Comunicata Scientiae
Horticultural Journal

ORIGINAL ARTICLE
published: 10 November 2021
https://doi.org/10.14295/CS.v12.3667

Yield performance of okra under potassium fertilization and number of plants per hole

Luiz Daniel Rodrigues da Silva*, Ademar Pereira de Oliveira, José Manoel Ferreira de Lima Cruz, André Luís Leite de Souza, Izaias Romario Soares do Nascimento

Federal University of Paraíba, Areia, Brazil
*Corresponding author, e-mail: danel.luiz06@hotmail.com

Abstract

The low-scale cultivation of okra in Brazil is related to the lack of technical-scientific information about its nutritional requirements and planting density. Thus, this study aimed to evaluate the effect of K_2O doses and the number of plants/hole on the yield and quality of okra cv. Santa Cruz. A complete randomized block design was used, with four replications, in a 6 x 2 factorial scheme, corresponding to six K_2O doses (0, 50, 100, 150, 200, and 250 kg ha^{-1}) and two planting densities (one and two plants/hole). The fruit mass, number of fruits/plant, fruit yield, total and commercial yield, and leaf potassium content were evaluated. The mean fruit mass and total yield did not adjust to any linear model but had higher values when two plants/hole were planted. The number of fruits/plant, fruit and commercial yield increased according to the K_2O doses increase and planting with two plants/hole. The potassium leaf content did not differ according to the different planting densities but increased significantly with the potassium doses. Plating with two plants/hole increased the K_2O requirement and provided a positive response in all analyzed traits. The application of K_2O doses between 115 and 185.5 t ha^{-1} using two plants/hole is recommended and promotes better yield and quality of okra cv Santa Cruz.

Keywords: *Abelmoschus esculentus*, mineral fertilizers, plant density

Introduction

Okra (Abelmoschus esculentus L.) is a vegetable of high nutritional value and witch great socio-economic importance worldwide, because your immature fruits are a rich source of fiber and minerals (Kamalesh et al., 2016; Maciel et al., 2018; Petropoulos et al., 2018). India is ranked as the largest producer of this crop, followed by China and Nigeria (Narayanamoorthy & Devika, 2018; Cavalcante Nunes et al., 2019; Kant & Singh, 2020). In Brazil, the Northeast and Southeast regions had the most significant production in 2017, with 32.337 and 60.610 tons, respectively (IBGE, 2020).

In Brazil, small producers are responsible for all national production due to the low cost and higher resistance to phytosanitary problems than other vegetable crops (Paes et al., 2012). Its low-scale Brazil production is due to the lack of technical and scientific information on the nutritional requirements and planting density to improve its development and productivity.

Potassium is an essential nutrient for plant metabolism that increases crop yield and fruit quality due to its enzyme activity increase, which metabolizes carbohydrates to synthesize amino acids and proteins (Zahedi, 2016; Chrysargyris et al., 2017). This nutrient is essential in plant production, especially in semi-arid regions, due to stomatal activity regulation to avoid water loss through transpiration and increase the accumulation of osmoprotectants for osmoregulation during water scarcity (Meena et al., 2016; Jha & Subramanian, 2017).

The ideal planting density can improve the plant performance because it can reduce and suppress weed infestation when plants are closely spaced (Omovbude & Udensi, 2018). It can also ensure the balance between vegetative growth and fruit development due to better use of nutrients and solar radiation (Strassburger et al., 2010).

Received: 16 November 2020
Accepted: 31 March 2021

Studies of potassium fertilization and plant density in okra production are necessary, given that an adequate plant density associated with potassium fertilization provides a greater yield (Strassburger et al., 2010; Meena et al., 2016). The interaction of the traits studied was reported only for broccoli by Hashem et al. (2018), with a significant total yield effect. Reports of potassium fertilization and planting density on okra productivity are scarce.

Therefore, this study aimed to evaluate the effect of potassium fertilization and the number of plants per hole on the yield and quality of okra cv Santa Cruz.

