

Evaluation of radish tubers (*Raphanus sativus*) Brassicaceae submitted to different doses of Si (Plus, GigaMix®)

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Received: May 20, 2022

Accepted: July 30, 2022

Published: October 01, 2022

Abstract

Silicon (Si) is the second most abundant element on Earth, being responsible for several benefits to plants, such as root development, aerial part, increase in photosynthetic rates and protection of plants against phytopathogens. The study aimed to evaluate different plant parameters in three radish cultivars (Long Scarlet Short Top “Long Red”, Comet and Round) at different doses of Silicon. Three varieties of radishes were used. Different doses of Si with 8% (g kg^{-1}) were tested for shoot and tuber development. The results showed that both the control and the Si dosages were not significant for the parameters number of leaves and fresh and dry mass of the shoot. As for the tuber diameter and weight parameters in the three cultivars, the response doses were significant even at the lowest concentration of 13.5 g kg^{-1} and maximum performance at the highest concentration of 75 g kg^{-1} , except for the Comet variety that presented greater weight in the intermediate concentration of 53.5 g kg^{-1} with 17.83 g. The response doses containing 8% of Si in the evaluated formula showed, in this study, excellent suitability for use applied directly in the soil on the three radish cultivars with a significant increase on the variable diameter and fresh weight.

Keywords: *Raphanus* genus, Crop, Horticultural, Leaf analysis, Foods.

Resumo

O Silício (Si) é o segundo elemento com maior em abundância na Terra, sendo esse responsável por diversos benefícios aos vegetais, como desenvolvimento de raízes, parte aérea aumento nas taxas fotossintéticas e proteção de plantas contra fitopatógenos. O estudo teve por objetivo avaliar diversos parâmetros de plantas em três cultivares de rabanetes (Vermelho Comprido, Cometa e Redondo) em diferentes doses de Silício. Foram utilizadas três variedades de rabanetes. Diferentes doses de Si com 8% (g kg^{-1}) foram testadas quanto ao desenvolvimento da parte aérea e dos tubérculos. Os resultados demonstraram que tanto o controle quanto as dosagens de Si não foram significativas para os parâmetros número de folhas e massas fresca e seca da parte aérea. Já para os parâmetros diâmetro e peso dos tubérculos nos três cultivares, as doses respostas foram significativas mesmo na menor concentração de $13,5 \text{ g kg}^{-1}$ e máximo desempenho na maior concentração de 75 g kg^{-1} , exceto para a variedade Cometa que apresentou maior peso na concentração intermediária de $53,5 \text{ g kg}^{-1}$ com 17,83 g. As doses respostas contendo 8% de Si no formulado avaliado demonstrou nesse estudo, excelente aptidão para uso aplicado diretamente no solo sobre os três cultivares de rabanete com aumento significativo sobre as variáveis diâmetro e peso fresco.

Palavras-chave: Gênero *Raphanus*, Colheita, Horticultura, Análise foliar, Alimentos.

Resumen

El silicio (Si) es el segundo elemento más abundante en la Tierra, responsable de varios beneficios para las plantas, como el desarrollo de las raíces, la parte aérea, el aumento de las tasas fotosintéticas y la protección de las plantas contra los fitopatógenos. El estudio tuvo como objetivo evaluar diferentes parámetros vegetales en tres cultivares de rábano (Vermelho Comprido, Cometa y Redondo) a diferentes dosis de Silicio. Se utilizaron tres variedades de rábanos. Se probaron diferentes dosis de Si al 8% (g kg^{-1}) para el desarrollo de brotes y tubérculos. Los resultados mostraron que tanto el control como las dosis de Si no fueron significativas para los parámetros número de hojas y masa fresca y seca del brote. En cuanto a los parámetros de diámetro y peso del tubérculo en los tres cultivares, las dosis de respuesta fueron significativas incluso a la concentración más baja de $13,5 \text{ g kg}^{-1}$ y el rendimiento máximo a la concentración más alta de 75 g kg^{-1} , a excepción de la variedad Cometa que presentó mayor peso en la concentración intermedia de $53,5 \text{ g kg}^{-1}$ con 17,83 g. Las dosis de respuesta que contenían 8% de Si en la fórmula evaluada mostraron, en este estudio, excelente idoneidad para el uso aplicado directamente en el suelo en los tres cultivares de rábano con un aumento significativo en las variables diámetro y peso fresco.

