

Agronomic performance of the beet Tall Top Early Wonder as a function of nitrogen and borate fertilization

Desempenho agrônômico da beterraba Tall Top Early Wonder em função da adubação nitrogenada e boratada

Rendimiento agronómico de la remolacha Tall Top Early Wonder en función de la fertilización con nitrógeno y borato

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Henrique Vasque

ORCID: <https://orcid.org/0000-0002-7023-0501>
São Paulo State University, Brazil
E-mail: henriquevasq@gmail.com

Ariel Santivañez Aguilar

ORCID: <https://orcid.org/0000-0003-2743-9147>
São Paulo State University, Brazil
E-mail: ariel.santivanez@unesp.br

Stefany Cristina de Melo Silva

ORCID: <https://orcid.org/0000-0002-9526-2980>
São Paulo State University, Brazil
E-mail: stefany.cm.silva@unesp.br

Andres Felipe Gaona Acevedo

ORCID: <https://orcid.org/0000-0002-1769-2483>
São Paulo State University, Brazil
E-mail: andresgaona80@gmail.com

Larissa Vasque Jácome

ORCID: <https://orcid.org/0000-0001-6146-3461>
São Paulo State University, Brazil
E-mail: larissa.vasque@unesp.br

Karina Aparecida Furlaneto

ORCID: <https://orcid.org/0000-0002-4469-9058>
São Paulo State University, Brazil
E-mail: karinafurlaneto1@gmail.com

Juliana Aparecida dos Santos

ORCID: <https://orcid.org/0000-0001-5086-1536>
São Paulo State University, Brazil
E-mail: juliana.aparecida@unesp.br

Vander Rocha Lacerda

ORCID: <https://orcid.org/0000-0003-0109-8030>
São Paulo State University, Brazil
E-mail: vanderroxal@gmail.com

Rogério Lopes Vieites

ORCID: <https://orcid.org/0000-0002-3865-0426>
São Paulo State University, Brazil
E-mail: rogerio.vieites@unesp.br

Abstract

The supply of nutrients in suitable proportions of nutrients in the beet culture is one of the most important factors in the growth process and root quality. However, few studies are evaluating the influence of the interaction between nutrients in this culture. The objective of this work was to evaluate the effects of the combination of nitrogen fertilization with boron on the production characteristics and quality of the beet Tall Top Early Wonder. The experiment was carried out at the São Manuel Experimental Farm (FCA/Unesp), located in São Manuel-SP. The experimental design was in randomized blocks, with four replications. The evaluated factors were: nitrogen and boric fertilization, in the factorial scheme (2 x 2), totaling 4 treatments: T1 (0 kg ha⁻¹ of N and 0 kg ha⁻¹ of B), T2 (0 kg ha⁻¹ of N and 4 kg ha⁻¹ of B), T3 (90 kg ha⁻¹ of N and 0 kg ha⁻¹ of B) and T4 (90 kg ha⁻¹ of N and 4 kg ha⁻¹ of B). The results showed that there was a positive interaction between nitrogen and boron when applied together, providing increases in productivity and greater uniformity in beetroots.

Keywords: *Beta vulgaris* L.; Interaction between nutrients; Plant nutrition; Commercial roots.

Resumo

O fornecimento adequado de nutrientes na cultura da beterraba é um dos fatores mais importantes no processo de crescimento e qualidade das raízes. Entretanto, são escassos estudos avaliando a influência da interação entre nutrientes nesta cultura. O objetivo deste trabalho foi avaliar os efeitos da adubação com nitrogênio com o boro nas características de produção e qualidade da beterraba Tall Top Early Wonder. O experimento foi realizado na Fazenda Experimental de São Manuel (FCA/Unesp), localizada em São Manuel-SP. O delineamento experimental foi em blocos ao acaso, com quatro repetições. Os fatores avaliados foram: Adubação nitrogenada e bórica, no esquema fatorial (2 x 2), totalizando 4 tratamentos: T1 (0 kg ha⁻¹ de N e 0 kg ha⁻¹ de B), T2 (0 kg ha⁻¹ de N e 4 kg ha⁻¹ de B), T3 (90 kg ha⁻¹ de N e 0 kg ha⁻¹ de B) e T4 (90 kg ha⁻¹ de N e 4 kg ha⁻¹ de B). Os resultados demonstraram que houve interação positiva entre o nitrogênio e o boro quando aplicados em conjunto, proporcionando incrementos na produtividade e maior uniformidade nas raízes de beterraba.

