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EFFECT OF ETHEPHON ON ALMOND BLOOM DELAY, YIELD, AND NUT QUALITY UNDER WARM CLIMATE CONDITIONS IN NORTHWESTERN MEXICO

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ABSTRACT

World almond (*Prunus dulcis* (Mill.) D.A. Webb) production is mostly located in areas where flowering is injured by low temperatures, and using ethephon (2-chloroethylphosphonic acid) to delay bloom is suggested as a measure to avoid frost damage. However, it is unknown if that practice could be beneficial in Mexico's warm climates. The objective of this study was to determine the effect of ethephon on almond bloom delay and yield. We evaluated foliar applications of ethephon at doses of 75, 150, and 300 mg L^{-1} at 10% leaf drop stage and at 150 mg L^{-1} during dormancy over 2 yr. In 2004, ethephon applied at 10% leaf drop stage delayed bloom by 7, 8, and 9 d at 75, 150, and 300 mg L^{-1}, respectively ($p < 0.01$), and in 2005, bloom delay was 3 d at 300 mg L^{-1}. Ethephon applied during dormancy delayed bloom 2 d in the first year, but showed no effect in the second year. Yield and fruit set were affected by ethephon applied at 10% leaf drop stage only in 2004. Neither yield nor fruit set were affected by ethephon applied during dormancy in both years. Pistil length, nut quality, harvest date, and gum exudation were not affected by ethephon. In accordance with the results, ethephon should not be recommended to delay bloom in almond orchards growing in Mexico's warm climates.

Key word*: Prunus dulcis*, frost damage, ethephon, yield, nut quality.

INTRODUCTION

Almond (*Prunus dulcis* (Mill.) D.A. Webb) could be an alternative fruit crop for northwestern Mexico due to its drought tolerance which provides high profitability per volume of water. It is also a non-perishable fruit with a high nutritional value (Grijalva-Contreras *et al*., 1996). Frost injury to almond buds, flowers, and small fruits is a major limiting factor in determining commercial production in many regions, and northwestern Mexico is no exception since blossoming occurs in the second and third week of January when frosts are common (Grijalva-Contreras and Valenzuela-Ruiz, 1991).An artificial delay of flowering would be beneficial to avoid frost damage under such conditions.

The almond flower bud tolerates temperatures around -7 °C, but significant damage can be caused at -1 °C. Although there are significant differences in sensitivity at the bloom stage among varieties, all varieties respond in the same manner once the petals have fallen and the tiny nut is exposed (25% injury after 30 min at -1.7 °C, and close to 100% kill at -2.8 °C) (Brewer, 1981).

Ethephon (2-chloroethylphosphonic acid) applied at 100 to 4000 mg L^{-1} in the fall has delayed bloom in the following spring in fruit trees and increased bud survival (Probsting and Mills, 1973; Dennis, 1976; Webster, 1984; Funt and Ferre, 1986; Gianfagna *et al*., 1986; Buban and Turi, 1986; Crisosto *et al*., 1990; Sloan and Matta, 1996; Ebel *et al*., 1999; Coneva and Cline, 2009). This benefit was offset by side effects, such as gummosis, flower abscission or failure of the floral bud to open, low fruit set, and yield reduction (Probsting and Mills, 1973; Dennis, 1976; Webster, 1984; Gianfagna *et al*., 1986; Crisosto *et al*., 1990; Coneva and Cline, 2009). Ethephon applications in prune (*Prunus domestica* L.) and peach (*Prunus persica* L.) trees at 250 and 500 mg L^{-1} at 10% leaf drop stage delayed bloom 13 and 16 d, respectively, and only 5 and 7 d when applied at 50% leaf drop stage.

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Fruit set and yield were reduced in peach but not in prune (Crisosto *et al*., 1990). Fall applications of ethephon delayed fruit maturity and increased winter hardiness resulting in higher yields because of frost avoidance (Buban and Turi, 1986; Crisosto *et al*., 1990; Funt and Ferre, 1986). However, ethephon has had contradictory results on harvest date and yield (Crisosto *et al*., 1990; Coneva and Cline, 2009).

Bloom delay is due to an increase of endodormancy and inhibition of flower bud development immediately after application (Coston *et al*., 1986; Gianfagna *et al*., 1986; Durner and Gianfagna, 1988; 1991). It is known that pistils from ethephon-treated trees are shorter and have a lower fresh weight during dormancy and through blooming (Durner, 1989). Pistils from peach trees treated with ethephon in the fall have more sucrose, more sorbitol, less water on a fresh weight basis, and are hardier than untreated pistils (Durner and Gianfagna, 1989).

The objective of this research study was to test the effectiveness of ethephon on almond tree bloom delay, yield, and nut quality.