Material and Methods

This study was conducted between September of 2019 and January of 2020, in the experimental area of the Federal University of Paraíba, Areia - Paraíba, located in the micro-region of Brejo Paraibano, at 574.62 m altitude, 6° 57 '26 S" of latitude, and 35° 45 '30 "W of longitude. According to the Köppen classification, the climate is type As', characterized as hot and humid, with an average annual precipitation of 1.350 mm, predominantly from March to August (Francisco & Santos, 2017; AESA, 2020). The meteorological conditions in the experimental period are shown in figure 1.

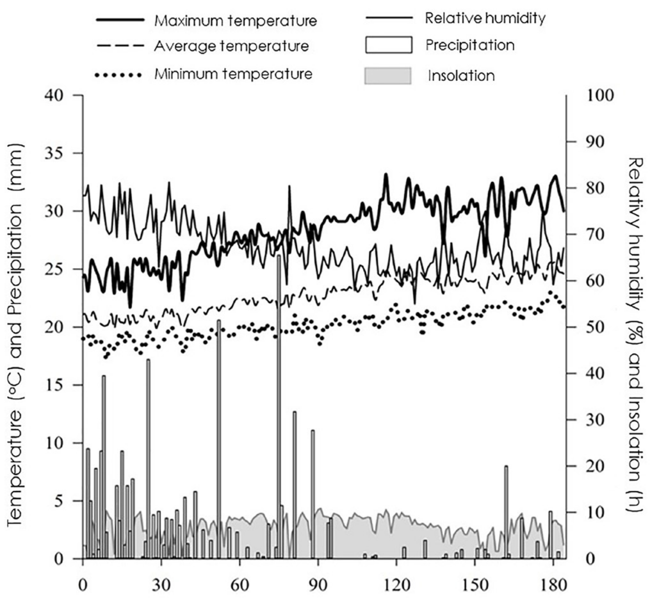

Figure 1. Meteorological records of the experimental area during the experiment, Areia-PB, 2020.

The soil of the experimental area was classified as Neosolo Regolítico Psamítico Dystrophic of loam sandy texture (Embrapa, 2009a). Soil samples were collected at a depth of 0-20 cm to determine chemical and physical properties. The following soil properties were obtained: pH in water (1: 2.5) = 5.74; P and K^+ = 41.14 and 61.25 mg dm^{-3}; Ca^2 + Mg^{2+} = 1.69 and 0.96 cmolc dm^{-3}; sum of exchangeable bases - SB ($Ca^{2++}Mg^{2++}K^+$) = 2.86 $cmol_c$ dm^{-3}; (H^{++} Al^{+3}) = 1.14 $cmol_c$ dm^{-3}; Al^{+3} = 0.00 $cmol_c$ dm^{-3}; cation exchange capacity - CEC [SB^+ (H^{++} Al^{+3})] = 3.99 $cmol_c$ dm^{-3} and percentage of saturation by exchangeable bases - V [(SB / CTC) 100] = 71.67%; OM = 14.78 g kg^{-1}. The V value above 50% for a pedologically dystrophic soil represents a eutrophic characteristic in response to liming and phosphate fertilization in previous years. The soil had 672 and 125 g kg^{-1} of coarse and fine sand, respectively; silt = 126 and clay 77 g kg^{-1}; soil density = 1.28 g cm^{-3}; particles density = 2.64 g cm^{-3}; total porosity = 0.51 m3 m^{-3}; textural class = Loam Sandy.

The soil was plowed and harrowed before planting. The planting fertilization consisted of 15 t ha^{-1} of bovine manure (5% humidity), 100 kg ha^{-1} of P_2O_5 (simple superphosphate), and the K_2O doses according to the experimental design. In the top dressing fertilization, 100 kg ha^{-1} of nitrogen (ammonium sulfate) was provided, divided into equal parts at 30 and 60 days after sowing (Filgueira, 2008), for all treatments.

