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Morphophysiological and productive changes of onion under vitamin application

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Abstract

Studies have been developed to improve cultivation conditions through the introduction of beneficial compounds, among which are vitamins. The present work aimed to investigate the effects of the application of vitamins in the onion crop. For that, five treatments were used, composed of different vitamins (ascorbic acid, thiamine, niacin and pyridoxine), in a concentration of 100 mg L^{-1} and a control treatment, with water application, via foliar spray. The characteristics of chlorophyll relative index, number of plant leaves, plant height, fresh leaf mass, leaf dry mass, bulb diameter, bulb mass and bulb yield were evaluated. It was found that the application of ascorbic acid and pyridoxine increased the relative levels of chlorophyll concerning the control treatment and those composed by the application of niacin and thiamine. In addition, for liquid photosynthesis, a superior result was shown when niacin and thiamine were applied, concerning the other treatments. It was concluded that the exogenous application of vitamins alters the physiological and developmental behavior of onion plants, but does not positively affect bulb yield. The increases in photosynthetic activity were not reversed in bulb development, but in the elongation of plant leaves. Finally, the use of the vitamins studied for onion cultivation is not recommended, under conditions similar to those of the present study.

Keywords: *Allium cepa* L.; abiotic stress; vitamin B1; vitamin B3; vitamin B6.

Alterações morfofisiológicas e produtivas da cebola sob aplicação de vitaminas

Resumo

Estudos vêm sendo desenvolvidos a fim melhorar as condições de cultivo através da introdução de compostos benéficos, dentre os quais encontram-se as vitaminas. O presente trabalho objetivou avaliar os efeitos da aplicação de vitaminas na cultura da cebola. Para tanto, utilizaram-se cinco tratamentos, compostos por diferentes vitaminas (ácido ascórbico, tiamina, niacina e piridoxina), em concentração de 100 mg L^{-1} e um tratamento controle, com aplicação de água, via pulverização foliar. Foram avaliadas as características de teor relativo de clorofila, número de folhas das plantas, altura de planta, massa fresca de folhas, massa seca de folhas, diâmetro de bulbo, massa de bulbo e a produtividade de bulbos. Verificou-se que a aplicação do ácido ascórbico e da piridoxina elevaram os teores relativos de clorofila em relação ao tratamento controle e aqueles compostos pela aplicação de niacina e tiamina. Em complemento, para a fotossíntese líquida foi evidenciado resultado superior quando aplicadas as vitaminas niacina e tiamina, em relação aos demais tratamentos. Concluiu-se que a aplicação exógena de vitaminas altera o comportamento fisiológico e de desenvolvimento das plantas de cebola, porém não afetando positivamente a produtividade de bulbos. Os incrementos quanto à atividade fotossintética não foram revertidos em desenvolvimento dos bulbos, mas sim em um alongamento das folhas das plantas. Por fim, não se indica a utilização das vitaminas estudadas para a cultura da cebola, em condições semelhantes ao do presente estudo.

Palavras-chave: *Allium cepa L.*; estresse abiótico; vitamina B1; vitamina B3; vitamina B6.

1. Introduction

Onion is one of the most important vegetables in the country, with high demand due to its aroma and flavor characteristics, which make it widely used as a condiment for food preparation, or even for use in salads. Its production is concentrated in the southern region of Brazil, where it has high socioeconomic importance, moving trade and generating employment due to the high need for labor (MARCUZZO, 2020).

Although the concentration of Brazilian onion production is related to regions with a mild climate, other locations have presented interesting conditions for onion cultivation. Such conditions, such as higher temperatures and lower rainfall, allow crop management for most of the year (FAYAD *et al.*, 2018), through environmental modification with irrigation. However, other obstacles, such as the physical-chemical composition of the soil, pests, diseases, light, and wind, among other factors, may limit the establishment, development and production of the crop in a region not yet commercially explored.

