uptake and crop yields with tomatoes in NFT. *Acta Hort.* 98:229–236.

Bass, R., H.M.C. Nijssen, T.J.M. van den Berg, and M.G. Warmenhoven. 1995. Yield and quality of carnation (*Dianthus caryophyllus* L.) and gerbera (*Gerbera jamesonii* L.) in a closed nutrient system as affected by sodium chloride. *Sci. Hort.* 61:273–284.

Greenway, H. and R. Munns. 1980. Mechanism of salt tolerance in nonhalophytes. *Annu. Rev. Plant Physiol.* 31:149–190.

Ontario Ministry of Agriculture and Food. 1987. Greenhouse tomato grading and packing manual. Fruit and Vegetable Inspection Branch, Ontario Ministry of Agriculture and Food, Ontario, Canada.

Papadopoulos, A.P. and S. Pararajasingham. 1998. Effects of controlling pH with HCl on the growth, yield and fruit quality of greenhouse tomato (*Lycopersicon esculentum* Mill.) grown by nutrient film technique (NFT). *HortTechnology* 8(2):193–198.

Sonneveld, C. and A.M.M. van der Burg. 1991. Sodium chloride salinity in fruit vegetable crops in soilless culture. *Neth. J. Agr. Sci.* 39:115–122.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures of statistics. McGraw Hill, New York.

Voisey, P.W. 1971. The Ottawa texture measuring system. *J. Can. Inst. Food Technol.* 4:91–103.

Winsor, G.W. 1979. Some factors affecting the quality and composition of tomatoes. *Acta Hort.* 93:335–346.

Winsor, G.W., J.N. Davies and M.I.E. Long. 1967. The effects of nitrogen, phosphorus, potassium, magnesium and lime in factorial combination on the yields of glasshouse tomatoes. *J. Hort. Sci.* 42:277–288.

Effect of Ethrel on Bloom Delay, Harvest Date, and Fruit Weight of 'Empress' Peach

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ADDITIONAL INDEX WORDS. *Prunus persica*, (2-chloroethyl) phosphonic acid

SUMMARY. Ethrel [(2-chloroethyl)phosphonic acid] was applied at 0, 100 or 200 ppm (mg·L⁻¹) for 3 years to the early maturing 'Empress' peach [*Prunus persica* (L.) Batsch] to determine if bloom delay by Ethrel reduces fruit weight at harvest. Trees were hand thinned at 0 or 3 weeks after full bloom to equalize cropload across Ethrel treatments and to determine if any reduction in fruit weight by Ethrel can be compensated by harvest with earlier thinning. Ethrel at 200 ppm (mg·L⁻¹) delayed bloom by 3, 0, and 7 days in 1994, 1996 and 1997, respectively. Despite bloom delay, Ethrel did not delay harvest or reduce fruit weight. Thus, earlier hand thinning was not necessary. Ethrel did not affect blossom density and was not phytotoxic to vegetative or reproductive organs. These results indicate that even with the shorter fruit growth period of early maturing peach cultivars such as 'Empress', there is sufficient time for fruit growth to recover on Ethrel treated trees so that fruit weight at harvest is not reduced.

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Late spring frost is the most important limiting factor for peach production in the southeastern U.S.A. Ethrel can increase survival of peach flower buds to late spring frosts by delaying bloom for up to 2 weeks when applied from late fall to early winter (Coston et al., 1986; Crisosto et al., 1990; Dennis, 1976; Sloan and Matta, 1996). The delay in development is apparently by prolonged endodormancy and delayed flower bud development after rest is completed (Coston et al., 1986; Durner and Gianfagna, 1988, 1991; Gianfagna et al., 1986). Ethrel also increases cold hardiness of peach flower buds (Crisosto et al., 1989; Durner and Gianfagna, 1988, 1991).

Reports have shown that Ethrel also affects harvest date, yield and its components especially fruit weight, but the reports have often been contradictory (Crisosto et al., 1990; Sloan and Matta, 1996). Ethrel can but does not always delay bloom, which delays early fruit growth. In some reports, Ethrel reduced early cropload by reducing flower bud density, but the phytotoxicity has not been consistent (Crisosto et al., 1989, 1990; Sloan and Matta, 1996). Ethrel may increase early cropload by increasing flower bud survival when late spring frosts occur. What is not clear is whether Ethrel's effect on fruit weight at harvest is a secondary effect due to its impact on cropload established earlier in the season. The effect on cropload is important since cropload affects fruit weight at harvest. An additional consideration is that Ethrel may delay physiological maturity of fruit (Funt and Ferree, 1986), although whether this is true under all conditions is not known.

