Research, Society and Development, v. 9, n. 10, e029108316, 2020
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i10.8316

Sulfur, gypsum and organic compost in production of collard greens

Enxofre, gesso e composto orgânico na produção de couve-de-folha

Azufre, yeso y compost orgánico en la producción de col rizada

Received: 09/09/2020 | Reviewed: 09/12/2020 | Accept: 09/14/2020 | Published: 09/16/2020

Maurício Dominguez Nasser
ORCID: https://orcid.org/0000-0002-4239-5958
Polo Regional Alta Paulista, Brasil
E-mail: mdnasser76@gmail.com
Antonio Ismael Inácio Cardoso
ORCID: https://orcid.org/0000-0003-3251-9491
Universidade Estadual Paulista "Júlio de Mesquita Filho", Brasil
E-mail: antonio-ismael.cardoso@unesp.br
Priscilla Nátaly de Lima Silva
ORCID: https://orcid.org/0000-0002-8047-0592
Universidade Estadual Paulista "Júlio de Mesquita Filho", Brasil
E-mail: priscilla_nataly@hotmail.com
Lidiane Fernandes Colombari
ORCID: https://orcid.org/0000-0001-5788-6947
Universidade Estadual Paulista "Júlio de Mesquita Filho", Brasil
E-mail: colombarifl@yahoo.com.br
Bruno Novaes Menezes Martins
ORCID: https://orcid.org/0000-0002-2664-6817
Universidade Estadual Paulista "Júlio de Mesquita Filho", Brasil
E-mail:brunonovaes17@hotmail.com

Abstract

Sulphated fertilizers, gypsum and organic matter are sources containing sulfur (S) which aids in growth and chemical composition of brassicas. Studies with S in collard greens (*Brassica oleracea* L.var. *acephala*) are rare. The objective of this work was to evaluate use of gypsum and organic compost at planting, followed by ammonium sulphate topdressing, on yield of collard greens. Treatments: organic compost (30 t ha^{-1}), or gypsum (1.2 t ha^{-1}) individually, organic compost plus gypsum. Total sulfur applied at 0; 93.31; 186.69, or 280 kg ha^{-1}, corresponding to 0; 465.5; 931 or 1400 kg ha^{-1} of ammonium sulphate, was divided into 7 applications. The N was fixed (280 kg·ha^{-1}), and complemented with 630, 415.1, 208.6 or 0 kg·ha^{-1} of urea. At 30 DAT, the first leaf samples, minimum of 20 cm in length, were collected; additional leaves were harvested every 10 days, in a total of 8 harvests. After each harvest total length (including leaf petiole), and leaf number per plant, width, and fresh weight were evaluated. Soil amendment and sulfur dose did not influence yield, and urea or ammonium sulfate can be used as a source of N. No symptoms of sulfur deficiency occurred and plants averaged 15.6 t ha^{-1} of leaves.

Keywords: *Brassica oleracea* L. var. *acephala*; Ammonium sulphate; Organic fertilizer; Plant nutrition.

Resumo

Fertilizantes sulfatados, gesso e matéria orgânica são fontes contendo enxofre (S) que auxiliam no crescimento e composição química das brássicas. Estudos com S em couve-de-folha (*Brassica oleracea* L.var. *acephala*) são raros. O objetivo deste trabalho foi avaliar a utilização de gesso e composto orgânico no plantio, seguido de cobertura de sulfato de amônio, na produção de couve-de-folha. Tratamentos: composto orgânico (30 t ha^{-1}), ou gesso (1,2 t ha^{-1}) individualmente, composto orgânico mais gesso. Enxofre total aplicado a 0; 93,31; 186,69, ou 280 kg ha^{-1}, correspondendo a 0; 465,5; 931 ou 1400 kg ha^{-1} de sulfato de amônio, e foi dividido em 7 aplicações. O N foi fixado (280 kg ha^{-1}) e complementado com 630, 415,1, 208,6 ou 0 kg · ha^{-1} de ureia. Aos 30 DAT, foram coletadas as primeiras amostras de folhas, com comprimento mínimo de 20 cm; folhas adicionais foram colhidas a cada 10 dias, em um total de 8 colheitas. Após cada colheita, foram avaliados o comprimento total (incluindo o pecíolo da folha) e o número de folhas por planta, largura e peso fresco. O preparo do solo e a dose de enxofre não influenciaram a produtividade, e ureia ou sulfato de amônio podem ser usados como fonte de N. Nenhum sintoma de deficiência de enxofre ocorreu e as plantas tiveram em média 15,6 t ha^{-1} de folhas.

