academicJournals

Vol. 11(35), pp. 3287-3292, 1 September, 2016
DOI: 10.5897/AJAR2016.11398
Article Number: 6062A7D60253
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Response of broccoli to sulphur application at topdressing in the presence or absence of organic compost at planting

Carla Verônica Corrêa*, Aline Mendes de Sousa Gouveia, Bruno Novaes Menezes Martins, Ana Emília Barbosa Tavares, Natália de Brito Lima Lanna, Antonio Ismael Inácio Cardoso and Regina Marta Evangelista

Faculdade de Ciências Agronômicas, Rua Doutor José Barbosa de Barros, 1780, 18610-307, Botucatu-SP, Brazil.

Received 5 July, 2016; Accepted 17 August, 2016

The literature has confirmed the efficacy of sulphur (S) when growing *Brassicaceae*. However, there are no studies with this nutrient on broccoli. Therefore, the aim of this study was to evaluate the response of broccoli (hybrid Avenger) to sulphur rates applied at top dressing in the presence or absence of organic compost at planting. The experimental design was a randomized complete block, with ten treatments (5 x 2 factorial design) and four repetitions. Treatments consisted of five S (ammonium sulphate) rates (0, 31, 62, 93 and 124 kg ha^{-1}); with organic compost (100 t ha^{-1}) in planting or without organic compost in planting. After harvesting, head fresh matter, head diameter and number of leaves were evaluated. In general, head diameter, head height and fresh matter increased in all treatments by adding organic compost. A quadratic effect was observed for head fresh matter and head height by applying organic compost (100 tha^{-1}), as the maximum values were 620.6 g and 17.2cm at the rate of 66.9 and 49.2 kg S ha^{-1}, respectively.

Key words: *Brassica oleracea* var. italica, fertilization, sulphate.

INTRODUCTION

Broccoli (*Brassica oleracea* var. *italica*) belongs to the B*rassicaceae* family. It is well known for its nutritional value, as it provides vitamins and fibre, preventing against some types of cancers and heart diseases; easily produced; and has already spread its popularity on global market (Keck, 2004; Baenas et al., 2016; Bachiega et al., 2016; Ciancaleoni et al., 2016). In Brazil, there are two types of broccoli cultivars, that is, “ramoso” and “single-head” (Filgueira, 2008).

“Ramoso” is characterized by a small main head; coarse-grained; a considered number of side shoots; multiple crops; and sold by the bunch (stems). Whilst,

*Corresponding author. E-mail: cvcorrea1509@gmail.com

"single-head" type features one large central head and reaches an average of about 400 g. Furthermore, "single-head" is more compact and presents fewer shoots than "ramoso". But, both consist of tightly closely buds; dark green colour and tender stems.

Among the crops, brassica has a good response to organic fertilization. Therefore, this type of fertilization benefits the soil, which supports plant growth by improving water retention and, consequently, penetration capacity; improving the structure; aeration; drainage; influencing microbial community and, hence, eliminating the undesirable ones; and increasing plant nutrient availability (Filgueira, 2008).

By using a large rate of organic compost (25 tha^{-1}), Diniz et al. (2008) showed the highest production of broccoli and large amount of dry matter in the experiment. The amounts of soil nutrients extracted by brassica are large, for example, sulphur (s) and nitrogen (Rathke et al., 2006; Berry et al., 2010). S is an essential nutrient for plant growth, as it forms amino acids; vitamins; cofactors; and secondary products, such as glucosinolates (Marschener, 2011). There are a few studies on the effects of S fertilizer with brassica under tropical conditions. There are some studies on cabbage, but no production differences were found due to application of S fertilizer (Correa et al., 2013).

Plants have different abilities to absorb, translocate and use sulfur and therefore require different amounts of available ground SO_4^{-2}. Some plants, such as those of the family of legumes, brassicas and Liliaceae only express their genetic potential in terms of productivity and quality when the availability of this nutrient is high, and then established a critical level of 10 mg dm^{-3}, while for the remaining species this low value to 5 mg dm^{-3}.

Considering these reference values for the surface layer of soil, about 50% of the total area of tropical soils and sub-tropical South America can be considered deficient in sulfur. The availability of organic sulfur to plants depends from the processing of the inorganic forms almost exclusively in the form of sulfate ($SO4^{-2}$). In tropical soil conditions due to increased precipitation and temperature there is a rapid depletion of organic matter and consequently low S content available to plants. In addition, both the total amount of sulfur as the adsorption capacity of SO_4^{-2} are lower in soils with low clay content and retention is further reduced by the application of lime and phosphate, practices these highly practiced in Brazil because present acidic soils. Thus, there is a shift of this ion to the deeper layers, where it can be adsorbed because of higher clay content and lower levels of organic matter and pH (Rheinheimer et al., 2005).