For the establishment of new areas for the cultivation of a particular culture, it is essential to generate information related to the edaphoclimatic conditions of the locality. This information may be related to management issues, such as spacing, fertilization, and cultural practices, among others. Also, there is the possibility of using beneficial compounds that help plants in their initial establishment, allowing greater protection against biotic and abiotic stresses. In this sense, vitamins show promising results, however, they still need in-depth studies for their insertion as technology in commercial production systems. Thiamine, niacin, pyridoxine and ascorbic acid are some of the vitamins for which positive results were obtained when they were applied to vegetables subjected to stress conditions (FAROOQ *et al.*, 2020; VENDRUSCOLO; SELEGUINI, 2020).

The effects related to the application of vitamins are mainly protective, in which vitamins play the role of activating secondary metabolism (VENDRUSCOLO *et al.*, 2019). For example, pyridoxine acts to protect the photosynthetic system of the plant, due to the activation of antioxidant enzymes and production of free proline, which results in increased levels of photosynthetic pigments (MOSAVIKIA *et al.*, 2020).

These vitamins are involved in different processes in plant organs, so their exogenous application enhances the correct functioning of the physiological system. For example, thiamine influences the defense against oxidative stress and the processes of the biosynthesis of lipids, branched-chain amino acids, myelin, nucleic acids and some neurotransmitters, such as gamma-aminobutyric acid (GABA), glutamate and acetylcholine (NUNES *et al.*, 2018).

Ascorbic acid protects physiological mechanisms against oxidation caused by reactive forms of oxygen (MOSAVIKIA *et al.*, 2020). These characteristics associated with a low cost and reduced environmental impact (VENDRUSCOLO *et al.*, 2018), justify further research to establish vitamins as a technology to be used in production systems.

In this context, under the hypothesis that the application of vitamins can result in growth and production gains, the objective of the study was to evaluate the effects of the application of vitamins in the onion crop.

2 - Material and Methods

2.1 Location and characterization of the experimental area

The project was implemented in the Experimental Farm of the State University of Mato Grosso do Sul, Cassilândia Unit (coordinates 19° 05’ 46” S and 51° 48’ 50” W and altitude of 521 m). According to the Köppen classification, the climate of the region is tropical rainy (Aw), with rainy summers and dry winters (winter precipitation less than 60 mm), with annual precipitation and an average temperature of 1,520 mm and 24.1 °C, respectively. The soil characteristics ontained before the experiment implantation were: Ca^{2+}: 24.0 $mmol_c$ dm^{-3}, Mg^{2+}: 14.0 $mmol_c$ dm^{-3}, K^+: 3.0 $mmol_c$ dm^{-3}, P (resin): 14.0 mg dm^{-3}, Organic matter: 13.0 g dm^{-3}, Al^{3+}: 0,0 $cmol_c$ dm^{-3}, H+Al: 17.0 $cmol_c$ dm^{-3}, pH ($CaCl_2$): 5.0, Cation exchange capacity: 58.0 $mmol_c$ dm^{-3}, Bases saturation: 71% (Embrapa, 2017).

2.2 Experimental design and treatments

The experimental design used was randomized blocks, with five treatments and four replications. The treatments consisted of four solutions of vitamins (Ascorbic acid, vitamin B1, vitamin B3 and vitamin B6) in a concentration of

100 mg L^{-1} and control treatment, with an application of water, via foliar spray.

Each plot had dimensions of 1.00 x 0.50 m (0.5 m^2), length and width, respectively, and consisted of 28 onion plants, spaced 0.08 m between plants and 0.25 m between rows (four rows with seven plants each). To obtain a useful plot, the central plants of the two internal lines were evaluated, excluding the two external lines and the plants of the ends of the lines, used as borders.

