ISSN 1808-8546 (ONLINE) 1808-3765 (CD-ROM)

USO DA FERTIRRIGAÇÃO PARA MANEJO EFICIENTE DA ADUBAÇÃO POTÁSSICA NA CULTURA DA BETERRABA

JUVENALDO FLORENTINO CANJA[1]; BENITO MOREIRA DE AZEVEDO[2]; MATHEUS AMORIM FERREIRA[2]; BRUNO HARRISSON DA SILVA MENDONÇA[2]; FRANCISCO HERMESON RODRIGUES COSTA[2] E ALEXSANDRO OLIVEIRA DA SILVA[3]

[1]Instituto de Desenvolvimento Rural, Universidade da Integração Internacional da Lusofonia Afro-Brasileira, Avenida da Abolição, 3 – Centro, 62790-000, Redenção – CE, Brasil, e-mail: batchijuve@gmail.com; ORCID (https://orcid.org/0000-0002-1342-4326)
[2] Departamento de Engenharia Agrícola, Universidade Federal do Ceará, Av. Mr Hull, Pici, 60455-760, Fortaleza-CE. Brasil, e-mail: benito@ufc.br; brunoharrisson5@gmail.com; hermesonrc@gmail.com; ORCID (https://orcid.org/0000-0001-7391-1719, https://orcid.org/0000-0002-9276-8177)
[3] Departamento de Engenharia Agrícola, Universidade Federal Rural de Pernambuco, rua dom Manoel de Medeiros, Dois Irmãos, 52171-900, Recife, PE, Brasil, e-mail: alexsandro.osilva@ufrpe.br; ORCID (https://orcid.org/0000-0001-5528-9874)

1 RESUMO

O uso da técnica de fertirrigação pode aumentar a eficiência do uso de fertilizantes pelas culturas possibilitando maiores produtividades. O objetivo deste trabalho foi determinar o potencial de produção e desenvolvimento da cultura da beterraba submetida a diferentes doses e formas de aplicação de potássio. O experimento foi realizado, na cidade de Fortaleza, Ceará, Brasil, entre agosto e outubro de 2022, em condições de campo com delineamento experimental em blocos casualizados, com quatro doses de potássio (0, 60, 120 e 240 kg ha^{-1}) e duas formas de aplicação (convencional e fertirrigada), com quatro repetições. Na adubação convencional foram aplicadas as doses de potássio na fundação e cobertura sendo parceladas em 60 e 40%, respectivamente. Na adubação fertirrigada foi feita a aplicação semanalmente. Foram avaliados altura da planta, número de folhas, diâmetro do tubérculo, comprimento do tubérculo, massa fresca do tubérculo, massa seca das folhas e produtividade. A forma de aplicação fertirrigada promoveu maior altura da planta, diâmetro do tubérculo, massa seca das folhas, massa fresca do tubérculo e produtividade, entretanto não foram observadas alterações no comprimento do tubérculo entre as formas de aplicação. Recomenda-se o uso de 176 kg ha^{-1} de K_2O para aplicação via fertirrigação e 240 kg ha^{-1} de K_2O para aplicação via adubação convencional na cultura da beterraba.

Palavras-chaves: *Beta vulgaris* L., potássio, quimigação.

CANJA, J. F.; AZEVEDO, B. M.; FERREIRA, M. A.; SILVA, B.H.; COSTA, F. H. R.; SILVA, A. O.
USE OF FERTIGATION FOR EFFICIENT MANAGEMENT OF POTASSIUM FERTILIZATION IN BEETROOT CROPS

Recebido em 05/11/2025 e aprovado para publicação em 10/12/2025
DOI: http://dx.doi.org/10.15809/irriga.2025v30p165-177

2 ABSTRACT

The use of fertigation can increase the efficiency of fertilizer use by crops, thereby increasing yields. The objective of this work was to determine the production and development potential of beet crops subjected to different doses and forms of potassium application. The experiment was conducted in Fortaleza, Ceará, Brazil, from August to October 2022 under field conditions using a randomized block design with four potassium application rates (0, 60, 120, and 240 kg ha^{-1}) and two application methods (conventional and fertigation), with four replications. In the conventional fertilization treatment, potassium was applied at planting and as topdressing, which were split into 60% and 40%, respectively. In the fertigation treatment, potassium was applied weekly. The following parameters were evaluated: plant height, number of leaves, tuber diameter, tuber length, fresh mass, dry mass, and yield. Increased plant height, tuber diameter, leaf dry mass, fresh tuber mass, and yield were associated with increased fertigation; however, no differences in tuber length were observed between the application methods. The application of 176 kg ha^{-1} K_2O via fertigation and 240 kg ha^{-1} K_2O via conventional fertilization for beetroot cultivation is recommended.

Keywords: *Beta vulgaris* L.*;* potassium; quimigation

3 INTRODUCTION

Beetroot (*Beta vulgaris) Amaranthaceae (*L.) is a tuberous vegetable native to Europe and belongs to the Amaranthaceae family. It is an annual, herbaceous crop that produces an edible tuberous root that is spherical to flattened-globular in shape and has a very sweet taste (Filgueira, 2008). Although it has adapted to low temperatures, its introduction to the northeast region of Brazil, characterized by high temperatures, is relatively recent because of the genetic improvement of this crop (Ebmeyer; Fiedler-Wiechers; Hoffmann, 2021). Therefore, understanding the ideal soil fertility conditions and fertilization needs for this crop is essential.