Palavras-chave: *Beta vulgaris* L.; Interação entre nutrientes; Nutrição de plantas; Raízes comerciais.

Resumen

El suministro adecuado de nutrientes en el cultivo de remolacha es uno de los factores más importantes en el proceso de crecimiento y la calidad de las raíces. Sin embargo, existen pocos estudios que evalúen la influencia de la interacción entre nutrientes en este cultivo. El objetivo de este trabajo fue evaluar los efectos de la combinación de fertilización nitrogenada con boro sobre las características de producción y calidad de la remolacha Tall Top Early Wonder. El experimento fue realizado en la Granja Experimental de São Manuel (FCA/ Unesp), ubicada en São Manuel-SP. El diseño experimental fue en bloques al azar, con cuatro repeticiones. Los factores evaluados fueron: fertilización nitrogenada y bórica, en el esquema factorial (2 x 2), totalizando 4 tratamientos: T1 (0 kg ha⁻¹ de N y 0 kg ha⁻¹ de B), T2 (0 kg ha⁻¹ de N y 4 kg ha⁻¹ de B), T3 (90 kg ha⁻¹ de N y 0 kg ha⁻¹ de B) y T4 (90 kg ha⁻¹ de N y 4 kg ha⁻¹ de B). Los resultados mostraron que hubo una interacción positiva entre el nitrógeno y el boro cuando se aplicaron juntos, proporcionando incrementos en la productividad y mayor uniformidad en las raíces de la remolacha.

Palabras clave: *Beta vulgaris* L.; Interacción entre nutrientes; Nutrición vegetal; Raíces comerciales.

1. Introduction

The beet (*Beta vulgaris* L.) belongs to the Chenopodiaceae family, typical of temperate climate, originating center on the Mediterranean coast region and North Africa (Tiveli et al., 2011). This vegetable stands out for having in its chemical composition, various nutritional properties beneficial to human health such as vitamins (B1, B2, B5 and C), potassium, iron, copper, zinc, manganese and bioactive compounds with antioxidant effects as phenolic compounds, flavonoids, anthocyanins and betalains (Sediyama et al., 2010; Mikołajczyk-bator & Pawlak, 2016).

The average productivity of beet in Brazil is 20 tons per hectare, reaching about 218 thousand tons of production per year (CNA, 2017). During the period 2018-2019, there was an increase of approximately 5% in the Brazilian production of beet, reflecting positively in the export index of this vegetable (Ceagesp, 2020).

With the increased consumption and also higher market demand for better quality products, it is essential that all stages of production, from the preparation and fertilization of the soil, planting, harvesting until they reach the consumer, are well planned and carried out in an integrated manner (Chitarra & Chitarra, 2005).

Among the cultivation practices, fertilizer has a great influence on the productivity and quality of vegetables, it is related to the regulation of physiological and biochemical processes of plants. The balance between macro and micronutrients improves the nutritional status of the plant, provides gains in production and product quality, and reduce spending on fertilizers and pesticides (Faquin & Andrade, 2004).

Otherwise, an inadequate supply of nutrients can cause undesirable changes in size, appearance, taste, and resistance against plant diseases and pests, which limits the production and results in post-harvest losses and losses to merchants. Know the nutritional needs of this vegetable is essential to the most appropriate preparation of fertilizer recommendations, which culminates in increased productivity and improved quality of the crop (Alves et al., 2008; Amorim et al., 2020).

