Comunicata Scientiae
Horticultural Journal

ORIGINAL ARTICLE
published: 14 December 2020
https://doi.org/10.14295/CS.v11i0.3352

Sulfur doses, organic compost and gypsum in macronutrients contents of collard greens leaves

Maurício Dominguez Nasser[1]*, Antonio Ismael Inácio Cardoso[2], Carla Verônica Corrêa[2]

[1]Agency Paulista Agribusiness Technology, Alta Paulista, Brazil
[2]São Paulo State University, Botucatu, Brazil
*Corresponding author, e-mail: mdnasser@apta.sp.gov.br

Abstract

Due to the lack of information related to fertilization of collard greens, the objective of the research was to evaluate the influence of sulfur doses in macronutrients contents in collard greens cultivated with organic compost and gypsum. Twelve treatments were evaluated in a split-plot: three types of soil preparation in plots and four sulfur doses top dressing in subplots. The three types of soil preparation were the incorporation of organic compost (30 t ha^{-1}); gypsum (1.2 t ha^{-1}); organic compost (30 t ha^{-1}) plus gypsum (1.2 t ha^{-1}). The total sulfur doses in top dressing were zero; 53.32; 106.68 and 160.00 kg ha^{-1} of S, equivalent to 0; 266; 532 and 800.0 kg $ha^{-1}$of ammonium sulfate. For standardization of the nitrogen dose (280 kg·ha^{-1}), applied in top dressing it was used urea. From the dry matter of commercial leaves, it was evaluated the N, P, K, Ca, Mg and S contents. The types of soil preparation do not affect all macronutrients content. The sulfur top dressing applied does not alter the contents of leaf macronutrients N, P, K and Ca on collard greens cultivated with organic compost and gypsum. The sulfur content presents a linear increase, while for the magnesium content there is decrease the higher the sulfur doses. The decreasing order of macronutrient content of commercial collard greens leaves was K> N> Ca> Mg> S> P, with averages 37.92, 36.50, 21.69, 4.50, 4.23, 3.80 g kg^{-1}, respectively.

Keywords: *Brassica oleracea* L. var. *acephala*, organic fertilizer, plant nutrition, sulfate

Introduction

Collard greens (*Brassica oleracea* L. var. *acephala*) is originated in Europe and belong to the family Brassicaceae. This vegetable produces leaves for several months, allowing more than one crop, being very cultivated and consumed in the world and Brazil (Trani et al., 2015).

In plant nutrition, brassica is characterized as plants that require sulfur (S) in great quantity compared with most agronomic crops, and this nutrient is present in cysteine and methionine, two important sulfur aminoacids in human nutrition. The low content of these aminoacids affect protein synthesis, and S deficiency decreases the production of chlorophyll, which negatively affects the growth of plants (Alvarez-Venegas et al., 2007).

The widespread use of concentrated formulations may aggravate the deficiency of this nutrient in the plants. However, some fertilizer containing S can be used, such as superphosphate, ammonium sulfate and potassium sulfate. Another contribution can be found in the use of gypsum, which provides calcium and sulfur by calcium sulfate. The gypsum favors physical properties, also decreases the excess aluminum, benefiting root growth, providing greater absorption of water present in the soil and the plants can get along better with dry (Dalla Nora et al., 2014; Freitas et al., 2017).

The fertilization with organic compost is also a source of sulfur. This fertilizer promotes the chemical, physical and biological soil, providing better conditions for the development of culture (Almeida Júnior et al., 2011).

However, the continued use of organic fertilization associated with chemical fertilizer can lead to excess or deficiency of nutrients, mainly due to nutritional imbalance, affecting the cost of production and even in crop productivity.

Received: 09 April 2020
Accepted: 05 September 2020

Corrêa et al. (2013) observed linear increase in the sulfur content of cabbage leaves when used potassium sulfate top dressing, and sulfur was the third most absorbed nutrient. In broccoli (Magro et al., 2009) and cauliflower (Cardoso et al., 2016) S was the second most accumulated nutrient in seeds. Despite the importance of sulfur for brassicas, Abdallah et al. (2010) observed that in colza (*B. napus*) plants deficient in sulfur showed no difference either in whole-plant and leaf biomass when compared to control plants with normal sulfur content. On the other hand, Santos et al. (2012) observed yield increasing in *B. napus* with the use of ammonium sulfate, compared to urea, as top dressing. In cauliflower (*B. oleracea* var. botrytis) Jamre et al. (2010) obtained the highest yield with sulfur fertilization (60 kg ha^{-1}), while for Gocher et al. (2017) the best dose was 20 kg ha^{-1} of S. For cabbage, Hemlata & Nawange (2015) obtained the maximum yield under treatment combination 150 kg ha^{-1} of N and 60 kg ha^{-1} of S.