A complete randomized block experimental design was used, with the treatments distributed in a 6x2 factorial scheme, composed of the K_2O doses (0, 50, 100, 150, 200, and 250 kg ha^{-1}), divided into equal parts at 30 and 60 days after sowing (Filgueira, 2008), and the number of plants per hole (one or two plants), in four replications. The plot consisted of 20 plants (four rows with five plants) and 1.00 m x 0.50 m plant spacing.

Sowing occurred by placing four seeds of the cultivar Santa Cruz per hole, followed by thinning at fifteen days after planting to set the treatments with one or two plants per hole, randomly in each treatment and replication.

Weeding was made manually with hoes. Irrigation was provided (drip tape system) with a flow rate of 1.75 L/h in a two-day irrigation shift in the absence of precipitation. The fungicide benomyl (20 ml/20 L of water) was sprayed every fifteen days after emergence, up to fifteen days before harvest, to control powdery mildew (Erysiphe polygoni).

A total of 23 harvests were performed starting at 55 days after sowing in two-day intervals when the fruits reached an intense green color. The fruit mass, number of fruits and commercial fruits per plant, K leaf content, and total and commercial fruit yield were evaluated.

The fruit mass was determined by dividing the production within the plot for the number of commercial fruits. The number of commercial fruits per plant was obtained by dividing the number of commercial fruits harvested by the number of fruits per plant in each plot and treatment. The production of fruits per plant was estimated by dividing the commercial fruit weight by the plant number. All results were expressed in grams, except for the number of fruits.

The total yield was estimated by the weight of all fruits harvested in the plot. The commercial yield was estimated by the weight of fruits considered commercial: fruits of 10 to 15 cm length, straight, without deformation, and intense green color (Filgueira, 2008). The results were expressed in t ha^{-1}.

Data were submitted to the analysis of variance. The F test compared mean squares, and the Tukey test compared means at 5% probability. Polynomial regression analyses were performed to compare the effects of K_2O doses on the evaluated traits, to fit the linear and quadratic model. The model with significance and a determination coefficient (R^2) higher than 0.60 was selected to explain the results. The Sisvar software was used (Sisvar, 2000).

Results and discussion

An interaction between treatments and mean fruit mass was observed. However, these values did not fit any regression model, with mean values of 16.24 g and 16.52 g, on planting with one and two plants per hole, respectively (Figure 2). That indicates that the potassium fertilization and plant density did not affect the weight of okra fruits. According to Ramos (2009), the mean fruit mass is one of the traits most prone to variation when plant densities are studied, a behavior not observed in this study.

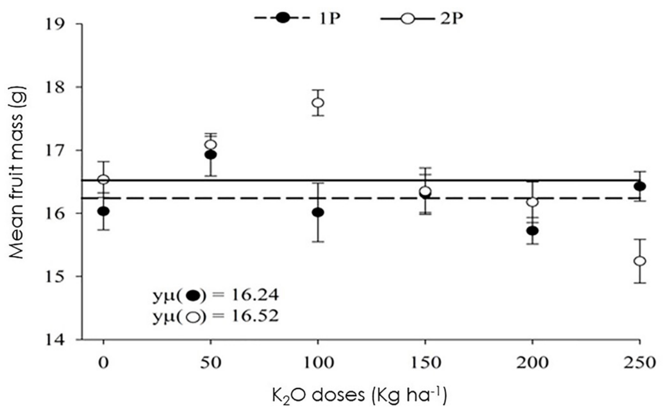

Figure 2. Mean fruit mass of okra under K_2O fertilization and planting with one or two plants per hole. Areia-PB, 2020.

The maximum values of fruits per plant in okra were 45 and 56 in the doses of 123.7 and 184 kg ha^{-1} of K_2O, for one and two plants per hole, respectively (Figure 3). These values are superior to those found by Oliveira et al. (2007) when evaluated the okra fertilization with bovine manure and potassium under the same edaphoclimatic conditions of the present study and obtained 37 fruits per plant.