2.3 Implementation and conduct of the experiment

The beds were corrected with limestone, aiming at a base saturation of 80%, and phosphate fertilization (400 kg P_2O_5 ha^{-1}) three months before planting, based on the soil analysis. Onion planting was carried out using bulbils obtained from a commercial farm located in the municipality of Lavínia, in São Paulo State. The bulbils were produced in raised beds, specific for this purpose. The hybrid used was the Akamaru (Seminis®), and the bulbils had diameters between 2 and 3 mm, which were buried in about 50% of their size. The application of vitamin solutions was performed when the plants reached about 20 cm in height, 25 days after planting. For that, an amount of solution equivalent to 200 L ha^{-1} was applied with a manual pump with a flow rate of 10 mL s^{-1}. In addition, two applications of fungicide (Mancozebe 800 g kg^{-1}) at 30 and 60 days after planting (2.5 kg ha^{-1}) and one application of insecticide (Metomil 215 g L^{-1}) at 30 days after planting (100 mL ha^{-1}). Weed control was performed manually at 15-day intervals.

2.4 Assessments carried out

At 65 days after planting, the physiological characteristics of photosynthesis (*A*), stomatal conductance (*gS*), intracellular CO_2 concentration (*Ci*) and transpiration (*E*) were evaluated using a photosynthesis meter (LCi, ADC Bioscientific, Hertfordshire, United Kingdom), in leaves of the middle third of the plants. Also, the instantaneous carboxylation efficiency (*EICI*) was calculated using the *A*/*Ci* ratio and the chlorophyll relative index was obtained using a digital chlorophyll meter. The measurements were carried out in three replications with two plants each.

When the characteristics that led to the harvest were observed (sales point), 80 days after planting, the characteristics of the number of leaves on the plants were evaluated; plant height, obtained with a measuring tape graduated in centimeters, measuring the distance from the soil surface to the highest point of the plant; fresh mass of leaves, obtained by weighing the aerial part after harvest, dry mass of leaves: obtained by weighing the leaves, after drying in an oven with forced air ventilation for 72 hours; bulb diameter: obtained with a digital caliper in the central portion of the bulb; Bulb mass, obtained by weighing the bulb after the leaves have been removed; bulb yield estimated for one hectare (Mg ha^{-1}).

