogen and potassium silicate

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ABSTRACT. The objective of this study was to evaluate the effect of nitrogen and potassium silicate on the production and commercial aspects of curly lettuce, Vera cultivar. The experimental design was completely randomized (CRD), with ten treatments and three replications. The treatments, arranged in a factorial design according to the Plan Puebla III matrix (Turrent & Laird, 1975), consisted of the combination of five doses of nitrogen (9; 54; 90; 126, and 171 kg ha^{-1}) and five doses of potassium silicate (1.15; 6.90; 11.50; 16.10, and 21.85 kg ha^{-1}). A control treatment without application of nitrogen and potassium silicate was also inserted. The crop was grown in a greenhouse, and the doses were applied as sidedressing using a drip micro-irrigation system. Total fresh matter, commercial fresh matter, non-commercial fresh matter, number of leaves and commercial trade index were evaluated. The commercial fresh matter and the number of commercial leaves per plant were affected only by nitrogen fertigation and increased linearly with an increase in the dose of nitrogen, with the best responses observed at the highest dose of this element (171 kg ha^{-1}). Potassium silicate only had an effect on non-commercial fresh matter, with no influence on the other characteristics.

Keywords: *Lactuca sativa* L., protected cultivation, micro drip irrigation, silicon.

Produção de alface em ambiente protegido sob fertirrigação com nitrogênio e silicato de potássio

RESUMO. Objetivou-se com este trabalho avaliar o efeito de doses de nitrogênio e silicato e potássio sobre o aspecto produtivo e comercial de alface crespa, cultivar Vera. O delineamento experimental utilizado foi inteiramente ao acaso (DIC), com dez tratamentos e três repetições. Os tratamentos, dispostos em esquema fatorial conforme a matriz Plan Puebla III (Turrent & Laird, 1975), consistiram da combinação de cinco doses de nitrogênio (9; 54; 90; 126 e 171 kg ha^{-1}) e cinco doses de silicato de potássio (1,15; 6,90; 11,50; 16,10 e 21,85 kg ha^{-1}). Também foi inserido um tratamento testemunha, sem aplicação de nitrogênio e silicato de potássio. A cultura foi conduzida em ambiente protegido e as doses foram aplicadas em cobertura, via fertirrigação utilizando-se sistema de microirrigação por gotejamento. Foi avaliada a massa fresca total, massa fresca comercial, massa fresca não comercial, número de folhas comerciais e índice comercial. A massa fresca comercial e o número de folhas comerciais por planta foram influenciados apenas pela fertirrigação nitrogenada e aumentaram linearmente com o incremento na dose de N, sendo suas melhores respostas observadas com a máxima dose deste elemento (171 kg ha^{-1}). O silicato de potássio teve efeito apenas na massa fresca não comercial, não influenciando nas demais características.

Palavras-chave: *Lactuca sativa* L., cultivo protegido, microirrigação por gotejamento, silício.

Introduction

Lettuce (*Lactuca sativa* L.) is a herbaceous plant that belongs to the Asteraceaes family. It is the foremost leafy vegetable consumed in Brazil and around the world, standing out for being a good source of vitamins and minerals (Stagnari, Galiene, & Pisante, 2015). In addition to the nutritional aspect, it is a crop of great importance from a socio-economic point of view, being a source of income for farmers.

Some factors are of fundamental importance in vegetable production for the proper development and growth of the crop. Plant nutrition is one of the most important factors and has a direct impact on the production and quality of vegetables. Fertigation in vegetable production is a tool that enables plants to be provided with the amount of nutrients demanded in each phenological stage, resulting in greater efficiency and economy in the use of fertilizers (Frizzone, Freitas, Rezende, & Faria, 2012).

According to Kano et al. (2010), potassium and nitrogen are the nutrients most accumulated by shoots in conventional vegetable farming systems. The importance of the functions these nutrients perform in plants has been recognized, such as in the formation of cellular components (Taiz & Zeiger, 2013) and in the regulation of osmotic potential and enzymatic activation (Stagnari et al., 2015).

While silicon is characterized as being a beneficial element for plants, it is not considered essential. This element has a direct influence on the intensification of photosynthesis and resistance to fungal and bacterial diseases, insects, drought, low temperatures and salinity (Epstein & Bloom, 2006). The use of silicon in lettuce production can promote greater physical performance and better quality (fewer senescent, insect damaged or diseased leaves) because of the positive effects of Si, Ca, Mg, and K absorption (Ferreira et al., 2010).