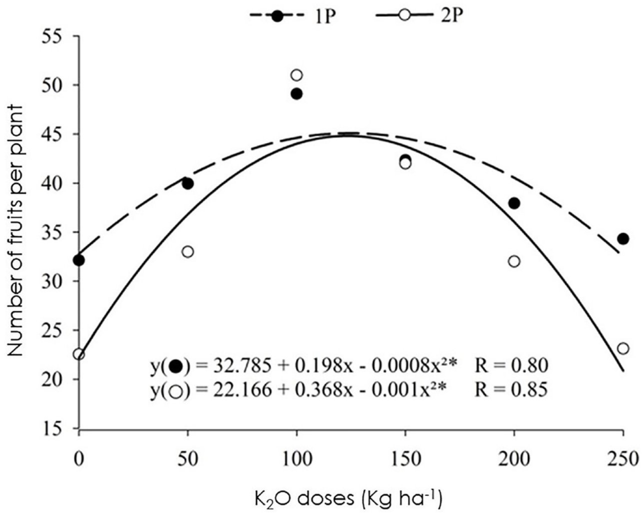

Figure 3. The number of okra fruits under K_2O fertilization and planting with one or two plants per hole, Areia-PB, 2020.

Sedyama et al. (2009) obtained similar results when evaluated the application of swine biofertilizer and planting with two plants per hole with 45.9 fruits per plant. The higher fruit number in lower plant density obtained by the authors is related to less competition between plants (Gaion et al., 2013). Therefore, a higher quantity of potassium is required in treatments with two plants per hole to promote a higher fruit number in the maximum dose efficiency. Potassium is the most required nutrient in most vegetables, favoring flowering and fruit formation (Araújo et al., 2012), therefore, linked to the increment in fruit number.

A statistical interaction on the production of fruits per plant with the factors studied (potassium doses x plant density) was observed, with a linear increase according to the K_2O doses for the treatment with two plants per hole, with a production of 584.25 g (48.57 % increment), at the maximum dose (250 kg ha^{-1}), and 538.57 g (31.08% increment), in the K_2O dose of 206.3 kg ha^{-1} with one plant per hole (Figure 4).

The production decrease according to the increment of potassium doses in the treatment with one plant per hole can be attributed to the adverse effects caused by nutrient excess. Potassium chloride was used (KCl), and its high chlorine concentration can cause phytotoxicity (Figueiredo et al., 2008). The same did not occur on treatments with two plants per hole, which can be explained by the higher number of plants for nutrition. These results are superior to those found by Alrawi (2018) when studied the foliar application of potassium and zinc on okra and obtained 372.9 g fruits per plant. This can be explained by the positive effects of potassium in the metabolic processes, water use, photosynthesis, and the translocation and allocation of sugars from the plant to the fruits, providing increments in fruit production (Dumbuya et al., 2017).

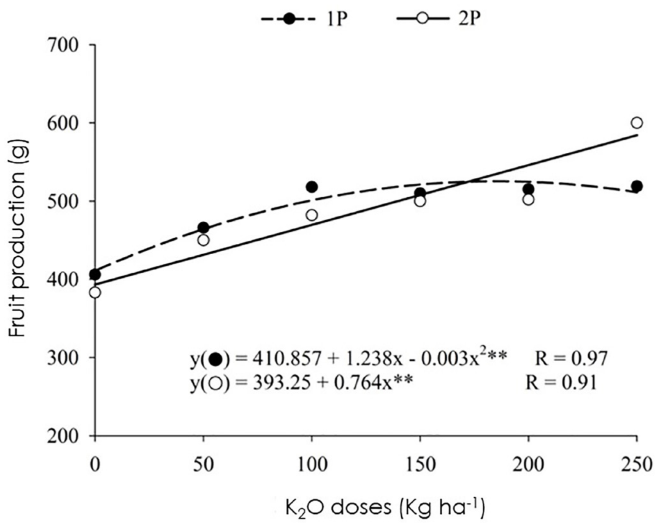

Figure 4. Fruit production per plant of okra under K_2O fertilization and planting with one or two plants per hole. Areia-PB, 2020.

