Comunicata Scientiae
Horticultural Journal

ORIGINAL ARTICLE
published: 19 June 2023
https://doi.org/10.14295/CS.v14.3931

Influence of different doses and sources of potassium fertilizer on zucchini squash production

André Luís Leite de Souza[1], Ademar Pereira de Oliveira[1], Luiz Daniel Rodrigues da Silva[1], Izaias Romario Soares do Nascimento[1]*, José Manoel Ferreira de Lima Cruz[2], Edileide Natália da Silva Rodrigues[1], Gemerson Machado de Oliveira[1]

[1]Federal University of Paraíba, Areia, Brazil
[2]Federal University of Lavras, Lavras, Brazil
*Corresponding author, e-mail: izaias.agronomia@gmail.com

Abstract

Potassium is an essential nutrient for the physiological and biochemical activities of a plant. Therefore, an adequate dose and source of this nutrient can increase zucchini squash production. This study aimed to evaluate the yield response of the zucchini squash cultivar 'Caserta' to different doses and sources of potassium. The experiment was conducted under field conditions in a completely randomized block experimental design in a 6 × 2 factorial scheme, with six K_2O doses (0, 50, 100, 150, 200, and 250 kg ha^{-1}) and two sources (potassium chloride and potassium sulfate), with four replicates. Fruit mass, fruit length, number of fruits per plant, and total and marketable fruit yields were evaluated. Fertilization with potassium sulfate and chloride sources increased fruit length and the number of fruits per plant. Potassium (K_2O) fertilization using potassium sulfate resulted in higher mass and total fruit yield. K_2O doses of 108.41 and 130.78 kg ha^{-1} in the potassium chloride and sulfate sources, respectively, provided the maximum marketable yield of fruits, at 22.84 and 27.0 t ha^{-1}, respectively. Doses of 108.41 kg ha^{-1} of potassium chloride and 130.78 kg ha^{-1} of potassium sulfate are recommended for a better commercial yield, with potassium sulfate being the best recommendation.

Keywords: *Cucurbita pepo*, mineral fertilization, production

Introduction

Zucchini squash (*Cucurbita pepo* L.) is a vegetable that belongs to the Cucurbitaceae family. This crop is of high socioeconomic importance owing to its profitability and use for human consumption (Wazir et al., 2019). The worldwide production of this vegetable has increased by 9% in the last five years (2012 to 2017), stabilizing in 2018 at 27 million tons, with China being the top producer (Novas et al., 2019). In Brazil, zucchini squash is among the ten vegetables with the highest economic value, and it is cultivated throughout the country (Fernandes et al., 2016).

Despite the importance of this crop, there is a dearth of information on the sources and doses of fertilizer suitable for different regions and the planting schedules to increase yield and avoid excessive use of fertilizers. This information is important, considering the fact that inadequate fertilization is a crucial factor that negatively affects the growth and productivity of this vegetable (Alves et al., 2019). Therefore, adequate and balanced fertilization is imperative to improve crop production.

Potassium (K) participates in many physiological and biochemical activities in plants, including cation-anion balance, water movement, osmoregulation, and energy transference (Hasanuzzaman et al., 2018; Nada & Metwaly, 2020). In addition, K directly participates in the activation of enzymes to produce proteins and carbohydrates, which determines the qualitative attributes of the fruit (Oosterhuis et al., 2014; Hasanuzzaman et al., 2018). It also increases the number of pistillate flowers, possibly through its hormone-synthesizing enzyme functions, resulting in gibberellins, which in turn increase the number and production of fruits per plant (Abduljabbar & Mohammed, 2010; Ferkry, 2016; Tu et al., 2017).