Palavras-chave: *Brassica oleracea* L. var. *acephala*; Sulfato de amônio; Fertilizante orgânico; Nutrição de plantas.

Resumen

Los fertilizantes sulfatados, el yeso y la materia orgánica son fuentes que contienen azufre (S) que ayudan en el crecimiento y la composición química de las brassicas. Los estudios con S en el repollo (*Brassica oleracea* L.var. *acephala*) son raros. El objetivo de este trabajo fue evaluar el uso de yeso y compost orgánico para la siembra, seguido de cobertura de sulfato de amonio, en la producción de col rizada. Tratamientos: compost orgánico (30 t ha^{-1}), o yeso (1.2 t ha^{-1}) individualmente, compost orgánico más yeso. Azufre total aplicado a 0; 93.31; 186.69, o 280 kg ha^{-1}, correspondiente a 0; 465.5; 931 o 1400 kg ha^{-1} de sulfato de amonio, y se dividió en 7 aplicaciones. El N se fijó (280 kg ha-1) y se complementó con 630, 415.1, 208.6 o 0 kg ha^{-1} de urea. A las 30 DAT se recolectaron las primeras muestras de hojas, con una longitud mínima de 20 cm; se recolectaron hojas adicionales cada 10 días, para un total de 8 cosechas. Después de cada cosecha, se evaluó la longitud total (incluido el pecíolo de la hoja) y el número de hojas por planta, ancho y peso fresco. La preparación del suelo y la dosis de azufre no influyeron en la productividad, y la urea o el sulfato de amonio se pueden utilizar como fuente de N. No se presentaron síntomas de deficiencia de azufre y las plantas tenían un promedio de 15,6 t ha^{-1} de hojas.

Palabras clave: *Brassica oleracea* L. var. *acephala*; Sulfato de amonio; Fertilizante organic; Nutrición vegetal.

1. Introduction

Demand for collard greens (*Brassica oleracea* L. var. acephala), which contains calcium, potassium, iron, vitamins, proteins, fiber and flavonoids, has increased in the world (Seo et al., 2019). It is reported to have anticancer action due to glucosinolates (Soundararajan & Kim, 2018). Glucosinolates are compounds formed through secondary plant metabolism, and concentrated in small amounts in foliar and seed cells, due to presence of sulphur (Martinez-Ballesta et al., 2013). Brassicas are demanding in sulfur (CQFS, 2004; Magro et al., 2009; Cardoso et al., 2016). Addition of S supports increased fresh and dry mass of collard greens (Park et al., 2018).

Superphosphate, ammonium sulphate and potassium sulphate contain S (Chien et al., 2011). Agricultural gypsum contributes to supply of calcium and sulphur as calcium sulphate. Gypsum can reduce toxicity of aluminium, favoring development of the root system, allowing improved absorption of water, resulting in improve drought resistance (Rahman et al., 2018).

In soil, sulphur is mainly inorganic form. The ability of soil to meet plant nutrient demands is related to organic matter content and its mineralization, which make S available as sulphate (Tiecher et al., 2012). In addition to providing nutrients, organic fertilization improves physical, chemical and biological soil properties (Almeida Jr. et al., 2011).

There is little information on sulphated fertilization in collard greens. Use of the Bokashi® compost and EM-4 did not differ from mineral fertilizer on fresh collard greens leaf weight (Shingo & Ventura, 2009). No studies evaluated effects of sulphated fertilization along with application of organic composts or agricultural gypsum in collard greens.