In current days, agriculture aims to develop a sustainable and productive manner, such as fertilizer best management practices to achieve a better production (Fageria and Baligar, 2005). Given all that has been earlier mentioned, this current study aimed to evaluate the response of broccoli to S application at top dressing, in the presence or absence of organic compost at planting.

MATERIALS AND METHODS

The experiment was conducted in the Sao Manuel Experimental Farm, Botucatu School of Agronomy, UNESP (22°46'28"S, 48°34'37"W; 740 m altitude), Brazil. According to the Köppen classification, the climate in the region is mesothermic, *Cwa*, that is, humid and subtropical, dry in the winter with a rainy season between November and April. The mean annual rainfall of São Manuel is 1445 mm; the mean annual temperature of the warmest month is 22°C; and the mean temperature of the coldest month is 17.5°C (Cunha and Martins, 2009).

The soil is classified as Dystrophic Red Latosol (Oxisoil) of texture sandy. Soil samples were collected for analysis at several sets from depths of 0 to 0,20m to determine their chemical attributes: pH in $CaCl_2$, 6.0; M.O., 10 g dm^{-3}; P_{resin},90 mg dm^{-3}; H+Al, 14 $mmol_c$ dm^{-3}; K, 3.2 $mmol_c$ dm^{-3}; Ca, 24 $mmol_c$ dm^{-3}; Mg, 8 $mmol_c$ dm^{-3}; SB, 35 $mmol_c$ dm^{-3}; CTC, 49 $mmol_c$ dm^{-3}; V%, 72; and S, 4.0 $mmol_c$ dm^{-3}.

The experimental design was a randomized complete block, with ten treatments (5 x 2 factorial schemes) and four replications; three rows, 11 plants per row, but only the central line were evaluated. It was applied five S rates (0, 31, 62, 93 and 124 $kgha^{-1}$) at planting in the presence (100 tha^{-1}) and without organic compost in planting. For the treatments receiving S topdressing fertilization, the highest rate of ammonium sulphate (23% S and 20% N) recommended by Raij et al. (1997) (108 kg N ha^{-1}) was used as reference. This rate is recommended from the state of São Paulo, Brazil.

With regards to the soil analysis, based on the recommendations of Raij et al. (1997), it was applied 60 kg N ha^{-1}; 200 kg P_2O_5 ha^{-1}; 120 kg K_2O ha^{-1}; in formulation 4-14-8 (NPK) and organic compost at planting by walking tractor. The organic compost Provaso® was chosen and its chemical analysis showed values of pH, 8.2; M.O, 13.3; N, 0.43; P_2O_5, 0.62; K_2O, 0.48; Ca, 1.61; Mg, 0.17; and S, 0.20, all expressed in g $kg^{-1}$of dry matter. The ratio of C/N was 19/1; and the moisture content of the compost was 38%.

In the topdressing fertilization, S was applied into three times, every 15 days after transplanting. According to the methodology described by Raij et al. (1997), it was applied N (108 $kgha^{-1}$) and K_2O (90 kg ha^{-1}) too, 1/3 of the respective doses in the same dates of the topdressing. The source of N and S was ammonium sulphate (23% S and 20% N). Additionally, source of N was completed with urea (45% N); and source of K was accomplished with potassium chloride (60% K_2O).

The hybrid Avenger® of Sakata was used. On March 6, 2014, sowing was performed in polypropylene trays of 200 cells, containing coconut fibre substrate for vegetable seedling production. On March 26, 2014, seedlings were transplanted separately into a microplot of size 0.5 x 0.4m. Sprinkler irrigation and weed hand control were used from culture tracts.

From 9 to 23rd of July, 2014, (90 the 110 days after sowing) plants were collected to evaluate the following characteristics: fresh matter; head height; head diameter; and number of green leaves. For matter, it was used a semi-analytical balance with a precision of 0.1g (expressed in grams per plant); for diameter, caliper was used (expressed in centimetres); and for height, a graduated ruler (expressed in cm). The harvesting of the clumps cutting was performed manually with the aid of a knife approximately 5 cm below the insertion of the inflorescence. three harvests were made

Table 1. Fresh matter; head diameter, head height (cm) in the presence (100 t ha^{-1}) or absence of organic compost with different rates of S topdressing at planting. FCA/UNESP, São Manuel-SP, 2014.