In research by Takeishi et al. (2009) evaluated the total accumulation of nutrients in cauliflower (yield 25.2 t ha^{-1}), the authors reported extraction kg ha^{-1} of 224.5 N ; 53.9 P; 156 K; 137.6 Ca; 21.8 63.4 Mg and S which demonstrated the superiority sulfur values for phosphorus and magnesium, highlighting the requirement of this nutrient.

Due to lack of information related to the nutrient content of collard greens leaves and the effect of topdressing fertilization, this research aimed at evaluating the influence of sulfur doses in nutrients contents of collard greens cultivated with compost organic and gypsum.

Material and Methods

The experiment was conducted at São Manuel Experimental Farm, belonging to the FCA / UNESP, in São Manuel-SP (geographic coordinates: 22 46 'south latitude, 48 34' west longitude of Greenwich and altitude of 750 m). The average temperature is 20.9 °C and annual average precipitation of 1,395 mm (Prado, 2013). The soil is a typical Dystrophic Red Latosol (Oxisol), and at a depth of 0-20 cm, results of chemical analyzes were: pH $_{(CaCl2)}$ = 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}; CEC = 49 mmol$_c$ dm^{-3}; and base saturation (V) = 76%.

Twelve treatments were evaluated in a split-plot, three types of soil preparation in plots and sulfur doses top dressing in subplots. The three types of soil preparation were obtained with the incorporation of pre-planting (2 days before transplantation of seedlings) the organic compost (30 t ha^{-1}) Visafértil® (trade mark); gypsum (1.2 t ha^{-1}); organic compost (30 t ha^{-1}) plus gypsum (1.2 t ha^{-1}). As recommendations Raij et al. (1997) to cover mineral fertilizer in collard greens, total sulfur doses top dressing were 0; 53.32; 106,68 and 160 kg ha^{-1} S, corresponding to 0; 266; 532 and 800.0 kg ha^{-1} of ammonium sulfate. For uniform top dressing dose of N (160 kg ha^{-1} of N) were used 360; 237.2; 119.2 and 0.0 kg ha^{-1} of urea. At 15 days after transplantation (DAT), fertilizers were applied to the surface of the soil and distributed around each plant, and repeated every 14 days, a total of four applications being ¼ of the total dose in each application. In the third and fourth topdressing, it was also added potash fertilizer (20 kg ha^{-1} K_2O in each application).

During the preparation of the soil, concurrently with treatment, the plots received 2.0 t ha^{-1} formulated 04-14-08. Then, if the rotavator used to incorporate the organic compost, gypsum and fertilizer in the soil.

In the organic fertilizers used the Visafértil® compost was analyzed in Soil Laboratory Resources and Environmental FCA, and had the following guarantees the natural %: 0.7 C; P_2O_5 1.0; 0.7 K_2O; 6.8 Ca; 0.4 Mg; S 0.4; U-65 22.0 ° C; 24.0 Total of MO-13 and C-Total; in mg kg^{-1} to natural: Na 2558; 67 Cu; 17316 Fe; Mn 577; 97 Zn. The C / N ratio is 19.1 and pH = 6.0.

The experimental design was used in a randomized block design with 4 replications and 18 plants per plot arranged in three rows of planting. As useful plot, it was considered the four main plants.

In 07.29.2016 was performed sowing collard greens, hybrid Hi-Crop® in Carolina Soil® substrate, packed in black polypropylene rigid trays with 162 cells containing one plant per cell. At 27 days after sowing the transplant was conducted in beds at a spacing of 0.50 m between rows and 1.60 m between plants following the quincunx system with 12,500 plants per hectare.

Sprinkler irrigation was used, applying a middle layer of 3 mm day^{-1} to avoid permanent wilting point. All the techniques used in conducting plants followed the recommendations of Trani et al. (2015).

The first harvest was made at 30 DAT, with leaves of at least 20 cm long, repeating every ten days, and finalizing assessments in the fourth harvest. They were determined as those commercial leaves with length greater than or equal to 20 cm and no apparent visual defects. The dry weight was obtained fresh and subsample consisted of three commercial leaves harvested per experimental plot in the second, third and fourth crops, drying in an oven at 65 ° C with forced air circulation until constant weight.

After weighing, the material was ground and digested for determination of N, P, K, Ca, Mg and S as shown by methodologies Malavolta et al. (1997).