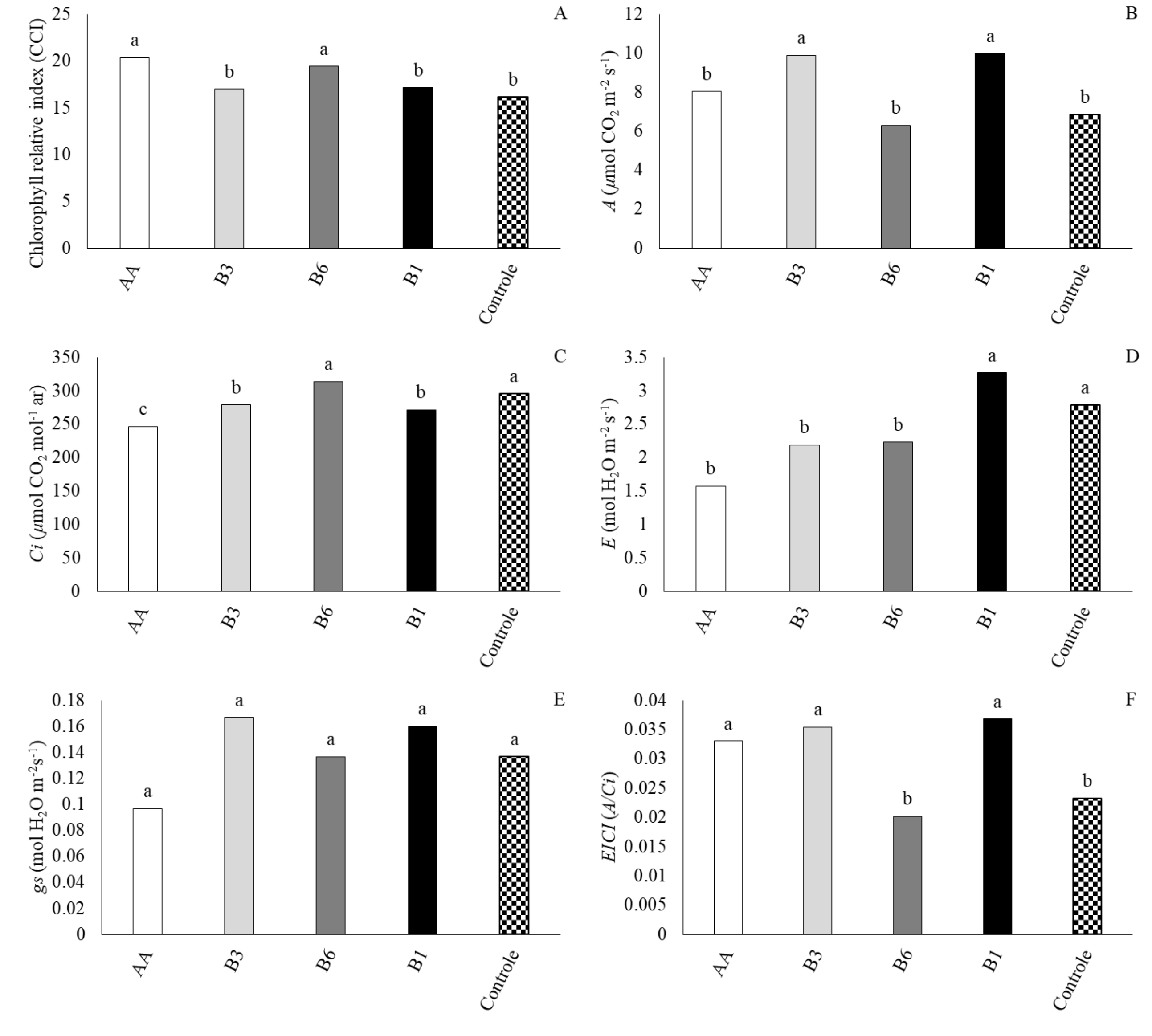
2.4 Statistical analysis

Data were submitted to preliminary normality and homoscedasticity tests. As the data of all variables presented normal distribution and homogeneous variances, they were submitted to analysis of variance and the means compared by the Scott-Knott test at 5% probability.

3 - Results and Discussion

It was found that the application of ascorbic acid (AA) and pyridoxine (B6) increased the relative levels of chlorophyll concerning the control treatment and those composed by the application of niacin (B3) and thiamine (B1) (Figure 1A). However, there was an inversion of the results for net photosynthesis, concerning treatments containing vitamins, in which there was superiority when applied vitamins B3 and B1, concerning the other treatments (Figure 1B).

Figure 1. Chlorophyll relative index (A), net photosynthesis (B), internal CO_2 concentration (C), transpiration (D), stomatal conductance (E) and intrinsic carboxylation efficiency (F) of onion plants treated with vitamin solutions. Different letters on the bars indicate a significant difference between the means (P < 0.05). Bars represent the mean values (n = 4). AA = Ascorbic acid; B1 = thiamine; B3 = niacin; B6 = pyridoxine.