Among the elements necessary for agricultural crops, potassium (K) plays several vital roles in the growth and development of vegetables, including beetroot (Artyszak; Gozdowski; Siuda, 2021; Silva; Silva; Klar, 2017; Xie *et al.,* 2022), and contributes to the proper development of tubers (Aksu; Altay, 2020b; Silva Silva; Klar, 2016; Silva *et al.,* 2015). Furthermore, potassium is associated with improved color, flavor, and resistance of vegetables to storage after harvest, making them more appealing to consumers (Aksu; Altay, 2020a; Artyszak; Gozdowski; Siuda, 2021). Therefore, ensuring adequate K levels in the soil is fundamental for plant growth and the production of high-quality crops, providing benefits for both farmers and consumers. Proper management of this nutrient is essential for optimizing the productivity and quality of cultivated vegetables (Barbosa *et al*., 2024; El-Mageed *et al*., 2022; Yan *et al*., 2022).

The conventional application of fertilizers is so called because it is a common and widely used practice in agriculture. However, it is important to mention that in some situations, this form of fertilization may present some limitations, such as the loss of nutrients through leaching in sandy soils (Demattê; Demattê, 2024)or the difficulty in achieving a homogeneous distribution of nutrients in large areas, which can increase fertilizer costs and often reduce the productive potential of crops (Shahena *et al*., 2021).

Among the fertilizers with the highest risk of loss, potassium fertilizers stand out, as they tend to move easily in the soil solution and, in some cases, can be washed to depths below the root zone, where plant roots cannot reach them, resulting in low availability of the nutrient for plants, thus reducing its effectiveness as a fertilizer (Silva; Silva; Bassoi, 2016).

One strategy to optimize the use of fertilizers such as K_2O, which is commonly used, is fertigation (Parra, 2019; Silva *et al*., 2024). This practice consists of injecting fertilizers into the irrigation system to transport the nutrients needed by plants (Kumar; Singh; Pathania, 2022; Parra, 2019), taking into account characteristics such as water quality (Lira *et al*., 2019) and fertilizer solubility. With respect to fertigation, it is possible to adjust the amounts of nutrients according to the specific demands of each plant growth phase. This precision in application contributes to a more efficient use of inputs and avoids the excess or scarcity of nutrients, favoring the healthy development of crops (Silva; Silva; Klar, 2016; Kumar; Singh; Pathania, 2022).

Given the above, the objective of this work was to determine the production and development potential of beetroot subjected to different doses and forms of potassium application.

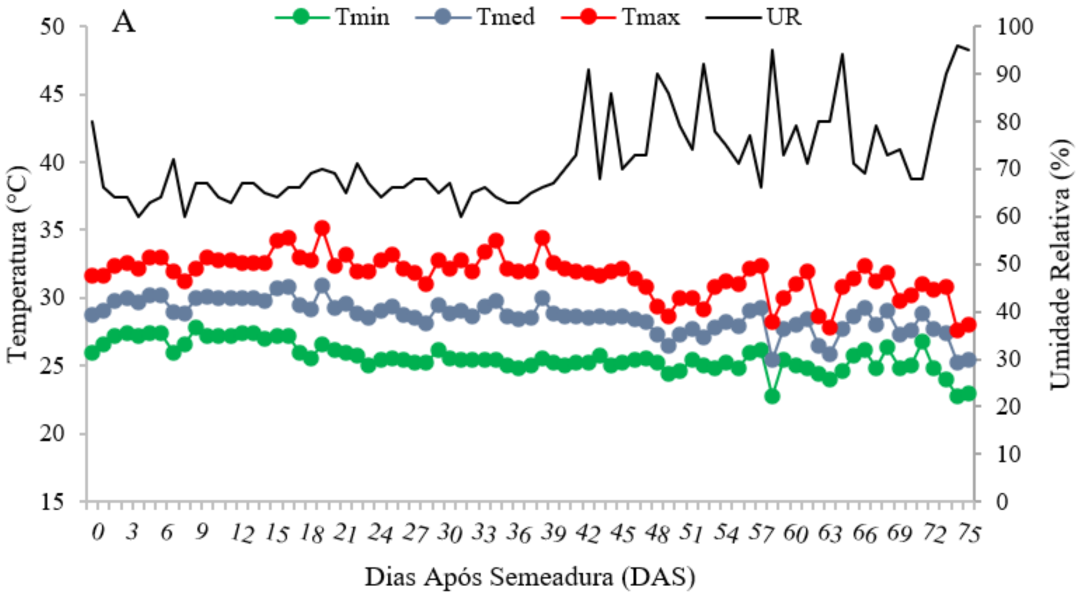
4. MATERIALS AND METHODS

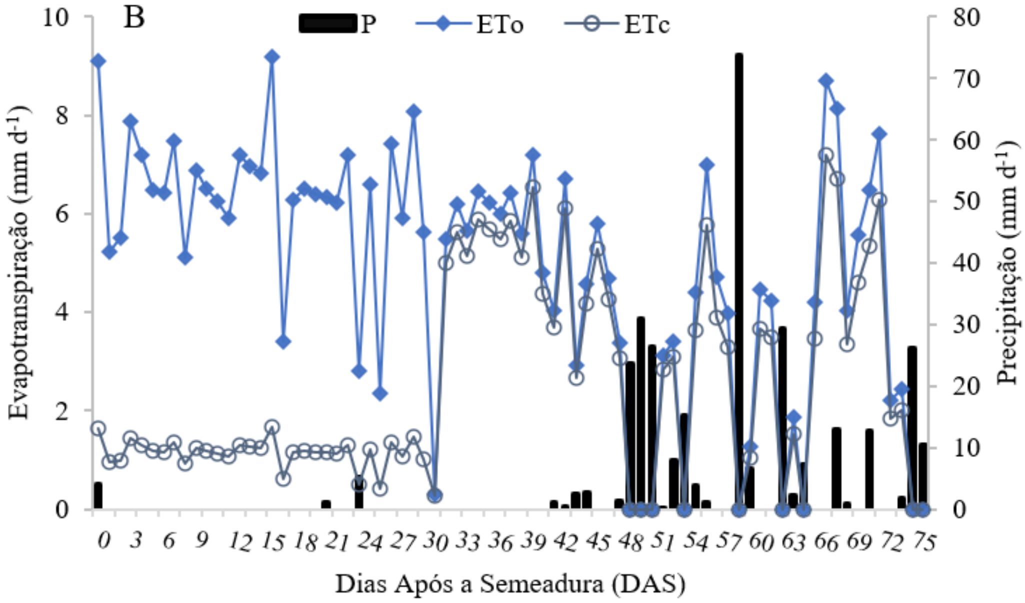
4.1 Location and characteristics of the experimental area