The adequate supply of nutrients to lettuce plants is a practice that needs to be researched to determine the best way to manage crop nutrition. In this context, given that potassium and nitrogen supply is important for lettuce, and considering the possible benefits that fertilization with silicon can offer to its culture, this study aimed to evaluate the effects of varying doses of nitrogen and potassium silicate when applied by fertigation on curly lettuce plants, cultivar Vera.

Material and methods

The experiment was conducted in a protected environment, at the Irrigation Technical Center (CTI) of the State University of Maringá (UEM) in the city of Maringá – Paraná State (23°23'56,50"S, 51°57'7,53"W). The experimental period took place between April 5, 2013 and June 18, 2013. The crop was installed in a protected environment, with an arch-type cover, measuring 30 m long, 6.9 m wide and 3.5 m in height. The regional climate is characterized as Cfa, subtropical, according to the classification of Koppen.

The soil where the experiment was installed is from the Dystroferric Red Nitosol class with clay texture (Empresa Brasileira de Pesquisa Agropecuária [EMBRAPA], 2013). For determining the chemical characterization of the soil, a sample was collected at the depth of 0.10 m, and the following results were obtained: pH ($CaCl_2$) = 7.00; pH (H_2O) = 7.80; organic matter and C = 26.43 and 15.33 g dm^{-3}, respectively; P = 105.19 mg dm^{-3}; K^+ = 0.31 $cmol_c$ dm^{-3}; Ca^{+2} = 6.20 $cmol_c$ dm^{-3}; Mg^{+2} = 1.45 $cmol_c$ dm^{-3}; Al^{+3} = 0.0 $cmol_c$ dm^{-3}; H^++Al^{+3} = 2.19 $cmol_c$ dm^{-3}; sum of bases = 7.95 $cmol_c$ dm^{-3}; CTC 10.14 $cmol_c$ dm^{-3}; base saturation = 78.41%; and S = 10.23 mg dm^{-3}.

The experimental design was completely randomized (CRD), with ten treatments and three replications. The treatments were arranged in a factorial design according to the Plan Puebla III matrix (Turrent & Laird, 1975) and consisted of the combination of five doses of nitrogen (9, 54, 90, 126 and 171 kg ha^{-1}) and five doses of potassium silicate (1.15, 6.90, 11.50, 16.10 and 21.85 kg ha^{-1}). A control treatment without the application of nitrogen and potassium silicate was also inserted.

Urea (45% N) was used as the nitrogen source (N) and Fertisilício® was used as the potassium silicate source. This product is classified as a leaf fertilizer, potassium silicate based, and contains 12% water-soluble Si (165.6 g L^{-1}) and 12% water-soluble K_2O (165.6 g L^{-1}). The application of nitrogen via irrigation water was carried out through a pre-prepared urea solution at 10% N (m v^{-1}). The doses of nutrients were divided into four applications during the cycle, using a spray volume of 15 L.

The preparation of the beds was carried out by soil tillage with rotary hoe. Subsequently, 0.5 kg of poultry waste and 40 kg ha^{-1} (urea, 45% N) per square meter were applied and incorporated into the soil.

Seedlings of curly lettuce (Cultivar Vera) were produced in polystyrene trays of 128 cells containing a commercial substrate. The seedlings were kept in a greenhouse until the time of transplanting, when they had four leaves. The plants were placed in plots with the spacing of 0.20 x 0.20 m between each seedling. Thirty-six plants, distributed in three rows of 12 plants, were allocated in each plot.

Irrigation was carried out by micro-irrigation through a drip system. The system was composed of a 0.5 hp centrifugal pump; a 500 L tank; a 32 mm diameter PVC main line; five 32 mm diameter PVC branch lines; a 32 mm diameter PVC main return line; six valves in each branch line; and two side lines for each plot, each consisting of 16 mm diameter polyethylene driplines and 12 pressure compensating emitters on each sideline.

The operating pressure used for the drip irrigation and fertigation was 10 m.w.c., with an average flow value of 0.84 L h^{-1} for each emitter and a CUC (Christiansen uniformity coefficient) of 95.47%. The irrigation was monitored using tensiometers installed at the depth of 0.10 m, and the value used as a reference was 15 kPa (Vilas Boas et al., 2007).

Evaluations were carried out on the eight central plants of each plot. Total fresh matter (MFT), commercial fresh matter (MFC), non-commercial fresh matter of shoots (MFNC), number of commercial leaves (NFC) and commercial trade index (IC) were evaluated.

