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Boron and calcium sprayed on 'Fuyu' persimmon tree prevent skin cracks, groove and browning of fruit during cold storage

Boro e cálcio pulverizado em árvores de caqui "Fuyu" previnem fissuras, estrias e escurecimento do fruto durante o armazenamento refrigerado

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ABSTRACT

Flesh softening, skin browning and rotting are chief problems during cold storage (CS) of 'Fuyu' Persimmon. We studied the effects of boron (B) and calcium (Ca) sprayed on the trees during three consecutive years, on the development of skin cracks, grooves and browning in persimmon fruit under CS in Farroupilha, RS, Brazil (29°31' south, 51°21' west, about 750 m altitude). A homogeneous orchard area of 0.5 ha was delimitated and three sets of five plants for each treatment were randomly selected. The persimmon trees were sprayed at a 20 day interval, from 15th January until harvest, for three consecutive years, with: T1) water; T2) calcium nitrate at 0.5% (m/v); T3) calcium chloride at 0.5% (m/v); and T4) boron at 0.3% (m/v). The fruit were harvest with orange-reddish colour; 18-20^{o}Brix, pulp firmness of 45 to 60N, and kept under CS at 0±1ºC for 45 days. The fruits were evaluated immediately before CS, after six hours at 23±2ºC after removal from CS, and after four days at 23±2ºC after removal from CS. Equally boron and calcium sprayed on the trees prevented skin cracks, skin grooves and skin browning. Besides, when boron was sprayed on the trees, the mentioned effects were additive in the following year.

Key words: ***Diospyrus kaki***, *postharvest injuries, micronutrients, macronutrients.*

RESUMO

As principais alterações indesejáveis observadas no período pós-colheita de caquis em armazenamento refrigerado (AR) são a perda de firmeza de polpa, e a ocorrência de escurecimento epidérmico e de podridões. Este trabalho teve por objetivo principal estudar as respostas da aplicação de boro (B) e cálcio (Ca), em três safras sucessivas, na prevenção da ocorrência de fissuras, estrias e escurecimento epidérmico de caquis "Fuyu". No pomar (Farroupilha-RS-Brasil, 29°31' Sul, 51°21' Oeste, aproximadamente 750m altitude) delimitou-se uma área homogênea de 0,5ha., marcando-se, ao acaso, três repetições de cinco plantas para cada tratamento: T1 – controle, caquizeiros não-pulverizados com B e Ca; T2 – pulverizações com Nitrato de Ca 0,5% (m/v); T3 – pulverizações com Cloreto de Ca 0,5% (m/v); e T4 - pulverizações com B 0,3% (m/v). As aplicações foram realizadas em três anos sucessivos a partir de 15 de janeiro a intervalos de 20 dias. Foram colhidos os caquis na coloração alaranjado-avermelhada, com 18-20^{o}Brix e 45 a 60N, que posteriormente foram armazenados em AR a 0±1ºC por 45 dias. As avaliações foram realizadas no dia do armazenamento, após seis horas a 23±2ºC a partir da retirada AR, e após quatro dias a 23±2ºC a partir da retirada do AR. Foi avaliada a ocorrência de frutas com fissuras, estrias e escurecimento epidérmico. Comprovou-se o efeito benéfico da aplicação de B ou Ca na prevenção de fissuras, estrias e escurecimento epidérmico. Adicionalmente, foi detectado o incremento da resposta à aplicação de B, que, além de prevenir (à semelhança das aplicações com Ca), apresentou efeito aditivo no segundo ano. O resultado sugere que as respostas às aplicações com B são progressivas.