K deficiency can be overcome through soil or

Received: 23 February 2022
Accepted: 28 April 2022

foliar application of different fertilizers available in the market. However, the choice must be based on the availability and resources for acquisition, management, and crop requirements. Potassium chloride (KCl) and sulfate (K_2SO_4) are among the main potassium fertilizers, which, owing to the accompanying ions, can cause distinct production responses (El-Mogy et al., 2019). In addition, yield reductions due to fertilization with KCl have been reported, which can be explained by its high salt content which impairs germination and plant growth. Similarly, the leaching of sulfate present in some fertilizers may reduce cationic nutrients, such as calcium, leading to soil acidification (Jung et al., 2011; Taiz et al., 2017). Therefore, information on sources and doses of potassium to improve zucchini yield and soil fertility is essential.

Studies of potassium fertilization for zucchini squash using different sources and doses are still limited. Fernandes et al. (2016) evaluated the effect of potassium fertilization on zucchini squash in Red Yellow Argisol soil and showed that a very high dose of potassium fertilizer (KCl) promoted the maximum fruit yield. Araújo et al. (2015) reported an increase in the potassium content in fruits and leaves when zucchini crops were treated with high doses of KCl. Araújo et al. (2014) studied the physicochemical properties of zucchini fruits in response to side-dressing potassium fertilization (KCl) and observed an increase in the parameters analyzed at different doses.

More studies on the response of zucchini squash to potassium fertilization are needed to improve its performance under different edaphoclimatic conditions. Therefore, this study aimed to evaluate the response of the zucchini squash cultivar 'Caserta' to fertilization with different sources and doses of potassium.

Materials and methods

This study was conducted between November 2018 and January 2019 in the experimental area of the Federal University of Paraíba, Campus II, Areia-Paraíba, located in the micro-region of Brejo Paraibano, at 574.62 m altitude, 6°57'26"S latitude, and 35°45'30"W longitude. According to Köppen's classification, the climate is of the As type, characterized as hot and humid, with an annual precipitation of 1.200 mm, with rains prevailing from March to August (Francisco & Santos, 2017). The meteorological conditions during the experimental period are shown in **Figure 1.**

The soil in the experimental area was classified as Neosol Regolithic, typical Psamitic (Santos et al., 2018), with a sandy loam texture. Before the experiment, soil samples were collected from a depth of 0–20 cm to determine their chemical and physical properties (**Table 1**).

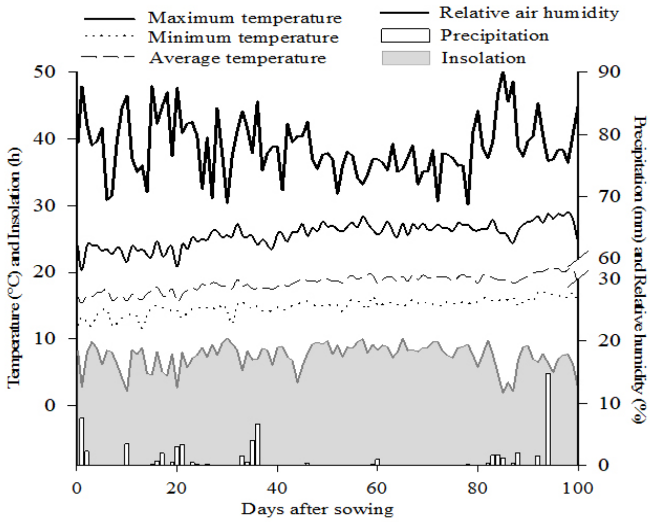

Figure 1. Meteorological data during the experimental period of zucchini squash cultivation under fertilization with different sources and doses of potassium.

Table 1. Soil properties of the experimental area for zucchini cultivation under fertilization with different potassium doses and sources

Chemical properties										
pH	P	K^+	Na^+	H^++Al^{3+}	Al^{3+}	Ca^{2+}	Mg^{2+}	BS	CEC	OM
H_2O (1:2.5)	----mg dm^{-3}----		-------------------------------------cmol$_c$ dm^{-3}--------------------------------------							g kg^{-1}
6.25	38.10	57.23	0.04	1.08	0.00	1.40	0.90	2.44	3.54	12.28

Physical characteristics						
Coarse sand	Fine sand	Silt	Clay	Soil density	Particle density	Total porosity
-------------------------------g kg^{-1}-------------------------------				-----------g cm^{-3}-----------		m^3 m^{-3}
670	123	125	74	1.27	2.62	0.50

A completely randomized block experimental design was used, in a 6 × 2 factorial scheme, with six doses of K_2O (0, 50, 100, 150, 200, and 250 kg ha^{-1}) and two sources (KCl and K_2SO_4), in four replicates. The experimental plot consisted of 20 plants distributed in four rows of five plants, all of which were considered for evaluation.

