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Cientific Paper

Tomato production in function of sulfur doses application

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Abstract

The importance of sulfur (S) has already been noted by various cultures, especially on production aspects; however it might be a limiting factor of productivity due to intensive cultivation system. The purpose of this study was to evaluate the sulfur application on the tomato productivity development. An experiment was conducted in a greenhouse, on 4 kg vessels of soil, in Guarapuava-PR. The experiment was arranged in entirely randomized blocks, of which 6 doses of S (0, 20, 40, 60, 80 and 100 mg kg^{-1}) in the form of agricultural gypsum along with 3 repetitions. Into the vessels it was transplanted a tomato plant (Abiru variety), cultivated for 115 days. The fruits were harvested, washed and weighed and the shoots were cropped, weighed and analyzed in relation to levels of carbon, nitrogen and sulfur. The tomato fruit production increased under sulfur doses, obtaining a 23 to 34% raise. The dry mass of the shoot, content and accumulation increased under the application of sulfur doses on the soil. The C/S and N/S relation decreased on the tomato shoot under sulfur doses, with variable values of 92 to 144 for C/S and 2.1 to 3.1 for N/S. The average relation of C:N:S found on the tomato shoot was of 112:2.4:1. The 2.6 N/S relation on the shoot was the one which presented balance of these nutrients on the tomato production obtainment.

Keywords: absorption; agricultural gypsum; sulfate; horticulture; fertilizer.

Produção de tomate em função da aplicação de enxofre

Resumo

A importância do enxofre (S) já foi constatada para diversas culturas, sobretudo nos aspectos de produção, entretanto pode ser um fator limitante da produtividade devido ao sistema intensivo de cultivo. O objetivo deste trabalho foi avaliar a aplicação de S no desenvolvimento e produtividade do tomateiro. Foi conduzido um experimento em casa de vegetação, em vasos de 4 kg de solo, em Guarapuava-PR. O experimento foi instalado em blocos inteiramente casualizados sendo 6 doses de S (0, 20, 40, 60, 80 e 100 mg kg^{-1}) na forma de gesso agrícola e 3 repetições. Nos vasos foram transplantadas uma muda de tomate (variedade Abiru), cultivadas por 115 dias. Os frutos foram colhidos, lavados e pesados e a parte aérea foi colhida, pesada e analisada em relação ao teor de carbono, nitrogênio e enxofre. A produção de frutos de tomate aumentou em função das doses de S, sendo obtido aumento de 23 a 34%. A massa seca da parte aérea, aumentou em função das doses de S aplicadas ao solo. A relação C/S e N/S diminuiu na parte aérea do tomateiro em função das doses de S, com valores variando de 92 a 144 para C/S e de 2,1 a 3,1 para N/S. A relação média de C:N:S encontrada na parte aérea do tomate foi de 112:2,4:1. A relação N/S de 2,36 na parte aérea foi a que representou equilíbrio entre esses nutrientes na obtenção da produtividade do tomateiro.

Palavras Chave: absorção; gesso agrícola; sulfato; olericultura; fertilizante.

Producción de tomate en cada solicitud de dosis de azufre

Resumen

La importancia del azufre (S) ha sido observada en diferentes culturas, especialmente en los aspectos de la producción, sin embargo, puede ser un factor limitante de la productividad debido al sistema de agricultura intensiva. El objetivo de este

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estudio fue evaluar la aplicación de S en el desarrollo y rendimiento del tomate. Se realizó un experimento en invernadero en contenedores de 4 kg de suelo en Guarapuava-PR. El experimento se realizó en bloques completos al azar con 6 dosis de S (0, 20, 40, 60, 80 y 100 mg kg^{-1}) en forma de yeso agrícola y con 3 repeticiones. En los contenedores se trasplantó una plántula de tomate (variedad Abiru), cultivadas durante 115 días. Los frutos fueran cosechados, lavado, pesados y analizados en relación a su contenido de carbono, nitrógeno y azufre. La producción de frutos de tomate aumentó en función de las dosis crecientes de S siendo obtenidos incremento del 23 hasta 34%. La masa seca de la parte vegetativa aumento con la dosis de S aportada al suelo. La relación C/S y en N/S disminuyó en el parte vegetativo del tomate como función de las dosis de S, con valores que van desde 92 hasta 144 para el C/S y 2.1 a 3.1 para N/S. La relación media de C:N:S para la parte vegetativa del tomate fue de 112:2,4:1. La relación N/S de 2,36 en la parte vegetativa fue la que presentó equilibrio entre estos nutrientes en la obtención de lo rendimiento del tomate.