It maybe that application of sulphated fertilizers in brassica crops, especially with application of agricultural gypsum, or organic compost, may increase availability of sulphate in soil, and increase production. The objective of this work was to evaluate production of collard greens using gypsum and organic compost at planting followed by ammonium sulphate topdressing.

2. Methodology

The experiment was conducted at São Manuel Experimental Farm, Faculdade de Ciências Agronômicas, Universidade Estadual Paulista, Botucatu campus, in São Manuel-SP city located at 22º 46' south latitude, 48 34' west longitude at 750 m. According to Köppen classification, the climate is warm temperate (mesothermal), and humid, with average temperature of the hottest month exceeding 22°C (Cunha & Martins, 2009). Annual average temperature is 20.9°C and annual average rainfall is 1,395 mm (Prado, 2013). The soil is a Dystrophic Red Latosol (Oxisol) with: pH ($CaCl_2$) = 6.3; MO = 13 g dm^{-3}; P = 82 mg dm^{-3}; H + Al = 12 $mmol_c$ dm^{-3}; K = 1.2 $mmol_c$ dm^{-3}; Ca = 28 $mmol_c$ dm^{-3}; Mg = 8 $mmol_c$ dm^{-3}; S = 3 mg dm^{-3}, SB = 37 $mmol_c$ dm^{-3}; CTC = 49 $mmol_c$ dm^{-3}, and V% = 76 from 0-20 cm.

On 29 July 2016 seed of collard greens, cv. Hi-Crop®, were sown in hard black polypropylene trays with 162 cells containing Soil Carolina® (Pardinho, SP, Brazil) substrate, at 1 seed per cell. Developing seedlings were kept in a greenhouse, with irrigation avoiding watering and without addition of fertilizers.

As seedlings developed 12 treatments were established in the field in a split-plot with 3 types of soil amendment and 4 doses of sulphur in subplots. Soil amendments, incorporated at 2 days pre-plant, were organic compost (30 t ha^{-1}) of Visafértil® (Mogi Mirim, SP, Brazil) or gypsum (1.2 t ha^{-1}) individually, organic compost plus gypsum. Based on recommendations (Raij & Trani, 1996) 40 kg ha^{-1} of N per application, and total doses of 0; 93.31; 186.69 or 280 $kgha^{-1}$ S (corresponding to 0; 465.5; 931 or 1,400 kg ha^{-1} of ammonium sulphate) were applied. The Visafértil® was analysed at the Laboratory of Soil Resources and Environmental Sciences of the College of Agricultural Botucatu and contained, in %: 0.7 N; 1.0 P_2O_5; 0.7 K_2O; 6.8 Ca; 0.4 Mg; 0.4 S; 22.0 U at 65°C; 24.0 total MO and 13total C. It also contained, in mg kg^{-1}: 2558 Na; 67 Cu; 17316 Fe; 577 Mn and 97 Zn. The C/N ratio was 19.1 at pH = 6.0. To standardize total N at 280 kg ha^{-1} N urea was applied at 630; 415.1; 208.6 or 0 kg ha^{-1}. Total sulfur was divided into 7split applications, spaced 14 days apart. Fertilizers were applied to the surface around each plant. At soil preparation, all treatments received 2 t ha^{-1} of 4N-14P-8K. After application of gypsum and/or compost and fertilizer, a rotavator bed former was used to make construct beds.

Twenty-seven-day old seedlings were transplanted manually into the field. The experimental design was a randomized complete block, with 4 replications and 18 plants per plot distributed in 3 rows with plants spaced at 50 m between rows and 1.60 m between plants. At 15 days post-transplanting (DAT) the first split fertilizer application occurred. Beginning with the third topdressing fertilizer was added as potassium chloride (20 kg ha^{-1} K_2O in each application). Planting and cultivation to harvest followed Trani et al. (2015). Irrigation was by overhead sprinkler twice daily.