Palabras clave: Género *Raphanus*, Cultivo, Horticultura, Análisis de hojas, Alimentos.

1. Introduction

Raphanus sativus L. is a tuberous vegetable species belonging to the group of small vegetables, being circumscribed in Brassicaceae f., with an annual cycle. The tubers are edible with high nutritional value, in addition, *R. sativus* has a wide variety of shapes and colors depending on the type of cultivar (Cavalcante et al., 2018). It is cultivated in several regions of the world such as in areas of the Mediterranean, Asia, Africa and the Americas (Yamane et al., 2009).

In Brazil, around 90% of production and consumption is registered in the Southeast and South regions, and the Brazilian States of Rio Grande do Sul and São Paulo are the largest consumers. In general, radish is red (external) and white (internal), with white varieties (external and internal) having a pungent or spicy flavor, with great benefits, being rich in vitamins (A, B1, B2, B6 and C), minerals such as Ca and Fe and dietary fiber. Studies have found that radish has considerable antioxidant, anticarcinogenic, diuretic, antiscorbutic and digestive enzyme stimulator activities, and these characteristics are attractive as a good option for cultivation (Camargo et al., 2007; Oliveira et al., 2014; Cavalcante et al., 2018; Araújo et al., 2020; Bonfim-Silva et al., 2020).

Among vegetables, the radish shows increasing demand for production, occupying a small production space, being used in several cuisines around the world (Moreira et al., 2019; Soares et al., 2020). According to Bonfim-Silva et al. (2020) and the Instituto Brasileiro de Geografia e Estatística (IBGE) of 2017, Brazil that year produced 10,500 tons of radishes. The radish has several cultivars such as var. saxa, sparkler, giant siculus, hybrid Margaret Queen, comet, round and long, with a short cycle, with harvest around 30 days after planting (Moreira et al., 2019).

The usual planting system is the row type, which can also be an excellent option between crop rotation. Among the various agricultural crops, the radish has full production presenting exuberant development, however, this will depend on fluctuating factors during cultivation, such as: temperature, planting season, moisture and soil nutrition that will or will not guarantee a prosperous harvest. As observed, the radish adapts better to sowing between the seasons in Autumn and Winter, with temperatures between 13 to 20 °C and short days, where these conditions provide a lasting vegetative state (Figueira, 2008).

Several researchers cite that productivity is closely linked to soil fertility (Santin et al., 2019; Gurgel et al., 2020). Soils with low nutritional contents will produce physiological disorders on the plant that will put productivity at risk. Studies show that *R. sativus* is an agricultural crop with low nutritional requirements, although doses and responses evaluating fertilizers have shown good results (Medeiros et al., 2019; Silva et al., 2019).

Agriculture has positively undergone great changes, and new vegetable producers have been adapting to this new concept of “modern agriculture” production. This new form of soil-plant management encourages the farmer to use in his radish crops, among other crops, fertilizers of organic origin that have a low impact on the environment and have a reduced cost due to the easy availability of components such as rock dust and ash by-product. from burning wood that contain varying levels of Ca, K, Mg, P and Zn (Ochecová et al., 2017; Tito et al., 2019). Several groups that seek to include organic fertilizers in the market, come every year, providing attractive formulations to the farmer who seeks to save on production costs and thus provide the final consumer with a quality organic product at an affordable price.

There are different organic formulas with variation in their concentrations for vegetables, these in the form of

powder, granules or emulsions, which can be applied in the juice or by foliar spray, ensuring greater contact in the roots and part of the area. Among these formulations, we can mention products that have a high concentration of silicon oxide (SiO) or silicon (Si) which is directly involved in the full development of plants.

Several studies present different results regarding the use of Si in the most varied vegetable crops, Wenneck et al. (2021) observed that the increase of Si in the cauliflower cultivation system has a positive influence on the economic increase in a protected environment, with the application of 150 kg ha⁻¹ of Si. Tessmann et al. (2015) also observed a positive effect in the application of doses of Si in pepper plants. The researchers obtained satisfactory results on the chlorophyll content, increase in dry mass, leaves and total production. Other studies such as Rodrigues et al. (2021) reported that the use of Si increased the number of leaves and helped to reduce the percentage of defoliation in *R. sativus*, although at a dose of 3 g L⁻¹ of Si they did not observe a greater effect on the mass of radishes produced. Oliveira et al. (2020a) did not observe a positive effect on mini tomato in two systems by foliar and soil application on tomato growth and number of fruits. Oliveira et al. (2020b) evaluated those unconventional vegetables have a good ability to accumulate Si in plant tissue, although it did not influence the biomass content in *Maranta arundinacea*, *Rumex acetosa*, *Amaranthus spinosus*, *Amaranthus viridis*, *Amaranthus retroflexus*, *Amaranthus deflexus*, *Amaranthus hybridus*, *Stachys byzantine* and *Sonchus oleraceus*.