Palavras-chave: ***Diospyrus kaki***, *distúrbios pós-colheita, micronutrientes, macronutrientes.*

INTRODUCTION

Among persimmon cultivars grown in Brazil, the variety 'Fuyu' stands out for presenting good adaptation and productivity with seedless intermediate-large size fruits (150 to 350g), yellow-reddish coloration and sweetish taste (MARTINS & PEREIRA, 1989). In southern Brazil, the harvest period goes from April to June, resulting, as for most fruits, in higher offer and

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lower prices in this period (FERRI et al., 2004a). In order to minimize this problem, studies have been aimed at enlarging the commercialization period and at delaying the maturation rate of fruits, either in the field or during the postharvest period (COLLINS & TISDELL, 1995; WOOLF et al., 1997; BRACKMANN et al., 1999; GIRARDI et al., 2003; HARIMA et al., 2003; FERRI et al., 2004a; FERRI & ROMBALDI, 2004; SALVADOR et al., 2004).

The main undesirable alterations observed during the postharvest period of sweet persimmon during cold storage (CS) are the loss of the flesh firmness, the occurrence of skin browning and rottenness. These problems become worse when fruits are removed from cold storage and kept at room conditions with temperatures above 15ºC (WOOLF et al., 1997).

Seeking for extending the harvest period, it was verified that pulverizations with gibberellic acid at concentrations of 50-100ppm, 20-30 days before the date established for the harvest, allow delaying harvest in 10-20 days. However, it was observed that such procedure affects negatively the yield of the orchard in the year following the application (FERRI et al., 2004b). Pulverizations with Calcium under the form of Calcium Chloride in the preharvest period also contribute for the improvement of the conservation potential (FERRI, 2000). However, these authors verified that the application of calcium reduces the beneficial effects of the application of gibberellic acid, applied with the objective of delaying harvest.

After harvest, the conservation of 'Fuyu' persimmon may be performed under CS at temperatures from 0 to 0.5ºC and relative humidity of 90-95%; with active or passive modified atmospheres (MA), with the employment of low-density polyethylene packages (LDPP), with thickness from 30 to 80µm (FERRI, 2000); and with controlled atmosphere (CA). In this case, in addition to temperature and relative humidity, O_2 and CO_2 concentrations are kept between 2.0-3.0kPa and 5.0-10.0kPa, respectively (BRACKMANN & SAQUET, 1995).

The skin browning in fruits is still a limiting factor for the storage of 'Fuyu' persimmon in southern Brazil (FERRI & ROMBALDI, 2004). In the research conducted by (GONÇALVES et al., 2004), it was observed that the browning characterized by skin cracks and grooves is associated to the delay on the fruit harvest, resulting in high soluble solids concentration and bioconversion of sucrose into glucose and fructose, thus increasing the localized osmotic pressure. Moreover, it was observed that the flesh under skin containing cracks and grooves presents sorbitol, molecule known in rosaceous for being synthesized and translocated through the phloem under stress conditions, for example, at low temperatures.

Based on this knowledge, the hypothesis that Boron and Calcium supplementation in the preharvest period may prevent from the occurrence of skin cracks/grooves and hence skin browning in persimmon fruits was raised. This hypothesis is also based on studies of (BROWN & HU, 1996), who reported that sorbitol may act as a translocation facilitating agent for not much movable cations such as Calcium and Boron through the phloem of plants. Thus, responses to the application of these cations may have accumulative effect, once these cations may be stored in vegetative and floral buds.

In this context, the main objective of this reserach was to study the responses to the application of Boron and Calcium in three successive years in the prevention of the occurrence of skin cracks, grooves and browning in 'Fuyu' persimmon.

MATERIAL AND METHODS

This study was conducted in 'Fuyu' persimmon trees established in commercial orchard in Farroupilha - RS – Brazil (29°31' south, 51°21' west, about 750m altitude), which injuries occurrence history has been followed since 2001 (FERRI et al., 2004b). The trials were performed in the harvests of 2003, 2004 and 2005. A homogeneous area of 0.5ha was delimitated and three sets of five plants per treatment were randomly marked.