At 30 DAT, the first leaf samples, minimum of 20 cm in length, were collected; additional leaves were harvested every 10 days, in a total of 8 harvests. After each harvest total length (including leaf petiole), and leaf number per plant, width, and fresh weight were evaluated from 4 plants from the central portion of plots. Leaves without apparent defect, and at least 20 cm in length, were considered marketable. From leaf fresh weights productivity was estimated, based on a population of 12,500 plants ha^{-1}.

Dry weight of 3 marketable fresh leaves per plot from the second, a third and fourth harvest was determined. Leaves were dried at 65°C in a forced air circulation oven until reaching constant weight.

According to Pereira et al. (2018), the present work used a methodology based on quantitative statistical analysis, therefore data were subjected to analysis of variance in Sisvar (Ferreira, 2010). If the interaction was significant it was used to explain results. If the interaction was not significant means were separated with Tukey's test, or regression.

3. Results and Discussion

Main effects of soil amendment and S dose, or their interaction, were not significant for all parameters evaluated (Table 1). Doses of S were not significant by polynomial regression analysis.

Research, Society and Development, v. 9, n. 10, e029108316, 2020
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i10.8316

Table 1. Marketable Leaves Length (MLL) and Marketable Leaves Width (MLW), Marketable Leaves Number (MLN) and Marketable Leaves Fresh Mass (MLFM) per plant, Marketable Leaves Dry Mass of Marketable Leaves (DMML) per hectare (ha), and fresh mass productivity (PROD) of collard greens marketable leaves grown on different soil amendment and S dose topdressing. São Manuel-SP, 2016.

Fators	MLL	MLW	MLN	MLFM	DMML	PROD
	---------cm--------		unit	g plant^{-1}	---------t ha^{-1} ---------	
Soil amendment (S.A.)						
Organic Compost (OC)	33.57	22.42	53.22	1267.22	1.55	15.8
Gypsum (G)	32.26	22.12	52.25	1167.18	1.48	14.6
OC + G	33.99	23.13	55.23	1312.05	1.61	16.4
CV1 (%)	5.52	6.64	16.53	30.73	29.63	30.73
F (S.A.)	3.90^{ns}	1.91^{ns}	0.47^{ns}	0.60^{ns}	0.33^{ns}	0.60^{ns}
Sulfur dose (S.)						
0.00 *kg ha^{-1}*	33.40	22.68	54.35	1278.40	1.58	16.0
93.31 *kg ha^{-1}*	33.45	22.62	53.44	1272.55	1.59	15.9
186.69 *kg ha^{-1}*	33.09	22.43	53.72	1241.77	1.53	15.5
280.00 *kg ha^{-1}*	33.15	22.48	52.74	1202.55	1.48	15.0
Overall average	33.27	22.55	53.57	1248.82	1.54	15.6
CV2 (%)	3.26	3.17	7.41	15.78	17.46	15.79
F (S.)	0.33^{ns}	0.30^{ns}	0.34^{ns}	0.37^{ns}	0.42^{ns}	0.37^{ns}
F (S.A. x S.)	0.48^{ns}	1.10^{ns}	0.84^{ns}	0.66^{ns}	0.47^{ns}	0.66^{ns}

^{ns} not significant at 5% the test F. Source: Authors.

The S doses did not affect leaf morphology, averages of 33.27 cm and 22.55 cm for length and width, respectively (Table 1).

Treatments produced marketable leaves; those longer than 20 cm with no signs of senescence (Azevedo et al., 2016). Shingo and Ventura (2009), studying various types of mineral and organic fertilizer in collard greens, cv. Georgia, obtained values for leaves of 11.8 to 20.2 cm in length and 8.4 to 16.1 cm width 57 days after transplanting. In leafy vegetables, nitrogen is directly related to productivity and leaf size (Rafik et al., 2010). Gypsum as a source of S, may favor nitrogen utilization by plants due to interaction between the elements, since absence of amino acids containing sulphur can promote accumulation of nitrogen in soluble amino acids, amines and amides which has no metabolic activity in plants (Mazid et al., 2011). Since all plants received some source of S at planting and/or in split applications, there should not have been a deficiency of nitrogen.