Among the essential nutrients for the development of beet culture, include nitrogen and boron (Trani et al., 2005). Nitrogen (N) is a constituent of many important molecules in the plant, such as proteins, nucleic acids, and secondary

metabolites, which play vital roles in the growth, and development of plants, contributing to increased productivity and quality of plant products (Chen et al., 2020). Deficiency of this nutrient causes significant morphological changes in the culture of beet, such as a reduction in plant development and the nutritional quality of the roots (Tivelli et al., 2011).

While boron (B) participates in plant sugar transport to the roots, in the formation of pectin in cell membranes, and the metabolism of glycid, influencing the productive performance and quality of vegetables (Kabu et al., 2013). The omission of this element in the plant, causes decreased absorption of water by the cell wall, reduced polysaccharide biosynthesis and, consequently, increased stiffness in the cell wall, reduced growth, and increased damage to beetroots (Malavolta, 2000).

Despite the importance of these fertilizers in the development and growth of the plant, the fertilizer efficiency does not occur in isolation. It depends, on the interactions that occur between other nutrients, which can be positive (synergistic) when one element helps the absorption of other or negative (antagonistic) when the absorption of one element is impaired by the presence of other (Prado, 2008).

Many studies have been conducted to better understand the mutual influence between nutrients and effects on plants in order to optimize the use of fertilizers and achieve maximum crop production (Silva & Trevizam, 2015; Silva et al., 2020). However, such studies are scarce in the cultivation of beet.

This work aimed to evaluate the effects of the combination of fertilization with nitrogen in coverage combined with boron in planting the production characteristics and quality of the beet Tall Top Early Wonder.

2. Methodology

The experiment was implemented at the São Manuel Experimental Farm, located in the municipality of São Manuel - SP, belonging to the Faculty of Agronomic Sciences (FCA) of the Universidade Estadual Paulista (UNESP), Botucatu Campus - SP, from March to June 2019. The geographical coordinates of the area are 22°44'28'' South latitude, 48°34'37'' West longitude, and altitude of 740 meters above sea level.

The predominant climate, according to the Köppen classification, is Cfa type, hot temperate climate (mesothermal), with rains concentrated in November to April and the average temperature of the hottest month above 22 ° C, with an average annual rainfall of 1,377 mm (Cunha & Martins, 2009).

The soil of the cultivation area is classified as a Dystrophic Red Latosol. The results obtained in the chemical analysis of the soil, before installation indicated: pH (CaCl₂) = 6,5; organic matter content = 19 g dm⁻³; H⁺Al³⁺ = 9 mmol_cdm⁻³; K = 2,5 mmol_cdm⁻³; P = 165 mg dm⁻³; Ca = 33 mmol_cdm⁻³; Mg = 9 mmol_cdm⁻³; soil base sum = 43 mmol_cdm⁻³; cation exchange capacity (CEC) = 52 mmol_cdm⁻³; soil base saturation = 82; S = 13 mg dm³; B = 0,14 mg dm⁻³; Cu = 2,5 mg dm⁻³; Fe = 58 mg dm⁻³; Mn = 4,7 mg dm⁻³ e Zn = 3,6 mg dm⁻³.

Fertilization was defined based on soil analysis and according to the recommendation described by (Trani et al., 1997). All treatments received the following fertilization: 20 kg ha⁻¹ of N (urea), 180 kg ha⁻¹ of P₂O₅ (triple superphosphate) and 120 kg ha⁻¹ of K₂O (potassium chloride) and covering fertilization 45 Kg ha⁻¹ de K₂O (potassium chloride), parceled out at 15, 30 and 45 days after transplanting the seedlings (DAT).

