

Post-harvest of onion due to fertilization with micronutrient

Pós-colheita da cebola em função da adubação com micronutrientes

Postcosecha de cebolla en función de la fertilización con micronutrientes

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Régis Cavalcante Vieira

ORCID: <https://orcid.org/0000-0002-4180-8474>
Universidade Federal Rural do Semi-Árido, Brazil
E-mail: vieiraregisc@hotmail.com

Leilson Costa Grangeiro

ORCID: <https://orcid.org/0000-0002-4613-3605>
Universidade Federal Rural do Semi-Árido, Brazil
E-mail: leilson@ufersa.edu.br

Nubia Marisa Ferreira Bertino

ORCID: <https://orcid.org/0000-0001-7159-6479>
Universidade Federal Rural do Semi-Árido, Brazil
E-mail: nubiamarisa1@hotmail.com

Romualdo Medeiros Cortez Costa

ORCID: <https://orcid.org/0000-0001-7789-2906>
Universidade Federal Rural do Semi-Árido, Brazil
E-mail: romualdocortez@gmail.com

João Paulo Nunes da Costa

ORCID: <https://orcid.org/0000-0002-5479-3814>
Universidade Federal Rural do Semi-Árido, Brazil
E-mail: jppoty@hotmail.com

Anderson Araujo Alves

ORCID: <https://orcid.org/0000-0002-7151-897X>
Universidade Federal Rural do Semi-Árido, Brazil
E-mail: alves.araujo07@gmail.com

Débora Silva Marcelino de Sousa

ORCID: <https://orcid.org/0000-0002-7665-6941>
Universidade Federal Rural do Semi-Árido, Brazil
E-mail: deborasmrancelino@gmail.com

Abstract

The onion (*Allium cepa* L.) is the third most cultivated vegetable and has great socioeconomic importance worldwide. Because it is highly perishable and has greater demand than supply, many post-harvest losses occur, most of them caused by inadequate storage conditions affecting the bulbs quality. This study aimed to evaluate the postharvest quality of onion as a function of fertilization with micronutrients, using the cultivar “Rio das antas”. The experiment was divided into two stages: field and laboratory. In the field, an experiment was installed between June and December 2019 at Experimental Farm Rafael Fernandes, in completely randomized blocks with nine treatments and four replications. The treatments consisted of the combined doses of B, Cu and Zn. In the laboratory, the experimental design was in completely randomized blocks in 9 x 4 split-plot design, with four replications. The treatments (micronutrients B, Cu and Zn) were arranged in the plots and the storage times were arranged in the subplots (0; 20; 40 and 60 days after harvest). Bulb firmness, soluble solids (°Brix), total soluble sugars and pungency were evaluated. The data were subjected to statistical analysis as a function of storage time, by the Sisvar program, applying regression analysis. The combined application of doses of 1-4-1 kg.ha⁻¹ of Boron, Copper and Zinc, respectively, presented the best results for pungency, firmness and sugars during storage, this being the most recommended treatment for not significantly different from higher doses, promoting more efficient use of inputs.

Keywords: *Allium cepa* L.; Storage; Boron; Copper; Zinc.

Resumo

A cebola (*Allium cepa* L.) tem uma grande importância socioeconômica em nível mundial, pois é a terceira olerícola mais cultivada. No entanto, por ser altamente perecível e com demanda superior à oferta, ocorrem muitas perdas pós-colheita, provocadas principalmente por inadequada condição de armazenamento que afetam consideravelmente a qualidade dos bulbos. Este estudo teve como objetivo avaliar a qualidade pós-colheita de cebola em função da adubação com micronutrientes, utilizando a cultivar “Rio das antas”. O experimento foi dividido em duas etapas: campo e laboratório. No campo, foi instalado um experimento entre junho e dezembro de 2019, na Fazenda Experimental Rafael Fernandes, em blocos casualizados completos com nove tratamentos e quatro repetições. Os