The commercial fresh matter was determined, after obtaining the total fresh weight, by removing senescent and/or damaged leaves not suitable for trade from the outer region of the plant. To determine the NFC, the leaves suitable for trade and consumption were counted. The IC was determined by the ratio between the MFC and MFT (Santos, Mendonça, Silva, Espínola, & Souza, 2011).

After being tabulated, data were submitted to analysis of variance using the statistical program SISVAR (Ferreira, 2011). Then, multiple linear regression analyses were performed, selecting statistical models based on the F-test for the regression ($p < 0.05$), F-test for lack of adjustment ($p > 0.05$), *t*-test for regression coefficients ($p < 0.05$) and the adjusted determination coefficient (R^2_{aj}). In the selection of statistical models, twelve possible linear models were studied, one being considered complete, that is: $\hat{Y}=\beta_0+\beta_1(N)+\beta_2(Si \text{ and } K_2O)+\beta_3(N)^2+\beta_4(Si \text{ and } K_2O)^2+\beta_5(N)(Si \text{ and } K_2O)$, where $\hat{Y}$ is the estimated value of the characteristic in question; β_0, β_1, β_2, β_3, β_4, β_5 are regression coefficients; N is the dose of N (kg ha^{-1}); and Si and K_2O is the dose of Si and K_2O (kg ha^{-1}).

Results and discussion

The results of the descriptive statistics for total fresh matter of shoots, commercial fresh matter of shoots, non-commercial fresh matter of shoots, number of commercial leaves per plant and commercial trade index are shown in Table 1.

The fertilization with nitrogen had effects on total fresh matter, commercial fresh matter, non-commercial fresh matter and number of commercial leaves. An effect of potassium silicate was observed only in non-commercial fresh matter.

The results of the regression analysis for the total fresh matter and commercial fresh matter were similar. In these cases, there was a positive linear correlation of these characteristics due to the increase in nitrogen levels (Figures 1 and 2).

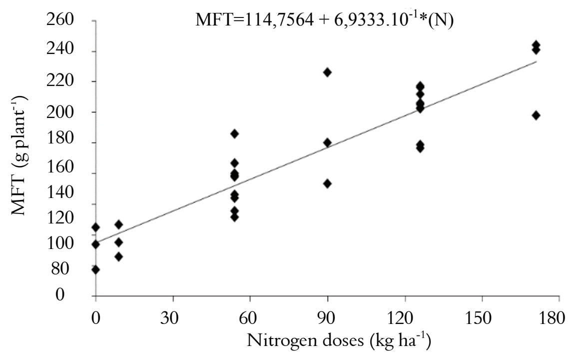

Figure 1. Total fresh matter (MFT) of curly lettuce, Vera cultivar, according to the nitrogen doses. *Significant by t-test ($p < 0.05$); [a] adjusted determination coefficient.

For total fresh matter, an increase of 25 kg ha^{-1} in the nitrogen dose was responsible for the addition of 17.33 g per plant, and the highest result (233.32 g per plant) was obtained with the maximum nitrogen dose (171 kg ha^{-1}) (Figure 1).

According to Taiz and Zeiger (2013), nitrogen participates in the formation of many cell components, including aminoacids and nucleic acids. An increase in vegetative growth, expansion of the photosynthetically active area and higher yield potential are possible results of a situation where there is an adequate supply of nitrogen (Filgueira, 2008).

Studying the application of four nitrogen sidedressing fertilization doses (0, 60, 120, and 180 kg ha^{-1}) and five doses of molybdenum via leaf fertilization (0, 35.1, 70.2, 105.3, and 140.4 g ha^{-1}) on lettuce, Raider cultivar, Resende, Alvarenga, Yuri, and Souza (2012) found that in the absence of molybdenum, the largest commercial fresh matter occurred at the dose of 66.4 kg ha^{-1} of nitrogen. In the present study, similar results were found; a productive benefit of lettuce was verified with nitrogen fertilization.

Table 1. Descriptive statstics for the characteristics total fresh matter (MFT), commercial fresh matter (MFC), non-commercial fresh matter (MFNC), number of commercial leaves (NFC) and commercial trade index (IC) of Vera lettuce.