The soil was prepared by plowing followed by harrowing. Cattle manure was applied to the foundation (15 t ha^{-1}, 5% moisture), along with 150 kg of P_2O_5 and the first of the three K_2O doses, as described in the experimental design. Nitrogen was top-dressed at a dose of 100 kg ha^{-1} of N, with the second of the K_2O doses at 25 days after sowing (DAS). At 40 DAS, the last of the K_2O doses were administered. The sources of P_2O_5 and N were triple superphosphate (46% P_2O_5 and 12% Ca) and urea (45% N), respectively.

The 'Caserta' zucchini cultivar seeds were directly sown by placing three seeds per hole at a 30 × 20 cm spacing. When the seedlings had two permanent leaves (15 DAS), thinning was performed, with one plant per hole. Weeding was manually performed during the experiments. Water was supplied through a drip tape irrigation system, with a flow rate of 2.0 L h^{-1} and a two-day irrigation shift, with an average irrigation depth of 5–8 mm day^{-1}, according to tank evaporation class A and precipitation. Phytosanitary control treatment was not performed because of the absence of critical levels of pests and diseases.

The harvests were collected manually every two days when the fruits were immature and green in color, with no apparent deformations and an average length of 15–20 cm (CEAGESPE, 2017).

Fruit length was measured with a millimeter ruler and the results were expressed in cm. The fruit mass was determined by dividing the plot production by the fruit number and was expressed in grams. The number of marketable fruits per plant was determined by counting the fruits (commercial standard) in each plot and dividing it by the number of plants. The total productivity was the weight of all the fruits harvested from the plot. Marketable yield corresponded to the weight of marketable fruits, with data expressed in tons per hectare (t ha^{-1}).

Data were subjected to analysis of variance, using the F test ($p \leq 0.05$) and polynomial regression analysis, to compare the responses to K_2O sources and doses by testing the linear and quadratic models. The R statistical software (R Core Team, 2022) was used for all analyses, with the packages "Tidyverse" (Wickham et al., 2019) and "GA" (Scrucca, 2013).

Results and discussion

Fertilization with KCl promoted a maximum fruit length of 19.13 cm at a dose of 107.50 kg ha^{-1} (Figure 2), with a reduction in the fruit length at higher doses, possibly because chloride ions disrupt the plant metabolism more than sulfate ions. Chloride (Cl^-) can inhibit gas exchange through indirect long-distance signals, which induce alkalinization of the apoplastic leaf pH, resulting in stomatal closure (Geilfus et al., 2015). It can also reduce the availability of soil N by inhibiting nitrification in the soil, thereby intensifying the leaching of the Ca^{2+} profile as a counterion (Khan et al., 2013). Therefore, high concentrations of Cl^- in the root zone can limit crop yields (Niu & Rodriguez, 2008; Niu et al., 2019).

When K_2SO_4 was used, the maximum fruit length was 19.77 cm at the highest dose (**Figure 2**). The increased response to K_2SO_4 can be attributed to the availability and balanced absorption of potassium and sulfate by plants, as both are essential macronutrients for the metabolic processes of the plant, fruit quality, and synthesis and translocation of essential amino acids (Hasanuzzaman et al., 2018; Kopriva et al., 2019).

Irrespective of the source, the fruit lengths were within the commercial standard for zucchini squash, which is between 7 and 20 cm, demonstrating the beneficial effect of potassium fertilization on this trait. According to Filgueira (2008), potassium is the most extracted macronutrient in most vegetables.