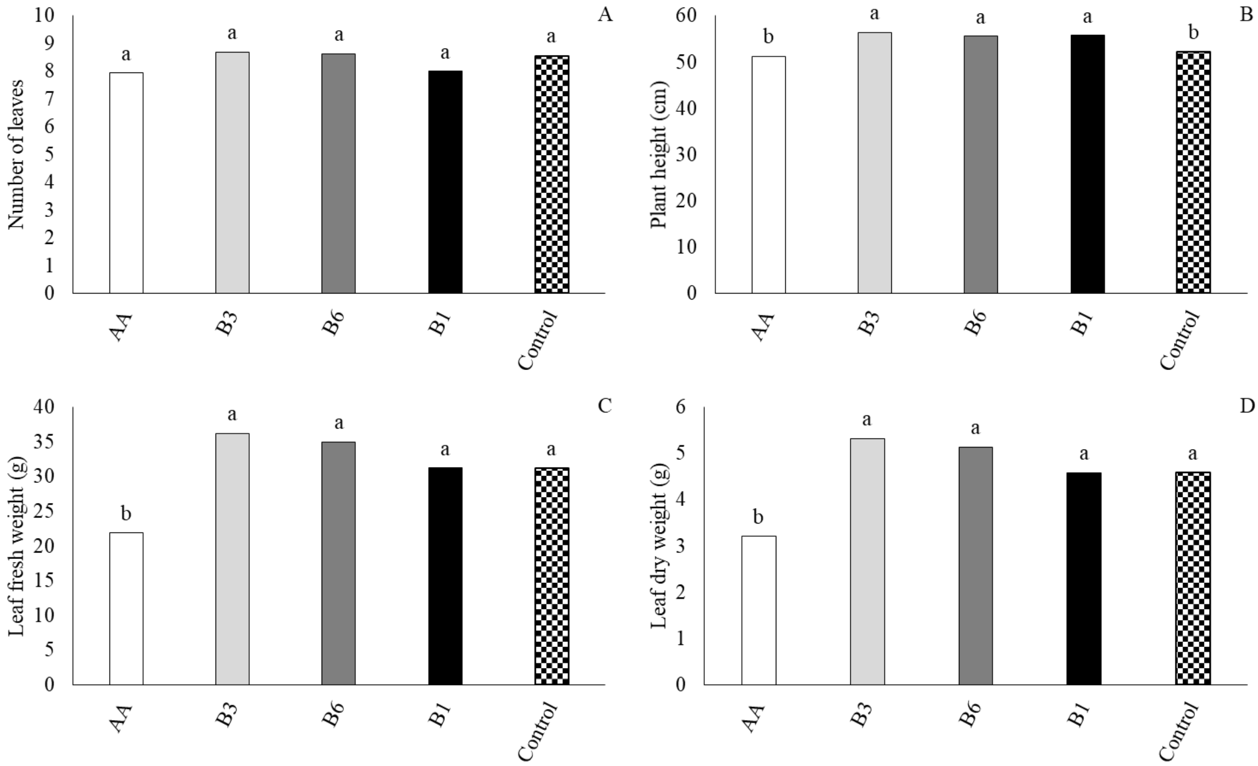
The elevation of chlorophyll relative index is related to the acting characteristics of ascorbic acid and pyridoxine, which protect the photosystem against photodegradation and oxidation caused by reactive oxygen species, increasing the photosynthetic pigment production capacity, the activities of antioxidant enzymes, and the production of free proline (MOSAVIKIA *et al.*, 2020; GAAFAR *et al.*, 2020). Similar results were obtained through the foliar application of ascorbic acid in radishes when it was found a great influence on all photosynthetic characteristics of the plant, and under water stress conditions there was a greater increase in these characteristics (SANTOS *et al.*, 2018).

For internal CO_2 concentration, the control and B6 treatments were superior to the others, while treatments B1 and B3 were also superior to treatment AA (Figure 1C). In addition, for transpiration, the control and B1 treatments were superior to the others (Figure 1D), while there was no difference between treatments for stomatal conductance (Figure 1E). In addition, the superiority of the treatments containing AA, B3 and B1 was observed for the intrinsic carboxylation efficiency characteristic (Figure 1F).

The higher values of internal CO_2 concentration may result from a lower activity of atmospheric carbon fixation, since there was an inversion between this characteristic and net photosynthesis (Figure 1B), indicating that CO_2 is not being used efficiently, as visualized for the carboxylation efficiency characteristic (Figure 1F). Also, the superiority of vitamins B3 and B1 is a result of the increased stomatal functionality of the plants, raising the gas exchange capacity, even under abiotic stress conditions (RAMOS *et al.*, 2022).

