Abscisic acid as a potential chemical thinner for peach

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Abstract – The objective of this work was to evaluate the effect of abscisic acid, applied at different rates and different fruit developmental stages, on the thinning of 'Chiripá' peach. Abscisic acid (ABA) at 500 mg L^{-1} was applied at three stages of fruit development based on lignin deposition: stage 1, at 24 days after full bloom (DAFB); stage 2, at 40 DAFB; and stage 3, at 52 DAFB. Only ABA application at stage 2 – 40 DAFB – reduced fruit set and the number of fruit per plant. Three ABA concentrations (350, 500, and 750 mg L^{-1}) were then applied at 40 DAFB. All rates increased fruit ethylene production and fruit abscission.

Index terms: abscission, pit hardening, plant growth regulators, plant hormones, stone fruit.

Ácido abscísico como potencial raleante químico de frutos de pessegueiro

Resumo – O objetivo deste trabalho foi avaliar o efeito do ácido abscísico, aplicado em diferentes doses e estádios de desenvolvimento dos frutos, no raleio de pessegueiro 'Chiripá'. O ácido abscísico (ABA) foi aplicado a 500 mg L^{-1}, em três estádios de desenvolvimento dos frutos, com base na deposição de lignina: estádio 1, aos 24 dias após a plena floração (DAPF); estádio 2, aos 40 DAPF; e estádio 3, aos 52 DAPF. Apenas a aplicação de ABA no estádio 2 – 40 DAPF – reduziu a frutificação efetiva e o número de frutos por planta. Três concentrações de ABA (350, 500 e 750 mg L^{-1}) foram, então, aplicadas aos 40 DAPF. Todas as doses resultaram em aumento da produção de etileno e abscisão dos frutos.

Termos para indexação: abscisão, endurecimento do caroço, regulador de crescimento vegetal, hormônios vegetais, frutíferas de caroço.

Fruit or flower thinning can promote an adequate source-sink balance to produce fruit with size, flavor, and color that meet consumer demands (Costa et al., 2013; Greene & Costa, 2013). Peach thinning is performed manually within a short period of time implicating in elevated labor costs (Greene & Costa, 2013). In many fruit producing areas, the available manpower to perform thinning is scarce, and the high cost of this operation has motivated research into alternative ways of thinning (McArtney et al., 2012).

The plant growth regulator ABA, which regulates different physiological functions during plant growth and development (Daszkowska-Golec & Szrajko, 2013), has been proposed to promote flower and fruit abscission in cherries (Zucconi et al., 1969). Recently, the application of ABA showed promising results for apple and pear thinning (Greene et al., 2011; Greene, 2012).

The objective of this work was to evaluate the effect of abscisic acid, applied at different rates and different fruit developmental stages, on thinning of 'Chiripá' peach.

This study was divided into two experiments performed in 2013 in a commercial peach orchard located in Morro Redondo, RS, Brazil (31°32'49,94"S, 52°34'42,42"W). Four-year-old 'Chiripá' trees grafted on the rootstock 'Capdeboscq' ('Lake City' x 'Intermediário'), and trained in a vase system at a 5x2 m spacing were used.

In the first experiment, treatments consisted of ABA applications (500 mg L^{-1}; ProTone, containing 10% a.i.) applied at three developmental stages, and controls without ABA. A nonionic surfactant at 0.1% was added to all treatment solutions. The sprayings were performed using a backpack sprayer, nozzles type JHC Jacto (Jacto, Pompeia, SP, Brazil), to the

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point of leaf wetting, with 1000 L ha^{-1}average water volume. Application timings were chosen based on lignin deposition on fruit pit, in order to identify the transition from phase I to phase II of fruit development, which is characterized by the pit hardening process and reduction of fruit growth. Lignin deposition was determined using ten randomly collected fruit, cut in half and placed in phloroglucinol solution, according to the method described by Callahan et al. (2009).

On the first application, at stage 1, 24 days after full bloom (DAFB), the average fruit diameter was 1.2 cm, and lignin deposition was not visible. On stage 2, 40 DAFB, fruit diameter was 2.4 cm, and shades of pink were observed in the endocarp, after fruit soaking in the phloroglucinol solution. On stage 3, at 52 DAFB, fruit diameter was 2.9 cm, and a more intense pink coloration was observed in the endocarp, which is the setting of the beginning of pit hardening (Figure 1). Temperature of application was 15,3° at stage 1, 19,6°C at stage 2, and 19,3°C at stage 3.

In this experiment fruit set (%) was determined by counting the number of flowers in six shoots, which were previously selected at random in each tree, and by the final number of fruit set. The total number of fruit per tree was counted before harvest.