The compounding effect of Ethrel on cropload and fruit weight at harvest may be more important for early maturing cultivars that have less time for fruit growth to recover than later maturing cultivars. The following study was conducted to determine whether Ethrel applied to delay bloom affects fruit weight and harvest date for the early season cultivar 'Empress' peach that were carefully hand thinned to levels similar to untreated trees. Two hand thinning dates were also included to determine whether earlier hand thinning could compensate for any loss in fruit weight at harvest of Ethrel treated trees.

Materials and methods

The experiment was conducted in 1994, 1995 and 1997 on the peach cultivar 'Empress' grafted onto 'Lovell' rootstock. The trees were planted in 1985 on a 15 × 20-ft (4.6 × 6.0-m) spacing at the Chilton Area Horticulture Substation in central Alabama. The soil type was a Luverne sandy loam. Except for Ethrel and hand thinning treatments, normal commercial practices were followed.

The experiment was conducted as a randomized complete block, 3 (Ethrel rate) × 2 (hand thinning date) factorial design. There were five blocks and single tree experimental units in each block. Trees were selected for uniformity in canopy volume. Each block consisted of a single row of trees with at least one untreated tree serving as a buffer between treated trees. Ethrel was applied once in mid-November in 1993, 1994, and 1996. Ethrel at 0, 100 or 200 ppm (mg·L⁻¹) mixed with 2% (v/v) of the surfactant Red Panther (80% alkyl polyoxyethylene ethers, Red Panther Chemical Co., Clarksdale, Miss.) was sprayed to the point of runoff with 1.32 gal/tree (5 L/tree) using a handgun at 40 psi (70.4 g·cm⁻²). The rates applied were equivalent to 200 gal/acre (1871 L·ha⁻¹). Flowers or fruit were hand thinned in 1994, 1995, and 1997 to a spacing of 6 inches (15 cm) at full bloom or 3 weeks after full bloom.

Five limbs per tree were tagged 12.5 inches (35 cm) from the tip and before bud swell. The stage of flower development was determined for all flower buds on each tagged branch at 4 to 10 day intervals through petal fall. Blooms were rated on a scale of 1 to 6 with 1 = tight bud, 2 = swollen bud, 3 = first pink, 4 = full pink, 5 = open and 6 = petal fall. In 1994 and 1995, flower bud density was calculated as the number of flower buds per centimeter of shoot length. Fruit were harvested based on conversion of the ground color from green to yellow except near the calyx, starting the third week in May. Since the fruit did not ripen uniformly, trees were harvested three to four times at 3- to 5-d intervals. All fruit were sorted by diameter, and weighed and counted in each diameter class at harvest. Since larger fruits were always heavier, fruit weight is used throughout the manuscript to indicate fruit size.

Bloom stage was analyzed as a blocked, Ethrel treatment by year fac-

torial on the date nearest to full bloom using the General Linear Model of the Statistical Analysis System (SAS Institute, Cary, N.C.). Since there was a significant interaction between Ethrel treatment and year across sampling dates, all data were analyzed by year. Bloom density was analyzed as Ethrel treatment by year factorial designs. Average fruit weight and total cropload were determined across all harvest dates and analyzed as Ethrel treatment by thinning date by year factorial designs. The effect of Ethrel on harvest date was determined using a weighted means average (Stembridge and Gambrell, 1974). There were five replications (trees) for each Ethrel and thinning treatment combination.

Results and discussion

The interaction between Ethrel treatment and year on bloom stage indicated that the response varied from year to year. Ethrel delayed full bloom in 1994 and 1997, but there was no statistically significant delay in 1995 (Table 1). Average bloom stage is shown on the date the controls were near full bloom but before petal fall to show differences in developmental stage between Ethrel treatments. Bloom stage was linearly but not quadratically related to Ethrel treatment in 1994 and 1997 and varied as much as a full stage of development between the controls and 200 ppm Ethrel treatment. Ethrel at 200 ppm delayed bloom by ≈4 d in 1994 and 7 d in 1997 compared to the controls.