Fertilization with KCl resulted in the production of zucchini squash fruits with mean weights of 662.58 g at an estimated dose of 106.16 kg ha^{-1} of K_2O, and 795.41 g at the maximum dose of K_2SO_4 (**Figure 3**).

The best performance with the K_2SO_4 source was possibly due to the balanced activation by potassium of the enzyme starch synthetase, which is associated with

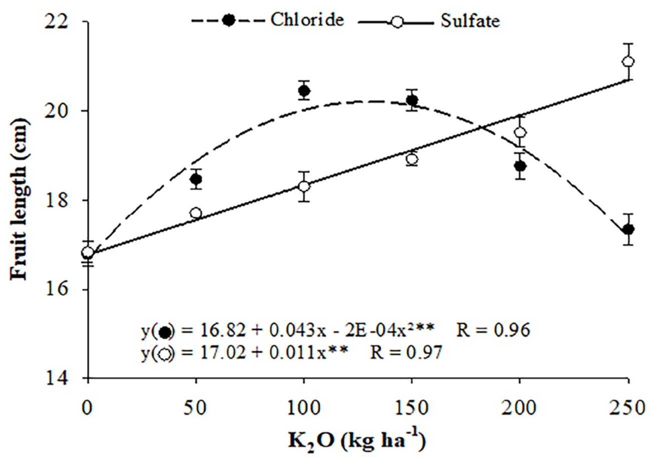

Figure 2. Fruit length of zucchini squash under fertilization with different sources and doses of potassium.

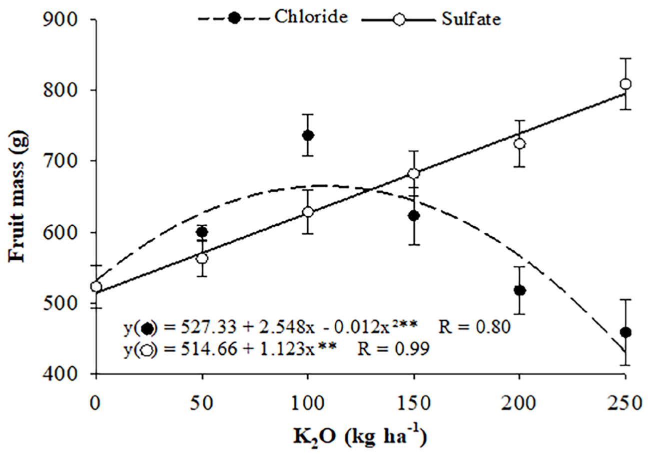

Figure 3. Zucchini squash fruit mass under fertilization with different sources and doses of potassium.

the synthesis of organic compounds containing sulfur, to meet the plant's metabolic demand, initially with the reduction of sulfates in the amino acid cysteine (Taiz et al., 2017; Hasanuzzaman et al., 2018).

Fernandes et al. (2016) evaluated different methods of application of potassium fertilizer in zucchini plants and obtained a fresh weight of 865.03 g, at a dose of 268.77 kg ha^{-1} of K_2O. It is important to highlight that, compared to the present study, the fruit mass responded satisfactorily to potassium fertilization, despite the greater mass. Potassium activates catalytic enzymes that promote the synthesis of carbohydrates, fats, and proteins (Chrysargyris et al., 2017), thereby improving mass accumulation.

K_2SO_4 at a dose of 120.0 kg ha^{-1} of K_2O resulted in a maximum number of marketable fruits per plant of 3.65. When KCl was used at a dose of 108.33 kg ha^{-1}, the maximum number of marketable fruits was 2.86 (**Figure 4**).

These results are considered adequate for this crop, regardless of the potassium source. Potassium fertilizer application elicited a positive response in this trait. Correa et al. (2018), working with zucchini squash, reported an increase in the number of fruits per plant when subjected to a dose of 75 kg ha^{-1} of K_2O. This demonstrates the fundamental role of potassium in crop performance with respect to its effects on various physiological processes, combined with other nutrients available to plants such as calcium and magnesium (Batista et al., 2018).