Palabras clave: absorción; yeso agrícola; sulfato; olericultura; fertilizantes.

Introduction

The reduction of crop yields can be related to intensive cultivation of soils with low rates of organic matter and loam, the use of concentrated fertilizers and the continuous sulfur (S) exportation, without replacement, which can lead to a decrease of the availability of that element to the plants, enabling its deficiency. The surface acidity correction, without soil incorporation, favors the sulfate (SO_4^{-2}) movement to deeper layers, which can be another aggravating factor on the availability decrease to the plants, in case there is an obstruction of the root growth in depth.

The plants, though capable of absorbing sulfur by the leaves (VITTI et al., 2006), have their major absorption rate through their roots. The sulfur found in the cells is taken from the soil solution as SO_4^{-2} (ALVAREZ V. et al., 2007) and transported to the root system, mainly by mass flow (SILVA et al., 2002). The sulfur rate on leaves of agricultural crops may vary from 1 to 5 g kg^{-1} (VITTI et al., 2006). This big variation depends on the availability in the soil, which may be the result of primary minerals, iron sulfide and the gypsum; atmospheric deposition; vegetal and animal residues; pesticides and fertilizers (ALVAREZ V. et al., 2007). Soils with high availability of this nutrient allow the plants to absorb quantities superior to their needs, characterizing a superfluous consumption (ALVAREZ, 2004). In these cases, part of the non-metabolized sulfur is stored in the form of SO_4^{-1}, generally in the cell vacuole.

The sulfur availability in the soil is directly proportional to the levels of loam, oxides and organic matter, being also influenced by the soil pH (CHAO et al., 1962). Both the total sulfur amount and the absorption capacity of S-SO_4^{-1} are lower in soils with low loam content, and its retention is still diminished by the application of limestone and phosphate (CAMARGO and RAIJ, 1989). Thus, the sulfate moves to deeper layers in the soil, where it can be absorbed due to the higher loam content, lower organic matter rate and lower pH levels (RHEINHEIMER et al., 2005). Plant nutrition studies showed positive effects of sulfur supply on the productivity of bean plants (CRUSCIOL et al., 2006; FURTINI NETO et al., 2000), radish (RHEINHEIMER et al., 2005), maize (RHEINHEIMER et al., 2005; TIECHER et al., 2012), lopsided oat (TIECHER et al., 2012) and sugarcane (FERNANDES et al., 2007).

The aim of this study was to evaluate the sulfur application on the productivity and development of tomato plants.

Material and Methods

The experiment took place in a greenhouse at Midwest State University (UNICENTRO), Guarapuava-PR, on the period of June to December of 2011. The experiment was conducted in plastic vessels filled with 4 kg of sieved soil (Latossolo Bruno[1]), sifted by 4 mm mesh strainers. The chemical characteristics found in the soil were pH ($CaCl_2$), 5.1; Organic Matter, 39.9 g dm^{-3}; P Mehlich, 0.7 mg dm^{-3}; H+Al, 41.4 $mmol_c$ dm^{-3}; K, 2.1 $mmol_c$ dm^{-3}; Ca, 27 $mmol_c$ dm^{-3}; Mg, 26 $mmol_c$ dm^{-3}; S-SO_4 5.1 mg dm^{-3}, CTC, 96.5 $mmol_c$ dm^{-3} and base saturation, 57.2%.

The soil liming was performed in order to raise the base saturation to 80%, with application of calcium carbonate. The soils were incubated for 7 days with humidity at 60% of water retention capability. The crop fertilization was constituted by the application of 134 mg $vessel^{-1}$ of urea, 2.86 g $vessel^{-1}$ of triple superphosphate and 500 mg $vessel^{-1}$ of potassium chloride, based on the soil analysis.

The experiment was arranged in completely

1 Brasiliam Soil Classification

randomized blocks, with three repetitions per treatment. The treatment was constituted of 6 sulfur doses of 0, 20, 40, 60, 80 and 100 mg kg^{-1}, in the form of agricultural gypsum. After 7 days of incubation, each vessel received a tomato plant, Abiru variety. The tomato seedlings were produced in a Styrofoam tray (40 cells) containing Plantmax substratum and transplanted into the vessels 30 days after its emergence.

