Brazilian Journal of Biosystems Engineering (2024), 18 1215

REGULAR ARTICLE

Cotton responses to potassium fertilization in Northeastern Brazil

Célia Maria da Silva[1], Aureliano de Albuquerque Ribeiro[1], Evandro Fabio da Silva[1], Mayana Garcias da Silva[1]

[1]Faculty of Technology Centec –Fatec Cariri, Juazeiro do Norte, CE, Brazil.

Regular Section
Academic Editor: Celso Antonio Goulart

Statements and Declarations

Data availability
All data will be shared if requested.

Institutional Review Board Statement
Not applicable.

Conflicts of interest
The authors declare no conflict of interest.

Funding
This research did not receive external funding.

Autor contribution
CMdaS: Responsible for conducting fieldwork, data collection, scientific writing; AdeAR: Scientific writing, review and guidance; EFdaS: Responsible for conducting fieldwork and data collection; MGdaS: Fieldwork support.

Abstract

Carrying out research evaluating the responses of cotton plants to potassium fertilization in different regions is of great importance, as it allows the development of recommendations for fertilization of this nutrient for the crop based on results from localized studies. Therefore, the aim of this work was to evaluate the responses of cotton plants to potassium fertilization in the climate and soil conditions of the Cariri region, located in the northeastern State of Ceará, Brazil. The experiment was conducted in an experimental area at the School of Technology (FATEC - Cariri campus), located in the city of Juazeiro do Norte, Ceará State. A completely randomized design (CRD) was adopted for statistics. The treatments were composed of a combination of five doses of potassium (0, 25, 50, 75, and 100 kg ha^{-1} of K_2O, equivalent to 0, 50, 100, 150, and 200% of the K recommended for cotton cultivation) with four replications. At 70 days after sowing, the plants were collected. Measurements were taken of stem diameter, number of leaves, root dry matter, shoot dry matter, total dry matter, number of floral buds, number of cotton balls, and cotton ball weight. Except for the shoot dry matter and the cotton ball weight, the remaining analysed variables were significantly influenced by potassium doses. Potassium doses between 65 and 100 kg ha^{-1} of K_2O maximized the growth, dry matter, and production components of the cotton plant in the soil and climate conditions of the Cariri region, northeastern Brazil.

Keywords

Cotton farming; Soil fertility; Potassium chloride.

Introduction

The cotton plant (*Gossypium hirsutum* L) is an important commercial crop, grown especially for fiber production (Keya et al., 2023). Every year, an average of 35 million hectares of cotton is planted across the planet. The world cotton trade generates around US$12 billion annually and involves more than 350 million people in its production. World cotton production is led by the Asian continent, with India in first place, China in second, the United States in third, and Brazil in fourth (ABRAPA, 2023). In Brazil, crop production is concentrated in the Center-West, Northeast, and Southeast regions (IBGE, 2023). In the 2021/2022 harvest, the area cultivated with cotton in Brazil totaled 1,600.5 thousand hectares, producing 6,273.5 thousand tons (CONAB, 2023).

Since the 2015/16 harvest, the State of Ceará has shown an evolution in cotton production that represents, in addition to aspects of volume growth, a characteristic of the resumption of cotton cultivation. They are the results of actions by farmers, companies, and government agencies, consolidated and made official in 2017 with the launch of the Cotton Culture Modernization Program created with the aim of rebuilding cotton farming in Ceará (EMBRAPA, 2017).

To maximize cotton yield, the conditions under which it is grown are crucial. Cotton plants are often subjected to potassium (K) deficiency in the soil (Fontana et al., 2020). The nutrient is the second most absorbed element by the cotton plant (Lima et al., 2019), performing an essential role in growth, development, production, and fiber quality (Raper, 2017), increasing crop water use efficiency and disease resistance (Wakeel et al., 2017), as well as improving photosynthetic activity (Hatfield & Dold, 2019). A deficiency of this nutrient results in premature senescence and decreases the crop's tolerance to stress, while its excess reduces productivity and yield, in addition to causing environmental pollution (Wu et al., 2019). Therefore, throughout the cotton cycle, maintaining adequate levels of this nutrient in the soil is essential to guarantee high yield (Shao et al., 2023).