The experiments were conducted in the experimental area of the Meteorological Station of the Department of Agricultural Engineering, Federal University of Ceará, Pici Campus, between August and October 2022. The experimental area is located in the city of Fortaleza, Ceará, Brazil, at an altitude of 19.5 m, latitude 03°43'02” S and longitude 38°32'35” W and 19.5 m. The climate of the region, according to the Köppen climate classification, is type Aw' (tropical rainy, very hot, with predominant rainfall in the summer and autumn seasons), with an average temperature of 26.5°C (Nogueira *et al*., 2023).

During the experiments, climate data were obtained from an automatic weather station located 10 meters from the experimental site. An average temperature of 28.6°C and a relative humidity of 72% were observed (Figure 1A). The cumulative precipitation was 310 mm, with the highest rainfall occurring in the last 20 days (183.5 mm) before the experiment ended (Figure 1B). The reference evapotranspiration (ETo) and crop evapotranspiration (ETc) averaged 4.90 mm d^{-1} and 2.50 mm d^{-1}, respectively.

Figure 1. Climatic data during the experiment.





Source: Author (2024)

The soil in the experimental area is classified as a red–yellow argisol with a sandy loam texture (Santos *et al*., 2018). Soil samples were collected at a depth of 0–0.20 m before the experiment was set up for analysis of the chemical and physical attributes of the soil (Table 1).

Table 1. Chemical and granulometric attributes of the 0–0.20 m layer of clayey soil.

pH	**CE**	**MO**	**P**	**K^+**	**Ca^{2+}**	**In**	**Mg^2**	**$H+Al^3$**	**SB**	**PST**	**V**
H2O	dS m^{-1}	g.kg^{-1}	--mg.kg^{-1} --		---------------cmol $_c$ .dm^{-3} ------------					---- (%) ---	
6.4	0.9	0.93	103	0.4	0.5	0.05	0.3	3.96	1.07	4	58.3

Clay	Silt	Total sand	Coarse sand	Fine sand
-----------------	---------------	g.kg^{-1}	---------------	-----------------
195	50	755	ns	ns

pH – hydrogen ion potential; OM – organic matter; P – phosphorus; K – potassium; Ca – calcium; Na – sodium; Mg – magnesium; H + Al – potential acidity; SB – sum of bases; V – base saturation; S – sulfur; EC – electrical conductivity.

Beetroot seeds of the early wonder cultivar were sown at a depth of 2 cm on top of the soil in beds that were 1.2 m wide and 0.3 m high, with three seeds per hole and a spacing of 0.3 × 0.15 m. During cultivation, weed control was carried out by weeding. After emergence, only one plant per hole was maintained. Planting fertilization was carried out using 17.4 kg ha^{-1} of urea (45% N), 38.4 kg $^{ha^{-1}}$ of potassium chloride (58% K_2O) and 116 kg ha^{-1} of single superphosphate (18% P_2O_5, 16% Ca, and 10% S). Topdressing (160 kg ha^{-1} of N) was based on the standards of [reference needed Tivelli *et al.* (2011)].

4.2. Experimental design and conduct

The experimental design was a randomized block design, with four potassium doses (0, 60, 120, and 240 kg ha^{-1} of K_2O) and two application methods (conventional and fertigation), totaling 32 experimental plots with four replications. Each plot consisted of 10 plants, totaling 320 plants in the experiment. For evaluation, the eight central plants of each plot were considered, and the border plants were discarded.

The irrigation system used was drip irrigation, with emitters having a flow rate of 1.5 L h^{-1} and an operating pressure of 10 mca. (Bernardo *et al.*, 2019)A centrifugal pump with a power of 0.5 hp was used. Irrigation management was carried out using climatic data, with the irrigation depth estimated by crop evapotranspiration (ETc) obtained through the product of ETo (Penman). Monteith - FAO) was used for the crop coefficient (Kc) as per [reference needed Allen, Pereira e Raes (1998)]. The location coefficient (Kl) was used to determine the localized evapotranspiration (ε $ETc_{loc} = ETc \times Kl$), which was obtained on the basis of the area occupied by the plants in relation to the total area (Bernardo *et al.*, 2019; Frizzone *et al.*, 2012). The spacing used between the drip tapes and emitters was equal to the crop spacing, with one emitter per plant. The efficiency of the irrigation system (Ea = 90%) was determined by the distribution uniformity (UD = 91%) and adequately irrigated area (AR = 90%) according to Frizzone. *et al.* . (2012).

A fertigation system was set up with an injector pump with a flow rate of 30 L h^{-1}, in which potassium fertilizer was inserted into reservoirs for suction and insertion into the system (Parra, 2019), which was used weekly for potassium doses via the application of potassium chloride (58% K2O).

