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Brackmann, Auri; Thewes, Fabio Rodrigo; de Oliveira Anese, Rogerio; Linke Junior, Wanderlei

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Preharvest boron application and its relation with the quality of 'Galaxy' apples after harvest and controlled atmosphere storage

Aplicação pré-colheita de boro e sua relação com a qualidade de maçãs 'Galaxy' após a colheita e armazenamento em atmosfera controlada

Auri Brackmann[I] Fabio Rodrigo Thewes[II]
Rogerio de Oliveira Anese[II] Wanderlei Linke Junior[II]

– NOTE –

ABSTRACT

The aim of this research was to evaluate the effect of preharvest boron application on the physical and chemical quality of 'Galaxy' apples after harvest and in controlled atmosphere storage during eight months, plus seven days of shelf life at 20°C. The experiment was performed with two treatments applied on the field: [1] Control (fruit without boron application) and [2] Foliar application of boron (four applications of 1.5kg ha^{-1}). Findings showed that the boron application promoted a higher ethylene production and respiratory rate and it application also reduced the flesh firmness in relation to the fruits without it. A similar result was obtained after eight months of storage plus seven days of shelf life. The preharvest application of boron makes it possible to harvest apples earlier due to the fact that it accelerates the fruit metabolism. However, the fruits end up presenting a lower storage potential as a result of the higher ethylene production, respiration rate, decay incidence, mealiness and a reduction of the healthy fruit percentage and flesh firmness after CA storage.

Key words: ***Malus domestica***, *decay, physiological disorders.*

RESUMO

O objetivo deste estudo foi avaliar o efeito da aplicação de boro em pré-colheita sobre a qualidade físico química de maçã 'Galaxy', após a colheita e armazenamento em atmosfera controlada, durante 8 meses mais sete dias de vida de prateleira a 20°C. O experimento foi composto por dois tratamentos aplicados a campo: [1] controle (frutos sem aplicação de boro) e [2] aplicação foliar de boro (quatro aplicações de 1,5kg ha^{-1}). Após a colheita, a aplicação de boro promoveu maior produção de etileno, taxa respiratória e reduziu a firmeza de polpa em relação aos frutos sem boro. Resultado similar foi obtido após oito meses de armazenamento mais sete dias de vida. A aplicação pré-colheita de boro torna possível antecipar a colheita pelo fato de que acelera o metabolismo dos frutos, mas os frutos tem menor potencial de armazenamento, pois apresentam alta produção de etileno, taxa respiratória, incidência de podridões, polpa farinácea e redução da porcentagem de frutos sadios e firmeza de polpa após o armazenamento em AC.

Palavras-chave: ***Malus domestica***, *podridões, distúrbios fisiológicos.*

The use of plant regulators is widely performed on the field in order to regulate plant growth, fruit development and maturation. Plant regulators and other products (Boron) are used more intensively on fruit production than any other crops. Application of Ethephon (2-chloroethylphosphonic acid) is extensively used to accelerate the apple maturation and promote skin coloration (STEFFENS et al., 2006; BAN et al., 2007). Application of boron can be used along with Ethephon in order to promote fruit maturation, skin coloration and staggered harvest (ERNANI et al., 2010). Furthermore, the application of boron 21 days after plantation (1.55kg ha^{-1}) kept a higher postharvest quality of crisphead lettuce (YURI et al., 2004) and presented a reduction in the levels of fruit drop and a higher quality of apples after harvest (DONG et al., 1997).