Data were subjected to analysis of variance and the significance was found by F test, the average values of tillage treatments were compared by Tukey's test at the 5% significance level. For sulfur doses regression was performed. We used the statistical program Sisvar.

Results and Discussion

The coverage of sulfur doses applied on collard greens cultivated with organic compost and gypsum were not significant for most of these content macronutrients in the leaves with the exception of magnesium and sulfur. The interaction between these factors was also no significant F test at the 5% probability (Table 1).

Table 1. Mean content of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) in commercial collard greens leaves using sulfur top dressing in different preparations of the soil. San Manuel, 2016.

Soil preparation	N	P	K	Ca	Mg	S
			g kg^{-1} of dry matter			
Organic Compost (OC)	37.33	4.01	38.67	22.58	4.57	3.96
Gypsum (G)	35.75	3.80	38.08	22.00	4.57	4.33
OC + G	36.42	3.58	37.00	20,50	4.36	4.40
S doses (kg ha^{-1})	N	P	K	Ca	Mg	S
				g kg^{-1} of dry matter		
0	36.44	3.93	40.33	22.22	4.81	3.99
53.32	37.11	3.70	36.56	22.11	4.58	4.23
106.68	37.00	3.66	37.56	21.44	4.34	4.26
160	35.44	3.90	37.22	21,00	4.26	4.44
Overall average	36.50	3.80	37.92	21.69	4.50	4.23
CV1 (%)	10.00	13.88	6.81	11.74	8.00	13.26
CV2 (%)	7.22	11.69	10.87	10.79	9.18	9.70
F (soil prep.)	0.57ns	1.95ns	1.29ns	2.14ns	1.34ns	2.16ns
F (S)	0.75ns	0.89ns	1.47ns	0.55ns	3.29 *	1.87ns
F (soil prep. x S)	1.20ns	0.56ns	2.96ns	0.78ns	0.85ns	1.84ns

ns not significant at 5% the test F

Among the macronutrients analyzed, it can be seen that potassium had greater leaf content, with an average of 37.92 g kg^{-1} of dry matter (DM) and nitrogen content very close to the mean of 36.50 g kg^{-1} MS (Table 1). These figures are within the proper range indicated by Trani et al. (2015) which is 20 to 40 and 30 to 55 g DM kg^{-1} for K and N respectively. The superiority of potassium and nitrogen was also found in collard greens leaves the work Corrêa et al. (2013), and Cardoso et al. (2016) in cauliflower, analyzing vegetative and reproductive part. The fact suggests special attention to replacement of these nutrients in the soil through fertilization top dressing, according to the recommendations of Trani et al. (2015).

There was suitable for foliar phosphorus second Trani et al. (2015), averaging 3.80 g kg^{-1} DM (Table 1), approximately 10% of potassium and nitrogen content. Probably, the high phosphorus content in the soil (P = 82 mg dm^{-3}) as indicated by Raij et al. (1997) was sufficient for the cultivation of collard greens, which explains the lack of significant differences between treatments.

The calcium in the leaves showed overall average of 21.69 g kg^{-1} DM (Table 1). The value lies within the range considered normal calcium by Trani et al. (2015) which is 15 to 25 g kg^{-1} in DM. It has been found that gypsum (16% Ca) used alone or in combination with the organic compost, did not increase the nutrient content in the leaves. However, the soil already had normal calcium content (28 mmol$_c$ dm^{-3}) was dispensed so that the liming.

In Figure 1 it was noted that even with decrease in magnesium leaf content, as increased sulfur doses top dressing collard greens leaf, the values found in the appropriate range of 3 to 7 g kg^{-1} DM second Trani et al. (2015). Besides not having, magnesium visual impairment was observed in leaves collected in the treatments possibly existing magnesium content in soil is enough for nutrition of the same. Probably the use of ammonium sulfate, which releases sulfate in the soil, can be formed ion pair with Mg^{2+} or even as ions leaching. Other factors that were associated and may be influenced are low soil CEC study, high level of Ca^{2+} in the soil (28 mmol$_c$ dm^{-3}). Frequent fertilization with potassium top dressing and the very removal of magnesium the crops (Foloni et al., 2006; Zambrosi et al., 2007). Despite this reduction in the contents was not impaired magnesium observed in leaves collected in the treatments.

By regression analysis, the sulfur leaf of collard greens recorded linear increase to the highest dose evaluated: 160 kg ha^{-1} (Figure 2). However, even in the absence of coverage S (dose 0), abnormality was not observed visually in the leaves. In the absence of topdressing with sulfur, the supply path gypsum or organic compost, or the two products together, in addition to the already present in the soil sulfur, have been sufficient to meet the requirements of plants in the nutrient and probably occurred luxury uptake at higher doses (Figure 2). Comparing with nitrogen, the N: S ratio was 8.6: 1. This proved suitable as Alvarez-Venegas et al. (2007), cited in plant tissues that the proportion of these two nutrients varies from 8: 1 to 15: 1.