4.3 Variables analyzed

After the plants were harvested, which occurred 80 days after sowing (DAS), the variables were analyzed, and five plants per experimental plot were manually removed at random.

Plant height (PH) was obtained by measuring the plants from the soil surface to the most developed leaf using a tape measure. The number of leaves (NL) was obtained by manual counting. The variables of tuber diameter (DT) and tuber length (CT) were obtained using a digital caliper (cm). The variable tuber fresh matter mass (TFM) was obtained after the tuber was separated from the leaves, which were weighed on a precision balance to 0.01 g. The variable leaf dry matter mass (LDM) was obtained after the plant material was packaged in paper bags and subjected to a constant temperature of 65°C in a drying oven until the samples reached a constant weight (approximately 48 h); the material was weighed on a precision balance (0.01 g). The variable productivity (P) was obtained considering the tuber fresh mass and the crop spacing and was estimated for an area of 1 ha.

The results were subjected to ANOVA (F test) using *R statistics software*. When significant at the 1% ($p<0.01$) or 5% ($0.05 < p$) probability level according to the F test, linear and quadratic regression models were used to estimate the behavior of the data.

5 RESULTS AND DISCUSSION

In the summary of the analysis of variance for the application methods (FA) factor, Table 2 shows a significant effect ($p<0.05$) for all the variables studied, except for the NF variable. With respect to the K2O dose factor, all the variables were influenced ($p<0.01$), whereas with respect to the interaction of the factors (FA × dose), only the NF variable was not influenced by the applied treatments.

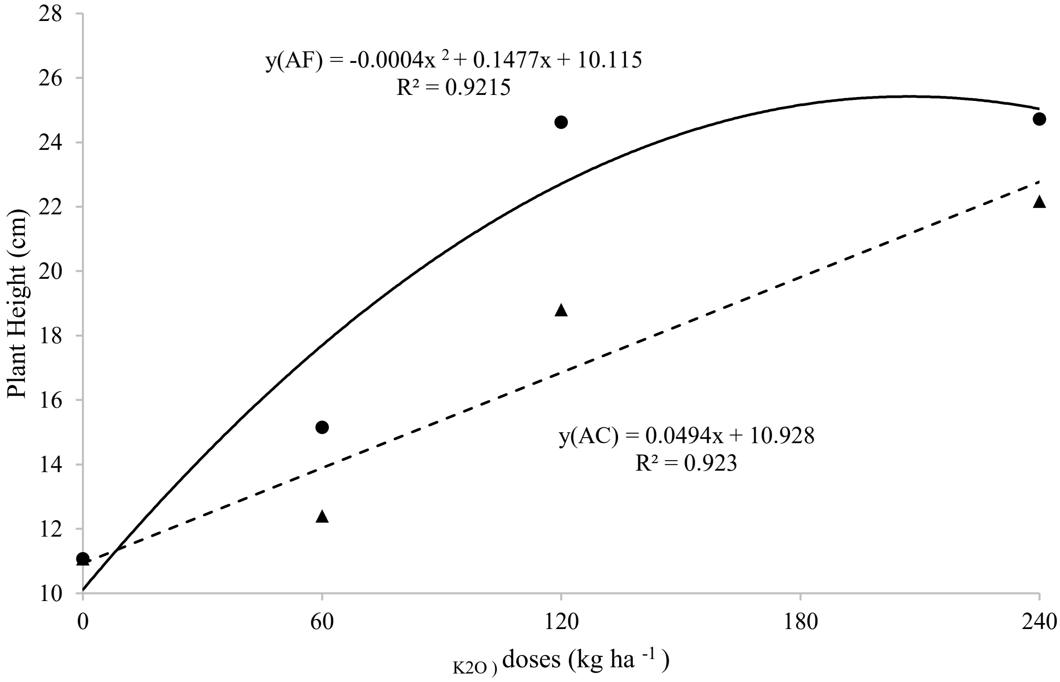
Table 2. Summary of the analysis of variance for the variables plant height (PH), number of leaves (NL), tuber diameter and length (TD and TL), tuber dry mass (TDM), leaf dry mass (LDM) and commercial yield (Y) of beet as a function of different potassium doses and application methods.

		Medium square						
FV	**GL**	**AP**	**NF**	**DT**	**CT**	**MFT**	**MSF**	**P**
Blocks	3	3.0 *	0.2 ns	0.9 ns	0.03 ns	77.4	1.2 **	470488.3 ns
FAN	1	61.8 **	0.7 ns	4.4 **	1.4 **	807.1 **	37.7 **	3992928.8 **
Doses (D)	3	288.8 **	19.5 **	19.7 **	14.7 **	1418.3 **	73.6 **	59569375.8 **
FA x D	3	11.36 **	0.9 ns	0.6 *	0.3 **	175.9 *	8.1 **	2213461.7 **
Residue	21	0.8	1.7	0.1	0.07	41.1	1.2	447021.2
CV (%)		5.33	16.92	13,13	8.88	10.33	12.92	10.62

FV – source of variation; GL – degrees of freedom; FA – application methods; Doses – doses of K2O; CV – coefficient of variation; ns – not significant; ** and * – significant at 0.01 and 0.05, respectively, according to Tukey's test.

The behavior of the AP variable as a function of different K_2O doses applied in conventional fertilization (AC) and fertigation fertilization (AF) for the beet production cycle is shown in Figure 2. For AF, the quadratic polynomial model was the most suitable, with the highest observed K_2O dose of 184.62 kg ha^{-1} for a maximum AP of 23.75 cm. For AC, the fit was linear, with a maximum AP of 22.78 cm.

Figure 2. Beetroot plant height as a function of the dose of potassium and method of application.