The experimental design used was randomized blocks, with four replications. Two factors were studied, nitrogen fertilization and boric fertilization, in the factorial scheme (2 x 2), totaling 4 treatments: T1 (0 kg ha⁻¹ of N and 0 kg ha⁻¹ de B), T2 (0 kg ha⁻¹ of N and 4 kg ha⁻¹ of B), T3 (90 kg ha⁻¹ of N and 0 kg ha⁻¹ de B) and T4 (90 kg ha⁻¹ of N and 4 kg ha⁻¹ of B).

The treatments with B (4 kg ha⁻¹) were applied in a single dose for planting fertilization and with N (90 kg ha⁻¹) in coverage, divided into 15, 30 and 45 (DAT). The sources of B and N were urea and borax, respectively. The beet cultivar studied was Early Wonder Tall Top. The beet seeds were sown in polypropylene trays with 288 cells, containing commercial

substrate for vegetables, placing one seed per cell. Thirty days after sowing, the seedlings were transplanted in beds of 1.0 m wide and 1.20 m long.

Each plot consisted of four longitudinal lines spaced at 0.25 m, and between plants of 0.10 m, with the plants of the two central lines of each plot being evaluated. The cultural treatments included the thinning of the seedlings in the tray, weeding performed every 15 days. The plants were irrigated with sprinklers and water provided to maintain 60% of the field capacity.

The harvest was performed 60 days after transplantation (DAT). The variables analyzed were: Plant height (cm), fresh and dry leaf weight (g/plant), root diameter (mm), dry and fresh root weight (g/plant), beet yield (t ha^{-1}) and classification of commercial roots according to the commercial classification implemented by Company of Warehouses and General Warehouses of São Paulo (Ceagesp, 2017). The data were subjected to analysis of variance (F test) ($p < 0,05$), using the Sisvar 5.3 statistical software (Ferreira, 2011).

3. Results and Discussion

The results showed significant effects for fertilization with nitrogen, as well as for its interaction with boron. However, there was no significant effect for the isolated factor borate fertilization in any evaluated feature (Table 1).

The addition of nitrogen in coverage promoted increases in all studied variables (Table 1). This result can be explained by the greater capacity for photosynthesis of plants that received nitrogen in cover, this because, this nutrient is part of the processes of growth, development and reproduction, as well as being essential for the formation of amino acids, proteins and carbohydrates in plants (Dupas, 2012; Taiz & Zeiger, 2013; Santos, 2021).

According to Table 1, the supply of nitrogen in coverage provided an average increase of 32% in the plant height, 50% in the dry leaf weight and 72% in the fresh leaf weight. Otherwise, inadequate nitrogen supply affects plant development and, consequently, root growth (Barreto, 2013). This fact was observed in the present study, where the omission of nitrogen caused an average reduction in roots production in the order of 30% for diameter, 33% for the dry weight, 40% for the fresh weight and 45% for beet yield (Table 1).

Alves et al. (2008) also found that an insufficient supply of nitrogen caused losses in the development of the beet, decreasing the height, the number of leaves, and beet yield. The authors concluded that nitrogen failure damaged the nutrition of this vegetable, which in turn, reflected in morphological changes, manifested as characteristic symptoms of nutritional deficiency of this nutrient.

Although there was no significant effect for the factor isolated borate fertilization at planting for any variable studied, a positive effect was observed for all variables analyzed when applied together with nitrogen (T4), with an increase in productivity (37.80 t ha^{-1}) in the order of 20% compared to treatment (T3) with nitrogen and without boron (31.44 t ha^{-1}).

The values of productivity of beetroots obtained in the present study are within the average of the values obtained by Corrêa et al. (2014), Magro et al. (2015), Candian et al. (2016), Silva et al. (2016) and Aguilar et al. (2021), ranging from 15 to 45 t ha^{-1} .