The soil amendment and S dose did not affect number of marketable leaves, avg. 53 leaves per plant. In assessing cv. Hi-Crop® with 20,000 plants ha^{-1}, under organic conditions, approximately 24 to 95 leaves per plant at each harvest were formed, almost 4 leaves per harvest (Corrêa et al., 2014). This was lower than the present work which averaged 6 leaves per plant per harvest. The cv. Hi-Crop® hybrid produces virtually no side shoots which, in addition to reducing cultivation, reduces competition, favoring leaves formed directly from the stem.

In other brassicas S can influence productivity of leaves. A linear response to number of rocket (*Eruca sativa* L.) leaves, up to 80 mg/plant, occurs when S is provided as ammonium sulphate (Soares et al., 2017).

There was a linear increase in number of leaves per plant in broccoli (*Brassica oleracea* var. italic Plenck) up to 124 kg ha^{-1} S applied as ammonium sulfate, even with application of organic composts to the soil (Corrêa et al., 2016). However, for inflorescence formation, 100 t ha^{-1} of 66.9 kg ha^{-1} S organic compost would be appropriate to maximize broccoli seed production. Despite reports in rocket and broccoli, for collard greens 'Hi-Crop®' split application of S did not affect yield. Producers may choose ammonium sulphate or urea, in accordance with the best cost/benefit. There was no effect for soil amendment and S dose on dry mass of leaves, average 1.54 t ha^{-1}.

Fresh yield was not affected by soil amendment and S dose, avg. 15.6 t ha^{-1} of marketable leaves. Although productivity is below the local average, 28 t ha^{-1} (IEA, 2016), this average is an estimate of a year cycle, 4 times longer than covered in this work. Yield of 42.19 to 46.03 t·ha^{-1} for ‘Hi-Crop®’ under organic management for 24 harvests over 6 months, averaged approximately 1.9 t ha^{-1}for each harvest (Corrêa et al., 2014), a value similar to 1.95 t ha^{-1}reported here, with fewer harvests.

Probably the supply route S gypsum or organic compost, and existing soil level before amendment was enough to meet needs of the plant during the 8 harvests of this work.

Approximately 75% of sulphur in the soil is in organic form (Bissani et al., 2008). The soil in this work was sandy in texture and low in organic matter content, 13 g dm^{-3}, indicating application of gypsum and/or the organic compost may have been sufficient. A recommendation of 70 to 80 kg ha^{-1} S is sufficient for brassicas, or no S, if 30 t ha^{-1}of organic compost (120 kg ha^{-1} of sulphur), or 1.2 t ha^{-1}gypsum (180 kg ha^{-1}of sulphur), is used to meet demand of the plant (Alvarez-Venegas et al., 2007).

Brassicas require higher sulfur values compared to most crops (CQFS, 2004) because these species accumulate high protein content (Jasinski et al., 2018). In cauliflower (*Brassica oleracea* var. botrytis L.) seed S was the second most accumulated element (Cardoso et al., 2016), indicating the importance of this nutrient for brassicas.

The S dose did not increase collard greens yield, probably due to "luxurious consumption". It can be inferred that use of ammonium sulphate or urea on collard greens supplies sufficient S. There were no sulphur deficiency symptoms. Use of lower sulphur rates may reduce production costs.

For future work, it is possible to evaluate other sources of organic fertilizers without the presence of gypsum, and in the case of collard greens, extend the evaluation period to at least one year of field production.

4. Conclusion

Sulphur topdressing does not influence collard greens production when using organic compost and / or gypsum in the soil amendment for planting.

References

Almeida Júnior, A. B., Nascimento, C. W. A., Sobral, M. F., Silva, F. B. V., & Gomes, W. A. (2011). Fertilidade do solo e absorção de nutrientes em cana-de-açúcar fertilizada com torta de filtro. Revista Brasileira de Engenharia Agrícola e Ambiental, 15 (10), 1004-1013.