Although, as previously discussed, the various studies diverge on the use of Si in vegetable crops, and in some studies, it was not possible to observe an increase in the development of radishes. However, we cannot generalize, as the results may vary among the different cultivars of *R. sativus*. Thus, the objective of this study was to evaluate parameters of radish plants in three cultivars (radish long red, Comet and Round redish) when cultivated under different doses of silicon from a commercial formulation.

2. Materials and Methods

Experiment area

The experiment was carried out in a greenhouse in the experimental area of the Instituto Federal Goiano, Rio Verde, Rio Verde, Goiás, Brazil from April to June 2022. Location of the experimental area (17°48'09.3"S and 50°54'06.5"W) with flat to slightly undulating topography with 5% slope, with an average height of 748 m in relation to sea level. The climate of the region, according to the classification of Köppen & Geiger (1948) has two well-defined seasons: a dry season from May to October and a rainy season from November to April.

Experiment design

The experimental design used was completely randomized, with five treatments (Si doses) and four replications (per dose), totaling 20 treatments. The first factor corresponded to 5 doses of Si (Plus, GigaMix[®]) (organic product), mixed mineral fertilizer, nature, solid powder, chemical characteristics: P₂O₅ 5.0%, P₂O₅ sol. citric acid 2% (conc. 1:100) 2%, Ca total content 5.6%, Mg total content 4.8% and Si total content 8% per Kg⁻¹, added to the conc. (0; 13.5; 32.5; 53.5 and 75 g Kg⁻¹ of Si to the substrate) as described by Gonzaga et al. (2020) adapted. Three varieties (var.) of radishes were used: Radish long red "Long Scarlet Short Top" (Isla), germination rate 94%, Comet radish (Isla) germination rate 94% and Round redish (Feltrin), germination rate 92%.

Plant substrate and experiment implementation

The substrate used was acquired in a house specialized in agricultural products, being of the BioPlant brand, with indication to produce seedlings of vegetable species. The substrate had the following composition: pine bark, manure, sawdust, coconut fiber, vermiculite, rice husk, ash, agricultural gypsum, calcium carbonate, magnesium, magnesium thermophosphate, Sphagnum peat and vegetable cake. The seedlings were prepared in seedling bags (8x12 cm). After filling with 1 kg of substrate added with different doses of Si, sowing was performed manually. The seeds of the three varieties of radishes were positioned in the center of each plastic bag with a depth of 0.5 cm, where they were then covered with a substrate containing the dosage of the product. Four seeds were used per plastic bag in order to guarantee one plant in each package. On the seventh day after planting, thinning was carried out, leaving one plant with greater vigor per experimental unit, twice a day, at the beginning between 7 am and 8 pm and between 5 pm and 6 pm in a system automated micro sprinkler irrigation (Pressure (MCA) 30, Flow (L/h) 415, and Diameter (m) 8.0) for 20 min as proposed by Araújo et al. (2020) adapted.

Variables analysed

After the maximum development of the seedlings, occurring with 30 days, the harvest was carried out to evaluate the characteristics: number of leaves (NL), aerial part fresh mass (APFM), aerial part dry mass (APDM), tuber weight (TW) and tuber diameter (TD) (Santi et al., 2013; Araújo et al., 2020). To weigh the fresh mass of shoots and tubers, an analytical precision balance in grams (g) was used. The fresh mass of the shoot was transferred to an oven for drying at $70\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ for 24 h. After this period, the shoot dry mass was determined in (g).

Statistical analysis

The results were submitted to regression analysis using the 2nd degree polynomial model or quadratic model using the statistical program Sisvar (version 5.1) by Ferreira, (2019).