Compost (t ha^{-1})	Sulphur rates (kg ha^{-1})				
	0	31	62	93	124
Head fresh matter (g $plant^{-1}$)					
Without	305.3[b]	432.5[b]	435.8[b]	466.0[b]	341.3[b]
With	351.0[a]	590.8[a]	631.0[a]	526.3[a]	467.5[a]
CV (%)			6.08		
Head diameter (cm)					
Without	15.7[b]	18.1[b]	19.0[b]	19.2[a]	18.3[b]
With	19.4[a]	20.7[a]	23.3[a]	19.4[a]	20.7[a]
CV (%)			6.35		
Head height (cm)					
Without	11.9[b]	12.4[b]	12.3[b]	15.4[a]	13.0[a]
With	15.4[a]	17.2[a]	18.3[a]	14.3[b]	14.4[a]
CV (%)			6.76		

Means followed by different letters differ by Tukey test at 5% probability.

because the inflorescences did not show up formed at the same time, demonstrating the non-uniformity of the hybrid employed.

Data were subjected to analysis of variance (ANOVA) and regression for S rates. For the S topdressing fertilization in the presence or absence of organic compost, means were compared by Tukey test ($p < 0.05$) by the Sisvar software (Ferreira, 2010).

RESULTS AND DISCUSSION

For all the traits, the interaction between the presence or absence of organic compost and S topdressing fertilization were significant, except of number of leaves per plant that had no differences with or without organic compost, as both presented an average of 24 leaves per plant. These results corroborates with the one found by Kano et al. (2008) and Ferreira et al. (2013), 23.5 and 24.0 per plant, respectively.

In general, all treatments with organic compost (100 t ha^{-1}) at planting have increased fresh matter, head diameter and head height (Table 1). Studies have revealed that organic fertilizers release nutrients (Cardoso et al, 2011), which are absorbed by plants, consequently, increasing the production (Dinis et al., 2008; Ferreira et al., 2013).

The recommended rates of organic compost for *Brassicaceae* lie generally between 10 to100 t ha^{-1}, but higher levels are not uncommon. However, the amount of organic compost may depend on the crop; quality assurance of the materials; soil properties; time management and environmental conditions (Villas et al., 2004; Ferris et al., 2012).

Additionally, in this experiment the soil was very sandy (more than 70% of sand), which requires more organic fertilizers than recommended. Furthermore, organic compost also improves the physical and biological properties of the soil when adequate macro and micronutrients are supplied (Reeve et al 2016). The organic compost benefits the soil, which supports plant growth by improving water retention and, consequently, penetration capacity; improving the structure; aeration; drainage; influencing microbial community. With regards to sulphur topdressing fertilization, a quadratic effect was obtained for head fresh matter according to the rates in the presence or absence of organic compost at planting (Figure 1).

The maximum values were estimated at 465.4g $plant^{-1}$ (without organic compost) and 620.6 g $plant^{-1}$(with organic compost) at the rate of 66.9 kg S ha^{-1}. For the control treatment (zero dose), it was obtained an increase in more than 50% for the head fresh matter, i.e., 158.5g $plant^{-1}$ (without organic compost) and 247.0 g $plant^{-1}$ (with organic compost). This result demonstrates the importance of applying sulphur to plant growth and development of plants (Khan et al., 2015; Asgher et al., 2014). Schonhof et al. (2007) observed an increase in the broccoli head matter by applying adequate rates of sulphur. Therefore, these results confirmed findings of previous studies on broccoli (Schonhof et al., 2007;