In this context, it is essential to carry out research in different regions of Brazil, aiming to develop recommendations for potassium fertilizer for cotton plants based on the results of regional studies, thus allowing the

* Corresponding author
E-mail address: aureliano@centec.org.br (A. A. Ribeiro)

https://doi.org/10.18011/bioeng.2024.v18.1215
Received: 28 January 2024/ Accepted: 07 April 2024 / Available online: 06 June 2024

application of correct amounts of this nutrient. Therefore, the objective of this study was to evaluate the responses of cotton plants to potassium fertilization in the climate and soil conditions of the Cariri region, northeastern Brazil.

Materials and methods

Location and characterization of the experiment

The experiment was conducted in an open air environment from March to May 2023 in an experimental area at the CENTEC (Centre for Technological Education) School of Technology (FATEC - Cariri campus), located in the city of Juazeiro do Norte, Ceará State, Brazil – with geographic coordinates 07°12'47"S, 39°18'55"W. The city is located at an altitude of 377 meters and has a climate ranging from Tropical Semi-Arid to Tropical Semi-Arid Mild, with an average temperature of 24 to 26 ºC, where the rainy season goes from January to May. The average rainfall is 925 mm (Lima & Ribeiro, 2012). Within Köppen's climate types (Köppen & Geiger, 1928), one can identify, as predominant in Juazeiro do Norte, the climate class BSW'h', that is, Semiarid Climate, with a short rainy season starting in summer and reaching its peak in the summer-autumn transition.

Experimental design and treatments

A completely randomized design (CRD) was adopted for statistics. The treatments were composed of a combination of five doses of potassium (0, 25, 50, 75, and 100 kg ha^{-1} of K_2O, equivalent to 0, 50, 100, 150, and 200% of the K recommended for cotton cultivation) with four replications.

The experimental unit was represented by an 8 L plastic pot containing a plant. The reference dose (100% of the K amount recommended for the crop) corresponded to 50 kg ha^{-1} of K_2O, according to the Fertilization and liming recommendation manual of the State of Ceará (UFC, 1993).

Characterization of the used soil

The soil used in the research was collected in an experimental area at the Centre for Technological Education (FATEC-Cariri) at a depth of 0 to 20 cm, being sieved and, after that, the pots were filled. At the lower end of each vessel, a 2 cm layer of gravel was placed. The chemical and physical characterization of the used product is found in Table 1.

Table 1. Chemical and physical characterization of the soil used in the experiment. Juazeiro do Norte, CE - 2024.

Chemical characteristics												
ECse	pH	C	OM	P	V	Ca	Mg	K	Na	SB	T	H+Al
dS m^{-1}	-	g kg^{-1}		mg dm^{-3}	%	--------------------cmol$_c$ dm^{-3}--------------------						
0.16	7.2	2.3	3.9	4.0	80	2.48	0.49	0.2	0.02	3.17	3.97	0.80
Physical characteristics												
Ds	Dp	P_T	Total sand		Coarse sand			Fine sand		Silt	Clay	Textural Class
--kg dm^{-3}--		%	------------------------g kg^{-1}---									
1.4	2.8	48	850.60		499.20			351.40		8.65	140.7	Medium sand

ECse - electrical conductivity of the saturation extract; pH - hydrogen potential; C - carbon; OM - organic matter; P - phosphorus; V - base saturation; Ca - calcium; Mg - magnesium; K - potassium; Na - sodium; SB -sum of exchangeable bases; T - cation exchange capacity; Ds - soil density; Dp - particle density; P_T - total porosity.

Conducting the experiment

Sowing was carried out by placing four seeds per pot. At 10 days after sowing, thinning was carried out, leaving one plant per pot. The Brazilian Agricultural Research Corporation (Embrapa) cultivar BRS 433FL B2RF was used.

Potassium fertilizer (0, 25, 50, 75, and 100 kg ha^{-1} of K_2O equivalent to 0, 50, 100, 150 and 200% of the K recommended for cotton cultivation) and nitrogen were divided into instalments, with 25% applied during thinning and the remainder applied in two equal instalments at 15 and 25 days after thinning. When sowing, 7.7 g of simple superphosphate was applied per pot. The source of potassium and nitrogen used was potassium chloride (60% K_2O and 48% Cl) and urea (45% N).