3. Results and Discussion

Table 1 presents the results of the parameters number of leaves and fresh and dry mass of the aerial part. The doses of Si did not significantly influence the vegetative structure of the plant. Possibly the way in which the Si source was applied in this study did not have a positive effect on the number and fresh and dry weight of leaves. Results like ours were observed by Pohlmann et al. (2019), however, from the foliar application of Si. The researchers obtained a variation between 6.75-8.25 number of leaves, fresh and dry phytomass of the shoot between 8.25-12.0 and 1.50-2.25 g, respectively, for the variety Vip Crimson Selection Especial of radish. Although the study by Lacerda et al. (2022) contradicts this study and by Pohlmann et al. (2019), as the researchers found a positive effect using a foliar application system. The vegetative gain on the fresh and dry mass parameters of the radish shoot was significant.

Table 1. Parameters number of leaves, fresh mass and dry mass of the aerial part of the Long red, Comet and Round varieties of radishes.

| Parameters | Number leaves | Aerial fresh mass | Aerial dry mass |
|------------|---------------|-------------------|-----------------|
| Varieties | (n°) | (g) | (g) |
| Long red | ns | ns | ns |
| CV (%) | 22.4 | 31.83 | 34.41 |
| Comet | ns | ns | ns |
| CV (%) | 19.83 | 39.72 | 39.26 |
| Round | ns | ns | ns |
| CV (%) | 9.61 | 28.05 | 26.01 |

Note: CV: coefficient of variation. F test for doses. ns: Not significant at the 1% probability level. Source: Authors, 2022.

As shown in Figure 1, letters (A, B and C) below, the components evaluated showed a significant difference between the percentages of Si incorporated into the substrate, these being the variables diameter (cm) and mass (g) of radish tubers in the varieties Long red, Comet and Round by adjustment in the quadratic regression.

Increasing Si doses showed positive results on diameter and mass gain in the three radish varieties. To the variety Long red, the control treatment showed a mean diameter of 1.56 ± 0.28 cm, for the lowest dose 13.5 g Kg^{-1} of Si, it exhibited a mean of 2.09 ± 0.09 cm and for the highest dose an average of 2.33 ± 0.08 cm. The $R^2 = 87.80\%$ of the increase in tuber diameter for this variety was due to the concentrations of Si by the quadratic equation and $CV\% = 7.15$, which indicated a good experimental precision. The average weight of the control was 18.28 g, in the first concentration with Si with an average of 21.18 g and for the highest concentration of 75 g Kg^{-1} with 22.18 g. The average tuber weight showed $R^2 = 83.28\%$ of the increment where it also suffered positive variation due to the concentrations of Si by the quadratic equation and $CV\% = 4.75$ indicating a good experimental precision (Figure 1, A).

To the variety Comet, the control treatment presented a mean diameter of 2.52 ± 0.32 cm, for the smallest dose containing 13.5 g Kg^{-1} of Si, it presented a mean of 3.04 ± 0.09 cm and for the dose 75 g kg^{-1} mean of $3.93 \pm$

0.03 cm. The $R^2 = 99.82\%$ of the increment for the diameter of the tubers in this variety due to the concentrations of Si by the quadratic equation and $CV\% = 5.87$ which indicated an excellent experimental precision. The average weight of the control was 10.17 ± 2.09 g, in the first concentration of 13.5 g kg^{-1} , mean of 11.47 ± 2.38 g and for the intermediate concentration of 53.5 g kg^{-1} with 17.83 g. The average tuber mass showed $R^2 = 95.21\%$ of the increment where it also suffered a positive variation due to the concentrations of Si by the quadratic equation and $CV\% = 11.65$, also indicating an excellent experimental precision (Figure 1, B).

Encouraging results were also obtained for variety Round, where the control treatment presented a mean diameter of 2.21 ± 0.24 cm, 2.97 ± 0.09 cm for the lowest dose of 13.5 g Kg^{-1} of Si and for the highest dose with 75 g kg^{-1} mean of 4.53 ± 0.13 cm. The $R^2 = 99.74\%$ of the increment for the diameter of the tubers in this variety was also due to the concentrations of the element Si determined by the quadratic equation and with $CV\% = 6.26$, which indicated an excellent experimental precision. This was observed for the mean mass of the control of 5.98 ± 2.41 g, in the first dose of 13.5 g kg^{-1} of 7.69 ± 1.07 g and for the highest concentration of 75 g kg^{-1} with 23.29 g. The average weight of the tuber evaluated showed $R^2 = 98.56\%$ of the increment, which also, as expected, showed a positive variation due to the concentrations of Si by the quadratic equation with $CV\% = 15.53$, indicating excellent experimental precision (Figure 1, C).