The reduction in the fruit number at higher doses of K_2O, regardless of the source, was possibly due to nutrient excess, causing soil salinization and imbalance in the absorption of other nutrients, impairing fruit formation (Batista et al., 2018).

KCl fertilization resulted in a maximum total yield of 28.73 t ha^{-1} at a dose of 115.62 kg ha^{-1} of K_2O. In contrast, K_2SO_4 resulted in a total yield of 34.02 t ha^{-1} at the maximum dose of K_2O (**Figure 5A**). The doses of 108.33 and 130.71 kg ha^{-1} of K_2O using KCl and K_2SO_4 sources, respectively, were responsible for the maximum marketable fruit yield of 22.84 and 27.0 t ha^{-1}, respectively (**Figure 5B**).

The response of the zucchini crop to K_2O

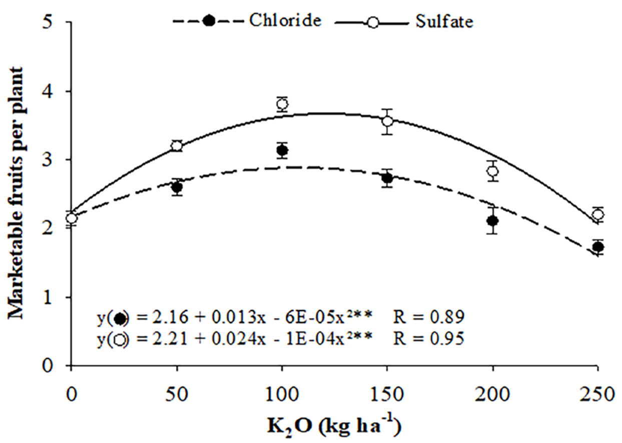

Figure 4. Number of zucchini squash marketable fruits per plant under fertilization with different sources and doses of potassium.

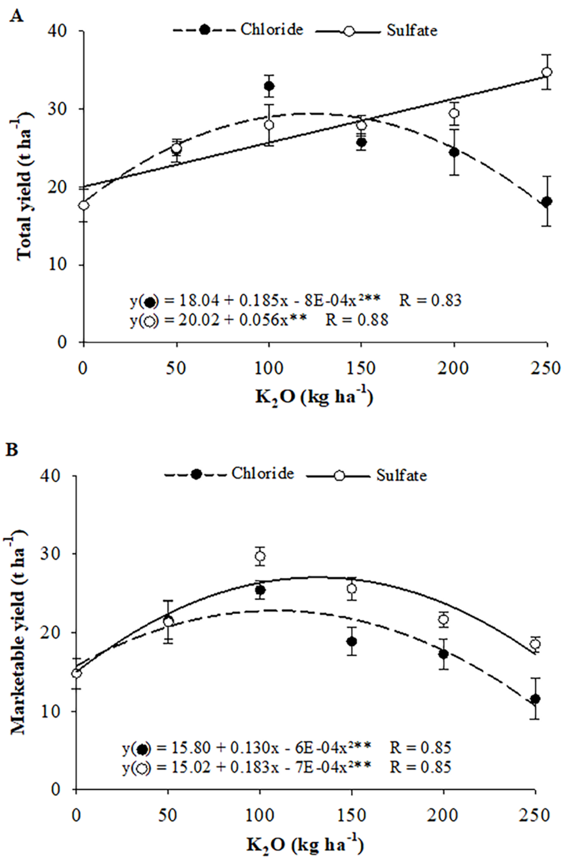

Figure 5. (A) Total and (B) marketable yield of zucchini squash under fertilization with different sources and doses of potassium.

fertilization is possibly related to the significant changes in plant metabolism provided by this nutrient, such as activating enzymes linked to photosynthesis and reserve accumulation (Filgueira, 2008; Oosterhuis et al., 2014; Batista et al., 2018). Correa et. (2018) reported an increase in cucumber yield when an estimated dose of 92.5 kg ha^{-1} K_2O was applied. Fernandes et al. (2016) reported that a dose of 300 kg ha^{-1} of K_2O promoted the highest productivity (36.828 kg ha^{-1}) of zucchini squash, which was higher than that obtained in the present study. This reinforces the need to research the potassium fertilization for this crop under different edaphoclimatic conditions.