MATERIALS AND METHODS

Orchard selection and management

Field studies were conducted in the experimental orchard of the Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP) located in Caborca (30º42´55'' N, 112º21'28'' W, 200 m.a.s.l.), Sonora, Mexico. The almond orchard, cv. Jordanolo on 'Nemaguard' peach rootstock, was planted at 5 x 5 m in February 1994 in sandy loam soil. Trees were maintained in accordance with commercial recommendations (Martínez-Téllez, 1988). Trees were furrow-irrigated and fertilized in both years with 15-15-15 at rates of 2.0 kg tree^{-1} (800 kg ha^{-1}) during dormancy and ammonium nitrate (300 kg ha^{-1}) during the first and second growing seasons. Trees were pruned in January in both years and fruit were not thinned. Finally, fruits were manually harvested in late July in both years. Weeds, insects, and disease were controlled with herbicides and pesticides as needed.

Ethephon application

Foliar applications of ethephon (Ethrel, Rhone Poulenc, France) were made to runoffs at 75, 150, and 300 mg L^{-1} at 10% leaf drop stage, and at 150 mg L^{-1} during dormancy in both years. Applications at 10% leaf drop stage were made on 29 November 2003 and 3 December 2004 while on 9 January 2004 and 10 January 2005 during dormancy. Applications were made with a gasoline-powered mist blower (Port 423, Solo, Sindelfingen, Germany) with 6.0 L of water per tree. Treatments were applied on the same trees in both years.

Measurements

Bloom delay was the difference between the control anthesis date and the treatment anthesis date. Fruit set was taken from four branches of every tree about 4 wk after anthesis began, pistil length from 300 flowers per replication, nut weight and inshell percentage from 800 nuts per plot, and yield per tree. Minimum and maximum temperatures at the site were measured with a thermometer during January, February, and March in both years.

Statistical analysis

Experimental design was a randomized complete block with single tree experimental units and four replications. ANOVA was run for the variables and means were separated by Duncan's multiple range test at 0.05.

RESULTS AND DISCUSSION

Bloom delay

Almond response to ethephon was different in both years. Ethephon applied at 10% leaf drop stage delayed bloom 7, 8, and 9 d at 75, 150, and 300 mg L^{-1}, respectively, in 'Jordanolo' almond trees in 2004 while in 2005 bloom delay was only 3 d at 300 mg L^{-1}. Ethephon applied on almond trees during dormancy delayed bloom 2 d only in 2004 (Table 1). Bloom delay during 2004 on almond trees was similar to peach, apricot, plum, sour cherry, and prune trees (Probsting and Mills, 1973; Dennis, 1976; Webster, 1984; Buban and Turi, 1986; Funt and Ferre, 1986; Gianfagna *et al*., 1986; Crisosto *et al*., 1990; Sloan and Matta, 1996; Ebel *et al*., 1999; Coneva and Cline, 2009). The absence of almond response observed in 2005 is similar to the results found in peach (Gianfagna *et al*., 1986; Ebel *et al*., 1999).

Table 1. Effect of ethephon on bloom delay of 'Jordanolo' almond trees.

Ethephon concentration	Bloom delay	
	2004	2005
mg L^{-1}	d	
Control	0b	0b
75	7a	0b
150	8a	2a
300	9a	3a
150 (Dormancy)	2b	0b
Significance	**	**

**Significant at P < 0.01. Means in a column followed by the same letter are not significantly different according to Duncan's Multiple Range (P < 0.05).

Differences observed in ethephon effectiveness in delaying bloom in both years may be due to differences in winter temperatures during bud expansion. In 2004, 15 d before bloom, the maximum and minimum temperatures averaged about 19.9 ºC and 4.0 ºC, respectively, while in 2005, the maximum and minimum temperatures averaged about 23.3 ºC and 7.9 ºC, respectively. Gianfagna *et al*. (1986) suggested that high temperatures during bud expansion in 2005 could speed bud development and minimize the effect of treatments.

One (-0.5 ºC) and five (0 to -0.5 ºC) frosts occurred from the pink bud stage to the pea-sized fruit stage in 2005 and 2004, respectively, indicating that bloom delay obtained in the treatments was not sufficient to escape frosts. Nevertheless, flowers were not damaged in either year.

Yield and fruit set

In 2004, ethephon applied at 10% drop leaf stage reduced nut yield linearly. Mean nut yield in trees treated with ethephon was 1.48 kg tree^{-1} while the control was 5.8 kg tree^{-1}. By contrast, ethephon at 150 mg L^{-1} applied during dormancy (100% drop leaf stage) did not affect yield (Table 2). Fruit set was very low (0.5 to 1.6%) in all treatments applied at 10% drop leaf stage while in non-treated trees and those treated during dormancy fruit set was 10.4 and 7.1%, respectively. In 2005, nut yield varied from 4.6 to 7.6 kg tree^{-1} and was not affected by ethephon in spite of the effect of the treatments on fruit set (Table 3).

Yield reduction in trees with ethephon application has already been observed (Webster, 1984; Crisosto *et al*., 1990; Coneva and Cline, 2009) although increments have also been reported when applications have avoided frost damage owing to bloom delay (Probsting and Mills, 1973; Buban and Turi, 1986; Gianfagna *et al*., 1986) or an increase of cold hardiness (Durner and Gianfagna, 1989).

Table 2. Effect of ethephon on nut yield of 'Jordanolo' almond trees.