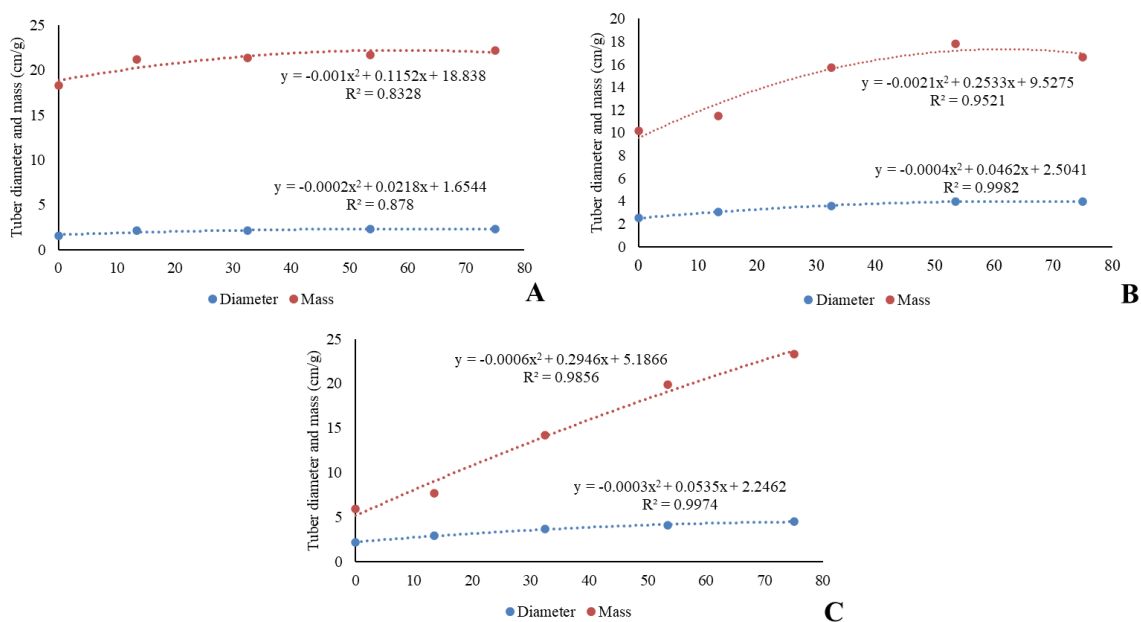


Figure 1. Doses, diameter and mass of radish tubers variety Long Red (A), Comet (B) and Round (C) as a function of Silicon doses added to the substrate. Source: Authors, 2022.

Different studies with radishes are available in the literature using different elements, groups of elements in nutritional formulations and products of animal origin such as earthworm humus and bovine, swine and poultry manure (Silva et al., 2015). Our results corroborate those of Lacerda et al. (2022) where they used the cultivar Apolo on doses of silicate which provided greater productivity in the radish crop. However, other studies differ from those presented, such as the study by Pohlmann et al. (2019) where they evaluated different doses of Si in the foliar application system for variety Vip Crimson Special Selection, where they did not observe a significant increase in the vegetative structure of the plant. This was also presented by Faria et al. (2013) about different Si doses not having significant gain over different radish cultivars. Vicedo et al. (2017) also working with radishes observed loss of fresh and dry mass in roots and shoots with substrate containing Si. This was also verified for other vegetables such as tomatoes, arugula and carrots, where doses of Si did not show increases in production (Pereira et al., 2003; Gerrero et al., 2011; Ludwig et al., 2015).

Three hypotheses raised about the results of this study are: 1st that the three varieties analyzed in terms of diameter and mass showed better adaptation to the only source of nutrient in the evaluated substrate; 2nd due to

the high percentage of Si in the formulation and in the doses used and, 3rd, Si increased the availability of superphosphate already contained in the formulation of the product used. In addition to these hypotheses, in the recent study published by Gonzaga et al. (2020) and other authors mention that Si causes an increase in plant tolerance to environmental stresses, nutritional imbalance, metal toxicity, increased resistance to pathogens and has a high interaction with N and P, thus increasing the use of these nutrients by plants, as suggested in this study.