Alvarez-Venegas, V. H., Roscoe, R., Kurihara, C. H., & Pereira, N. F. (2007). Enxofre. In: Novais, R. F., Alvarez-Venegas, V. H.; Barros, N. F., Fontes, R. L. F., Cantarutti, R. B., & Neves, J. C. L. (Ed.). Fertilidade do solo. Sociedade Brasileira de Ciência do Solo, Viçosa, MG, Brasil. p. 595-646.

Azevedo, A. M., Andrade Júnior, V. C., Pedrosa, C. E., Valadares, N. R., RF Andrade, R. F., & Souza, J. R. S. (2016). Study of genetic repeatability in cabbage clones. Horticultura Brasileira, 34 (1), 54-58.

Bissani, C. A., Gianello, C., Camargo, F. A. O., & Tedesco, M. J. (2008). Soil fertility and crop fertilization management. Porto Alegre, Metrópole. 344p.

Cardoso, A. I. I., Claudio, M. T. R., Nakada-Freitas, P. G., Magro, F. O., & Tavares, A. E. B. (2016). Phosphate fertilization over the accumulation of macronutrients in cauliflower seed production. Horticultura Brasileira, 34 (2), 196-201.

Chien, S. H., Gearhart, M. M., & Villagarcía, S. (2011). Comparison of Ammonium Sulfate With Other Nitrogen and Sulfur Fertilizers in Increasing Crop Production and Minimizing Environmental Impact: A Review. Soil Science, 176, 327-335.

CQFS - Soil Chemistry and Fertility Commission - CQFSRS/SC. (2004). Fertilization and liming manual for the states of Rio Grande do Sul and Santa Catarina. 10. ed. Porto Alegre, SBCS - Núcleo Regional Sul/UFRGS. 400p.

Corrêa, A. L., Abboud, A. C. S., Guerra, J. G. M., Aguiar, L. A., & Ribeiro, R. L. D. (2014). Green manure by intercropping crotalaria with baby corn before kale under organic management. Revista Ceres, 61 (6), 956-963.

Corrêa, C. V., Gouveia, A. M. S., Martins, B. N. M., Tavares, A. E. B., Lanna, N. B. L., Cardoso, A. I. I., & Evangelista, R. M. (2016). Response of broccoli to sulphur application at topdressing in the presence or absence of organic compost at planting. African Journal of Agricultural Research, 11 (35), 3287-3292.

Cunha, A. R., & Martins, D. (2009). Climate classification for the municipalities of Botucatu and São Manuel, SP. Irriga, 14 (1), 1-11.

IEA – Institute of Agricultural Economics. Paulista Production Statistics. (2016). Recuperado de http://ciagri.iea.sp.gov.br/nia1/subjetiva.aspx?cod_sis=1&idioma=1

Jasinski, S., Chardon, F., Nesi, N., Lécureuil, A., & Guerche, P. (2018). Improving seed oil and protein content in Brassicaceae: some new genetic insights from Arabidopsis thaliana. Oilseeds and fats, Crops and Lipids, 25 (6), D603.

Ferreira, D. F. (2010). Sisvar – Variance Analysis System. Versão 5.3. Lavras - MG: UFLA.

Magro, F. O., Cardoso, A. I. I., & Fernandes, D. M. (2009). Accumulation of nutrients in broccoli seeds in function of rates of organic compost. Cultivando o Saber, 2 (4), 49-57.

Martínez-Ballesta, M. C., Moreno, D.A., & Carvajal, M. (2013). The Physiological Importance of Glucosinolates on Plant Response to Abiotic Stress in Brassica. International Journal Molecular Sciences, 14 (6), 11607-11625.

Mazid, M., Khan, T. A., & Mohammad, F. (2011). Response of crop plants under sulphur tolerance: a holistic approach. Journal of Stress Physiology & Biochemistry, 7 (3), 23-57.