The fruit yields obtained in this study were higher than those considered adequate in Brazil, ranging from 10 to 20 t ha^{-1} (Feijó et al., 2008; Batista et al., 2020). This can be attributed to the increase in size and fruit yield promoted by potassium fertilization, and its effects on the redistribution of assimilates between the vegetative and productive parts (Taiz et al., 2017; Mardanluo et al., 2018).

Adequate doses of K_2O favor the formation and translocation of carbohydrates, thereby improving the production of marketable fruits (Filgueira, 2008; Zörb et al., 2014). Therefore, it is likely that during plant growth and development, K_2O doses, regardless of the source, and the nutrients initially present in the soil, were responsible for the maximum marketable yields.

The marketable yield of zucchini squash obtained using K_2SO_4 was 18.21% higher than that obtained using KCl. This may be due to the composition of K_2SO_4, which contains 18% sulfur. The absorption of this nutrient, in the form of sulfate (SO_4^{-2}), promotes the formation of amino acids (cysteine, cysteine, and methionine), which are essential for metabolic processes (Taiz et al., 2017; Kopriva et al., 2015). Moreover, the sulfate may have formed gypsum ($CaSO_4$) in the presence of calcium, improving the soil fertility, which favored the development of the root system and nutrient absorption (Taiz et al., 2017; Zoca & Penn, 2017), ensuring the best productivity.

The reduction in productivity under increasing doses of K_2O was possibly due to the nutritional imbalance in the plants, caused by Cl^- or SO_4^{2-} ions, as these promote soil salinization when in excess, thereby limiting the availability of water and reducing the absorption of cations such as calcium (Ca^{2+}) and magnesium (Mg^{2+}) and thus negatively affecting crop productivity (Machado et al., 2017; Taiz et al., 2017).

Conclusions

Potassium fertilization should be provided to increase the productive traits of the zucchini squash cultivar 'Carseta.' Doses of 108.33 kg ha^{-1} of KCl and 130.71 kg ha^{-1} of K_2SO_4 are recommended for better commercial yield, and K_2SO_4 is recommended as the best fertilizer option.

Acknowledgments

The authors would like to thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the sponsorship granted for this study and the Universidade Federal da Paraíba (UFPB) for their support during the execution of the experiment.

References

Alves, J.D.M., Lima, AS., Suassuna, C.D.F., Figueiredo, F.R., Silva, T.I., Mesquita, E.F., Mesquita, F.D.O 2019. Growth and gas exchange of Cucurbita pepo L. under nitrogen and silicon fertilization. Journal of Agricultural Science 11: 83-90.

Abduljabbar, M.I., Mohammed, G.H. 2010. Effect of foliar application of potassium and IAA on growth and yield of two cultivars of squash (Cucurbita pepo L.). Tikrit Journal for Agricultural Sciences 10: 229-241.

Araújo, H.S., Cardoso, A.I.I., Evangelista, R.M., Takata, W.H.S., Silva, E.G. 2014. Características físico-químicas de frutos de abobrinha-de-moita em função de doses de potássio em cobertura. Revista Colombiana de Ciências Hortícolas 8: 230-241.

Araújo, H.S., Cardoso, A.I.I., Oliveira Júnior, M.X., Magro, F.O. 2015. Teores e extração de macronutrientes em abobrinha-de-moita em função de doses de potássio em cobertura. Revista Brasileira de Ciências Agrárias 10: 389-395.