Statistic	Characteristics				
	MFT (g)	MFC (g)	MFNC (g)	NFC	IC
Minimum	97.15	94.29	2.65	13.00	0.90
Maximum	243.84	235.83	19.71	21.63	0.98
Standard deviation	41.43	39.57	4.23	2.01	0.02
General average	170.92	161.12	9.79	16.68	0.94
C.V. 1 (%)	24.24	24.56	43.19	12.05	2.39
C.V. 2 (%)*	11.75	13.18	35.52	8.53	2.40

* Variation coefficient of the experiment, in which s = (QMR) $^{(1/2)}$, "s" is the standard deviation and "QMR" is the residual mean square.

In the present study, the productive aspect of lettuce was favored by nitrogen application, and the maximum production (219.66 g per plant) was verified at the highest dose (171 kg ha^{-1}). In a study by Silva, Pereira, Reis, Lima, & Taveira (2008) with four water depths (91.99, 142.79, 186.34, and 237.14 mm), combined with four doses of nitrogen (0, 80, 160, and 320 kg ha^{-1}), in lettuce, cultivar Raider, and grown under greenhouse conditions, it was observed that the estimated maximum productivity occurred with 208.03 mm and 290.5 kg ha^{-1} of nitrogen.

In a study that evaluated nitrogen doses (0, 141.5, 283, 566, and 1,132 mg per pot) and lettuce cultivars (Lucy Brown, Tainá, Vera, Verônica and Elisa), Mantovani, Ferreira, and Cruz (2005) observed that the maximum production of lettuce, cultivar Vera, was obtained with the application of 770 mg of nitrogen per pot, which corresponds, according to the authors, to approximately 163 kg ha^{-1} of nitrogen.

The commercial fresh matter was increased by 16.26 g per plant with an increase of 25 kg ha^{-1} in the nitrogen dose, and the best response (219.66 g per plant) occurred with the highest nitrogen dose, which was 171 kg per ha (Figure 2).

There was significant influence of nitrogen and potassium silicate application via fertigation on non-commercial fresh matter, which increased in a linear manner according to the increase in nitrogen (Figure 3) and potassium silicate doses (Figure 4). The maximum non-commercial fresh matter (13.65 g per plant) was observed at the highest dose of nitrogen (171 kg ha^{-1}).

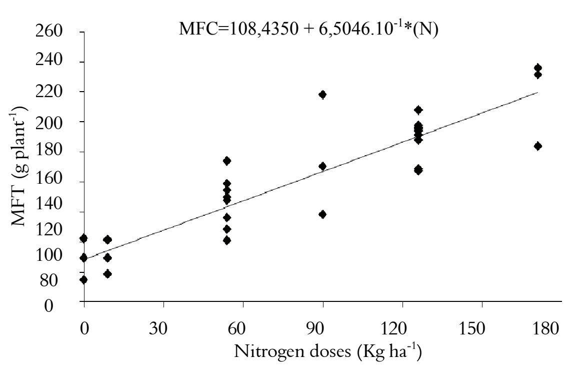

Figure 2. Commercial fresh matter (MFC) of curly lettuce, Vera cultivar, in relation to nitrogen doses. *Significant by t-test ($p < 0.05$); [a] adjusted determination coefficient.

In regards to the potassium silicate doses, a similar behavior was verified. The maximum non-commercial fresh matter (13.19 g per plant) was observed at the maximum dose of potassium silicate (21.85 kg ha^{-1}) (Figure 4).

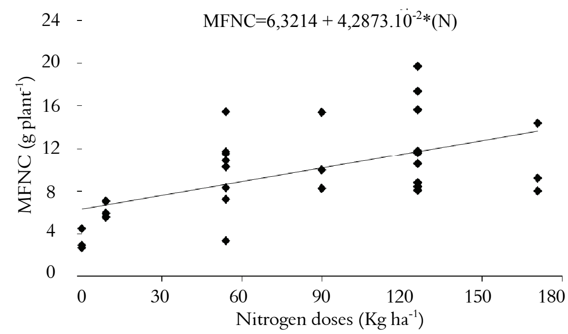

Figure 3. Non-commercial fresh matter (MFNC) of curly lettuce, Vera cultivar, in relation to nitrogen doses. *Significant by t-test ($p < 0.05$); [a] adjusted determination coefficient.