Ethephon concentration	Yield[1]	
	2004	2005
mg L^{-1}	kg tree^{-1}	
Control	5.80a	5.88a
75	2.50b	7.60a
150	1.14b	6.28a
300	0.80b	4.66a
150 (Dormancy)	6.30a	4.60a
Significance	**	NS

[1]Yield based on inshell nut.
**Significant at P < 0.01; NS: non significant. Means followed by the same letter are not significantly different according to Duncan´s Multiple Range (P < 0.05).

Table 3. Effect of ethephon on pistil length and fruit set of 'Jordanolo' almond trees.

Ethephon concentration	Pistil length		Nut weight	
	2004	2005	2004	2005
mg L^{-1}	mm		%	
Control	12.2a	10.2a	10.4a	7.8b
75	11.1a	10.3a	1.6b	10.7a
150	11.8a	10.9a	0.5b	7.9ab
300	11.3a	11.8a	0.9b	5.7b
150 (Dormancy)	12.3a	10.1a	7.1a	8.9a
Significance	NS	NS	**	*

*Significant at P < 0.05; **significant at P < 0.01; NS: non significant. Means in a column followed by the same letter are not significantly different according to Duncan's Multiple Range (P < 0.05).

On the other hand, fruit set reductions due to ethephon applications have been previously reported (Dennis, 1976; Crisosto *et al*., 1990; Coneva and Cline, 2009), and they are apparently associated to defective megaspore development or to carbohydrate reserve deficiency (Dennis, 1976). In several fruit trees, reduction in fruit set produced by ethephon is an obstacle for its commercial use, and the same could occur in the case of almond; in other fruit trees, such as peach, reduction in fruit set could be beneficial since hand thinning could be reduced (Coneva and Cline, 2009).

Pistil length was not affected by ethephon applications in either year (Table 3), and these results differ from those reported by Durner (1989).

Nut quality

Inshell percentage and nut weight were not affected by ethephon treatments in both years (Table 4). In 2004, inshell percentage varied from 58 to 62% and from 60 to 63% in 2005. On the other hand, nut weight in 2004 varied from 0.82 to 0.97 g and from 0.90 to 1.11 g per nut

Table 4. Effect of ethephon on nut quality of 'Jordanolo' almond trees.

Ethephon concentration	Inshell		Nut weight	
	2004	2005	2004	2005
mg L^{-1}	%		g	
Control	62a	62a	0.82a	0.95a
75	60a	63a	1.02a	1.10a
150	59a	63a	1.01a	1.03a
300	58a	60a	1.03a	0.90a
150 (Dormancy)	60a	62a	0.97a	1.00a
Significance	NS	NS	NS	NS

NS: non significant (P < 0.05).
Means in a column followed by the same letter are not significantly different according to Duncan's Multiple Range (P < 0.05).

in 2005. By contrast, an increase in fruit size and quality was reported in peach treated with ethephon at a similar rate (Coneva and Cline, 2009).

Ethephon neither caused gum exudation on scaffold limbs reported by Dennis (1976) and Gianfagna *et al*. (1986) nor delayed the harvest date observed in peach by Funt and Ferre (1986).

CONCLUSIONS

In accordance with the results, ethephon should not be recommended to delay bloom in almond orchards growing in northwestern Mexico's warm climates.

RESUMEN

Efecto del ethephon en el retraso de la floración, la producción y la calidad del almendro, bajo condiciones de clima caliente del Noroeste de México. La producción de almendra (*Prunus dulcis* (Mill.) D.A. Webb) en el mundo está situada sobre todo en las áreas donde la floración es dañada por bajas temperaturas, y se sugiere el uso del ethephon (ácido 2-cloroetil fosfónico) para retrasarla, como una medida para evitar daños por helada. Sin embargo, no se sabe si esa práctica podría ser beneficiosa bajo los climas calientes de México. El objetivo de este estudio fue determinar el efecto del ethephon (ácido 2-cloroetil fosfónico) sobre el retraso de la floración y la producción de la almendra. Evaluamos la aplicación foliar de ethephon en dosis de 75; 150 y 300 mg L^{-1} en la etapa de 10% de caída de la hoja, y en 150 mg L^{-1} en la etapa de dormancia, durante 2 años. En el 2004, ethephon aplicado en la etapa de 10% de caída de la hoja retrasó la floración por 7; 8 y 9 d a 75; 150 y 300 mg L^{-1} respectivamente ($p < 0,01$), y en 2005 el retraso de la floración fue de 3 d a 300 mg L^{-1}. El ethephon aplicado durante dormancia retrasó la floración 2 d en el primer año pero no hubo efecto en el segundo año. El rendimiento y el amarre de fruta fueron afectados por el ethephon aplicado en la etapa de 10% de caída de la hoja en 2004, pero no en 2005. Ni la producción ni el amarre de fruta fue afectada en ambos años por el ethephon aplicado durante dormancia. La longitud del pistilo, la calidad de la almendra, la fecha de cosecha y la exudación de la goma no fueron afectadas por el ethephon. Acorde a estos resultados, el ethephon no se debe recomendar para retrasar la floración en las huertas de la almendra que crecen bajo climas calientes de México.

Palabras clave: *Prunus dulcis*, daño por helada, ethephon, producción, calidad de la almendra.

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