The total yield under the potassium doses and planting with one or two plants per hole did not fit any regression model (Figure 5). In treatments with one plant per hole, 18.2 t ha^{-1} was obtained, while for two plants per hole, it reached 29.16 t ha^{-1}, a 60.2% increment.

Similarly, Gaion et al. (2013) found that higher planting density provided higher yield for the cultivars 'Santa Cruz 47' and 'Colhe Bem IAC,' indicating that denser cultivation is advantageous in this crop. Salau & Makinde (2014) also reported an increment in okra yield at higher planting density. According to Broek et al. (2002), the yield is variable, and usually, it stands around 20 t ha^{-1} for this crop, corroborating the results obtained in this study.

The doses of 122.5 kg ha^{-1} and 115 kg ha^{-1} of K_2O promoted the higher commercial fruit yield, with a maximum of 25.6 t ha^{-1} and 29.2 t ha^{-1}, for one and two plants per hole, respectively (Figure 6). Although the potassium doses did not affect total yield, this nutrient is of great importance, considering that it provides changes in plant metabolism, enzyme activity related to photosynthesis and favors the uptake of other nutrients, especially in sandy and low-fertility soils (Raij, 2017). Potassium is the most required nutrient by okra plants due to its activity on several physiological processes directly affecting the yield (Santos et al., 2019).

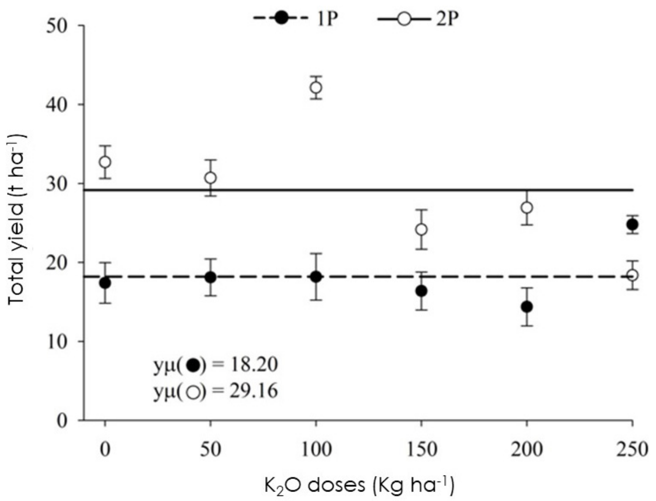

Figure 5. Total yield of okra under K_2O fertilization and planting with one or two plants per hole. Areia-PB, 2020.

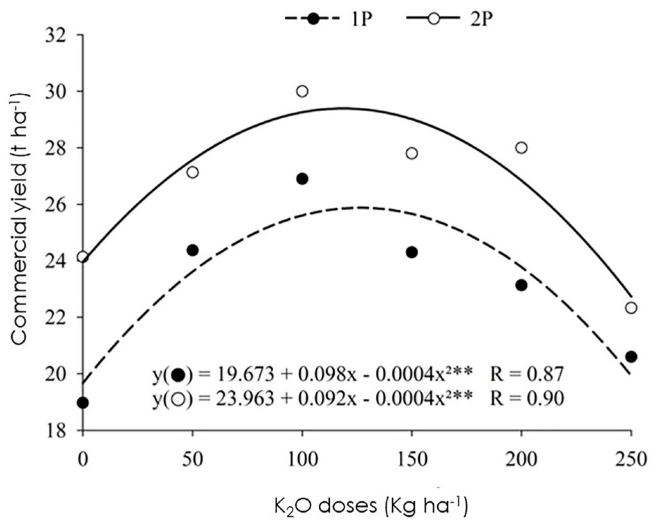

Figure 6. Commercial yield of okra under K_2O fertilization and planting with one or two plants per hole. Areia-PB, 2020.