During the experiment, it was conducted phytosanitary tracts for plague and disease control, through acaricide and fungicide spraying when necessary. The coverage fertilization was performed with KCl and urea, on 80 and 220 mg kg^{-1} doses of K and N, respectively, split in four applications throughout the experiment. When the flowering started, it was conducted leaf fertilization with boron on the concentration of 1 g L^{-1}.

The plants were harvested at the end of the cycle, 115 days after the transplant. The fruits were washed and weighed, and the tomato shoot was cut close to the ground, washed, dried in a greenhouse at 65º C, weighed and milled. The shoot samples were analyzed in relation to levels of carbon (C), nitrogen (N) and sulfur (S). The total levels of C and N in the samples were determined by dry combustion (1075º C) in a LECO TruSpec Micro equipment, and the sulfur level was determined by dry combustion (1350º C) with the assistance of a LECO S-144 equipment. The C and N levels were used to calculate the C/S and N/S relations on the tomato shoot.

The data were subjected to a variance analysis, and when significance was found it was performed a regression analysis for the sulfur doses. In this analysis, the choice of the regression model was based on the significance of the regression coefficients and on the highest value of the determination coefficient. The statistical analyses were conducted by using the Assistat 7.6 program, beta version.

Results and Discussion

In relation to fresh fruits production, the sulfur addition in the soil promoted productivity raise of the tomato plant, whereas in relation to control treatment the production raised 23 to 34%. The highest fruit productivity (243 g $vessel^{-1}$) was obtained from 75.7 mg kg^{-1} of sulfur (Figure 1A). The sulfur application studied by ZELENÁ et al. (2009) showed that the sulfur influenced the tomato productivity in a different way from those studied by the authors, of which the highest dose of sulfur for the Sejk variety promoted a fruit productivity raise, which was not noticed on the Proton variety.

The sulfur application is not only important for the tomato fruit production raise, but also for other characteristics; among them, the lycopene, which in a study conducted by ZELENÁ et al. (2009) demonstrated that the sulfur application, regardless of its source, significantly influenced the lycopene concentration and the red coloring of two tomato varieties. The authors found that only the nitrogen addition on tomato does not promote lycopene changes in the fruits.

The dry matter production of the tomato shoot (MSPA), in function of the sulfur doses applied to the soil, increased quadratically (Figure 1B). The MSPA production raise reached 77% above the control treatment, with the application of 100 mg kg^{-1} of S. ORMAN (2012); working with sulfur doses of 0, 50, 100 and 200 mg kg^{-1} for tomato cultivation, it hasn't showed significant effect of the MSPA production increase as well, in soil 40% loam soil. However, ORMAN and KAPLAN (2011) reported that the tomato MSPA production increased 6 to 8% with the sulfur application on doses of 0, 50, 100, 150, 200 and 400 mg kg^{-1}, in an 18% loam soil. For the alfalfa plant, MOREIRA et al. (1997) observed that the gypsum doses applied as sulfur sources and the mowing season influenced sensitively the dry matter production.

The sulfur application in the soil promoted increase of sulfur rate on the tomato shoot (Figure 2A), since the levels rose until the highest applied dose (100 mg kg^{-1}). The shoot sulfur doses varied from 2.7 on control treatment to 4.1 g kg^{-1} under the dose of 100 mg kg^{-1} of sulfur. In a study conducted by ORMAN (2012), the concentration of sulfur in the tomato plant increased with the applied doses, when the levels varied from 5.3 to 6.3 g kg^{-1} on the shoot. The same concentration raise on the shoot was obtained by ORMAN and KAPLAN (2011), when the sulfur levels varied from 4.1 to 5.9 g kg^{-1}.

SANTOS et al. (2007), working with ammonium sulfate as sulfur source, found foliar levels on the order of 5.3 to 7.9 g kg^{-1} of sulfur. According to SANTOS et al. (2007), the range described by the authors as sulfur sufficiency for the tomato plant is between 3 and 8 g kg^{-1}.