Boron is a nutrient that is expressively used in apple production. Its application (sprinkling) helps the formation of the pollinic tube, which increases fecundation, and has a relation with the calcium

[I]Departamento de Fitotecnia, Centro de Ciências Rurais (CCR), Universidade Federal de Santa Maria (UFSM), 97105-900, Santa Maria, RS, Brasil. E-mail: auribrackmann@gmail.com. Corresponding author.
[II]Programa de Pós-graduação em Agronomia, Centro de Ciências Rurais (CCR) Universidade Federal de Santa Maria (UFSM), Santa Maria, RS, Brasil.
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transportation and absorption (MARSCHNER, 1997; WOJCIK et al., 1999). Insufficient boron supply does not inhibit the pollen germination, but it does negatively affect the extension of the pollinic tube. A small pollinic tube elongation, along with a low boron concentration, is related to the callose synthesis, which induces the synthesis of phytoalexins (comprising phenols) in the stigma. This pathway is a defense mechanism similar to the plant response to microbial infection (MARSCHNER, 1997). Nevertheless, there are no researches regarding the effect of preharvest boron application on apples quality after harvest. Thus, the objective of this research was to evaluate the effect of preharvest boron application on the physical and chemical quality of 'Galaxy' apples at the time of harvest and after eight months under a controlled atmosphere storage plus seven days of shelf life.

The study was carried out in two stages. The first stage was carried out on the field in the city of Vacaria (RS - Brazil), in a commercial orchard with 6 year old plants, spaced 3.5 meters between lines and 0.80 meters between plants and the rootstock used was EM-9. The second stage was carried out at the Postharvest Research Center (NPP) of the Universidade Federal de Santa Maria (UFSM). The experiment was performed with two treatments applied on the field: [1] Control (only water application) and [2] Foliar application of boron, four applications of boric acid (1.5kg ha^{-1}), with an output of 1,000L ha^{-1}, were carried out. The first boron application was performed one month before the expected harvest date and the other three applications were done weekly until the harvest. The concentration and application of boron were based on the methodology proposed by ERNANI et al. (2010). Each treatment was composed of five replicates, with two plants per plot and 30 fruits were harvested from each plant. Then, the fruits were separated into two lots and transported to the NPP, where the physical and chemical analysis were carried out on the first lot. Thereafter, the fruits of the second lot were placed in a hermetically closed chamber (0.233m^3) for storage, at a temperature of 1.5°C (±0. 1), during eight months. The storage condition adopted had a controlled atmosphere similar to the one used for commercial storage with 1.2kPa of O_2 + 2.5kPa of CO_2, and the relative humidity was maintained at 94% (±1.0). The methodology described in WEBER et al. (2012) was adopted in order to maintain the desired storage condition and the relative humidity. The following analysis were performed after harvest and eight months of CA storage plus seven days of shelf life at 20°C (relative humidity of 82±5%): a) Ethylene production: assessed by gas chromatography. A sample of approximately 1.5kg of fruits was placed into a 5 liter container and hermetically closed for about two hours. Next, two samples of 1mL were taken from the container and injected into the gas chromatograph, the results were expressed in μL C_2H_4 $kg^{-1}h^{-1}$; b) Respiratory rate: determined by the air circulation of the same container used to ethylene measuring through a gas analyzer, the data were expressed in mL CO_2 $kg^{-1}h^{-1}$, according to the methodology proposed by STEFFENS et al. (2007); c) Flesh firmness: determined with a penetrometer (11mm) introduced in the pulp, the results were expressed in Newton (N); d) Iodine-starch: determined by cutting the fruit and immerging the pulp in a solution of iodine during one minute, after this the fruits were classified in levels (0-10), where 0=100% of starch and 10=0% of starch; e) Decay incidence; f) Mealiness; g) Flesh breakdown: evaluated by counting the fruits that presented any symptons of these physiological disorders, expressed in percentage; h) Healthy fruit: determined by the total of fruits minus the fruits that showed any symptons of decay incidence, pulp crack, mealiness and flesh breakdown, with the results expressed in percentage; i) Soluble solids: obtained by refractometry, the results were expressed in °Brix; j) Titratable acidity: determined by titration of a solution that contained 10mL of juice diluted in 100mL of distilled water, with a solution of NaOH 0.1N, the results were expressed in meq 100mL^{-1}. A variance analysis (ANOVA) was conducted for each characteristic evaluated; the averages were submitted to the Tukey test at 5% error probability. The data expressed in percentage were transformed with the arc.sin $((x/100)^{0,5})$ formula and then submitted to the variance analysis.