Irrigation was done daily and manually, being carried out slowly until the water drained from the pot could be observed, thus reaching field capacity in all pots.

Analysed Variables

At 50 days after sowing (DAS), the number of floral buds (NFB) was counted. At 70 DAS, the plants were collected. Measurements of stem diameter (SD), number of leaves (NL) and number of cotton balls (NCB) and cotton ball weight (WCB) were taken. The diameter of the stem was obtained with the aid of a digital caliper. To count the number of leaves, only photosynthetically active leaves were considered.

The different parts of the plants (roots, stem, leaves, flowers, flower buds, and cotton balls) were separated, packed in paper bags, and placed to dry in an oven with forced air circulation, maintaining the temperature in the range of 65 to 70 °C. After drying, each sample was weighed on an analytical balance, allowing the root dry matter (RDM), shoot dry matter (SDM), and total dry matter (MST) to be obtained.

Statistical analysis

The data obtained were subjected to analysis of variance (ANOVA) and, when significant by the F test, the effects of different doses of potassium were subjected to regression analysis. The equations that best fit the data were chosen based on the highest coefficient of determination (R^2). Statistical analyzes were carried out using the statistical software SISVAR®, version 5.3 (Ferreira, 2011). Graphs were generated on Microsoft Excel.

Results and discussion

Potassium doses significantly influenced stem diameter ($p <0.01$), number of leaves ($p <0.01$), root dry matter ($p <0.01$), total dry matter ($p <0.01$), number of floral buds ($p <0.01$), and number of cotton balls ($p <0.05$) of the cotton plant (Table 2).

The increase in potassium fertilization provided increases in the diameter of the plant stem up to the estimated dose of 74 kg ha^{-1} of K_2O, obtaining a maximum value of 10.79 mm, which corresponds to an increase of 16.75% when compared to the value obtained in plants that did not receive potassium fertilization (Figure 1A). In a study carried out with the same culture, Tian et al. (2023) observed that, 125 days after sowing, plants grown in soil with a medium concentration of potassium (150 mg K_2O Kg^{-1} soil) showed an increase of 4.78% in stem diameter compared to plants grown in soil with potassium deficiency (0 mg K_2O kg^{-1} soil). On the other hand, in the semiarid region of Pernambuco, in an experiment conducted under field conditions and evaluation times different from those of the present study, Lima et al. (2019) found that potassium doses did not significantly affect the stem diameter of cotton plants.

For the number of leaves, a linear effect was observed in relation to the doses tested, that is, as the dose of potassium increased, there was a corresponding increase in the number of leaves (NL). It was also observed that, with the application of 100 kg ha^{-1} of K_2O, an average value was obtained for the number of leaves equal to 36.25, representing an increase of 20.83% in relation to the treatment in which potassium was not applied (Figure 1B). Similarly, Dewdar & Rady (2013), in a 2-year field experiment carried out in Egypt, found that the number of leaves per plant increased significantly with the application of potassium to the soil. According to Pettigrew (2008), potassium fertilization plays a crucial role in increasing the number and size of leaves, which improves the photosynthetic activity of plants.

Table 2. Summary of analysis of variance for stem diameter (SD), number of leaves (NL), root dry matter (RDM), shoot dry matter (SDM), total dry matter (TDM), number of flower buds (NFB), number of cotton balls (NCB) and cotton ball weight (WCB) of cotton plants grown under different doses of potassium in the Cariri region. Juazeiro do Norte, CE - 2024.