Batista, M.A., Inoue, T.T., Esper-Neto, M., Muniz, A.S. 2018. Princípios de fertilidade do solo, adubação e nutrição mineral. In: Brandão-Filho, JUT., Freitas, PSL., Berian, LOS., Goto, R. (ed.) Hortaliças-fruto [online]. EDUEM, Paraná, Brazil. p. 113-162.

Batista, C.M., Mota, W.F., Pegoraro, R.F., Gonçalves, R.E.M., Aspiazú, I. 2020. Production of italian zucchini in response to N and P fertilization. Revista Brasileira de Ciências Agrárias 15: 1-6.

CEAGESPE. 2017. Norma de classificação de abobrinha e medidas das hortaliças. Ministério da Agricultura, Pecuária e Abastecimento, São Paulo, Brasil. 29 p.

Chrysargyris, A., Drouza, C., Tzortzakis, N. 2017. Optimization of potassium fertilization/nutrition for growth, physiological development, essential oil composition and antioxidant activity of Lavandula angustifolia Mill. Journal of soil science and plant nutrition 17: 291-306.

Corrêa, C.V., Gouveia, A.M.S., Martins, B.N.M., Lanna, N.B.L., Tavares, A.E.B., Mendonça, V. Z., Jorge, L.G., Cardoso A.I.I., Evangelista, R. M. 2018. Effect of top-dressed potassium fertilization on the yield and quality of cucumber. Journal of Plant Nutrition 41:1345–50

El-Mogy, M.M., Salama, A.M., Mohamed, H.F., Abdelgawad, K.F., Abdeldaym, E.A. 2019. Responding of long green pepper plants to different sources of foliar potassium fertiliser. Agriculture 65: 59-76.

Feijó, S., Storck, L., Lúcio, A.D.C., Lopes, S.J., Garcia, D.C., Carpes, R.H. 2008. Heterogeneity index of zucchini yield on a protected environment and experimental planning. Horticultura Brasileira 26: 35-39.

Fernandes, C.N., Azevedo, B.M.D., Camargo, D.C., Dias, C.N., Rebouças, M.D.O., Costa, F.R. 2016. Potassium fertilizer applied by different methods in the zucchini crop. Revista Brasileira de Engenharia Agrícola e Ambiental 20: 643-648.

Ferkry, W.A 2016. Improving squash (Cucurbita pepo L.) plant growth, sex expression and yield by foliar application of potassium and ethephon under high summer temperature conditions. Journal of Productivity and Development 21: 383-403.

Filgueira, F.A.R. 2008. Novo manual de Olericultura: agrotecnologia moderna na produção e comercialização de hortaliças. UFV, Viçosa, Brasil. 421p.

Francisco, P.R.M., Santos, D. 2017. Climatologia do Estado da Paraíba. UFCG, Campina Grande, Brasil. 75 p.

Geilfus, CM., Mithöfer, A., Ludwig-Müller, J., Zörb, C., Muehling, K.H. 2015. Chloride-inducible transient apoplastic alkalinizations induce stomata closure by controlling abscisic acid distribution between leaf apoplast and guard cells in salt-stressed Vicia faba. New Phytologist 208: 803-816.

Hasanuzzaman, M., Bhuyan, M.H.M., Nahar, K., Hossain, M., Mahmud, J.A., Hossen, M., Fujita, M. 2018. Potassium: a vital regulator of plant responses and tolerance to abiotic stresses. Agronomy 8: 31.

Jung, K., Ok, Y.S., Chang, S.X. 2011. Sulfate adsorption properties of acid-sensitive soils in the Athabasca oil sands region in Alberta, Canada. Chemosphere 84: 457-463.

Kopriva, S., Calderwood, A., Weckopp, S.C., Koprivova, A. 2015. Plant sulfur and big data. Plant Science 241: 1-10.

Kopriva, S., Malagoli, M., Takahashi, H. 2019. Sulfur nutrition: impacts on plant development, metabolism, and stress responses. Journal of Experimental Botany 70: 4069-4073.