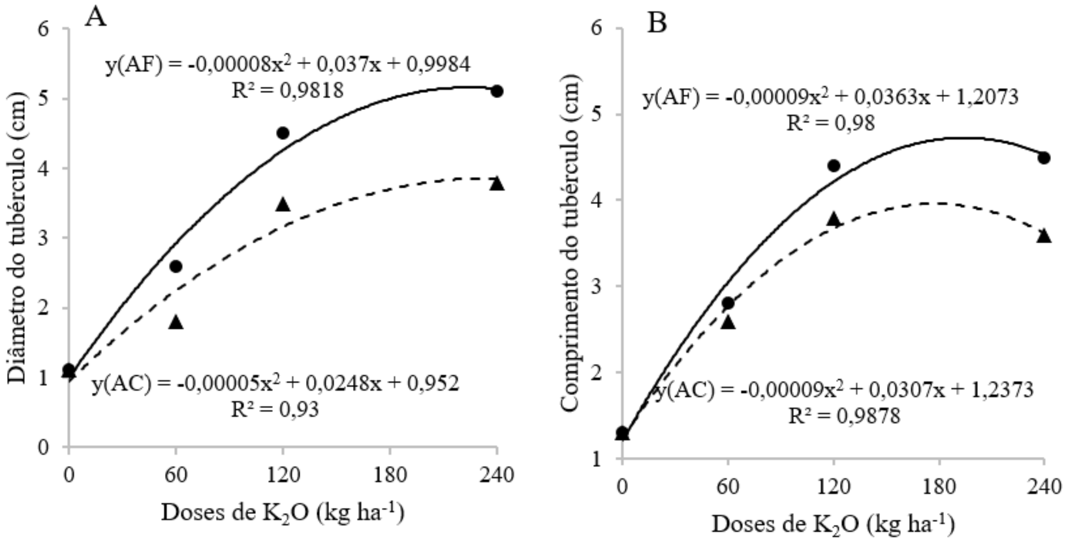


Source: Author (2024)

In studies on fertigation management in beet cultivation, Silva; Silva e Klar (2015)values close to 41 cm for AP were observed, differing from those observed in the present study. However, the transplanting technique and differences in the cultivation of this vegetable may have contributed to the observed differences. Higher doses of K_2O contributed to the development of the crop, in agreement with the results obtained in the literature, in which K is among the elements with the highest absorption by the crop, contributing to its adequate development (Artyszak; Gozdowski; Siuda, 2021; Silva; Silva; Klar, 2017).

The behavior of the DB variable as a function of different doses of K_2O applied conventionally and via fertigation is shown in Figure 3A. The adjustment was quadratic for both forms of K_2O application, where the maximum values for the DB variable were 5.27 cm for optimal doses of 231.25 kg ha^{-1} and 4.03 cm for 248 kg ha^{-1} of K_2O for AF and AC, respectively. The behavior of the CB variable, where the adjustment was quadratic for both fertilization methods, with the maximum values for the variable being 4.87 cm for an optimal dose of 201.7 kg ha^{-1} of K_2O and 3.85 cm for 170 kg ha^{-1} of K_2O, respectively, for AF and AC (Figure 3B).

Figure 3. Diameter (A) and length (B) of the beet bulb as a function of the dose of potassium and method of application.

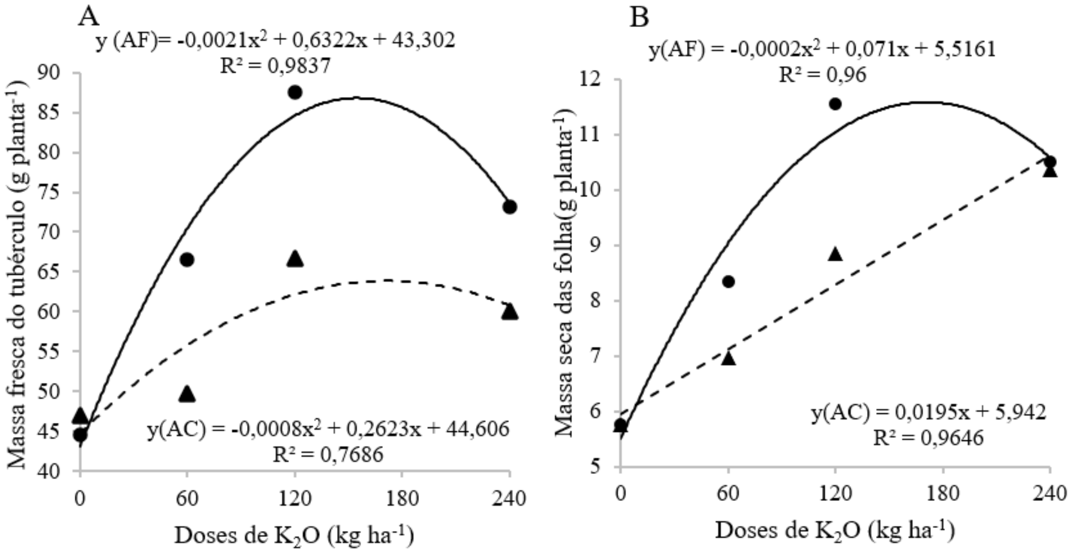


Source: Author (2024)

Potassium ions ($^{K+}$) present in the soil solution can be adsorbed by the soil, absorbed by plants, or leached. Therefore, potassium losses due to leaching are significant and require greater caution in crops grown in sandy soils. This favors the use of localized irrigation systems and fertigation (Silva *et al.*, 2020; Yan *et al.*, 2022), as these factors promote greater development of vegetables such as beetroot. The moisture content, close to field capacity (Gabriel Filho *et al.*, 2022; Silva *et al.*, 2015), maintained by drip irrigation systems, along with adequate potassium fertilization, (El-Mageed *et al.*, 2022)favors tuber development and other growth parameters in this crop.