No decay incidence or flesh breakdown were reported after the harvest plus seven days of shelf life, however, the fruits treated with boron showed a higher ethylene production in relation to the fruits without boron (Figure 1A). This fact shows that the fruits exposed to the application of boron during pre-harvest had a higher metabolism, which accelerated the maturation. The higher ethylene production induced an elevated respiration rate on the same treatment (Figure 1B). Perhaps the higher respiration rate is related to the pathway that the glucose follows. Previous studies suggested that a high boron concentration stimulates the glucose consumption by glycolysis and a low concentration of boron by pentose-P cycle (MARSCHNER, 1997). Apples have a climacteric metabolism, in which a peak in the ethylene production occurs and, subsequently,

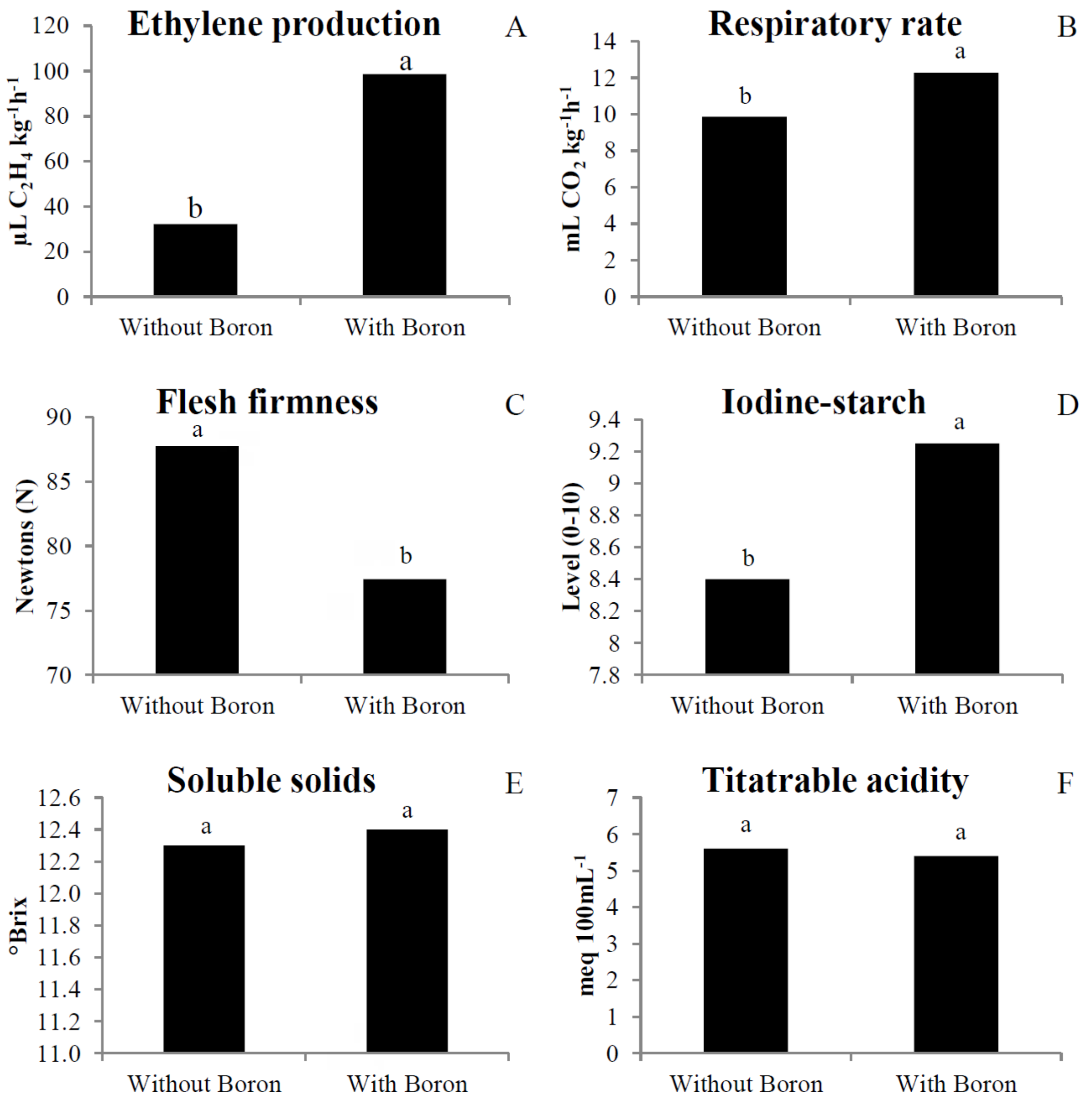

Figure 1 - Ethylene production, respiratory rate, flesh firmness, iodine-starch, soluble solids and titratable acidity of 'Galaxy' apples after harvest plus seven days of shelf life at 20°C. Vacaria, RS, Brazil, 2015. *Averages followed by the same letters in the same variable do not differ by Tukey's test, at 5% probability ($p<0.05$).

on the respiration rate (STEFFENS et al., 2007). The higher ethylene production and respiration rate culminated in a reduction of flesh firmness (Figure 1C). WEBER et al. (2012) also suggested that high ethylene production and respiration rate decreasead the flesh firmness. Concerning the iodine-starch, a lower starch concentration was reported in the fruits submitted to the boron application (Figure 1D), indicating that these fruits had a higher metabolism and were riper in relation to the fruits that did not receive the application of boron. However, the higher metabolism of fruits with boron did not result in a lower level of soluble solids and titratable acidity after the harvest (Figure 1E and F).

Regarding the effect of the boron application after CA storage, no significant difference was observed in the flesh breakdown (1.32%) and in titratable acidity (4.66meq 100mL^{-1}) levels. The ethylene production and the respiration rate, observed upon opening the chamber, had the same response to