In the second experiment, treatments consisted of three ABA applications at, 300, 500 and 750 mg L^{-1} at stage 2, and of controls without application. Manual thinning was performed at 42 DAFB. Fruit abscission (%) was determined by the time and after application. At 2, 7, 10, and 15 days after application (DAA), four fruit per replicate were collected from plants for ethylene quantitation. Two fruit were randomly selected and placed in hermetically sealed 50 mL bottles kept at 25±1°C for 48 hours. At the end of this period, an aliquot of 1 mL of the headspace inside the bottles was collected, using a hypodermic syringe, which was injected into a gas chromatograph Shimadzu GC-14B, (Shimadzu, Kyoto, Japan) equipped with a fused silica capillary column (30 m x 0.25 mm x 0.1 mm) and a flame ionization detector.

Treatments were arranged in a randomized block design, with five replicates of three trees per plot, using the central tree as observation, and two trees as borders. Data were submitted to analysis of variance (p≤0.05), and, when significant, mean comparisons were performed by Duncan's test, at 5% probability.

Application timing of ABA was crucial to reduce fruit set and the total number of fruit per tree (Figure 1). As to timing of application, stages 1 and 3 did not differ from the control treatment. At stage 2, ABA (500 mg L^{-1}) caused excessive thinning, sharply reducing the number of fruit per tree in comparison to the other treatments.

Some studies have applied ethephon as chemical thinning during pit hardening (Sardaki, 2012; Taheri et al., 2012). Costa et al. (2013) recommended the application of ethephon when pit length is between 9 and 11 mm. Parker et al. (2012) applied ABA (270 mg L^{-1}) in 'Contender' peach, at the time of pit hardening, and found no effect on fruit set or final crop load. According to results shown here the application timing of ABA for peach fruit thinning strongly influences the abscission.

The carbohydrate balance model developed for apples showed that fruit are more sensitive to chemical thinning when there is a carbohydrate deficit within the tree (Lakso et al., 2006). Applications of ABA at stages 1 and 3 did not reduce crop load. However, ABA

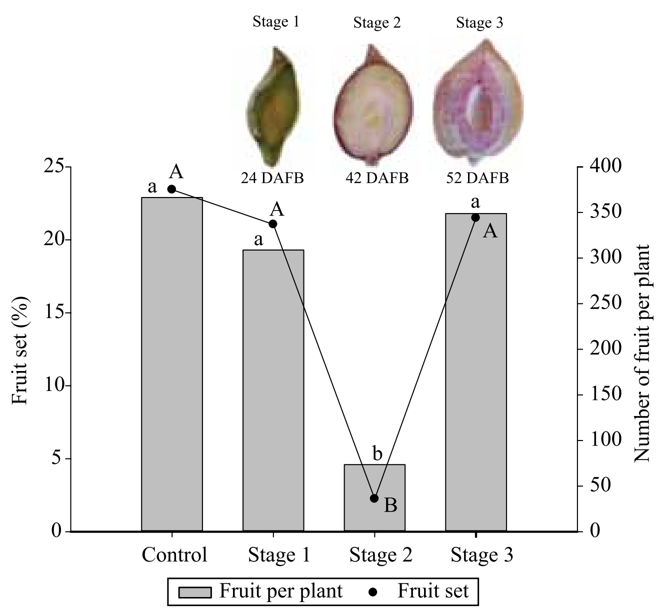

Figure 1. Effect of abscisic acid (500 mg L^{-1}) on fruit set and the number of fruit per plant at three different stages of fruit development for 'Chiripá' peach in 2013. Different lowercase letters indicate differences in the number of fruit per plant. Different capital letters indicate differences in fruit set, by Duncan's test, at 5% probability.

application at stage 2 significantly reduced crop load. This suggests that trees were spending more energy at this stage, which resulted in a carbohydrate deficit and favored chemical thinning.

Lignin biosynthesis is an energetically costly process, since a large amount of carbon and energy is used in the production of an unrecoverable structural substance such as lignin (Rogers et al., 2005; Hu et al., 2011). During the transition from phase I to phase II (35-45 DAFB), Hu et al. (2011) observed that the primary metabolic pathway is repressed, and competition between the biosynthesis pathways of lignin and flavonoids occur.

Early fruit drop was observed at 2 DAA; however, the greatest fruit abscission was observed between 7 and 15 DAA for 500 and 750 mg L^{-1}, and at 10 DAA for 350 mg L^{-1} (Figure 2 A). Then, the effect of ABA gradually decreased and no further fruit drop was observed after 25 DAA. In trees without chemical thinning (ABA 0 mg L^{-1}), natural fruit abscission was 32%, while the ABA rates 350, 500, and 750 mg L^{-1} resulted in a thinning of 79, 87 e 90%, respectively.

After ABA application, fruit ethylene production was stimulated (Figure 2 B). The peak of ethylene production was observed at 5 DAA, when fruit treated with ABA at 500 and 750 mg L^{-1} produced approximately 3.5 times more ethylene than the control fruit. After that point, all fruit showed a decrease of ethylene production. At 10 DAA, all ABA treated fruit still had higher ethylene production than the control fruit and, finally, at 15 DAA, control fruit and ABA treated ones did not differ for ethylene production.