The experimental treatments consisted of spraying the persimmon trees with a calcium or boron solutions, from January 15th until harvest, at 20 days interval: T1) water (control); T2) Calcium nitrate 0.5% (m/v); T3) Calcium chloride 0.5% (m/v); T4) Boron 0.3% (m/v). In 2003, for each experimental treatment, the first set of five plants was sprayed. In 2004, for each experimental treatment, two sets of five plants were sprayed. In 2005, for each experimental treatment, all the three sets of five plants were sprayed. Therefore, for each treatment, one third of the trees were treated for three consecutive years; one third were treated for two consecutive years and one third of the trees were treated for one year only. For the evaluation of treatments, fruits were only harvested when presenting an orange-reddish coloration, total soluble solids concentration of 18-20ºBrix and 45-60N of flesh firmness. Each sample was composed of 60kg of fruits. Twenty kilograms were aimed at the initial evaluations and two sub-samples of 20kg each were stored under

CS at 0ºC±1ºC and RH of 92±5%. The storage period was of 45 days. The evaluations were performed at the storage day, six hours after removal from CS and four days after removal from CS with maintenance of fruits at temperature of 23ºC±2ºC and relative humidity (RH) of 72±5%.

As variables for the evaluation of treatments, the occurrence of fruits with skin cracks, grooves and browning was evaluated and only those with symptoms larger than 0.5mm were considered. Since each sample was composed of 20kg of fruits, the fruits were counted and the percentage of fruits presenting symptoms was calculated. Additionally, the B and Ca contents in the flesh of fruits and floral buds were determined, adopting collection procedures described by VERÍSSIMO et al. (2006), and analysis procedures described by FREIRE (1998). To do so, cubes of approximately 1.0cm were collected from the equatorial region of 20 fruits belonging to each sample. These cubes were gathered in order to form the work sample, in which analyses were performed in triplicate. For buds, the sampling was performed at the first fortnight of September every year, with 50 buds collected from each plant (5 to 15 plants per treatment). The 50 buds were pulled to form the work sample, in which analyses were performed in triplicate. Sanest (ZONTA & MACHADO, 1991) was used for statistical analysis. The percentage data was normalized according to the equation *f(x) = arcsine x*. ANOVA was performed using the F test (P<0.01). Means of treatment were compared using the Duncan's test (P<0.01).

RESULTS AND DISCUSSION

Almost 50% of the fruit evaluated in this study was affected by skin cracks, grooves and browning at harvest and the percentage of affected fruit increased during CS (Figure 1). This fact was supposedly known, once the history of this orchard is similar to others from the highland regions of the Santa Catarina and Rio Grande do Sul where the occurrence of these injuries is significant, above all when the harvest of persimmon is performed in more advanced maturation stages, as in the case of this experiment.

In this study we observed that application of Ca or B, even in a sole production year, contributes for the prevention of skin cracks, grooves and browning both at the harvest occasion and after CS. Good results were obtained with the application of Ca or B, regardless the source used (Figure 1).