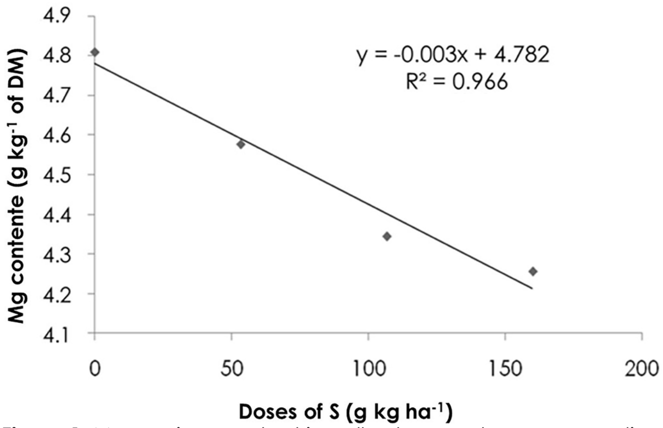

Figure 1. Magnesium content in collard greens leaves according to sulfur doses in top dressing. São Manuel, 2016.

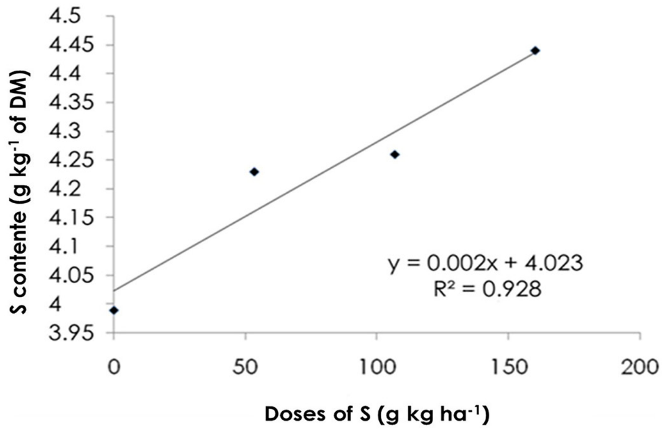

Figure 2. Sulfur content in collard greens leaves according to sulfur doses in top dressing. San Manuel, 2016.

The order decreasing the foliar levels in collard greens leaves was: K> N> Ca> Mg> S> P, with potassium being more extracted nutrient and sulfur being higher than the phosphorus and very close to the magnesium content. This result was similar to the study of cabbage leaves, which Corrêa et al. (2013) observed the following order of nutrients: K> N> S> Ca> P> Mg. Cauliflower (inflorescence) was descending order N> K> Ca> S> Mg> P (Castoldi et al., 2009), and leaf, stem and inflorescence N> K> Ca> O> P> Mg (Takeishi et al., 2009); where in these studies, the sulfur was superior to phosphorus and magnesium. In cauliflower (Cardoso et al., 2016), the S was the second most nutrient found. Considering the same botanical species, B. *oleracea*, one realizes that the order, although similar, are not the same. Sometimes different organs, such as leaves, inflorescences and seeds, can compare the difference. Other times, may influence the body's age and mobility of nutrients. For example, the search Cardoso et al. (2016) was the nutrient calcium with a higher content in leaves. However, these analyzes were performed at the end of the cycle, after harvesting the seeds. Thus, usually more nutrients accumulated in the young leaves, C and K had already been partly translocated to the fruits and seeds, and Ca, slightly movable in the plant, and the leaves remained. Therefore, the information on foliar content of nutrients by the plants are very important for the proper management of fertilization, aimed at better utilization of nutrients combined with lower production costs. However, the whole context has to be carefully analyzed. In this study, all the nutrients present in the leaves are exported from the field and require replacement.

Conclusions

Sulfur doses does not change contents of the macronutrients N, P, K and Ca on collard greens cultivated with organic compost and gypsum, while for the sulfur content are obtained linear increase occurs and magnesium foliar decreased.

The decreasing order of macronutrient content of commercial collard greens leaves was K>N>Ca> Mg> S> P, with averages 37.92, 36.50, 21.69, 4.50, 4.23, 3.80 g kg^{-1}, respectively.

Acknowledgements

The authors thank the Agency Paulista Agribusiness Technology (APTA, Brazil), and the São Paulo Research Foundation (FAPESP, Brazil), for granting of financial support for research and scholarships.