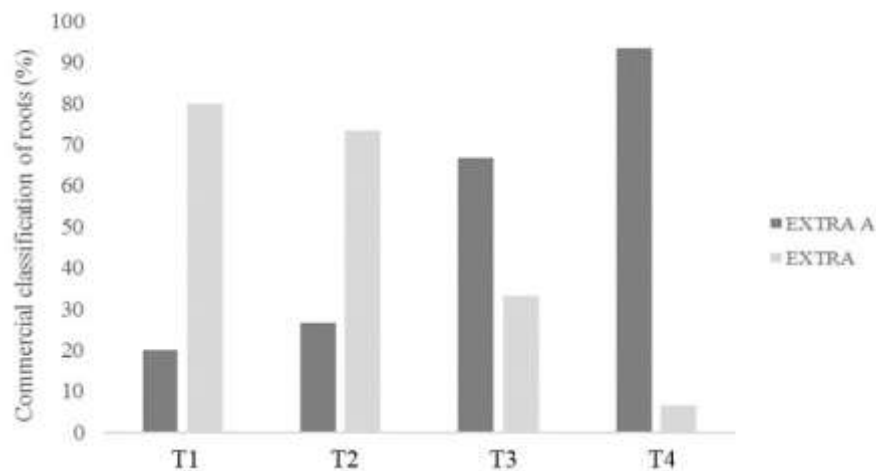
Table 1. Plant height (cm), fresh and dry leaf weight (g/plant), root diameter (mm), dry and fresh root weight (g/plant), beet yield (t ha⁻¹), as a function of nitrogen and boron fertilization.

Leaf				
Nitrogen level		Plant height	Fresh weight	Dry weight
Kg/ha			0 Kg/ha of B	
0		28,33 B	49,66 B	3,86 B
90		36,58 Ab	79,33Ab	5,35 Ab
Average		32,46	64,50	4,61
4 Kg/ha of B				
0		29,75 B	50,50 B	4,53 B
90		39,83 Aa	93,01 Aa	7,24 Aa
Average		34,79	71,75	5,89
Average doses of N				
0		29,04 b	50,08 b	4,19 b
90		38,20 a	86,16 a	6,30 a
CV		10,31	16,79	18,35
Root				
Nitrogen level	Diameter	Dry weight	Fresh weight	Beet yield
0 Kg/ha of B				
0	41,19 B	11,45 B	65,65 B	17,04 B
90	53,52 Ab	16,57 Ab	102,19 Ab	31,44 Ab
Média	47,35	14,01	83,92	24,24
4 Kg/ha de B				
0	42,69 B	14,67 B	67,94 B	20,91 B
90	65,61 Aa	22,20 Aa	121,25 Aa	37,80 Aa
Média	54,14	18,43	94,59	29,10
Average doses of N				
0	41,94 b	13,06 b	66,79 b	18,97 b
90	59,56 a	19,38 a	111,72 a	34,62 a
CV	13,34	18,66	17,58	17,58

Capital letters compare nitrogen doses within each boron dose and boron averages. Small letters compare doses of boron within each nitrogen dose and averages of nitrogen, according to the Tukey test ($p < 0.05$). Source: authors.

Regarding the commercial classification of the roots, it was observed that the treatment with nitrogen and boron (T4) achieved the best results, with roots in the extra group A in the order of 93% (Figure 1). In addition, for the same treatment, greater homogeneity in root size was found, which is an important factor in determining the visual quality and commercial classification of beets (Ceagesp, 2017), while the treatment with nitrogen and without boron (T3) was 66,7%.

Figure 1. The productivity of beetroots according to commercial classifications of roots (Extra A and Extra AA), as a function of nitrogen fertilization in cover and boric in planting.



Source: authors

On the other hand, the nutritional imbalance between nitrogen and boron causes damage to the development of crops, probably due to the nutritional deficiency that these elements cause in the physiological part of the plant (Alves et al, 2008; Gondim, 2009). Similar results were obtained in the present study, with the decrease in plant height, fresh and dry mass of leaves and roots, negatively reflecting on productivity and homogeneity of the roots.

4. Conclusion

The interaction between nitrogen and boron positively influenced the agronomic performance of beet, with a synergistic effect when the two elements were applied together, providing increased productivity with larger and more homogeneous roots.

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