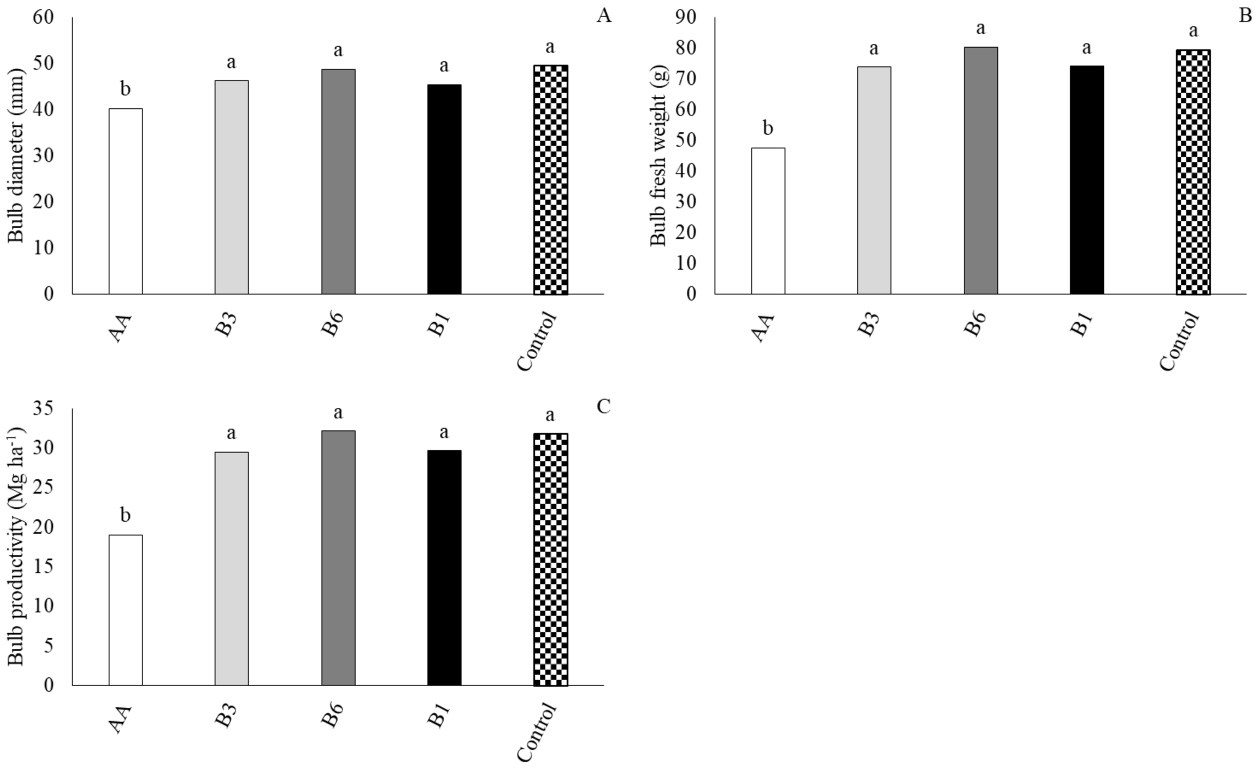
There was no significant difference between treatments for the number of leaves (Figure 2A). However, the treatments with B3, B6 and B1 were superior to the others concerning plant height (Figure 2B). In addition, for both the fresh mass and dry mass of leaves, the inferiority of the treatment composed by AA was verified.

Figure 2. Leaf number (A), plant height (B), leaf fresh mass (C) and leaf dry mass (D) of onion plants treated with vitamin solutions. Different letters on the bars indicate a significant difference between the means (P < 0.05). Bars represent the mean values (n = 4). AA = Ascorbic acid; B1 = thiamine; B3 = niacin; B6 = pyridoxine.