VS	Medium square								
	DF	SD	NL	RDM	SDM	TDM	NFB	NCB	WCB
K dose	4	1.92^{**}	37.12^{**}	13.3^{**}	18.95^{ns}	59.32^{**}	42.57^{**}	7.25^{*}	304.42^{ns}
Residue	15	0.23	6.35	0.65	22.06	21.41	7.10	2.13	274.35
Total	19	-	-	-	-	-	-	-	-
CV (%)		4.74	7.81	9.43	7.41	6.44	14.33	17.18	21.25

VS= Variation source; DF = Degree of freedom; CV= Coefficient of variation; **,* = Significant at 1% and 5%, respectively, ns = not significant

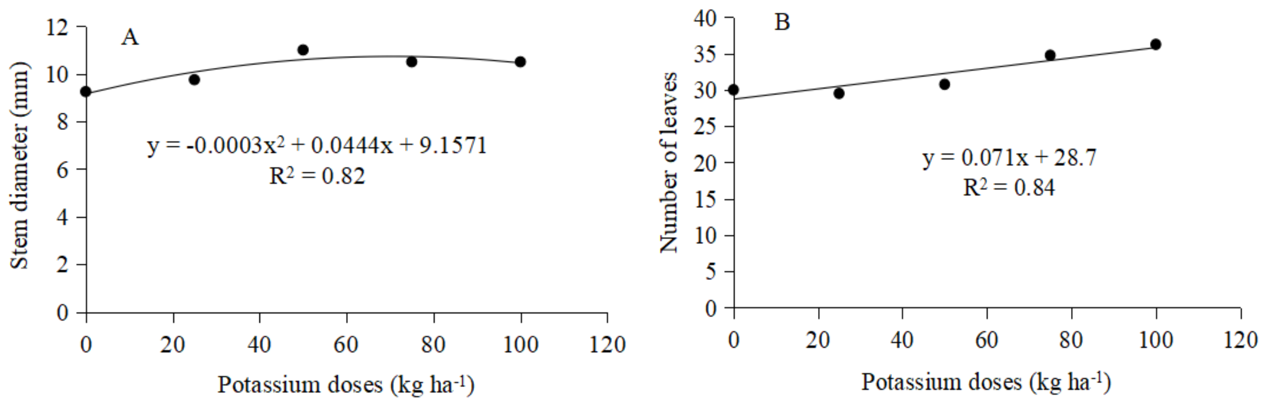

Figure 1. Stem diameter (A) and number of leaves (B) of cotton plants grown under different doses of potassium in the Cariri region.

Plant root dry matter increased to the estimated dose of 69.77 kg ha^{-1} of K_2O reaching a maximum value of 9.97 g. From this dose, there was a decrease of 4.71% when comparing the value obtained at a dose of 69.77 kg ha^{-1} of K_2O with that obtained at a dose of 100 kg ha^{-1} of K_2O (Figure 2A). In the same culture, Tian et al. (2023), in research carried out under pot conditions in China, found that plants grown in soil with an average concentration of potassium (150 mg K_2O kg^{-1} soil) showed higher root dry matter values compared to plants grown in deficient soil (0 mg K_2O kg^{-1} soil) and high concentration of potassium (300 mg K_2O kg^{-1} soil). Excess potassium in the soil inhibits root development and reduces root dry matter (He et al., 2019; Naciri et. al., 2021; Pantha et al., 2022).

The maximum TDM (74.72 g) was obtained when an estimated dose of 65.52 kg ha^{-1} of K_2O was applied and, from this value, a decrease occurred (Figure 2B). Meanwhile, Hu et al. (2015) verified in China, that the maximum value of total dry matter in two cotton cultivars (Simian 3 and Siza 3) grown under field conditions on a clayey soil was obtained at a dose of 300 kg ha^{-1} of K_2O. Hussain et al. (2021), in an experiment carried out under field conditions with three cotton cultivars in the semi-arid region of Pakistan, observed that the maximum value of total dry matter, in all cultivars evaluated, was obtained at a dose of 120 kg ha^{-1} of K_2O.