Although not only presents data on the use of chemical formulations, biofertilizers also demonstrate excellent aptitude in the development of vegetables. In this sense, Araújo et al. (2020) evaluated different dose responses of earthworm humus on tuber development of radish variety hybrid Margaret Queen. The researchers observed a substantial gain with the increment of even the lowest humus dose averaging 33.70 cm and the highest 100% humus dose averaging 35.66 cm. The largest tuber diameter was observed in a dose containing 40% with a mean of 39.34 cm. When compared to weight, the control presented only 5.15 g, in the first and maximum doses containing 20-100% humus, the average weight was 23.18 and 36.88 g respectively. When verifying the use of biofertilizers, Rodrigues et al. (2013) obtained satisfactory results on the diameter of radish tubers applying bovine manure, the researchers still in this study, attribute the good results to the type of organic source, where it stood out when compared to treatment and mineral fertilization.

4. Conclusions

The use of a mineral source containing 8% of Silicon used in the fertilization in protected cultivation evaluated in the three varieties of Radish long red, Comet radish and Round redish, contributed positively to the increase in the diameter and mass of the tubers, according to the results through the adjusted cubic equation. The recommendation on the source of Si showed good results at the lowest dose, and maximum gain at the highest dose, where these were verified for the two variables with the best dose-response results.

5. Acknowledgments

To the Instituto Federal Goiano, Rio Verde, Goiás, Brazil; the Faculdade Rio Verde, Rio Verde, Goiás, Brazil; the Laboratório de Química Tecnológica; the Fundação de Amparo a Pesquisa do Estado de Goiás (FAPEG), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), and Financiadora de Estudos e Projetos (FINEP).

6. References

- Araújo, R. G. V., Lima, J. R. B., Silva, A. B., Santos, G. T., Silva, J. M. & Paes, R. A. (2020). Desenvolvimento de tubérculos de rabanete em função de diferentes concentrações de húmus de minhoca. *Ciência Agrícola*, 18(3), 1-5. <https://doi.org/10.28998/rca.v18i3.9333>
- Bonfim-Silva, E. M., Fernandes, G. B., Alves, R. D. S., Castañón, T. H. F. M. & Silva, T. J. A. (2020). Adubação mineral, orgânica e organomineral na cultura do rabanete. *Brazilian Journal of Development*, 6(5), 23300-23318. <https://doi.org/10.34117/bjdv6n5-037>
- Camargo, G. A., Consoli, L., Lellis, I. C. S., Mieli, J. & Sasaki, E. K. (2007). Bebidas naturais de frutas perspectivas de mercado, componentes funcionais e nutricionais. *Revista Brasileira de Engenharia de Biosistemas*, 1(2), 179-195. <https://doi.org/10.18011/bioeng2007v1n2p179-205>
- Cavalcante, J. A., Lopes, K. P., Pereira, N. A. E., Silva, J. G., Pinheiro, R. M. & Marques, R. L. L. (2018). Extrato aquoso de bulbos de tiririca sobre a germinação e crescimento inicial de plântulas de rabanete. *Revista Verde de Agroecologia e Desenvolvimento Sustentável*, 13(1), 39-44. <http://www.gvaa.com.br/revista/index.php/RVADS>
- Faria, L. M. V., Gomes, M. B. & Silva, T. R. (2013). Resposta morfológica do rabanete à aplicação de diferentes doses de silício na linha de semeadura. *Revista Eletrônica da Univar*, 2, 121-128.
- Ferreira, D. F. (2019). Sisvar: a computer analysis system to fixed effects split plot type designs. *Brazilian Journal of Biometrics*, 37(4), 529-535. <https://doi.org/10.28951/rbb.v37i4.450>
- Filgueira, F. A. R. (2003). Novo manual de olericultura: agrotecnologia moderna na produção e comercialização de hortaliças. Universidade Federal de Viçosa, 2ª Ed., 421 p.
- Gonzaga, T. O. D., Araújo, C., Andrade, A. L., Santos, J. M. R., Silva, G. B. & Silva, V. L. (2020). Produção de