For tuber fresh mass (TFM) and leaf dry mass (LDM), the behavior of these variables as a function of different potassium doses applied through conventional fertilization and fertigation is shown in Figure 4. For the MFT variable (Figure 4A), a quadratic fit was observed for K_2O doses via AF, with the highest MFT values (90.9 g $^{\text{plant}^{-1})}$ observed for the 150.5 kg ha^{-1} K_2O dose. For application via AC, the fit was quadratic, with the highest MFT values observed (66.11 g $\text{plant}^{-1)}$ for the 163.9 kg ha^{-1} K_2O dose· For the MSF variable (Figure 4B), K_2O doses via AF were fitted to the quadratic model, with the highest values observed (11.8 g $\text{plant}^{-1)}$ at 177.5 kg ha^{-1} ^{K_2O}. For application via AC, the fit was linear, with an increase of 0.0195 g plant^{-1} $^{\text{for each}}$ K_2O dose applied.

Figure 4. Fresh beetroot pulp and dried beetroot leaf pulp as a function of the dose of potassium and method of application.

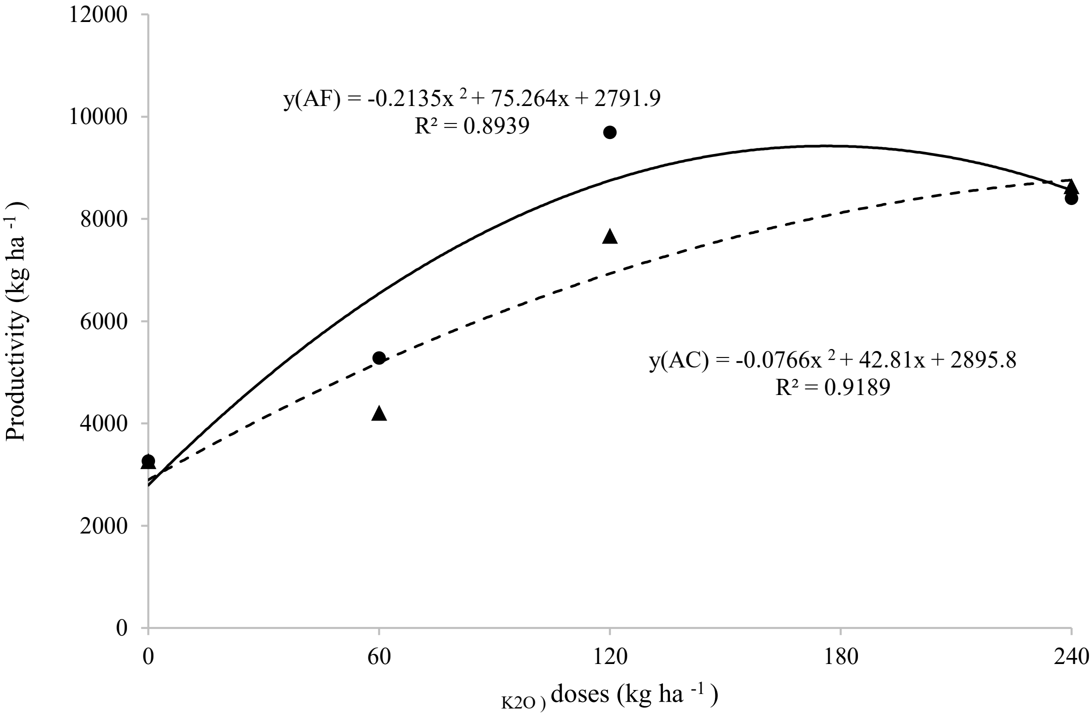


Source: Author (2024)

Among the advantages observed with the application of K_2O via fertigation in this experiment, the reduction in applied doses compared with conventional fertilization stands out, providing better results with smaller quantities of applied fertilizer. The results of this research corroborate the studies of [reference needed] El-Mageed *et al.* (2022), in which the authors observed that the use of 144 kg ha^{-1} of K_2O provided the best results for beet cultivation. However, the soil fertility conditions, climatic conditions, and cultivar may affect the dose applied to this crop.

For productivity, the behavior as a function of different potassium doses applied through conventional fertilization and fertigation are shown in Figure 5. For all the cases studied, the quadratic model proved to be the most suitable, with the highest observed values for the variable P of 9,425 (VF) and 8,758 (AC) kg ha $^{-1}$ as a function of doses of 176.26 and 240 kg ha $^{-1}$ of K2O, respectively.

Figure 5. Commercial productivity of sugar beet as a function of the dose of potassium and method of application.



Source: Author (2024)

These results highlight the need for correct fertilizer application, as well as adequate doses of K_2O, which can maximize productivity while optimizing costs. This is because the absorption of K by the crop is high, and excessive applications can lead to luxury consumption Silva, Silva e Klar (2017), as demonstrated in studies on nutrient accumulation in beet crops. In addition to productivity, the application of potassium fertilizers can improve other important crop attributes, such as the concentration of sugar (Artyszak; Gozdowski; Siuda, 2021), increase water availability through drought tolerance (Aksu; Altay, 2020b), and increase commercial value. Silva, Silva e Klar (2016),Studies on fertigation in beet crops have shown that increased soil electrical conductivity due to fertilization, exceeding 4 dS m^{-1}, can negatively affect crop productivity; therefore, it is important to split fertilizer applications throughout the cycle.