Due to the increase of MSPA and sulfur level on the tomato shoot, the sulfur accumulation on tomato plants rose, in function of the applied

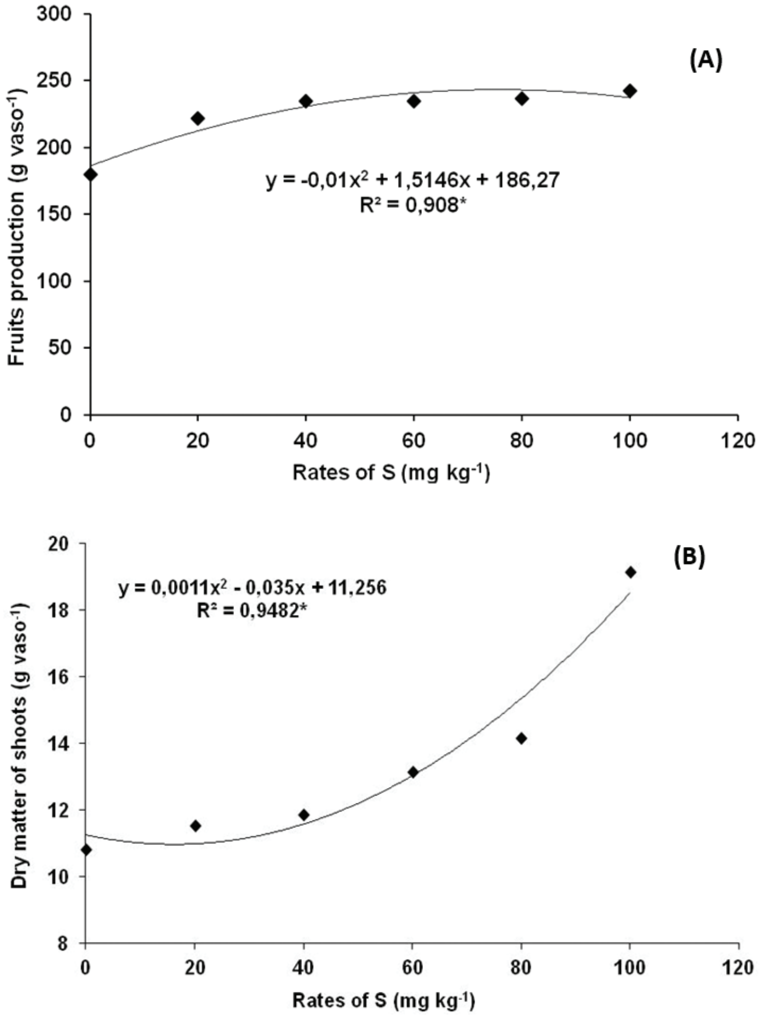

Figure 1. Regression between the sulfur doses applied with fruit production (A) and the dry matter of the tomato shoot (B). * Significant at 5%.

sulfur doses (Figure 2B). According to PRADO et al. (2011), evaluating the absorptions of macronutrients and micronutrients on the Raisa tomato variety, throughout the cultivation season, observed that the sulfur was the least to accumulate, up to the concentration of 0.54 plant^{-1}.

The C/S relation was calculated on all treatments and, as it is shown on Figure 3A, this relation decreased with the raise of sulfur doses applied in the soil. The decrease of this relation was of 36% of the control treatment (C/S of 144) to the dose of 100 mg kg^{-1} (C/S of 92).

The study of the interaction between sulfur and nitrogen, in N/S relation, is directly related to the change of physiological and biological responses of plants (JAMAL et al., 2010). According to JAMAL et al. (2010), the study of the N/S relation can assist on the recommendations of a balanced fertilization of these nutrients for a certain culture.

The N/S relation was also calculated for the tomato shoot and it was observed that this relation decreased with the sulfur application in the soil (Figure 3B). For the N/S relation, the decrease was of 32%. A good relation between the nutrients is important in order to maintain balance between the sulfur and the other nutrients; in case of imbalance