Planting with two plants per hole promoted a 14.06% increment compared to planting with one plant (3.6 t ha^{-1}), which indicates that this crop can reach higher yields at higher planting density, as reported by Gaion et al. (2013), with a commercial fruit yield of 38.76 t ha^{-1} at the plant spacing of 0.1 m between plants and 1.0 to 1.2 m between rows, superior to the present study. Maurya et al. (2013) also obtained higher okra yield on the cultivar 'Clemson Spineless' at higher planting density (30 cm x 45 cm). Onyegbule et al. (2012) studied poultry manure fertilization and population density of okra and observed high commercial yield at the highest density of 3 plants per hole (40 cm x 90 cm). This higher commercial yield is attributed to the number of plants per unit area, which, under adequate nutritional levels, positively affected the production per plant and consequently in the accumulated per unit area.

The yield decrease with the decrease of K_2O

doses can be attributed to a possible increase in soil salinity and reduced uptake of other cations, such as Ca and Mg, caused by excessive K_2O fertilization. Also, the high uptake of the accompanying ion Cl^-, can cause disturbances in the P present in plant tissue (Cardoso, 2018).

A significant isolated effect of potassium (K) leaf content for the K_2O doses was observed, with a higher value of 35 g kg^{-1} of K in the dose of 127.6 t ha^{-1} (Figure 7), which ranges in the appropriate level for okra (20-40 g kg^{-1}), according to Trani et al. (2008), and (25-40 g kg^{-1}) Embrapa (2009b). It followed the commercial fruit yield behavior due to the distribution of this macronutrient in the plant, directly linked to its mobility in the leaves (Malavolta, 2006). On the other hand, the decrease in K leaf content with the increase of the K_2O doses is possibly due to nutritional imbalance, caused by the K content initially in the soil, associated with the provided fertilization, which reflected negatively in the plants (Melo et al., 2006).

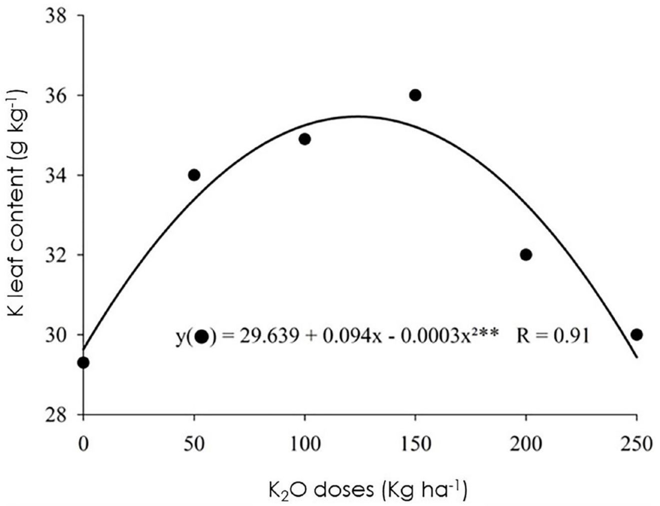

Figure 7. Potassium (K) leaf content in okra under K_2O fertilization. Areia-PB, 2020.

Conclusions

Fertilization of K_2O in doses between 115 and 185.5 t ha^{-1} and planting density of two plants/hole increased the yield and quality of okra cv Santa Cruz.

References

AESA - Agência Nacional de Águas e Saneamento Básico. Climatologia – chuvas. 2020. http://www.aesa.pb.gov.br/aesa-website/meteorologia-chuvas/climatologia/ <Acesso em 10 de set. de 2020>

Alrawi, A. 2018. Effect of foliar application with potassium and zinc on growth, pod yield and seed production of okra. *Iraqi Journal of Agricultural Sciences* 49: 1041-1048.

Araújo, HS., Quadros, BRD., Cardoso, AII., Corrêa, CV. 2012. Doses de potássio em cobertura na cultura da abóbora. *Pesquisa Agropecuária Tropical* 42: 469-475.

Broek, RVD., Iacovino, GD., Paradela, AL., Galli, M. 2002. Controle alternativo de oidio (*Erysiphe cichoracearum*) em quiabeiro (*Hibiscus esculentum*). *Ecossistema* 27: 23-26.