6 CONCLUSION

The application of potassium fertilizers via fertigation has proven to be efficient, increasing productivity and optimizing the applied dose.

The use of 176 kg ha^{-1} of K2O for fertigation and 240 kg ha^{-1} of K2O for conventional fertilization in beet cultivation is recommended.

Splitting potassium fertilization during beet cultivation can be an important strategy for reducing losses due to leaching, but further research on this topic is needed.

7 REFERENCES

AKSU, G.; ALTAY, H. The effects of potassium applications on drought stress in sugar beet: part I. sugar beet quality components. **Journal of Scientific Perspectives** , Çanakkale , v. 4, no. 2, p. 157-168, 2020a.

AKSU, G.; ALTAY, H. The effects of potassium applications on drought stress in sugar beet. **Sugar Tech** , New Delhi, vol. 22, no. 6, p. 1092-1102, 2020b. DOI: https://doi.org/10.1007/s12355-020-00851-w. Available at: https://link.springer.com/article/10.1007/s12355-020-00851-w. Accessed on: 12 Mar. 2026.

ALLEN, RG; PEREIRA, LS; RAES, D. **Crop evapotranspiration: guidelines for computing crop water requirements** . Rome : FAO, 1998. (Irrigation and Drainage Paper , no. 56). Available at: https://www.fao.org/4/x0490e/x0490e00.htm. Accessed on: May 5, 2020.

ARTYSZAK, A.; GOZDOWSKI, D.; SIUDA, A. Effect of the application date of fertilizer containing silicon and potassium on the yield and technological quality of sugar beet roots. **Plants** , Bassel, vol. 10, no. 2, p. 1-12, 2021.

BARBOSA, A.; SOUSA, GG; SOUZA, MVP; FREIRE, MHC; GOES, GF; PEREIRA, AP A; VIANA, TVA; COSTA, RN T.; LACERDA, CF; SILVA, G. F.; ROLIM, MM. Brackish Water, Phosphate Fertilization and Trichoderma in the Agronomic Performance of Beet Crops. **Agronomy** , Basel, v. 14, n. 6, article 1306, 2024. Available at: https://www.mdpi.com/2073-4395/14/6/1306. Accessed on: March 4, 2025.

BERNARDO, S.; MANTOVANI, EC; SILVA, DA; SOARES, AA. **Irrigation Manual** . 9th ed. Viçosa, MG: UFV, 2019. 545 p.

DEMATTÊ, JLI; DEMATTÊ, JAM. **Management of sandy soils** : fundamentals and applications. 1st ed. Piracicaba: LSO: ESALQ, 2024. 350 p. Available at: https://doi.org/10.11606/9786587391496. Available at: https://www.livrosabertos.abcd.usp.br/portaldelivrosUSP/catalog/book/1403. Accessed January 12 , 2025.

EBMEYER, H.; FIEDLER-WIECHERS, K.; HOFFMANN, CM Drought tolerance of sugar beet – Evaluation of genotypic differences in yield potential and yield stability under varying environmental conditions. **European Journal of Agronomy** , Amsterdam, v. 125, article 126262, 2021.

EL-MAGEED, TAA; MEKDAD, AAA; RADY, MOA; ABDELBAKY, AS; SAUDY, HS; SHAABAN, A. Physio-biochemical and agronomic changes of two sugar beet cultivars grown in saline soil as influenced by potassium fertilizer. **Journal of Soil Science and Plant Nutrition** , Berlin , v. 22, p. 3636-3654, 2022. DOI: https://doi.org/10.1007/s42729-022-00916-7. Available at: https://link.springer.com/article/10.1007/s42729-022-00916-7. Accessed on: 05 Mar. 2026.

FILGUEIRA, FAR. **New Manual of Vegetable Growing** . 3rd ed. Viçosa, MG: UFV, 2008. 209 p.

FRIZZONE, JA; FREITAS, PSL; REZENDE, R.; FARIA, MA **Microirrigation** : drip and microsprinkler irrigation. 1st ed. Maringá : EDUEM, 2012. 356 p.

GABRIEL FILHO, LRA; SILVA, AO; GABRIEL, CPC; PUTTI, FF. Fuzzy modeling of the effect of irrigation depths on beet cultivars. **Engenharia Agrícola** , Jaboticabal, v. 42, n.1, p. e20210084, 2022. DOI: https://doi.org/10.1590/1809-4430-Eng.Agric.v42n1e20210084/2022. Available at: https://www.scielo.br/j/eagri/a/w7LFbCYLghzfkpWGXpMW9np/?lang=en. Accessed On : March 15 , 2026.

KUMAR, A.; SINGH, H.; PATHANIA, S. Potassium Fertigation Improved Growth, Yield and Quality of Kinnow Mandarin in Potassium Rich Soils. **Communications in Soil Science and Plant Analysis** , Oxfordshire, v. 53, no. 14, p. 1767-1776, 2022.

LIRA, RM; SILVA, Ê. FF; SILVA, AO; MEDEIROS, PRF; SILVA, GF; SOARES, HR. Watercress and Chinese cabbage in a hydroponic system using groundwater. **Revista Caatinga** , Mossoró, v. 32, n. 4, p. 1038-1047, 2019. DOI: https://doi.org/10.1590/1983-21252019v32n420rc. Available at: https://www.scielo.br/j/rcaat/a/VPp9bpkgdT7xqptSPPVmPqs/?lang=en. Accessed on : January 15 , 2026.