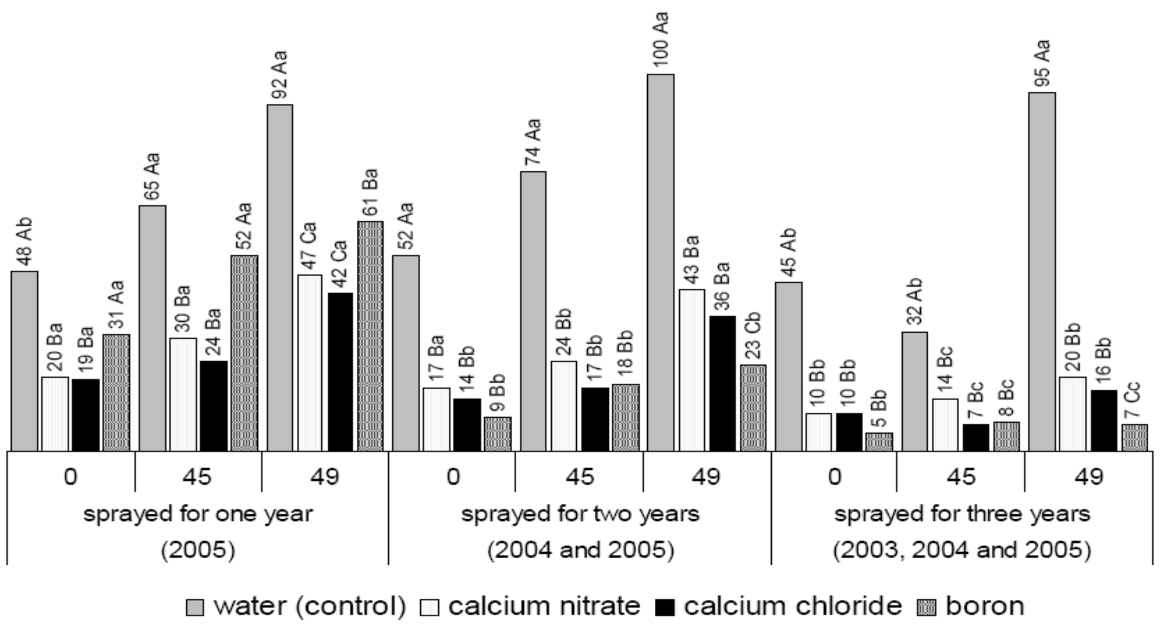

Figure 1 - Occurrence of injuries (skin cracks, grooves and browning) in 'Fuyu' persimmon fruits during the postharvest. The fruits were harvested from plants sprayed with: water (control, T1), calcium nitrate 0.5% (T2), calcium chloride 0.5% (T3), or boron 0.3% (T4). The plants were sprayed at 20 day interval, from 15^{th} January until harvest. The fruits were evaluated immediately before the cold storage (0), after 45 days of cold storage at 0°C (45) and after 45 days of cold storage at 0°C plus 4 days at 23±2°C (49). Means of treatment (n = 20) were compared by Duncan's test (P<0.01). Means of different treatments compared into the same postharvest evaluation group (e.g. 48, 20, 19, and 31), do not differ from each other if the capital letter on top of the columns is the same. Means of the same treatment (e.g. T1) compared between different postharvest evaluations groups (e.g. 48, 65, 92, 52, 74, 100, 45, 32, and 95) do not differ from each other if the lower case letter on top of the column is the same.

In experimental units where treatments were applied for two consecutive years (Figure 1), a beneficial effect of the application of B or Ca on the prevention of skin cracks, grooves and browning was observed. In addition, the application of B, besides preventing skin cracks, grooves and browning (similarly to the application of Ca), also presented an additive effect in the following year. This result suggests that responses to applications with B are progressive, what could be verified when fruits from trees that were sprayed with this cation for three consecutive years were evaluated (Figure 1).

Based on determinations of the B and Ca concentrations in the buds that originate the fruit and in the flesh of persimmon fruit (Figure 2), it was observed that the prevention of injuries (Figure 1) was directly associated with the increase of B and Ca concentration. The concentration of B in the fruits from plants sprayed with this cation increased up to the third evaluation year and contributed to prevent the occurrence of skin cracks, grooves and browning. Moreover, the higher concentration of B in the buds of these plants resulted in a general reduction in the occurrence of fruit injuries.

This browning of fruits observed after removal from the CS must be related with the exposition of fruits to room temperatures (23°C ± 2°C), so that the enzymatic activity increases expressively and leads to the occurrence of skin cracks, grooves and browning. Boron presents the capacity of inhibiting these injuries when compared to Ca, and as a result, determines a higher occurrence and severity of skin browning. It was also observed that the occurrence of skin browning increased as the storage time elapsed and that the concentration of skin damages increased drastically after 45 days of storage.