Khan, S.A., Mulvaney, R.L., Ellsworth, T.R. 2014. The potassium paradox: Implications for soil fertility, crop production and human health. Renewable Agriculture and Food Systems 29: 3-27.

Machado, R.M.A., Serralheiro, R.P. 2017. Soil salinity: effect on vegetable crop growth. Management practices to prevent and mitigate soil salinization. Horticulturae 3: 1-30.

Mardanluo, S., Souri, M.K., Ahmadi, M. 2018. Plant growth and fruit quality of two pepper cultivars under different potassium levels of nutrient solutions. Journal of Plant Nutrition 41: 1604-1614.

Nada, M.M., Metwaly, E.E. 2020. Response of growth, yield and fruit quality of squash plants to foliar application with potassium silicate and magnesium sulfate under high temperature stress. Journal of Plant Production 11: 195-200.

Niu, G., Rodriguez, D.S. 2008. Responses of growth and ion uptake of four rose rootstocks to chloride-or sulfate-dominated salinity. Journal of the American Society for Horticultural Science 133: 663-669.

Niu, G., Davis, T.D., Masabni, J. 2019. A review of salinity tolerance research in horticultural crops. Journal of Arid Land Studies 29: 53-59.

Novas, N., Álvarez-Bermejo, J.A., Valenzuela, J.L., Gázquez, J.A., Manzano-Agugliaro, F. 2019. Development of a smartphone application for assessment of chilling injuries in zucchini. Biosystems Engineering 181: 114-127.

Oosterhuis, D.M., Loka, D.A., Kawakami, E.M., Pettigrew, W.T. 2014. The physiology of potassium in crop production. Advances in Agronomy 126: 203-233.

R Core Team. 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Rawat, J., Sanwal, P., Saxena, J. 2016. Potassium and its role in sustainable agriculture. In: Meena, VS., Maurya, BR., Verma, JP., Meena, RS. Potassium solubilizing microorganisms for sustainable agriculture. Springer, New Delhi, Índia. p. 235-253.

Santos, H.G., Jacomine, P.K.T., Anjos, L.H.C., Oliveira, V.A., Lumbreras, J.F., Coelho, M.R., Almeida, J.A., Araújo Filho, J.C., Oliveira, J.B., Cunha, T.J.F. 2018. Sistema brasileiro de classificação de solos. EMBRAPA, Brasília, Brasil. 355 p.

Scrucca, L. 2013. GA: a package for genetic algorithms in R. Journal of Statistical Software 53: 1-37.

Taiz, L., Zeiger, E., Møller, M.L., Murphy, A. 2017. Fisiologia e desenvolvimento vegetal. Artmed, Porto Alegre, Brasil. 888 p.

Tu, B., Liu, C., Tian, B., Zhang, Q., Liu, X., Herbert, S.J. 2017. Reduced abscisic acid content is responsible for enhanced sucrose accumulation by potassium nutrition in vegetable soybean seeds. Journal of Plant Research 130: 551-558.

Wazir, Z.A., Singh, A., Ramana, N. 2019. Seasonal incidence of fruit fly on Summer squash (Cucurbita pepo L.) and effect of weather parameters on population dynamics of fruit fly Bactrocera cucurbitae (Coquillett). Journal of Entomology and Zoology Studies 7: 167-170.

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L.D.A., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T.L., Miller, E., Bache, M.S., Müller, K., Ooms, J., Robinson, D., Seidel, D.P., Spinu, V., Takahashi, K., Vaughan, D., Wilke, C., Woo, K., Yutani, H. 2019. Welcome to the Tidyverse. Journal of Open Source Software 4: 1686.

Zörb, C., Senbayram, M., Peiter, E. 2014. Potassium in agriculture-status and perspectives. Journal of Plant Physiology 171: 656-669.

Zoca, S.M., Penn, C. 2017. An important tool with no instruction manual: a review of gypsum use in agriculture. Advances In Agronomy 144: 1-44.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.