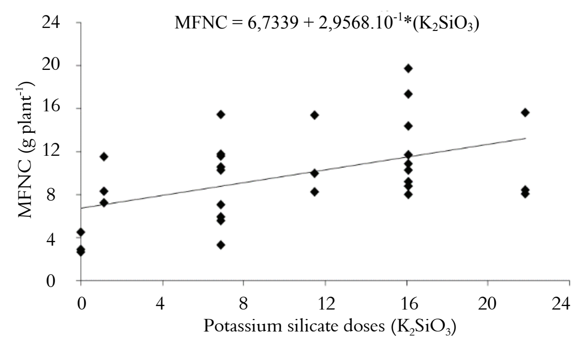

Figure 4. Non-commercial fresh matter (MFNC) of curly lettuce, Vera cultivar, in relation to potassium silicate doses (K_2SiO_3). *Significant by t-test ($p < 0.05$); [a] adjusted determination coefficient.

It is likely that the increase in the non-commercial fresh matter of shoots, which occurred due to the increase in both nitrogen and potassium silicate doses, followed the increase in the total fresh matter of shoots as a function of the increase in the doses of N. Still, there was no loss to the commercial quality of lettuce, as there were benefits to the commercial fresh matter and number of commercial leaves per plant characteristics as the dose of N was increased. The absence of fertigation effects with nitrogen and with potassium silicate on the commercial trade index also corroborates this finding.

Koetz, Coelho, Costa, Lima, and Souza (2006), in evaluating different irrigation frequencies associated with doses of potassium chloride (100, 150, 200, and 250 kg ha^{-1}) applied via fertigation on lettuce (Raider cultivar) in a greenhouse, observed that the maximum yield was obtained with the dose of 119.36 kg ha^{-1} of K_2O. This effect of the potassium doses was not observed in the present experiment.

With the supply of silicon and potassium to lettuce, the present study aimed to evaluate its effect on the reduction of non-commercial fresh matter of shoots (senescent or damaged leaves) and increase in the commercial trade index. However, an increase in non-commercial fresh matter of shoots and the absence of fertigation effects with potassium silicate on the commercial trade index were observed. Thus, with regard to the result obtained for non-commercial fresh matter in the present study, there was disagreement with the result obtained by Ferreira et al. (2010), where an evaluation of the application of increasing doses of calcium silicate on three lettuce cultivars (Raider, Regina and Vera) concluded that with an increase in calcium silicate doses, there was a reduction in fresh matter percentage of senescent and diseased leaves.

Only nitrogen fertigation significantly influenced the number of commercial leaves per plant, which correlated linearly with the increase in N doses (Figure 5). There was an increase of 0.72 in the number of commercial leaves per plant, conditioned by an increase of 25 kg ha^{-1} in the dose of nitrogen; in this case, the highest value (19.27 leaves per plant) was obtained with the maximum dose of N (171 kg ha^{-1}).

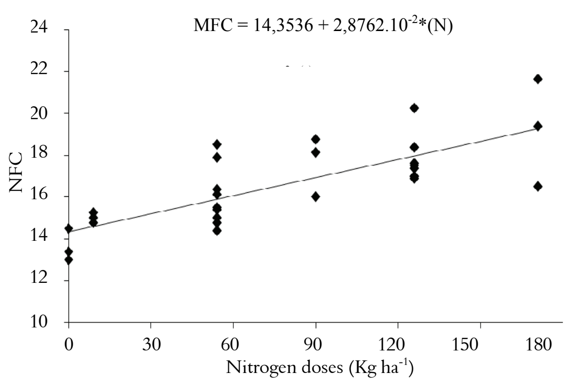

Figure 5. Number of commercial leaves (NFC) of curly lettuce, Vera cultivar, in relation to nitrogen doses. *Significant by t-test ($p < 0.05$); [(a)] adjusted determination coefficient.

There was no significant influence of nitrogen fertigation and potassium silicate fertigation on the commercial trade index, considering that the regression analysis selected no statistical model for this response variable, and its overall average was 0.94, as shown in Table 1.

Santos et al. (2011) studied eight lettuce cultivars and found no significant difference between cultivars, with regard to the commercial index, and obtained an average of 0.70. This value was numerically lower than the overall average for commercial trade index found in the present study, which was 0.94. It is probable that the value of 0.94, as shown in this study, is related to a good commercial quality lettuce due to the use of a protected environment and drip micro irrigation. With the use of these techniques, there is the possibility, for example, that less water accumulates on the leaves of the plants, resulting in a reduced proliferation of diseases or injuries.

Conclusion

Nitrogen had a positive effect on the production variables of lettuce.

The highest total fresh matter, commercial fresh matter and number of commercial leaves per plant were obtained at the dose of 171 kg N ha^{-1}.

There was no effect of potassium silicate on the productive characteristics of lettuce plants, except for non-commercial fresh matter.

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