Park, Y. J., Lee, H. M., Shin, M., Arasu, M. V., Chung, D. Y., Al-Dhabi, N. A., & Kim, S. J. (2018). Effect of different proportion of sulphur treatments on the contents of glucosinolate in kale (Brassica oleracea var. acephala) commonly consumed in Republic of Korea. Saudi Journal of Biological Sciences, 25 (2), 349–353.

Prado, R. C. (2013). Climatic review (1971 a 2006). São Manuel-SP. Recuperado de http://www.fca.unesp.br/#!/instituicao/departamentos/solos-recursos-ambientais/sra/estacao-meteorologica/resenha-climatologica/

Pereira, A. S., Shitsuka, D. M., Parreira, F. J., & Shitsuka, R. (2018). Metodologia da pesquisa científica. [e-book]. Santa Maria. Ed. UAB/NTE/UFSM. Recuperado de https://repositorio.ufsm.br/bitstream/handle/1/15824/Lic_Computacao_Metodologia-Pesquisa-Cientifica.pdf?sequence=1.

Rafiq, M. A., Ali, A., Malik, M. A., & Hussain, M. (2010). Effect of fertilizer levels and plant densities on yield and protein contents of autumn-planted maize. Pakistan Journal of agricultural Sciences, 47 (3), 201-208.

Rahman, M.A., Lee, S.-H., Ji, H.C., Kabir, A.H., Jones, C.S., & Lee, K.-W. (2018). Importance of Mineral Nutrition for Mitigating Aluminum Toxicity in Plants on Acidic Soils: Current Status and Opportunities. International Journal Molecular Sciences, 19 (10), 3073.

Seo, J., Puligundla, P., & Mok, C. (2019). Decontamination of collards (Brassica oleracea var. acephala L.) using electrolyzed water and corona discharge plasma jet. Food Science Biotechnology, 28 (1), 147–153.

Shingo, G. Y., & Ventura, U. M. (2009). Collard greens yield with mineral and organic fertilization. Semina: Ciências Agrárias, 30 (3), 589-594.

Soares, M. M., Bardiviesso, D, M., Barbosa, W. F. S., & Barcelos, M. N. (2017). Topdressing arugula crop with sulfur. Revista de Agricultura Neotropical, 4 (1), 49-52.

Soundararajan, P., & Kim, J. S. (2018). Anti-Carcinogenic Glucosinolates in Cruciferous Vegetables and Their Antagonistic Effects on Prevention of Cancers. Molecules, 23 (11), 2983.

Tiecher, T., Santos, D. R., Rasche, J. W. A., Brunetto, G., Mallmann, F. J. K., & Piccin, R. (2012). Crop responses and sulfur availability in soils with different contents of clay and organic matter submitted to sulfate fertilization. Bragantia, 71 (4), 518-527.

Trani, P. E., & Raij, B. van. (1996). Vegetables. In: Raij, B van., Cantarella, H., Quaggio J. A., & Furlani, A. M. C. (Eds.). Fertilization and liming recommendations for São Paulo State. 2. ed. Campinas: Instituto Agronômico. (Boletim IAC, nº 100). p. 155-186.

Trani, P. E., Tivelli, S. W., Blat, S. F., Prela-Pantano, A., Teixeira, E. P., Araújo, H. S., Feltran, J. C., Passos, F. A., Figueiredo, G. J. B., & Novo, M. C. S. S. (2015). Collard greens: from planting to post harvest. Campinas: Instituto Agronômico. 36p. (Série Tecnologia APTA. Boletim Técnico IAC, 214). Recuperado de http://www.iac.sp.gov.br/publicacoes/publicacoes_online/pdf/BoletimTecnico214.pdf.

Research, Society and Development, v. 9, n. 10, e029108316, 2020
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i10.8316

Percentage of contribution of each author in the manuscript

Maurício Dominguez Nasser 35%

Antonio Ismael Inácio Cardoso 20%

Priscilla Nátaly de Lima Silva 20%

Lidiane Fernandes Colombari - 15%

Bruno Novaes Menezes Martins - 10%