References

Abdallah, M., Dubousset, L., Meuriot, F., Etienne, P., Avice, J.C., Ourry, A. 2010. Effect of mineral sulphur availability on nitrogen and sulphur uptake and remobilization during the vegetative growth of *Brassica napus* L. *Journal of Experimental Botany* 61: 2635-2646.

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: 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, Brazil. p. 595-646.

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: 196-201.

Castoldi, R., Charlo, H.C.O., Vargas, P.F., Braz, L.T. 2009. Crescimento, acúmulo de nutrientes e produtividade da cultura da couve-flor. *Horticultura Brasileira* 27: 438-446.

Correa, C.V., Cardoso, A.I.I., Claudio, M.T.R. 2013. Produção de repolho em função de doses e fontes de potássio em cobertura. *Semina: Ciências Agrárias* 34: 2129-2138.

Dalla Nora, D., Amado, T.J.C., Bortolotto, R.P., Ferreira, A.O., Reichardt, K., Santi, A. L. 2014. Subsoil chemical amelioration and crop yields under continuous long-term no-till in a subtropical Oxisol. *African Journal of Agricultural Research* 9: 3338-3349.

Freitas, L.A., Mello, L.M.M., Yano, E.H., Pereira, D.S., Rosestotelato, L.L.R., Souza, F.H. 2017. Residual de gesso e manejos conservacionistas sobre atributos físicos do solo. *Cultura Agronômica* 26: 483-491.

Foloni, J.S.S., Rosolem, C.A., Garcia, R.A. 2006. Efeito da calagem e sulfato de amônio no algodão. II – Concentração de cátions e anions na solução do solo e absorção de nutrientes pelas plantas. *Revista Brasileira de Ciência do Solo* 30: 433-442.

Gocher, P., Soni, A.K., Mahawar, A.K. 2017. Effect of NPK and sulphur on yield, yield attributes and economics of cauliflower (*Brassica oleracea* var. botrytis L.) variety Pusa Syntheti. *International Journal of Current Advanced Research* 6: 39050-3953.

Hemlata, V., Nawange, D.D. 2015. Effect of different levels of nitrogen and Sulphur on the growth, Yield and quality of cabbage [*Brassica oleracea* var. capitate L.]. *Agricultural Science Digest* 35: 52-154.

Jamre, B.R., Nagaich, K.N., Verma, H. 2010. Effect of different levels of sulphur and zin on growth and yield of cauliflower (*Brassica oleracea* var. botrytis L.). *The Asian Journal of Horticulture* 5: 323-325.

Magro, F.O., Cardoso, A.I.I., Fernandes, D.M. 2009. Acúmulo de nutrientes em sementes de brócolis em função de doses de composto orgânico. *Cultivando o Saber* 2: 49-57.

Malavolta, E., Vitti, G.C., Oliveira, S.A. 1997. *Avaliação do estado nutricional das plantas: princípios e aplicações*. 2.ed. Potafós, Piracicaba, Brazil. 319 p.

Prado, R.C. 2013. *Resenha climatológica* (1971 a 2006). São Manuel-SP. http://www.fca.unesp.br/#!/instituicao/departamentos/solos-recursos-ambientais/sra/estacao-meteorologica/resenha-climatologica/. <Access on 31 May. 2019>

Raij, B.V., Cantarella, H., Quaggio, J.A., Furlani, A.M.C. (Ed.). 1997. *Recomendações de adubação e calagem para o Estado de São Paulo*. 2.ed. rev. e atual. Instituto Agronômico/Fundação IAC, Campinas, Brazil. 285 p.

Santos, F., Borsoi, A., Secco, D., Souza, S.N.M., Frigo, E.P. 2012. Nitrogen and sulfur sources in the culture of *Brassica napus* L. var. oleifera. *Journal of Food, Agriculture & Environment* 10: 516-518.

Takeishi, J., Cecílio Filho, A.B., Oliveira, P.R. 2009. Crescimento e acúmulo de nutrientes em couve-flor ‘Verona’. *Bioscience Journal* 25: 1-10.

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. *Couve de folha: do plantio à pós-colheita*. Instituto Agronômico, Campinas, Brazil. 36 p. http://www.iac.sp.gov.br/publicacoes/publicacoes_online/pdf/BoletimTecnico214.pdf.<Access on 10 nov. 2019>.

Zambrosi, F.C.B., Alleoni, L.R.F., Caires, E.F. 2007. Aplicação de gesso agrícola e especiação iônica da solução de um Latossolo sob sistema plantio direto. *Ciência Rural* 37: 110-117.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.