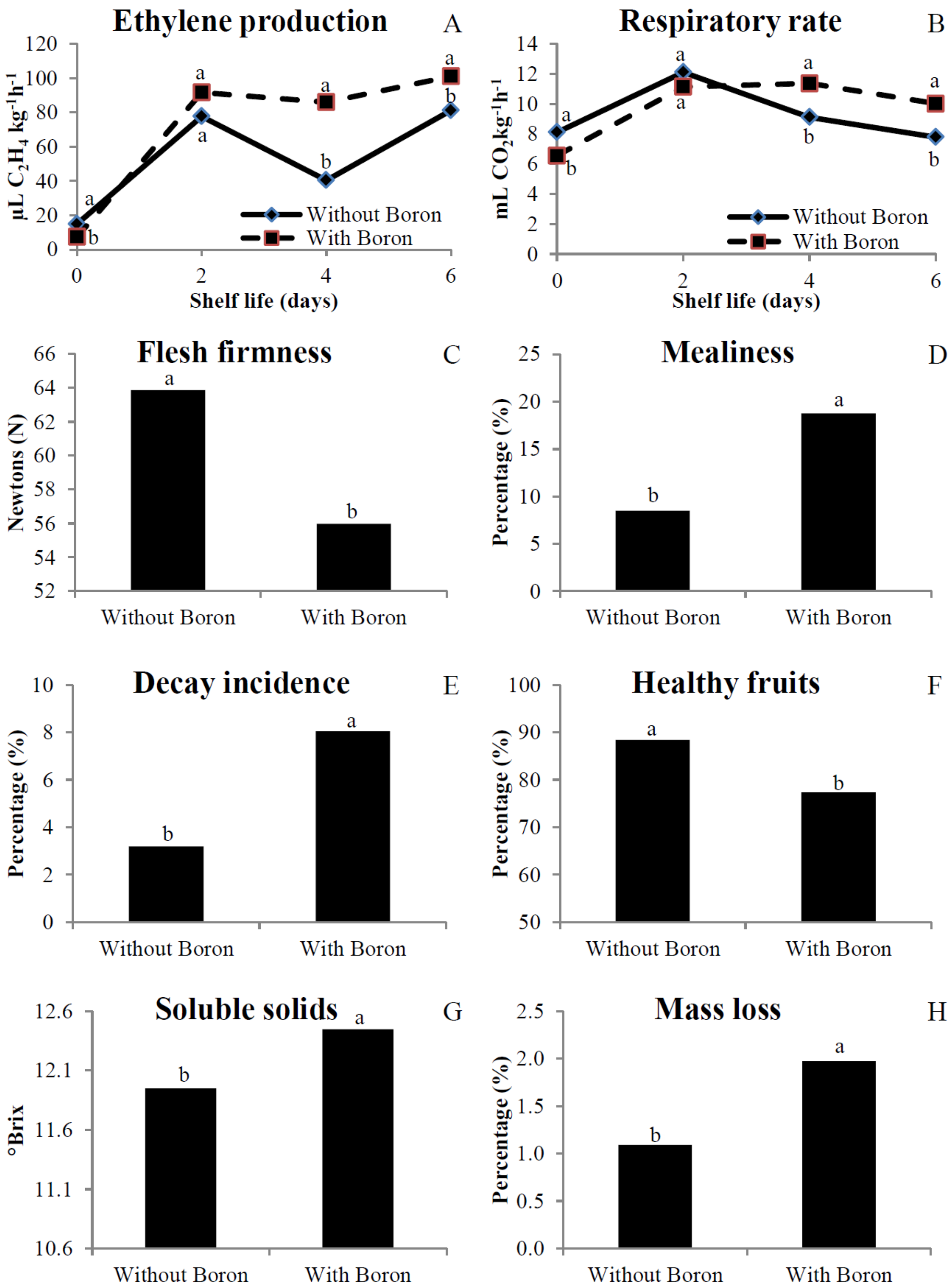

Figure 2 - Ethylene production, respiratory rate, flesh firmness, mealiness, decay incidence, healthy fruits, soluble solids and mass loss of 'Galaxy' apples after eight months in CA storage (1.5±0.1°C and 1.2kPa O_2+2.5kPa CO_2) plus seven days of shelf life at 20°C. Santa Maria, RS, Brazil, 2015. *Averages followed by the same letters in the same variable do not differ by Tukey's test, at 5% probability ($p<0.05$).

the application of boron (Figure 2A and B), whilst the fruits that did not receive boron presented a higher metabolism. However, after four and six days of shelf life, the response to boron application was the opposite. This higher ethylene production and respiration rate, after four and six days of shelf life, culminated in lower flesh firmness (Figure 2C). Nevertheless, the lower flesh firmness may be correlated to the higher mealiness on fruits submitted to the boron application, once some researchers suggested that ethylene production activates enzymes that degrade the cell wall, decrease the flesh firmness and increase mealiness (PAYASI et al., 2009).

A higher fungal susceptibility due to the higher decay incidence (Figure 2E) and lower percentage of healthy fruits (Figure 2F) were also verified on the fruits submitted to boron. These results suggest that fruits submitted to the application of boron cannot be stored for a long time without presenting a significant quality loss, such as high decay incidence and low percentage of healthy fruit. However, fruits with boron showed higher levels of soluble solids (Figure 2G) due to the higher metabolism of fruits submitted to this treatment, leading in cell wall degradation (Figure 2C and D). Similar results were obtained in 'Royal Gala' apples (BRACKMANN et al., 2007) and peaches (PINTO et al., 2012).

The preharvest application of boron makes possible to harvest apples earlier due to the fact that it accelerates the fruit metabolism. However, the fruits end up presenting a lower storage potential as a result of the higher ethylene production, respiration rate, decay incidence, mealiness and a reduction of the healthy fruit percentage and flesh firmness after CA storage.

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