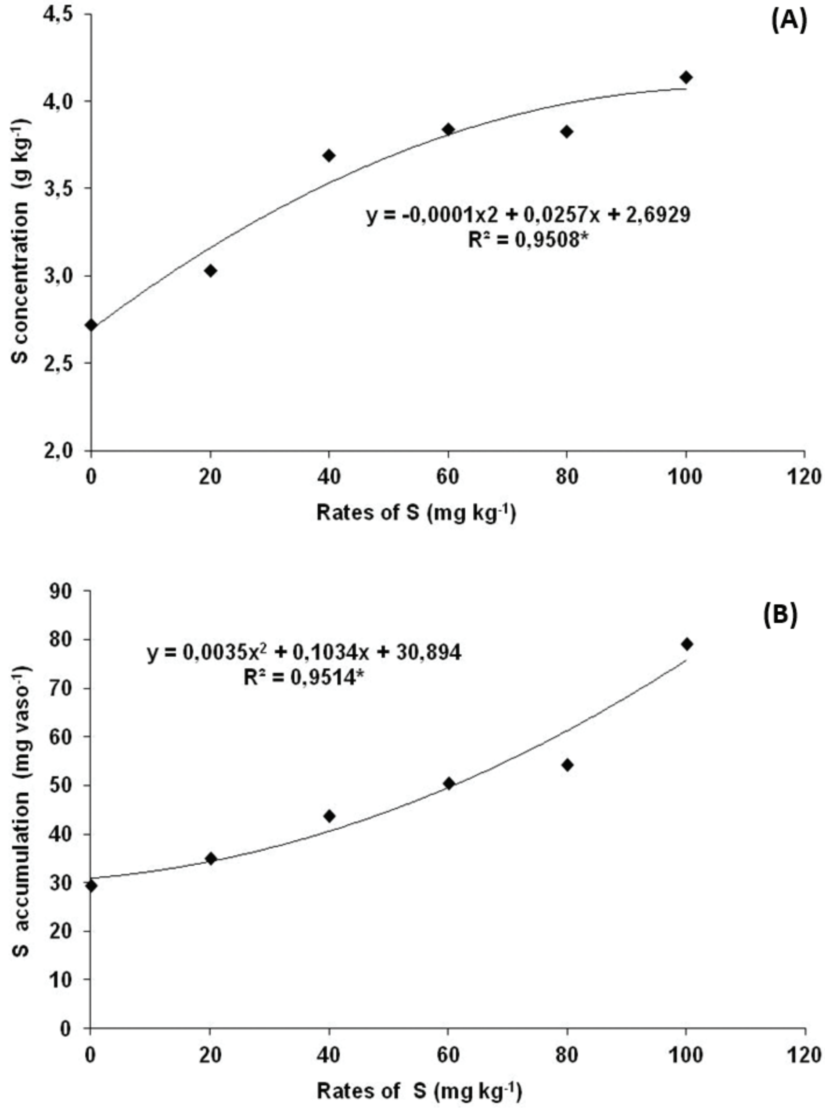

Figure 2. Regression between the applied sulfur doses and the sulfur content (A) and accumulation (B) on the tomato shoot. * Significant at 5%.

it can reduce the absorption of certain nutrients and compromise the plant growth. Wheat plants cultivated in sandy loam soil responded to the sulfur applications through a higher absorption of this element and a lower N/S relation (WARMAN and SAMPSON, 1994). For the canola, JANZEN and BETTANY (1984) found that the cultivation yield was obtained only when the nitrogen and sulfur availability was balanced. The authors verified that the optimum ratio was estimated as 7:1 and found that the excessive sulfur application in relation to the nitrogen availability produced an overwhelming sulfur accumulation in the plants tissues and a reduced seed production. The N/S relation of 9.4 to 6.4 can be considered adequate to the palm tree growth (ABO-RADY et al., 1988).

ORMAN (2012) found a varying N/S relation of 3 to 4.46 and ORMAN and KAPLAN (2011) found values of 5.85 to 3.49, both for tomato cultivation. For the values verified by ORMAN and KAPLAN (2011) a decrease of this relation occurred with the raise of the sulfur dose applied. The 5.06 to 4.47 proportion,