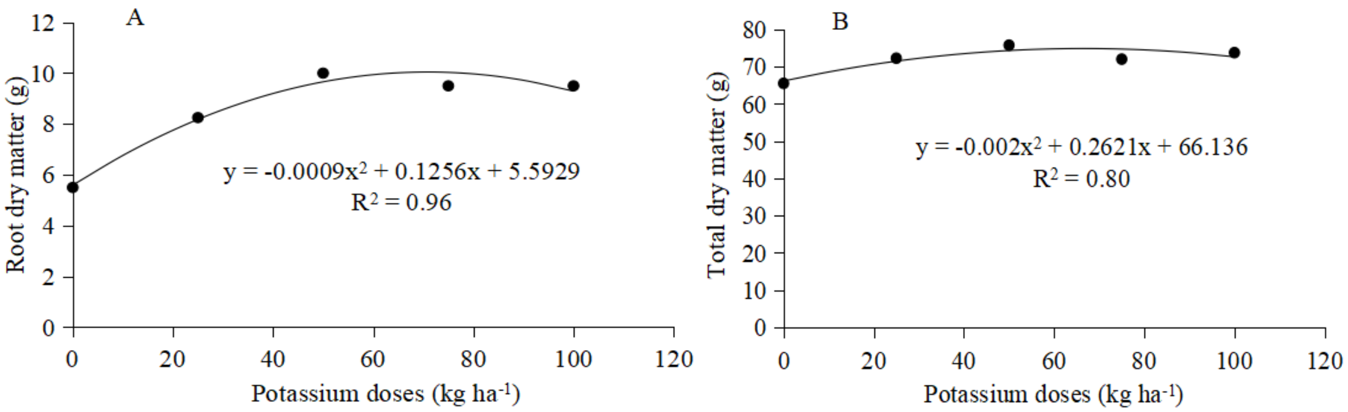

Figure 2. Root dry matter (A) and total dry matter (B) of cotton plants grown under different doses of potassium in the Cariri region.

For the number of floral buds, a maximum value of 21.5 was obtained at the estimated dose of 104.77 kg ha^{-1} of K_2O, which corresponds to an increase of 50.87% when compared to the value obtained in plants that did not receive potassium fertilization (Figure 3A). Under field conditions in the Cerrado region of Goiás State - Brazil, Vidal et al. (2017) concluded that, in the cotton cultivar BRS-371, the highest number of floral buds (43.14) was found at a dose of approximately 200 kg ha^{-1} of K_2O. In the same culture, Loka et al. (2019) found that plants that received optimal amounts of potassium had almost 50% more flower buds compared to plants deficient in this nutrient.

The increase in potassium fertilization also provided increases in the number of cotton balls on the plants up to the estimated dose of 77.6 kg ha^{-1} of K_2O, obtaining a maximum value of 9.19, which corresponds to an increase of 47.0% when compared to the value obtained in plants that did not receive potassium fertilization (Figure 3B). In a field experiment carried out in Rio Verde, Goiás State - Brazil, Martins (2015) found that, in the cotton cultivar BRS-286, the highest number of cotton balls (5.36) was found at a dose of approximately 200 kg ha^{-1} of K_2O.

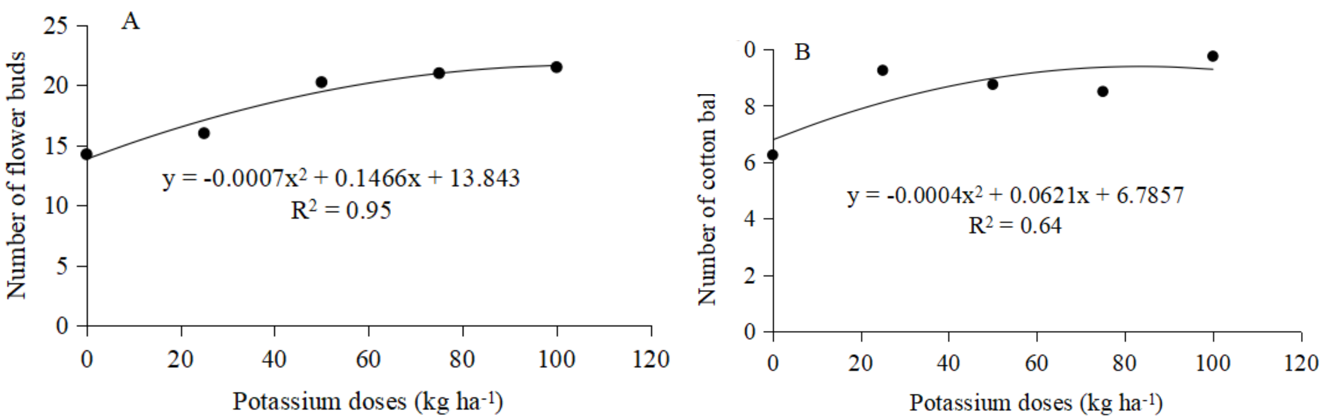

Figure 3. Number of floral buds (A) and number of cotton balls (B) of cotton plants grown under different doses of potassium in the Cariri region.