tratamentos foram constituídos pelas doses combinadas de B, Cu e Zn. No laboratório, o delineamento experimental foi em blocos casualizados completos em parcelas subdivididas 9 x 4, com quatro repetições. Nas parcelas, foram dispostos os tratamentos (micronutrientes B, Cu e Zn) e nas subparcelas, os tempos de armazenamento (0; 20; 40 e 60 dias após a colheita). Foram avaliadas firmeza de bulbo, sólidos solúveis ($^{\circ}$ Brix), açúcares solúveis totais e pungência. Os dados foram submetidos à análise estatística em função do tempo de armazenamento, pelo programa Sisvar, aplicando-se análise de regressão. A aplicação combinada das doses de 1-4-1 kg ha⁻¹ de Boro, Cobre e Zinco, respectivamente, apresentou os melhores resultados para pungência, firmeza e açúcares durante o armazenamento, sendo este tratamento o mais recomendado por não se diferenciar significativamente das doses mais elevadas, promovendo o uso mais eficiente dos insumos.

Palavras-chave: *Allium Cepa L*; Armazenamento; Boro; Cobre; Zinco.

Resumen

La cebolla (*Allium cepa L.*) tiene una gran importancia socioeconómica a nivel mundial, ya que es la tercera hortaliza más cultivada. Sin embargo, como es altamente perecedero y la demanda supera la oferta, existen muchas pérdidas poscosecha, provocadas principalmente por condiciones de almacenamiento inadecuadas, que afectan considerablemente la calidad de los bulbos. Este estudio tuvo como objetivo evaluar la calidad poscosecha de la cebolla en función de la fertilización con micronutrientes, utilizando el cultivar "Rio das antas". El experimento se dividió en dos etapas: campo y laboratorio. En campo, se instaló un experimento entre junio y diciembre de 2019, en la Fazenda Experimental Rafael Fernandes, en bloques completos al azar con nueve tratamientos y cuatro repeticiones. Los tratamientos consistieron en las dosis combinadas de B, Cu y Zn. En el laboratorio, el diseño experimental fue en bloques completos al azar en parcelas divididas de 9 x 4, con cuatro repeticiones. En las parcelas se dispuso los tratamientos (micronutrientes B, Cu y Zn) y en las subparcelas los tiempos de almacenamiento (0; 20; 40 y 60 días después de la cosecha). Se evaluó firmeza de bulbo, sólidos solubles ($^{\circ}$ Brix), azúcares solubles totales y pungencia. Los datos fueron sometidos a análisis estadístico en función del tiempo de almacenamiento, por el programa Sisvar, aplicando análisis de regresión. La aplicación combinada de dosis de 1-4-1 kg ha⁻¹ de Boro, Cobre y Zinc, respectivamente, mostró los mejores resultados de picor, firmeza y azúcares durante el almacenamiento, siendo este tratamiento el más recomendado ya que no difiere significativamente de otros tratamientos dosis más altas, promoviendo un uso más eficiente de los insumos.

Palabras clave: *Allium cepa L*; Almacenamiento; Boro; Cobre; Zinc.

1. Introduction

Factors such as improved quality, size, color, flavor, increased postharvest life, prevention against physiological disturbances are a consequence of the significant importance that micronutrients have on horticultural production (Ganeshamurthy et al. 2018).

The preservation of the onion's skin, firmness and flavor are fundamental factors for its commercialization, and also for its long-term storage, since the greatest amount of water loss occurs through the skin, through water vapor, causing a reduction in the quality (Yoo,2012).

The onion (*Allium cepa L.*) has great socioeconomic importance worldwide, as it is the third most cultivated vegetable, only behind potatoes and tomatoes (FAO, 2020).

In Brazil, onion cultivation occupied an area of 48,629 hectares, with a production of 1,549,587 tons and an average yield of 31,954 kg. ha⁻¹ (IBGE, 2018). In Rio Grande do Norte state, onion production is relatively recent, concentrated in the municipalities of Baraúna and Mossoró, with a planted area of 605 hectares (IBGE, 2013).