- mudas de alface (*Lactuca sativa*) submetidas a diferentes doses de Silício. *Scientific Electronic Archives*, 13(1),1-7. <http://dx.doi.org/10.36560/1312020863>
- Guerrero, A. C., Borges, L. S. & Fernandes, D. M. (2011). Efeito da aplicação foliar de silício em rúcula cultivada em dois tipos de solos. *Bioscience Journal*, 27(4), 591-596. <https://seer.ufu.br/index.php/biosciencejournal/article/view/8246/7749>
- Gurgel, A. L. C., Santana, J. C. S., Theodoro, G. F., Difante, G. S., Almeida, E. M., Arcanjo, A. H. M., Costa, C. M., Costa, A. B. G. & Fernandes, P. B. (2020). Compactação do solo: efeitos na nutrição mineral e produtividade de plantas forrageiras. *Revista Científica Rural*, 22(1), 13-29. <https://doi.org/10.30945/rcr-v22i1.3154>
- Ibge – IBGE. Instituto Brasileiro de Geografia e Estatística. (2017). Access in: 24/05/2022. Available from: <https://www.ibge.gov.br/explica/producao-agropecuaria/>
- Köppen, W. & Geiger, R. (1928). *Klimate der Erde*. Gotha: Verlagcondicionadas. Justus Perthes. Wall-map 150 cm x 200 cm.
- Lacerda, V. R., Acevedo, A. F. G., Marques, I. C. S., Dellabiglia, W. J., Ferraz, A. K. L., Basílio, L. S. P. & Broetto, F. (2022). Silicon as a mitigator os water déficit stress in radish crop. *Scientia Horticulturae*, 291, 1-10. <https://doi.org/10.1016/j.scienta.2021.110600>
- Ludwig, F., Mayer, R. H. & Schmitz, J. A. K. (2015). Silício via foliar na produção e qualidade de cenoura. *Revista Cultivando o Saber*, 8(4), 373-383. <https://cultivandosaber.fag.edu.br/index.php/cultivando/article/view/662>
- Medeiros, T. S., Gomes, A. R. M. G., Alves, M. P. B., Marcelino, A. S., Santos, D. M., Giongo, A. M. M. & Costa, A. R. (2019). Produção de rabanete (*Raphanus sativus* L.) cultivado sob níveis de esterco bovino e respiração basal do solo. *Brazilian Applied Science Review*, 3(2), 1348-1357. <https://doi.org/10.34115/basr.v3i2.1424>
- Moreira, R. S., Santos, M. R., Sousa, R. A., Almeida, R. S., Junior, F. A. G. & Coelho, W. A. A. (2019). Agronomic performance and yield of radish cultivars. *Revista de Agricultura Neotropical*, 6(3), 6-11. <https://doi.org/10.32404/rean.v6i3.3345>
- Ochecová, P., Mercl, F., Košnář, Z. & Tlustoš, P. (2017). Fertilization efficiency of Wood ash pellets amended by gypsum and superphosphate in the ryegrass growth. *Plant, Soil and Environment*, 63(2), 47-54. <https://doi.org/10.17221/142/2016-PSE>
- Oliveira, T. A., Silva, R. P., Silva, B. L., Santos, F. F., Cavalcante, L. S., Silva, M. C., Albuquerque, J. M. S. & Neto, A. L. S. (2020a). Caracterização química, fisiológica e pós-colheita de plantas de tomateiro adubadas com silício via solo e foliar. *Brazilian Journal of Development*, 95097-95105.
- Oliveira, L. C. P., Souza, D. C., Silva, L. F. L., Guerra, T. S., Resende, L. V. & Silva, M. L. S. (2020b). Efeito da adubação silicatada em hortaliças não convencionais. *Revista de Ciências Agroveterinárias*, 19(2), 224-229. <https://doi.org/10.5965/223811711922020224>
- Oliveira, G. Q., Biscaro, G. A., Motomiya, A. V. A., Jesus, M. P. & Filho, P. S. V. (2014). Aspectos produtivos do rabanete em função da adubação nitrogenada com e sem hidrogel. *Journal of Agricultural Science*, 3, 89-100.
- Pereira, H. S., Vitti, G. C. & Korndorfer, G. H. (2003). Comportamento de diferentes fontes de silício no solo e na cultura do tomateiro. *Revista Brasileira de Ciências do Solo*, 27(1), 101-108. <https://doi.org/10.1590/S0100-06832003000100011>
- Pohlmann, V., Knies, A. E. & Ludwig, F. (2019). Adubação foliar silicatada na cultura do rabanete. *Revista Cultivando o Saber*, 12(2), 108-117. <http://177.53.200.37/index.php/cultivando/article/view/935>
- Rodrigues, J. F., Reis, J. M. R. & Reis, M. A. (2013). Utilização de esterco em substituição a adubação mineral na cultura do rabanete. *Revista Tropica: Ciências Agrárias e Biológicas*, 7(2), 160-168. <https://doi.org/10.0000/rtcab.v7i2.1110>
- Rodrigues, D. S., Assis, F. A., Assis, G. A., Carvalho, F. J., Marafeli, É. A. M. (2020). Qualidade, desempenho fitotécnico e incidência de artrópodes em rabanete submetido ao silício e *mulching*. *Acta Iguazu*, 10(1), 132-145. <http://doi.org/10.48075/actaiguaz.v10i1.26801>
- Santin, D., Benedetti, E. L., Barros, N. F., Almeida, I. C., Simiqueli, G. F., Neves, J. C. L., Wendling, I. & Reissmann, C. B. (2019). Adubação nitrogenada e intervalos de colheita na produtividade e nutrição da