Cardoso, S.S. 2018. Rendimento e qualidade de batata-doce em função de doses e fontes de K_2O. 49p. (Dissertação de Agronomia) - Universidade Federal da Paraíba, Areia, Brazil.

Cavalcante Nunes, J., Andriolo, J.L., Cargnelutti Filho, A., Araújo da Silva Nunes, J., Gomes Pinheiro, S.M. 2019. Temperatura base, filocrono y eficiencia de uso de radiación de cultivares de okra. *Idesia* (Arica) 37: 7-16.

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.

Dumbuya, G., Sarkodie-addo, J., Daramy, M.A., Jalloh, M. 2017. Effect of Vine Cutting Length and Potassium Fertilizer Rates on Sweet Potato Growth and Yield Components. *International Journal of Agriculture and Forestry* 7: 88-94.

EMBRAPA. Empresa Brasileira de Pesquisa Agropecuária. Centro Nacional de Pesquisa de Solos. Sistema Brasileiro de Classificação de Solos. Brasília: Produções de Informações, 2009a. 412p.

EMBRAPA. Empresa Brasileira de Pesquisa Agropecuária. Manual de análises químicas de solos, plantas e fertilizantes. 2.ed. revista e ampliada Brasília, 2009b. 627p.

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

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

Gaion, L.A., Ito, L.A., Galatti, F.S., Braz, L.T. 2013. Densidade de plantio na cultura do quiabo. *Nucleus* 10: 199-206.

Hashem, AL., AL-Abbas, N.M.H., Mohamed, B.N.J 2018. Effect of cultivation distances and potassium fertilization on the growth and yield of broccoli (*Broccoli Brassica oleracea var. italica Plenck*). *Euphrates Journal of Agriculture Science* 10: 163-174.

IBGE. Sistema IBGE de recuperação automática – SIDRA. 2017. https://sidra.ibge.gov.br/tabela/6619#resultado <Acesso em 10 de nov. de 2020>

Jha, Y., Subramanian, RB 2016. Regulation of plant physiology and antioxidant enzymes for alleviating salinity stress by potassium-mobilizing bacteria. In: Meena, VS., Maurya, BR., Verma, JP., Meena, RS. (ed.) *Potassium solubilizing microorganisms for sustainable agriculture. Springer, New Delhi, India*. p. 149-162.

Kamalesh, P., Subrata, D., Asraf, A.K., Pranabesh, C. 2016. Phytochemical investigation and hypoglycaemic effect of Abelmoschus esculentus. *Research Journal of Pharmacy and Technology* 9: 162-164.

Kant, K., Singh, J.P. 2020. Resource use efficiency in okra in Meerut district of Western Uttar Pradesh. *Journal of Pharmacognosy and Phytochemistry* 9: 2114-2116.

Maciel, G.M., Finzi, R.R., Marra, A.W.C., Carvalho, F.J., Nogueira, A.P.O. 2018. Agronomic potential and selection of okra hybrids to obtain potential genitors. *Horticultura Brasileira* 36: 112-117.

Malavolta, E. 2006. *Manual de nutrição mineral de plantas*. Agronômica Ceres, São Paulo, 638 p.

Maurya, R.P., Bailey, J.A., Chandler, J.S.A. 2013. Impact of plant spacing and picking interval on the growth, fruit quality and yield of okra (*Abelmoschus esculentus (L.) Moench*). *American Journal of Agriculture and forestry*1: 48-54.

Melo, R., Ferreira, P.A., Matos, A.T., Ruiz, H.A., Oliveira, L.B. 2006. Deslocamento miscível de cátions básicos provenientes da água residuária de mandioca em colunas de solo. *Revista Brasileira de Engenharia Agrícola e Ambienta*l 10: 456-465.