Even the lowest ABA tested concentration (350 mg L^{-1}) caused an excessive reduction of the number of fruit per tree; 500 and 750 mg L^{-1} concentrations drastically reduced the number of fruit per tree (Figure 2 C). In 'Bartlett' pear, Greene (2012) observed a reduced crop load, as petals fell when ABA at 500 mg L^{-1} was applied at full bloom, and when fruit were 10 mm diameter, with the more intense thinning observed at the more advanced developmental stages. In 'Autumn Rose Fuji' apple, a greater thinning was observed with increasing ABA rates (0, 50, 150, 300, and 1000 mg L^{-1}) applied in 2008 (Greene et al., 2011). A phytotoxic effect was observed on leaves, for all ABA rates, causing leaf chlorosis.

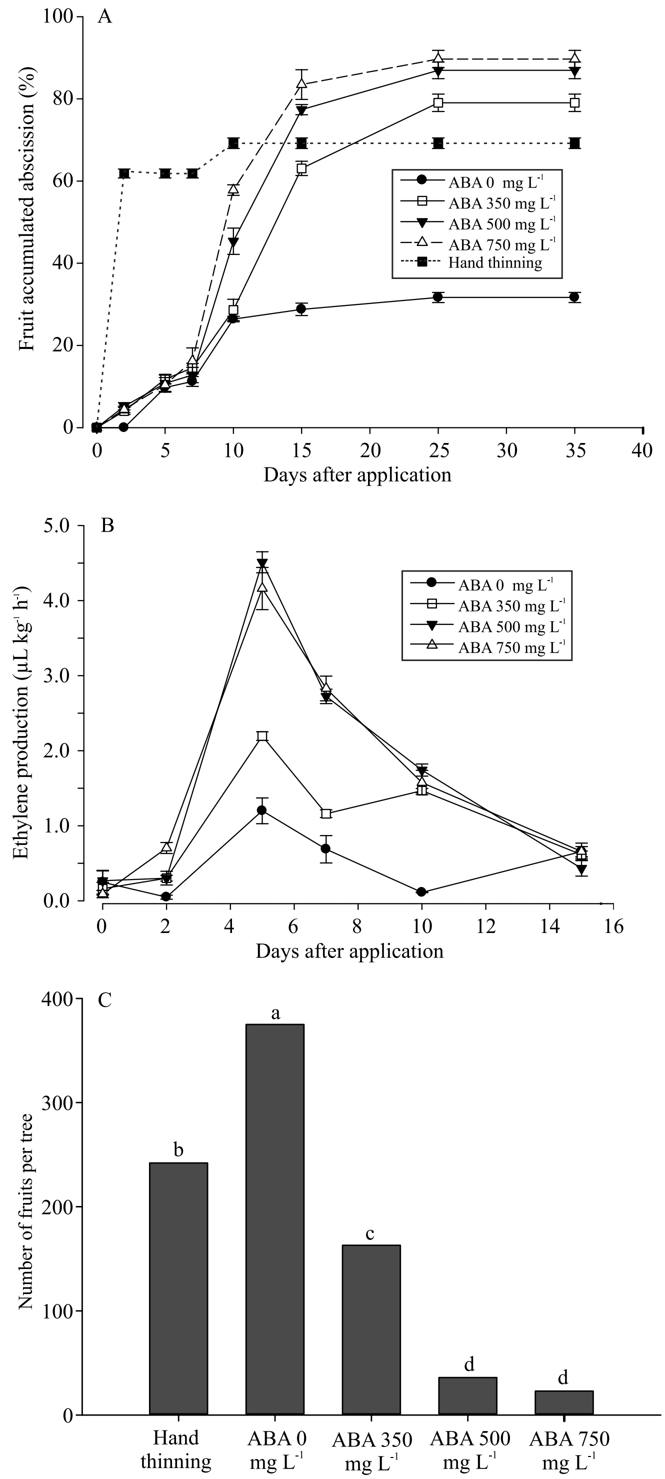

Figure 2. Effect of the application of different ABA concentrations on 'Chiripá' peach: A, fruit abscission, vertical bars represent standard error of the mean (n=5); B, ethylene production, vertical bars represent standard error of the mean (n=3); C, number of fruit per tree, means followed by different lowercase letters within bars are statistically different, by Duncan's test, at 5% probability.

The exogenous ABA application increased ethylene production of 'Chiripá' peach fruit and resulted in fruit abscission. Fruit abscission was dependent on their developmental stage and on the ABA applied concentration. New experiments are underway to investigate tree energetic costs at the time of transition from fruit cell division (phase I) to pit hardening (phase II), to better understand the source: sink ratio in this specific period.

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