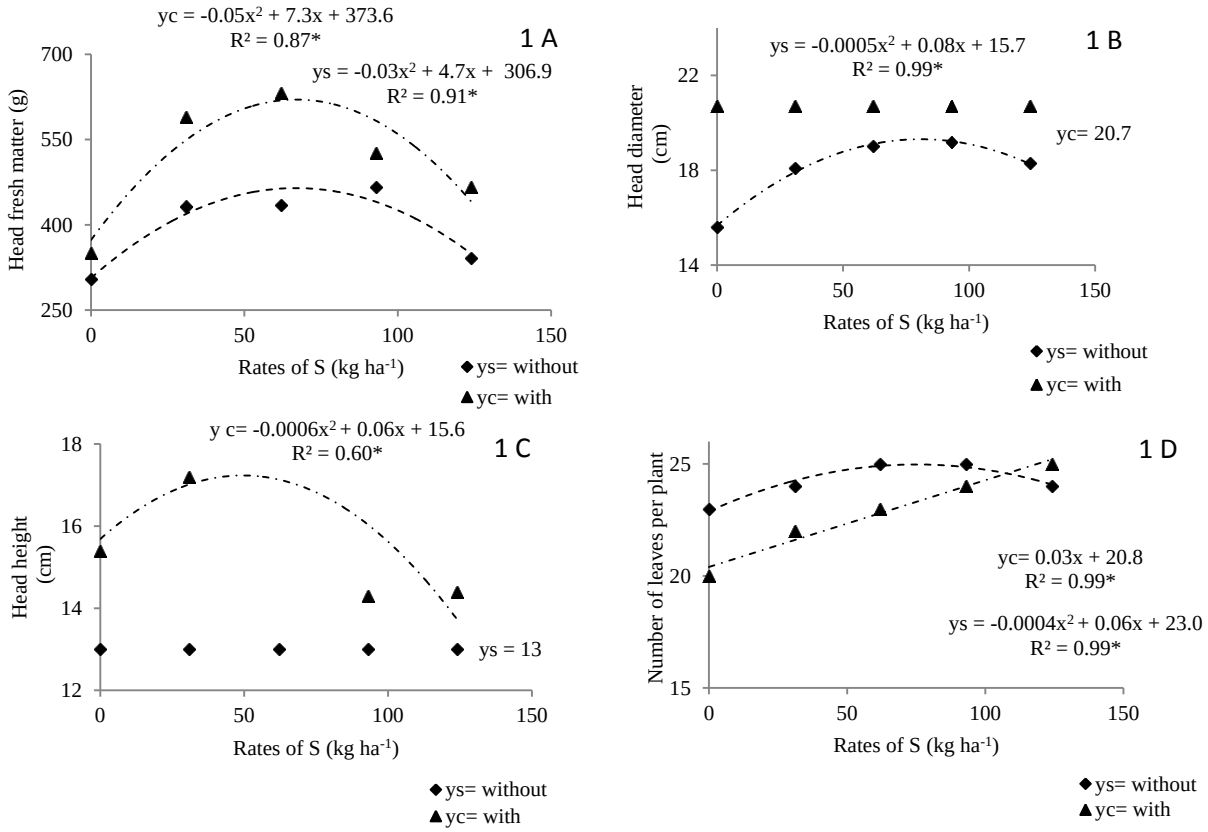

Figure 1. Fresh matter, head diameter, head height and number of leaves per plant by applying different rates of S topdressing in with (y_c) or without (y_s) of organic compost at planting. FCA/UNESP, São Manuel-SP, 2014.

Elwan et al., 2010).

For the treatments in the absence of fertilizer, the minimum value was 306.9 g plant^{-1}. However, with organic compost, the maximum value was 620.6 g plant^{-1} by applying 66.9 kg ha^{-1}of S in topdressing. Therefore, the results were close to those found by Diniz et al. (2008), Lalla et al. (2010) and Freitas et al. (2011), who obtained maximum value which ranged from 405 to 600 g plant^{-1} in broccolis. Although, these results were lower than those reported by Kano et al. (2008), who obtained a maximum value of 963.2 g plant^{-1}. Bearing in mind the different management and environmental conditions, the results were compatible.

For the head diameter, a quadratic effect was obtained, reaching the maximum value of 19.3 cm by applying 81.1 kg ha^{-1} of S in topdressing without organic compost (Figure 1 B). However, it was not observed any difference between the analysis of variance and regression to the sulphur rates when organic compost was added, with an average of 20.7cm. Therefore, the application of organic compost within the studied range may dispense any further application of S in topdressing. These results corroborates with the one found by Pizetta et al. (2005) and Kano et al. (2008), 20.4 and 20.5 cm in broccolis, respectively. However, these values were higher than those reported by Lalla et al. (2010) and Ferreira et al. (2013), that is, 15.5 cm and 13.0 cm, respectively. For the head height, it presented an average of 13.0 cm without organic compost at planting. However, it was observed a quadratic effect with organic compost, reaching a maximum value of 17.2 cm at a rate of49.2 kg S ha^{-1} (Figure 1 C).