In relation to the incidence of skin cracks and grooves, no significant difference was observed between calcium-based nutrients applied. However, when the fruits were removed from the CS, the injury rate was lower for fruits treated with calcium nitrate. After four days at 23°C ± 2°C, the occurrence of skin browning was higher in fruits treated with calcium chloride. In all the treatments, increases in the respiratory rate and the quick evolution of fruits in their senescence probably made them more susceptible to skin injuries.

Skin cracks, grooves and browning are considered the worth problem in the postharvest of 'Fuyu' persimmon (BRACKMANN et al., 1999; GIRARDI et al., 2003; FERRI et al., 2004a). Our results show that these disturbs are partially prevented by supplying Ca and B to the plants in successive years. The exact causes of this behaviour were not the focus of this work. Considering that calcium and boron contributes to cell wall stability and maintenance of endomembrane system, respectively (COLLINS & TISDELL, 1995; NATALE et al., 2005), it is possible that these mechanism may be associated with the prevention of the mentioned injuries.

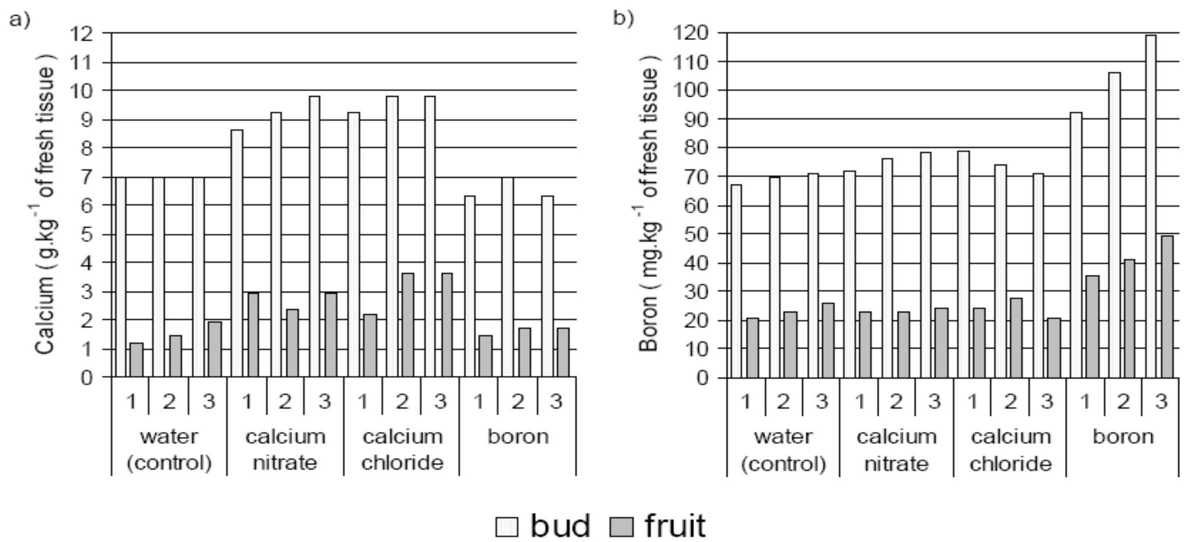

Figure 2 - Concentration of calcium (a) and boron (b) in buds and fruits of "Fuyu" persimmon plants sprayed with: T1) water (control), T2) calcium nitrate 0.5%, T3) calcium chloride 0.5%, or T4) boron 0.3%, at 20 day interval, from 15th January until harvest, for one (1), two (2) and three (3) consecutive years. The fruits were evaluated immediately before the cold storage (0), after 45 days of cold storage at 0°C (45) and after 45 days of cold storage at 0°C plus 4 days at 23±2°C (49)

CONCLUSIONS

There is a beneficial effect of the application of boron, calcium nitrate and calcium chloride on the prevention of skin cracks, grooves and browning of Fuyu persimmon, providing additive effect when applied in successive years, suggesting that the responses to the application of boron are progressive.

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