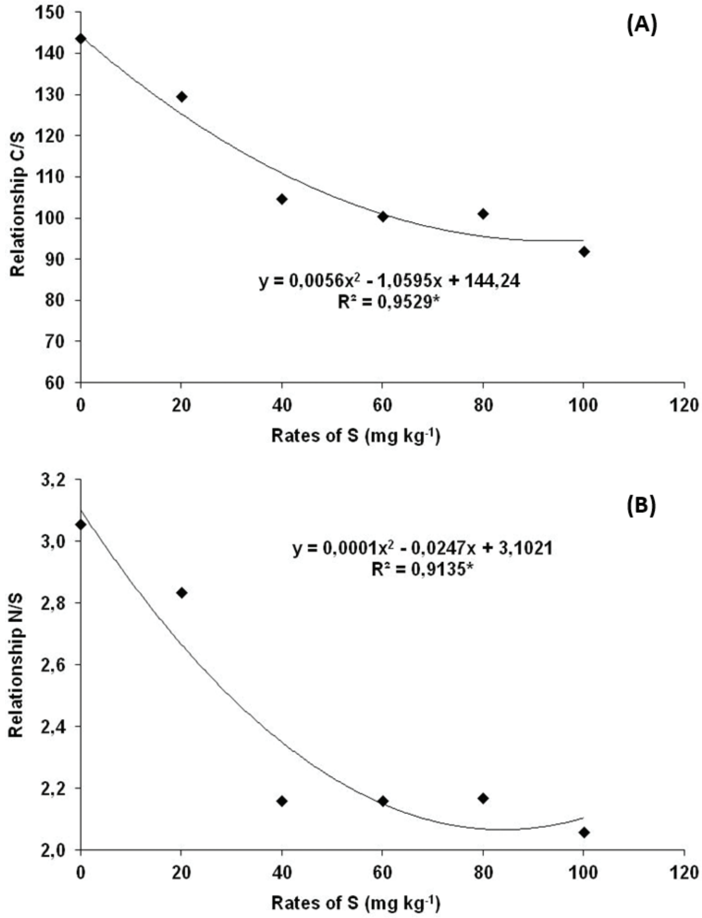

Figure 3. Regression between the applied sulfur doses and the C/S (A) and N/S (B) relations on the tomato shoot. * Significant at 5%.

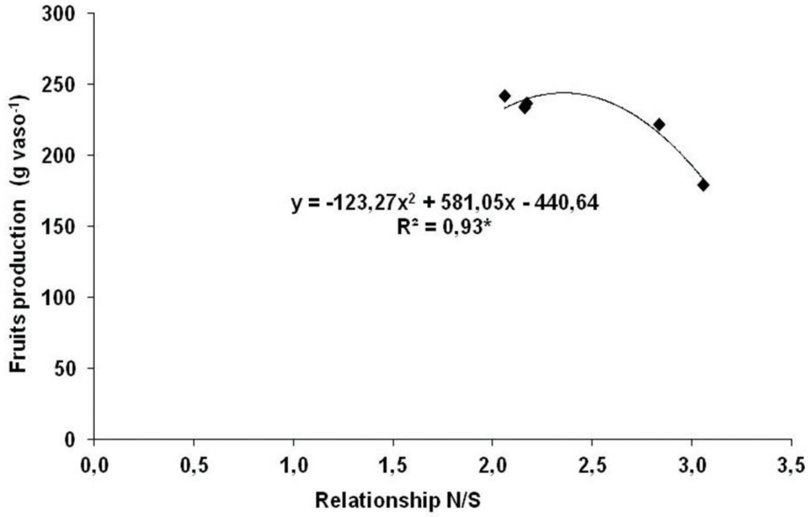

Figure 4. Correlation between the N/S relation and the tomato fruit production. *Significant at 5%.

according to the authors, can be considered adequate for the tomato cultivation. CRUSCIOL et al., (2006) verified a decrease of the N/S relation on the sulfur application in coverage for the bean plant culture.

The relation between the N/S ratio and the tomato fruit production increased quadratically, and obtained the highest fruit production (244 g vessel^{-1}) with 2.36 N/S relation (Figure 4). For the bean plant, the N/S relation of 25.5 was obtained by CRUSCIOL et al. (2006) to the maximum productivity of the culture, and the N/S value of 20.15 was obtained by FUTINI NETO et al. (2000) to the bean cultivation. An exact range or value of the N/S relation can be essential in obtaining the highest culture productivity (CRUSCIOL et al., 2006).

Conclusion

The sulfur application promoted fruit production raise and increase of the tomato shoot dry matter.

The average relation C:N:S found on the tomato shoot was of 112:2.4:1. The N/S relation of 2.36 on the tomato shoot demonstrates to have the best balance between these nutrients on the obtaining of tomato productivity.

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