NOGUEIRA, DB; SILVA, AO; GIROLDO, AB; SILVA, APN; COSTA, BRS. Dry spells in a semiarid region of Brazil and their influence on maize productivity. **Journal of Arid Environments** , Amsterdam, v. 209, article 104892, 2023. DOI: https://doi.org/10.1016/j.jaridenv.2022.104892. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0140196322001872?via%3Dihub. Accessed on: March 22, 2026.

PARRA, IRV **Fertirrigación** : from theory to practice . 1st ed. Chillán: Editorial Universidad de Concepción, 2019. 253 p.

SANTOS, HG; JACOMINE, PKT; ANJOS, LHC; OLIVEIRA, VA; LUMBRERAS, JF; COELHO, MR; ALMEIDA, JA; ARAÚJO FILHO, JC; OLIVEIRA, JB; CUNHA, TJF. **Brazilian soil classification system** . 5th ed. Brasília, DF: Empresa Brasileira de Pesquisa Agropecuária: Centro Nacional de Pesquisas de Solos, 2018. 356 p.

SHAHENA, S.; RAJAN, M.; CHANDRAN, V.; MATHEW, L. Conventional methods of fertilizer release. In: LEWU, FB; VOLOVA, T.; THOMAS, S.; RAKHIMOL, KR (org). **Controlled release fertilizers for sustainable agriculture** . 1st ed. Amsterdam: Academic Press, 2021. Chapter 1, pp. 1-24. Available at: https://doi.org/10.1016/B978-0-12-819555-0.00001-7. Available at: https://www.sciencedirect.com/science/chapter/edited-volume/abs/pii/B9780128195550000017?via%3Dihub. Accessed January 12 , 2025.

SILVA, AO; COSTA, BRS; OLDONI, H.; SILVA, DJ; BASSOI, LH Potassium fertigation and organic fertilization in 'Syrah' grape in Northeastern Brazil: yield, must characteristics and phenolic compounds. **Oeno One** , Villenave d'Ornon , v. 58, n. 1, p. 1-11, 2024. DOI: https://doi.org/10.20870/oeno-one.2024.58.1.7799. Available at: https://oeno-one.eu/article/view/7799. Accessed on: March 15, 2025.

SILVA, AO; SILVA, BA; SOUZA, CF; AZEVEDO, BM; BASSOI, LH; VASCONCELOS, DV; BONFIM, GV; JUAREZ, JM; SANTOS, AF; CARNEIRO, FM Irrigation in the age of agriculture 4.0: management, monitoring and Precision . **Revista Ciência Agronômica** , Fortaleza, v. 51, p. 1-17, 2020. DOI: https://doi.org/10.5935/1806-6690.20200090. Available at: https://periodicos.ufc.br/revistacienciaagron omica/article/view/84922. Accessed on: January 22, 2026.

SILVA, AO; SILVA, DJ; BASSOI, LH Nitrate and potassium concentration in fertigated soil cultivated with wine vines. **Science and Agrotechnology** , Lavras, v. 40, n. 3, p. 305-316, 2016.

SILVA, AO; SILVA, Ê. FF; KLAR, AE. Accumulation and export of macronutrients in beetroot under different fertigation and salinity management. **Bragantia** , Campinas, v. 76, n.1, p.125-134, 2017.

SILVA, AO; SILVA, Ê. FF; KLAR, AE. Management of fertigation and soil salinity in the growth of beet crops. **Agricultural Engineering** , Jaboticabal, v. 35, n. 2, p. 320-241, 2015. DOI: https://doi.org/10.1590/1809-4430-Eng.Agric.v35n2p230-241/2015. Available at: https://www.scielo.br/j/eagri/a/WBH8rPZ7fDpzYywvvpX9g7q/?lang=pt. Accessed On : March 12 , 2026.

SILVA, AO; SILVA, YES. FF; KLAR, AE Yield of beet cultivars under fertigation management and salinity control in a protected environment. **Chilean Journal of Agricultural Research** , Chillán , v. 76, no. 4, p. 463-470, 2016.

SILVA, AO; SILVA. Ê. FF; BASSOI, LH; KLAR, AE. Development of beet cultivars under different soil water tensions. **Horticultura Brasileira** , Brasília, DF, v. 33, n. 1, p. 12-18, 2015. DOI: https://doi.org/10.1590/S0102-053620150000100003. Available at: https://www.scielo.br/j/hb/a/WnV6F67yR3Pv33JSGZLkPhx/?lang=pt. Accessed on: March 15, 2026.

TIVELLI, SW; FACTOR, TL; TERAMOTO, JRS; FABRI, EG; MORAES, ARA; TRANI, PE; MAY, A. **Beetroot** : from planting to marketing. Campinas: IAC, 2011. 45 p. (Technical Bulletin, no. 210).

XIE, X.; Zhu, Q.; Xu, Y.; MA, X.; DING, F.; LI, G. Potassium Determines Sugar Beets' Yield and Sugar Content under Drip Irrigation Condition. **Sustainability** , Basel, v. 14, no. 19, article 12520, 2022. DOI: https://doi.org/10.3390/su141912520. Available at : https://www.mdpi.com/2071-1050/14/19/12520. Accessed On : March 12 , 2026.

YAN, F.; XIAOQIANG, L.; WENQIANQ, B.; FAN, J.; ZHANG, F.; XIANG, Y.; HOU, X.; PEI, S.; DAI, Y.; ZENG, H.; WANG, Y. Multiobjective optimization of water and nitrogen regimes for drip-fertigated sugar beet in a desert climate. **Field Crops Research** , Amsterdam, vol. 288, article 108703, 2022. DOI: https://doi.org/10.1016/j.fcr.2022.108703. Available at: https://www.sciencedirect.com/science/article/abs/pii/S037842902200274X?via%3Dihub. Access On : March 16 , 2026.