- erva-mate e em frações de carbono e nitrogênio do solo. *Ciência Florestal*, 29(3), 1199-1214. <https://doi.org/10.5902/1980509810843>
- Santi, A., Scaramuzza, W. L. M. P., Neuhaus, A., Dallacort, R., Krause, W. & Tieppo, R. C. (2013). Desempenho agrônômico de alface americana fertilizada com torta de filtro em ambiente protegido. *Horticultura Brasileira*, 31(2), 338-343. <https://doi.org/10.1590/S0102-05362013000200027>
- Silva, P. F., Matos, R. M., Júnior, G. J. D., Alencar, A. E. V. & Neto, J. D. (2015). Índice de colheita e partição de assimilados do rabanete sob fertirrigação nitrogenada. *Enciclopédia Biosfera*, 11(21), 1176-1190. <https://www.conhecer.org.br/enciclop/2015b/agrarias/indice%20de%20colheita%20e%20particao.pdf>
- Silva, R. R., Carvalho, P. H. M. S., Silva e Silva, J., Conta, W. R. S., Queiroz, S. O. P. & Santos, F. F. (2019). Produção de rabanete sob diferentes manejos de irrigação. *Revista Brasileira de Agricultura Irrigada*, 13(4), 3588-3598.
- Soares, P. P. S., Mesquita, N. L. S., Almeida, J. R., Coutrim, R. L., Cairo, P. A. R. & Silva, L. D. (2020). Crescimento, qualidade de raízes e atividade da redutase do nitrato em plantas de rabanete submetidas a doses de potássio e fontes de nitrogênio. *Scientia Plena*, 16(6), 1-9. <https://doi.org/10.14808/sci.plena.2020.060205>
- Tessmann, M., Bortolotti, M. B., Rodrigues, R. R., Reis, B. B., Suñé, A. S. & Barros, A. C. S. A. (2015). In: Semana Integrada. XXI Congresso de Iniciação Científica da Universidade Federal de Pelotas, 2015, Brasil. http://cti.ufpel.edu.br/siepe/arquivos/2015/CA_04029.pdf
- Tito, G. A., Chaves, L. H. G., Souza, F. G., Cavalcante, A. R., Fernandes, J. D. & Vasconcelos, A. C. F. (2019). Efeito do vermicomposto enriquecido com pó de rochas na química do solo e cultura de rabanete. *Revista Verde de Agroecologia e Desenvolvimento Sustentável*, 14(4), 506-511. <https://doi.org/10.18378/rvads.v14i4.6562>
- Viciedo, D. O., Prado, R. M., Toledo, R. L., Santos, L. C. N. & Calzada, K. P. (2017). Response of radish seedlings (*Raphanus sativus* L.) to different concentrations of ammoniacal nitrogen in absence and presence of silicon. *Agronomía Colombiana*, 35(2), 198-204. <https://doi.org/10.15446/agron.colomb.v35n2.62772>
- Wenneck, G. S., Saath, R., Rezende, R., Andrean, A. F. B. A., Santi, D. S. & Terassi, D. S. (2021). Análise econômica da utilização de silício no cultivo de couve-flor em ambiente protegido na região noroeste do Paraná. *Irriga*, 1(2), 335-343. <https://doi.org/10.15809/irriga.2021v1n2p335-343>
- Yamane, K. L. N., Lu, N. & Ohnishi, O. (2009). Multiple origins and high genetic diversity of cultivated radish inferred from polymorphism in chloroplast simple sequence repeats. *Breeding Science*, 59(1), 55-65. <https://doi.org/10.1270/jsbbs.59.55>

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