In order to have successive increases in productivity, it is necessary that the application of nutrients is carried out in the best way. According to Ganeshamurthy et al. (2018) the unbalanced application of nutrients causes the appearance of generalized deficiencies of micronutrients and a reduction in the response per unit of nutrient applied to horticultural crops.

Currently, in addition to increased production, several alternatives are being studied to reduce losses, which lead to a reduction in productivity and consequently in revenue, since vegetables in general, when not stored correctly, have a reduced post-harvest life, due to mainly temperature variation and pathogen attack

Among the alternatives, storage is an important tool, as it allows an increase in the post-harvest life of the bulb, thus promoting the supply of onions for a longer period of time and with the quality required by the market in periods when there is a shortage of supply (Moretti, 2004).

Storage at low temperatures maintains good quality, with positive changes in the composition of the onion, showing that temperature is a determining factor in increasing the post-harvest life of bulbs (Sharma, et al., 2015; Sharma & Lee, 2016).

This high perishability of onion bulbs considerably reduces the quality of the product, thus influencing the price paid by the market (Resende et al., 2010). Then, the objective of this work was to evaluate the post-harvest conservation of onion as a function of fertilization with micronutrients.

2. Methodology

The field experiment was carried out from June to November 2019 at the Experimental Farm Rafael Fernandes, belonging to the Federal Rural University of the Semi-Árido (UFERSA), located in the district of Alagoinha, rural area of the municipality of Mossoró- Rio Grande do Norte state, Brazil (latitude of 5°3'37"S, 37°23'50"W and altitude of 72 meters). The soil is classified as Argisol (EMBRAPA et al., 2018). The physical and chemical characterization of the soil at depth from 0 to 20 cm is shown in Table 1.

Table 1 - Chemical and physical characterization of the soil in the experimental area, at the Rafael Fernandes Experimental Farm, Mossoró, Rio Grande do Norte state, Brazil, 2019.

pH	P	K	Ca	Mg	H+Al	SB	CTC	V	M.O	B	Cu	Zn
H ₂ O	--mg dm ⁻³ --			-----cmole dm ⁻³ -----				%	g.kg ⁻¹	----- mg dm ⁻³ -----		
4,80	5,00	29,64	0,41	0,13	1,57	0,63	2,2	29	5,59	0,18	0,20	0,70

H+Al: Potential acidity; SB: Sum of bases; CTC: Cation exchange capacity; V: Base saturation; M.O.: Organic matter. Source: Authors.

The soil preparation consisted of plowing, harrowing, and making the beds. The planting fertilization was carried out based on the soil analysis (Table 1), using 210 kg ha⁻¹ of P₂O₅ (Silva, 2018), in the form of simple superphosphate. Top dressings were carried out weekly via fertigation, starting 22 days after sowing (DAS) and ending at 84 DAS. 99.04 kg ha⁻¹ of N were applied; 40.51 kg ha⁻¹ of P₂O₅, 213.94 kg ha⁻¹ of K₂O, 13.77 kg ha⁻¹ of Mg and 47.5 kg ha⁻¹ of Ca.

The sources of fertilizers used were purified MAP, urea, potassium nitrate, calcium nitrate, potassium chloride and magnesium sulfate. The micronutrients doses were established according to the soil analysis (Table 1) and fertilizer recommendation for onion crops according to Trani et al. (2014). As micronutrient sources were used, boric acid; copper sulfate and zinc sulfate.

The experimental design was in randomized complete blocks with nine treatments and four replications. The treatments consisted of the combined application of micronutrients B, Cu and Zn (Table 2). The plots were dimensioned in 3.5 x 1.0 m wide, containing eight rows of plants, spaced 0.10 x 0.06 m, using the cultivar hybrid Rio das Antas. The six central rows of plants in the plot were considered as useful area, discarding two plants at each end of the rows.