The organic matter is a source of all the macro and micronutrients necessary for the development of vegetables. In the presence of organic matter is observed larger heads precisely for allowing nutrient supply, and improved soil characteristics such as increased water retention, increased aeration. It can be seen that for the characteristic head diameter, S have little influence in the presence of organic matter, and absence of organic matter influence its diameter at low doses. Excessive doses of S do not contribute to increase the size of

broccoli head. Excessive doses can be lost by leaching very common in sandy soils with low organic matter as used in this research. The application of organic matter allows improvements as greater availability of nutrients, and lower losses by leaching. From the figures in general, there is a great deal of sulfur (66.9 kg ha^{-1}) and organic compound (100 t ha^{-1}) for best broccoli yields, showing the interaction between chemical and organic fertilizers.

The number of leaves per plant presented a linear effect to the equation in the presence of organic compost at planting. However, a quadratic effect was observed without organic compost, reaching a maximum average of 25.3 per plant by applying 75 kg Sha^{-1}in topdressing (Figure 1 D). These values are close to those reported by Ferreira et al. (2013), who obtained a higher number of leaves per plant (that is, 24 leaves) with bokashi compost (10 t ha^{-1}) in the broccoli production.

In general, the application of S in topdressing influenced all the evaluated traits of the head. S is constituent of diverse enzymes used for the synthesis of hormones, proteins, vitamins, and enzyme cofactors and a precursor for several metabolites such as ethylene, polyamines, plays a role in photosynthesis; nitrogen fixation; chlorophyll biosynthesis; and micro and macronutrients uptake (Salvagiotti et al., 2009). Thus, it is an essential element for the plant growth and production (Leustek, 2002).

Despite all these functions, S has been neglected by most of the researchers. In brassica, there are reports that this nutrient are accumulated to more than twice the P levels (Yamada et al., 2007); it is also the second most accumulated nutrient in cauliflower seeds (Cardoso et al., 2016). Although, the effect of S on the head characteristics is often quadratic, indicating that in excess can be harmful. Taking into account, the highest rate of this study (124 kg S ha^{-1}), it was just obtained by using the highest rate of N recommended by Raij et al. (1997), but this amount of N, as ammonium sulphate, can be detrimental. Considering all the treatments with organic compost (100 t ha^{-1}) (Figure 1), it reached 373.6 g for head matter (0 dose); maximum value of 620.6g (at a rate of 66.9 kg S ha^{-1}); and 510.0 g (at a rate of 124 kg S ha^{-1}).

Therefore, within this study conditions; and to be recommended as a topdressing fertilizer, only half of N should be applied, as ammonium sulphate; and the other half as another source, which should not contain any sulphur.

Conclusion

At planting, organic compost increased broccoli production. Moreover, there was the largest head matter by applying up to 66.9 kg ha^{-1} of S in topdressing and 100 t ha^{-1} of organic compost.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The authors would thank the Coordination for the Improvement of Higher Education Personnel (CAPES) and National Council for Scientific and Technological Development (CNPq) to scholarship granted for the studies.

REFERENCES

Asgher M, Khan NA, Khan MIR, Fatma M, Masood A (2014). Ethylene production is associated with alleviation of cadmium-induced oxidative stress by sulfur in mustard types differing in ethylene sensitivity. Ecotoxicol. Environ. Safety 106:54-61.

Baenas N, Villaño D, García-Viguera C, Moreno DA (2016). Optimizing elicitation and seed priming to enrich broccoli and radish sprouts in glucosinolates. Food Chem. 204:314-319.

Bachiega P, Salgado JM, Carvalho JE, Ruiz ALTG, Schwarz K, Tezotto T, Morzelle MC (2016). Antioxidant and antiproliferative activities in different maturation stages of broccoli (*Brassica oleracea Italica*) biofortified with selenium. Food Chem. 190:771-776.

Berry PM, Spink J, Foulkes MJ, White PJ (2010). The physiological basis ofgenotypic differences in nitrogen use efficiency in oilseed rape (*Brassica napus* L). Field Crops Res. 119:365-373.

Ciancaleoni S, Onofri A, Torricelli R, Negri V (2016). Broccoli yield response to environmental factors in sustainable agriculture. Eur. J. Agron. 72:1-9.

Correa CV, Cardoso AII, Claúdio MTR (2013) Cabbage production in function of doses and sources of potassium coverage. Semina 34(5):2129-2138.

Diniz ER, Santos RHS, Urquiaga SS, Peternelli LA, Barrella TP, Freitas (2008) Growth and broccoli production organic compound doses system function. Cienc. Agrotec. 32 (5):1428-1434.