Conclusions

Potassium doses between 65 and 100 kg ha^{-1} of K_2O maximized the growth, dry matter and production components of the cotton plant in the soil and climate conditions of the Cariri region, northeastern Brazil.

References

ABRAPA. (2023). Algodão no mundo. Disponível em: https://abrapa.com.br/Paginas/dados/algodao-no-mundo.aspx. Acesso em: 01 dez. 2023.

CONAB. (2023). Acompanhamento da safra brasileira. Disponível em: https://www.conab.gov.br/info-agro/safras/serie-historica-das-safras. Acesso em: 28 dez. 2023.

Dewdar, M. H., & Rady, Mostafa. (2013). Influence of soil and foliar applications of potassium fertilization on growth, yield and fiber quality traits in two Gossypium barbadense L. varieties. African Journal of Agricultural Research, 8 (19), 2211-2215. https://doi.org/10.5897/AJAR12.1861

EMBRAPA. (2017). Programa busca retomada da produção de algodão no Ceará, Brasília, DF. Disponível em: https://www.embrapa.br/busca-de-noticias/-/noticia/30248953/programa-busca-retomada-da-producao-de-algodao-no-ceara. Acesso em: 25 dez. 2023.

Ferreira, D. F. (2011). Sisvar: a computer statistical analysis system. Ciência e Agrotecnologia, 35 (6), 1039-1042. https://doi.org/10.1590/S1413-70542011000600001

Fontana, J. E., Wang, G.,Sun, R.; Xue, H., Li, Q.,Liu, J., Davis, K. E.,Thornburg, T. E., Zhang, B., Zhang, Z., & Pan, X. (2020). Impact of potassium deficiency on cotton growth, development and potential microRNA-mediated mechanism.Plant Physiology and Biochemistry, 153, 72-80. https://doi.org/10.1016/j.plaphy.2020.05.006

Hatfield, J.L., & Dold, C. (2019). Water-use efficiency: advances and challenges in a changing climate. Frontiers in Plant Sciense, 10 (103). https://doi.org/10.3389/fpls.2019.00103

He, Y., Li. R., Lin, F., Xiong, Y., Wang, L., Wang, B., Guo, J., & Hu, C. (2019). Transcriptome changes induced by different potassium levels in banana roots. Plants, 9 (1). https://doi.org/10.3390/plants9010011

Hu, W., Yang, J., Meng, Y., Wang, Y., Chen, B., Zhao, W., Oosterhuis, D. M.,& Zhou, Z. (2015). Potassium application affects carbohydrate metabolism in the leaf subtending the cotton (Gossypium hirsutum L.) boll and its relationship with boll biomass. Field Crops Research, 179, 120-131. https://doi.org/10.1016/j.fcr.2015.04.017

Hussain, S., Ali, H., & Gardezi, S. T. R. (2021). Soil applied potassium improves productivity and fiber quality of cotton cultivars grown on potassium deficient soils. Plos One, 16(4). https://doi.org/10.1371/journal.pone.0250713

IBGE. (2023). Levantamento sistemático da produção agrícola. Disponível em: https://www.ibge.gov.br/estatisticas/economicas/agricultura-e-pecuaria/9201levantamento-sistematico-da-producao-agricola.html?=&t=resultados. Acesso em: 28 dez. 2023.

Keya, S.S., Mostofa, M.G., Rahman, M.M., Kumar, A., Sultana, S., Ghosh, P. K., ANIK, T.R., Ahsan, S. M., Rahman, A., Jahan, N., & Tran, L. S. P. (2023). Salicylic acid application improves photosynthetic performance and biochemical responses to mitigate saline stress in cotton. Journal of Plant Growth Regulation, 42, 5881-5894. https://doi.org/10.1007/s00344-023-10974-5

Köppen, W., & Geiger, R. (1928). Klimate der Erde. Gotha: Verlag Justus Perthes.