Table 2 - List of treatments according to micronutrients doses. UFERSA. Mossoró-Rio Grande do Norte state, Brazil, 2019.

Treatments	Doses of micronutrients kg.ha ⁻¹		
	Boron	Copper	Zinc
1	0	0	0
2	1	2	1
3	1	2	2
4	2	2	1
5	2	2	2
6	1	4	1
7	1	4	2
8	2	4	1
9	2	4	2

Source: Authors.

The irrigation system used was microsprinkler until 22 DAS, to ensure better seed germination, and in the remainder of the cycle, dripping, with four hoses per seedbed, spaced at 0.20 m, with self-compensating drippers and average flow 1.5 L h⁻¹, spaced 0.30 m apart. The irrigations were carried out daily and the depths were determined based on the evapotranspiration of the crop (Allen et al., 2006), applying a total depth of 904.51 mm ha⁻¹.

The water used in irrigation came from a deep tubular well, from the sandstone aquifer Açu, Rio Grande do Norte state, Brazil, and has the following characteristics: pH 7.1; EC = 0.61 dS m⁻¹; 0.65; 1.73; 2.50; 1.90; 1.60; 0.0; and 4.00 mmolL⁻¹ of respectively K⁺, Na⁺, Ca⁺², Mg⁺², Cl⁻, CO₃⁻² and HCO₃⁻ and RAS of 1.2 mg L⁻¹.

Sowing was performed manually, placing 2 to 3 seeds per 2.0 cm deep pit, spaced 0.10 x 0.06 m. Thinning was carried out 20 days after sowing (DAS), leaving one plant per hole.

During the conduct of the experiment, manual weeding and phytosanitary control were carried out according to the needs of the culture. Irrigation was suspended at 120 DAS when 70% of the plants were overturned, and the curing process began. After 20 days of suspension of irrigation, the bulbs were harvested and cleaned. The onions were placed in netting bags, in a laboratory with natural ventilation, and this location had a maximum temperature ranging from 33 to 34° C and humidity ranging from 69 to 70% in the hottest hours of the day (13-14 hours) during the storage period.

After harvesting, in the laboratory, the analyzes were performed at each storage time (0, 20, 40 and 60 days after harvest), with 10 commercial bulbs being sampled per plot for each storage time, totaling 40 bulbs, observing the variables:

Firmness (N): determined using a manual-operated “penetrometer” that measures the bulb's resistance to penetration by a pistil until the shell breaks on the two opposite sides at the midpoint of the bulbs, taking two readings per bulb;

Soluble solids (SS): directly determined in the homogenized juice, by reading in a digital refractometer, results expressed in °Brix (AOAC, 2002);

Total soluble sugars (TSS): performed by the Antrona method described by Yemm; Willis (1954), with the results expressed in (%);