Elwan MWM, Abd El-Hamed KE (2011). Influence of nitrogen form, growing season and sulfur fertilization on yield and the content of nitrate and vitamin C of broccoli. Sci. Hortic. 127(3):181-187.

Fageria NK, Baligar VC (2005). Enhancing nitrogen use efficiency in crop plants.Adv.Agron. (88):97-185.

Ferreira S, Souza RJ, Gomes LAA (2013). Summer broccoli productivity with different doses of Bokashi. Rev. Agrogeoambiental 5(2):31-38.

Ferris H, Sánchez-Moreno S, Brennan EB (2012). Structure, functions and interguild relationships of the soil nematode assemblage in organic vegetable production. Appl. Soil Ecol. 61:16-25.

Ferreira DF (2010). Sisvar system for statistical analysis. Lavras: UFLA. Available in: <http://www.dex.ufla.br>. Acesso em: 20 nov. 2014.

Filgueira FAR (2008). New manual of horticulture: modern agro-technology in the production and marketing of vegetable. Viçosa: UFV P 421.

Keck AS, Finley JW (2004). Cruciferous vegetables: cancer protective mechanisms of glucosinolate hydrolysis products and selenium. Integr. Cancer Ther. 3(1):5-12.

Kano C, Godoy AR, Higuti ARO, Castro MM, Cardoso AII (2008). Broccoli production in function of tray type and seedling age. Cienc. Agrotecn. 32 (1):110-114.

Khan MIR, Nazir F, Asgher M, Per TS, Khan NA (2015).Selenium and sulfur influence ethylene,formation and alleviate cadmium-induced oxidative stress by improving proline and glutathione production in wheat. J. Plant Physiol. (173):9-18.

Lalla JG, Laura VA, Rodrigues APDC, Seabra Júnior S, Silveira DS, Zago VH, Dornas MF (2010). Competition broccoli cultivars single head type in Campo Grande. Hortic. Bras. 28 (3):360-363.

Leustek T (2002). Sulfate metabolism. In: Somerville CA, Meyerowitz EM (Eds.), The Arabidopsis Book. American Society of PlantBiologists, Rockville, MD pp. 1-17.

Marschener H (2011). Mineral Nutrition of Higher Plants. Academic Press, 3 edition, New York P 672.

Pizetta LC, Ferreira ME, Cruz MCP, Barbosa JC (2005). Broccoli response, cauliflower and cabbage to fertilization with boron in sandy soil. Hortic. Bras. 23(1):51-56.

Raij BV, Cantarella H, Quaggio JÁ, Furlani AMC (1997). Recommendations fertilization and liming for the state of São Paulo. Campinas: Instituto Agronômico&Fundação IAC P 285.

Rathke GW, Behrens T, Diepenbrock W (2006).Integrated nitrogen management strategies to improve seed yield, oil content and nitrogen efficiency of winter oilseed rape (*Brassica napus* L.): A review. Agric. Ecosyst. Environ. (117):80-108.

Reeve JR, Hoagland LA, Villalba JJ, Carr PM, Atucha A, Cambardella C, Davis DR, Delate K (2016). Organic Farming, Soil Health, and Food Quality: Considering Possible Links. Adv. Agron. pp. 1-49.

Rheinheimer DS, Alvarez JW, Osorio Filho BD, Silva LS, Bortoluzzi EC (2005). Response cultures for sulfur application and sulfate levels in a sandy soil under no-tillage. Ciênc. Rur. Santa Maria 35(3):562-569.

Salvagiotti F, Castellarin JM, Miralles DJ, Pedrol HM (2009). Sulfur fertilization improves nitrogen use efficiency in wheat by increasing nitrogen uptake. Field Crop Res. (113):170-177.

Schonhof I, Blankenburg D, Mueller S, Krumbein A (2007). Sulfur and nitrogensupply influence growth, product appearance, and glucosinolate concentration of broccoli. J. Plant Nutr. Soil Sci. 170(1):1-8.

Villas BRL, Passos JC, Maximino D, Büll LT, Cezar VRS, Goto R (2004). Effect of doses and types of organic compounds in the production of lettuce in two soils under protected environment. Hortic. Bras. 22(1):28-34.

Yamada T, Abdala SRS, Vitti GC (2007). Symposium on nitrogen and sulphur in brazilian agriculture. (Piracicaba, SP), Anals... IPNI, Brasil P 722.