Meena, V.S., Bahadur, I., Maurya, B.R., Kumar, A., Meena, R.K., Meena, S.K., Verma, J.P. 2016. Potassium-Solubilizing Microorganism in Evergreen Agriculture: An Overview. In: Meena, VS., Maurya, BR., Verma, JP., Meena, RS. (ed.) *Potassium solubilizing microorganisms for sustainable agriculture*. Springer, New Delhi, India. p. 1-20.

Narayanamoorthy, A.; Devika, N. 2018. Economic and resource impacts of drip method of irrigation on okra cultivation: an analysis of field survey data. *Journal of Land and Rural Studies* 6: 15-33.

Oliveira, A.P.D., Dornelas, C.S.M., Alves, A.U., Alves, A.U., Silva, J.A.D., Oliveira, A.N.P.D. 2007. Resposta do quiabeiro às doses de fósforo aplicadas em solo arenoso. *Horticultura Brasileira* 25: 180-183.

Omovbude, S., Udensi, E.A. 2018. Response of okra [*Abelmoschus esculentus (L.) Moench*] and weeds to plant spacing and weeding regime in a humid forest agro-ecology of South-Eastern Nigeria. *Journal of Applied Life Sciences International* 18: 1–13.

Onyegbule, U.N., Ngbede, S.O., Nwanguma, E.I., Ohaneje, A. 2012. Evaluation of okra performance to different rates of poultry manure and plant population density. *Continental. Journal Agriculture Sciences* 6: 56-63.

Paes, H.M.F., Esteves, B.S., Sousa, E.F. 2012. Determinação da demanda hídrica do quiabeiro em Campos dos Goytacazes, RJ. *Revista Ciência Agronômica* 43: 256-261.

Petropoulos, S., Fernandes, Â., Barros, L., Ferreira, I.C. 2018. Chemical composition, nutritional value and antioxidant properties of Mediterranean okra genotypes in relation to harvest stage. *Food Chemistry 242*: 466-474.

Ramos, A.R., Dias, R.D.C.S., Aragão, C.A. 2009. Densidades de plantio na produtividade e qualidade de frutos de melancia. *Horticultura brasileira* 27: 560-564.

Raij, BV 2017. *Fertilidade do solo e manejo de nutrientes.* IPNI, Piracicaba, Brazil. 420 p.

Santos, H.C., Pereira, E.M., Medeiros, R.L., Costa, P.M.D.A., Pereira, W.E. 2019. Production and quality of okra produced with mineral and organic fertilization. *Revista Brasileira de Engenharia Agrícola e Ambiental* 23: 97-102.

Salau, A.W., Makinde, E.A. 2015. Planting density and variety on Okra growth, yield, and yield duration. *International Journal of Vegetable Science* 21: 363-372.

Sedyama, M.A.N., Santos, M.R.D., Vidigal, S.M., Salgado, L.T., Pedrosa, M.W., Jacob, L.L. 2009. Produtividade e estado nutricional do quiabeiro em função da densidade populacional e do biofertilizante suíno. *Bragantia* 68: 913-920.

Sisvar. Sistema para análise de variância, para Windows versão 4.3. Lavras, Universidade Federal de Lavras, 2000.

Strassburger, A.S., Peil, R.M.N., Schwengber, J.E., Medeiros, C.A.B., Martins, D.D.S., Silva, J.B. 2010. Crescimento e produtividade de cultivares de morangueiro de "dia neutro" em diferentes densidades de plantio em sistema de cultivo orgânico. *Bragantia* 69: 623-630.

Trani, P.E., Passos, FA., Teodoro, MCCL., Santos, VJ., Frare, P 2020. Calagem e adubação para a cultura do quiabo. www.iac.sp.gov.br/Tecnologias/Quiabo/Calagem_Quiabo.htm <Acesso em 12 de set. de 2020>

Zahedi, H. 2016. Growth-promoting effect of potassium-solubilizing microorganisms on some crop species. In: Meena, V.S., Maurya, B.R., Verma, J.P., Meena, R.S. (ed.) *Potassium solubilizing microorganisms for sustainable agriculture*. Springer, New Delhi, India. p. 31-42.

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.