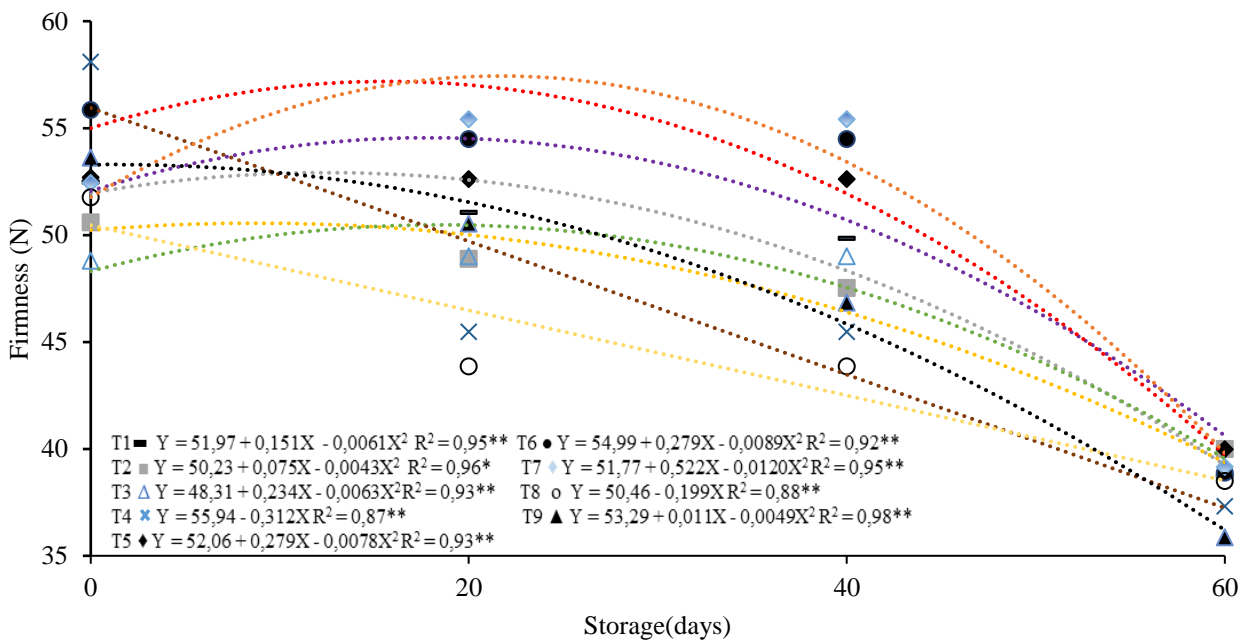
Pungency (µmol g⁻¹ of pyruvic acid): determined through the quantification of pyruvic acid, using the reagent 2,4-dinitrophenylhydrazine (DNPH), according to the method described by Schwirmer and Weston (1961) who classified pungency, measured as a function of amount of pyruvic acid, such as onion weak (2 to 4 µmol g⁻¹), intermediate (8 to 10 µmol g⁻¹) and strong (15 to 20 µmol g⁻¹).

Data were subjected to analysis of variance, and the means were compared by Tukey test at 5% probability, and when there was a significant effect for doses and storage times, regression analysis was performed with the aid of Sisvar software (Ferreira, 2011).

3. Results

For firmness, it was observed that there was a linear adjustment of the equations for treatments 4 and 8 which corresponds to 2-2-1 and 2-4-1 kg.ha of B, Cu and Zn respectively with the other doses being adjusted to the quadratic model, with an increase until 20 days after harvest (DAC) followed by a decrease until the end of the period evaluated (Figure 1).

Figure 1 - Firmness of onion bulbs as a function of storage time, cultivar Rio das Antas, Mossoró, UFERSA, 2019.



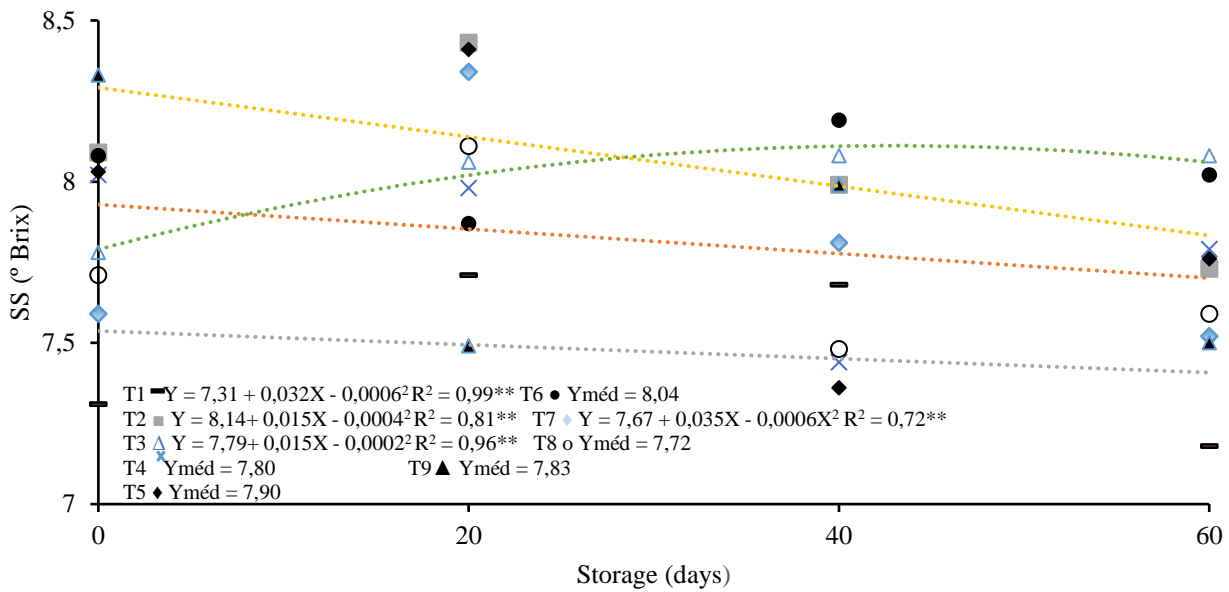
Source: Authors.