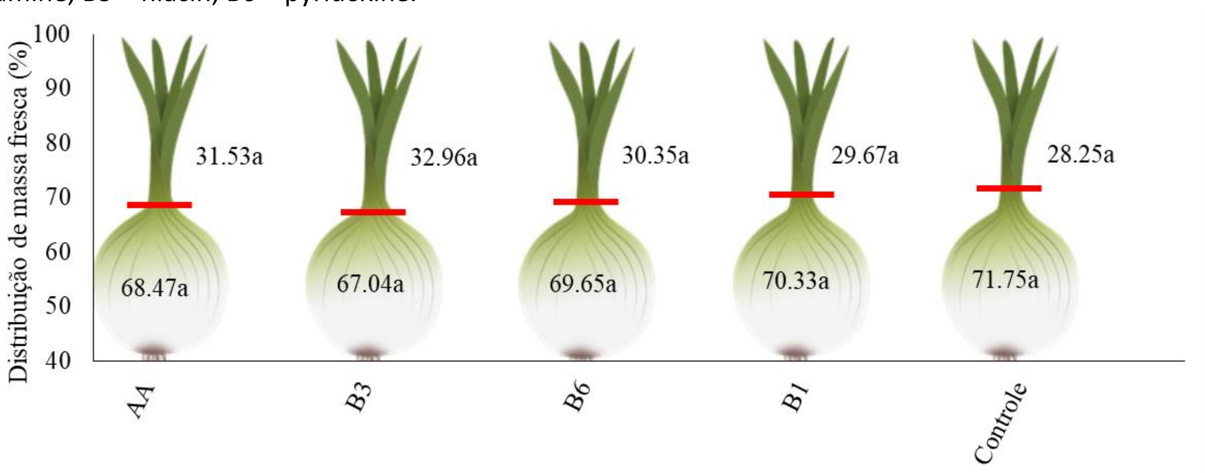
Regarding the diameter, mass, and yield of onion bulbs, it was found that only the treatment containing AA was inferior to the control treatment, and the other treatments resulted in no significant effect (Figure 3).

Figure 3. bulb diameter (A), bulb fresh mass (B) and bulb yield (C) of onion treated with vitamin solutions. Different letters on the bars indicate a significant difference between the means (P < 0.05). Bars represent the mean values (n = 4). AA = Ascorbic acid; B1 = thiamine; B3 = niacin; B6 = pyridoxine.



Despite the differences in partial masses, the distribution of fresh mass across plants was similar, with no significant difference between treatments (Figure 4).

Figure 4. Fresh mass distribution in onion plants treated with vitamin solutions. AA = Ascorbic acid; B1 = thiamine; B3 = niacin; B6 = pyridoxine.



The results observed in this study, in which there is an alteration of the physiological behavior of the plants, however, without significant differences in the biometric and productive characteristics are probably related to the adequate condition of cultivation to which the plants were submitted. For, it is observed that the studies developed with other species show the pronounced effect of the application of vitamins in crops where there is an action of stress factors, such as salinity (VENDRUSCOLO; SELEGUINI, 2020) or water stress (VENDRUSCOLO *et al.*, 2020).

In addition, the results may be related to the natural presence of high levels of vitamins in this species (SAMI *et al.*, 2021). In this sense, for species with high natural vitamin contents in their composition, it is necessary to use higher concentrations of vitamins for a significant effect to occur, as observed for mustard (VENDRUSCOLO *et al.*, 2017).

Based on the results obtained and on the studies performed by other researchers, the potential for the use of vitamins in production systems is evident. However, the development of new research should seek to clarify the interactions of these compounds with the different cultivated species, establishing the form of management to be adopted to obtain the maximum efficiency of this technology.

The exogenous application of vitamins alters the physiological and developmental behavior of onion plants but does not positively affect the productivity of bulbs. In addition, the increases in photosynthetic activity were not reversed in bulb development, but the elongation of the leaves of the plants. Finally, we do not indicate the use of the vitamins studied for the culture of onions, in conditions similar to the present study, with the need for further studies.

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