Lima, B. L. C., Silva, E. F. F., Bezerra, J. R. C., Silva, G. F., Cruz, F. J. R., Santos, P. R., & Campeche, L. F. S. M. (2019). Agronomic performance of colored cotton influenced by irrigation with treated domestic sewage and potassium fertilization in semiarid region of Brazil. Dyna, 86 (210), 74-80. https://doi.org/10.15446/dyna.v86n210.77022

Lima, G. G., & Ribeiro, S. C. (2012). Geomorfologia e paisagem do município de Juazeiro do Norte/CE: relações entre a natureza semiárida e os impactos antrópicos. Revista Geonorte, 2 (4), 520 – 530.

Loka, D. A., Oosterhuis, D. M., Baxevanos, D., Vlachostergios, D., & Hu, W. (2019). How potassium deficiency alters flower bud retention on cotton (Gossypium hirsutum L.). Archives of Agronomy and Soil Sciense, 65 (4), 521-536. https://doi.org/10.1080/03650340.2018.1511894

Martins, Y. A. M. (2015). Comportamento de cultivares de algodão submetidas a diferentes níveis de recomendação de potássio em dois sistemas de cultivo [Dissertação de mestrado]. Instituto Federal de Educação, Ciência e Tecnologia Goiano.

Naciri, R., Lahrir, M., Benadis, C., Chtouki, M., & Oukarroum, A. (2021). Interactive effect of potassium and cadmium on growth, root morphology and chlorophyll a fluorescence in tomato plant. Scientific Reports, 11(1). https://doi.org/10.1038/s41598-021-84990-4

Pantha, P., Oh, D-H., Longstreth, D., Dassanayake, M. (2022). Living with high potassium: balance between nutrient acquisition and K-induced salt stress signaling. Plant Physiology. 191(2), 1102–1121. https://doi.org/10.1093/plphys/kiac564

Pettigrew, W. (2008). Potassium influences on yield and quality production for maize, wheat, soybean and cotton. Physiologia Plantarum, 133 (4), 670-681. https://doi.org/10.1111/j.1399-3054.2008.01073.x

Raper, T. (2017). Cotton and potassium: Background and the potential to increase efficiency. Crops and Soils, 51 (1), 16-19. https://doi.org/10.2134/cs2018.51.0103

Shao, J., Dong, H., Jin, Y., Li, P., Sun, M., Feng., & Zheng, C. (2023). Effects of soil potassium levels on dry matter and nutrient accumulation and distribution in cotton. Journal of Cotton Research, 6 (10). https://doi.org/10.1186/s42397-023-00145-y

Tian, H., Sun, H., Zhu, L., Zhang, K., Zhang, Y., Zhang, H., Zhu, J., Liu, X., Bai, Z., Li, A., Tian, L., Liu, L., & Li, C. (2023). Response of in situ root phenotypes to potassium stress in cotton. PeerJ, 11. https://doi.org/10.7717/peerj.15587

UFC. (1993). Recomendações de adubação e calagem para o Estado do Ceará. Fortaleza: Imprensa Universitária, 247p.

Vidal, V. M., Soares, F. A.L., Teixeira, M. B., Sousa, A. E. C., & Cunha, F. N. (2017). Potassium fertilization and soil management systems for cotton crops. Revista Caatinga, 30 (3), 568 – 577. https://doi.org/10.1590/1983-21252017v30n304rc

Wakeel, A., H.U. Rehman., & H. Magen. (2017). Potash use for sustainable crop production in Pakistan: A review. International Journal of Agriculture & Biology,19 (3), 381-390. https://doi.org/10.17957/IJAB/15.0291

Wu, X., Wang, D., Riaz, M., Zhang, L., & Jiang, C. (2019). Investigating the effect of biochar on the potential of increasing cotton yield, potassium efficiency and soil environment. Ecotoxicology and Environmental Safety, 182 (30). https://doi.org/10.1016/j.ecoenv.2019.109451