The greatest reduction in firmness in onion bulbs in the storage period occurred in the T4 treatment, decreasing from 58.1 N at season 0 to 37.3 N at 60 DAC. At the end of the storage period, T5, which corresponds to the maximum doses of Cu and Zn, presented the highest average for firmness with 39.9 N.

In the first evaluation carried out on the day of harvest, the application of micronutrients provided the highest levels of SS, with the maximum observed (8.33 °Brix) reached at the dose of 2, 4 and 2 kg.ha⁻¹ of B, Cu and Zn respectively. The lowest levels of SS during storage (7.47 °Brix) were obtained in the absence of nutrient application. It was observed that the highest means for SS in this experiment occurred at 20 DAC, having a linear decrease with the passage of storage time.

Treatments T3 and T6 which corresponds to 1-2-2 and 1-4-1 kg.ha⁻¹ of B, Cu and Zn respectively presented the most linear results throughout storage, not differing statistically from each other, with higher SS values at 60 days (8.08 °Brix and 8.03 °Brix, respectively) (Figure 2).

Figure 2 - Total soluble solids (°Brix) in onion bulbs as a function of storage time, cultivar Rio das Antas, Mossoró, UFERSA, 2019.

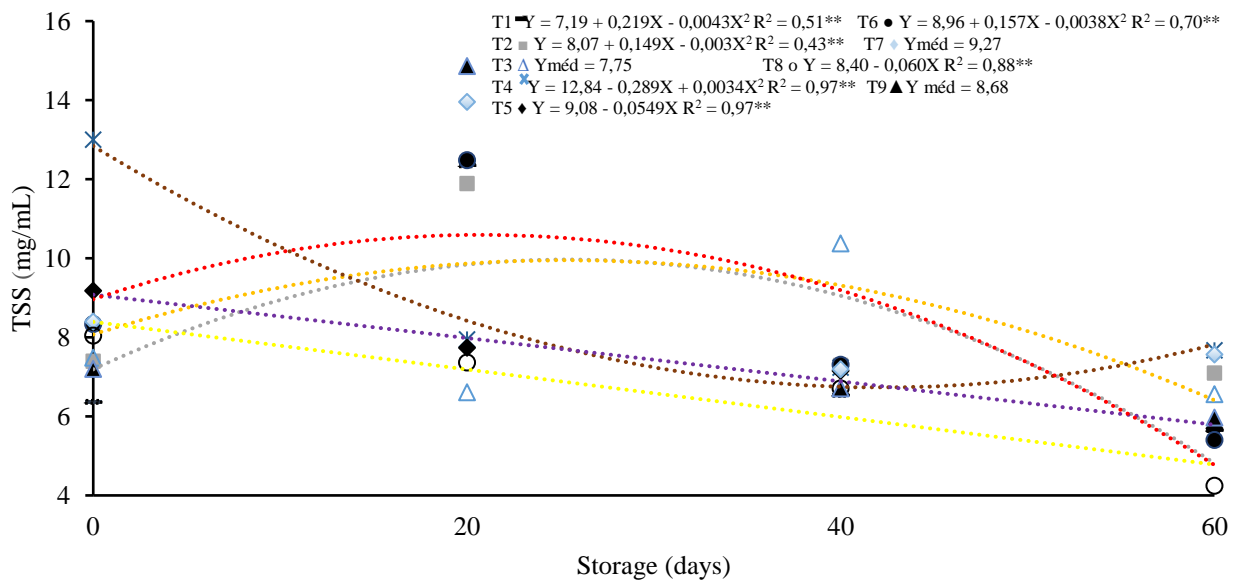


Source: Authors.

The maximum values observed in the variable of total soluble sugars were 9.27 mg/mL and 8.95 mg/mL for doses T7 and T4, respectively, with an average variation of 6.58 to 9.27 mg/mL throughout storage (Figure 3).

The result presented was similar to the soluble solids content (Figure 2), where there was an increase until approximately 20 days, followed by a reduction until the end of the storage time.

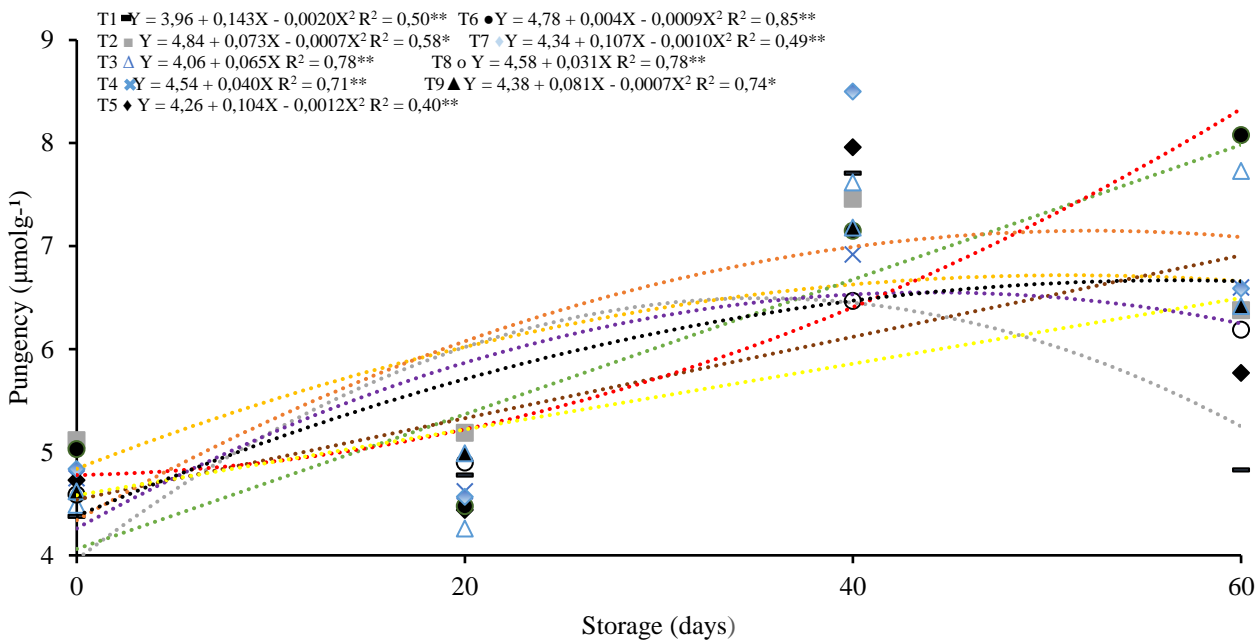
Figure 3 - Sugars (TSS) in onion bulbs as a function of storage time, cultivar Rio das Antas, Mossoró, UFERSA, 2019.



Source: Authors.

For pungency, the maximum values found were 8.50 μmolg^{-1} pyruvic acid at 40 days in T7 and 8.08 μmolg^{-1} pyruvic acid at 60 days in T6, which represent the minimum doses of boron and maximum doses of copper, with the treatment means ranging from 5.42 to 6.18 $\mu\text{mol g}^{-1}$ during storage (Figure 4). The applied doses presented a classification variation of 'slightly pungent' and 'pungent', according to Weston (1961).

Figure 4 - Pungency in onion bulbs as a function of storage time, cultivar Rio das Antas, Mossoró, UFERSA, 2019.



Source: Authors.

The pungency of the onions, as a function of the storage period, showed an increase from 40 days onwards, which was possibly associated with a greater loss of onion mass as, with the loss of moisture, and a reduction in pungency from 45 days onwards storage, which was possibly caused by the use of acids in breathing (Figure 4).

4. Discussion

• Firmness

The reduction in firmness may have been influenced by the loss of water to the atmosphere and by the presence of fungi that accelerate the deterioration process. This observed result shows the importance of copper in this variable of onion skin firmness. Copper, through its enzymes such as polyphenol and ascorbate, is responsible, among other functions, for the formation of phenolic compounds that are precursors of lignin, making cell walls more resistant (Kurtz, 2015). Also according to the authors, Cu is a precursor to other substances, such as melanin and phytoalexins, which influence the improvement of bulb firmness, consequently increasing the storage period.

• Total Soluble Solids (°Brix)

It was observed that the highest means for SS in this experiment occurred at 20 DAC, having a linear decrease with the passage of storage time.

According to Huertas et al. (1999) this reduction may be related to the beginning of the senescence period where soluble solids are being used more in respiration than produced. Woldetsadik and Workneh (2010) also observed an increase in the soluble solids content at the beginning of storage and then a reduction until the end of the period.

According to Pak et al (1995), one of the reasons for this behavior is due to the fructans are hydrolyzed into fructose during the initial storage, result in a higher soluble solids, but with a decrease of dormancy and early sprouting, sucrose is being transformed into organic acids causing a decrease in the soluble solids content.

- **Total Soluble Sugars**

The maximum values observed in the variable of total soluble sugars were 9.27 mg/mL and 8.95 mg/mL for doses T7 and T4, respectively, with an average variation of 6.58 to 9.27 mg/mL throughout storage

According to Pak et al. (1995), the initial increase followed by a reduction until the end of the storage time, can be explained due to the increase in respiration, a behavior that was already expected, as according to Chitarra and Chitarra (2005) sugars represent 90% of the content of soluble solids in onions.

The adequate supply of micronutrients favors the increase in sugar and carbohydrate contents, and may contribute to increase the synthesis of phenols, which act in the defense mechanism as antifungal and antibacterial (Dridi et al., 2018; Trivedi; Dhumal, 2017).

The micronutrients copper, iron, manganese and zinc act by activating the defense mechanism, being cofactors of superoxide dismutases (SODs) that act in the detoxification of reactive oxygen species (ROS) contributing to better post-harvest quality and storage of bulbs (El- Tohamy et al., 2009).

- **Pungency**

The pungency of onions, depending on the storage period, increased after 40 days and reduced pungency after 45 days. By breaking the cells, the interaction between flavor and aroma precursors with the enzyme allinase present in the vacuole begins (Lancaster; Boland, 1990). This enzyme converts these precursors into pyruvate and sulfenic acids. During this storage period there is a reduction in the activity of this enzyme, and consequent accumulation of these precursors, thus increasing the pungency content.

5. Conclusion

The combined application of doses of 2-2-1 kg ha⁻¹ of Boron, Copper and Zinc, respectively, showed the best results for sugars during storage.

T6, which corresponds to the maximum dose of Copper and the minimum dose of Boron and Zinc, presented as minor variations for firmness and pungency.

Due to the low amount of information on micronutrients in the region, future work with different doses should be carried out in order to find the most balanced doses for the crop and for the region.

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