The lack of bloom delay in 1995 was not related to temperature. The average maximum/minimum temperatures the week before full bloom were 66 °F/39 °F (18.7 °C/4.0 °C) in

1994, 70 °F/47 °F (21.0 °C/8.4 °C) in 1995 and 74 °F/56 °F (23.5 °C/13.3 °C) in 1997, respectively. The lack of delay in 1995 may be related to the stage of plant development in November when the trees were sprayed. In 1995, there was significant drought stress from May through August with only 7.9 inches (20.1 cm) of precipitation during that period. The 1995 drought promoted early dormancy as indicated by the extent of autumn leaf abscission. About 90% of the leaves had dropped in 1995 before spraying sprayed, whereas in 1994 and 1997 only 50% of the leaves had dropped before spraying. Crisosto et al. (1989) showed that Ethrel sprayed on trees with 50% leaf drop had greater bloom delay than 100% leaf drop.

Flower bud density was not affected by Ethrel treatment (Table 2). These results differ from some reports that show that Ethrel applied at these rates reduced bloom density (Crisosto et al., 1990; Gianfagna et al., 1986; Sloan and Matta, 1996), although others reported no reduction in bloom density at these concentrations (Crisosto et al., 1989; Dennis, 1976; Williams, 1989).

Cropload was similar across Ethrel and thinning treatments at harvest. Harvest date was not delayed by Ethrel treatment, despite the delay in bloom. Also, average fruit weight and fruit distribution in the various diameter classes (data not shown) were also not affected. These data suggest that at least some of the contradictory effects of Ethrel on yield and harvest date as reported in the literature is due to its effect on cropload. Ethrel can adjust cropload by directly reducing flower bud density, or increasing flower bud density in spring by

Table 1. Effect of Ethrel on 'Empress' peach bloom development. Bloom stage was measured on 15 Mar. 1994, 17 Mar. 1995, and 5 Mar. 1997.

Analysis of variance	Avg bloom stage ^z		
	1994	1995	1997
Ethrel	***	NS	***
Contrasts			
Linear	***	NS	***
Quadratic	NS	NS	NS
Means			
Ethrel (ppm)			
0	4.8	4.3	4.4
100	4.2	3.7	3.9
200	4.1	3.9	3.2

^zBloom stages: 1 = tight bud, 2 = swollen bud, 3 = first pink.

NS,***Nonsignificant at *P* = 0.05 or significant at *P* = 0.001.

Table 2. Effect of Ethrel (ppm) on 'Empress' peach bloom density, cropload, and fruit weight at harvest, and harvest date determined using a weighted means average. Thinning date is weeks after full bloom.

Analysis of variance	Bloom density (blooms/7.9 inches)	Cropload (fruit/tree)	Fruit wt (g)	Harvest date
Ethrel (E)	NS	NS	NS	NS
Thinning date (T)	--- ^z	NS	NS	NS
E × T	---	NS	NS	NS
Year (Y)	***	***	***	NS
Y × E NS	NS	NS	NS	
Y × T	---	**	*	NS
Y × E × T	---	NS	NS	NS
Means				
E				
0	51	447	109	0 ^y
100	52	473	109	0.4
200	51	534	107	0.7
T				
0	---	459	110	--- ^x
3	---	511	107	---
Year				
1994	41 b	579 a	107 b	--- ^x
1995	62 a	273 b	116 a	---
1997	---	579 a	103 b	---

^zNot included in the model.

^yMeans presented are the number of days delayed compared to the control.

^xMeans not shown since there were no true controls for thinning or year for determining days harvest was delayed or advanced.

NS, *, **, *** Nonsignificant or significant at $P = 0.05$, 0.01 , or 0.001 , respectively.

increasing survival to killing frosts. However, this study demonstrates that fruit weight, yield and harvest date are similar when cropload is carefully adjusted to similar levels for Ethrel treated and control trees.

Since the delay in fruit growth shortly after bloom did not result in smaller fruit at harvest, thinning fruit earlier is not necessary to compensate for any delay in fruit growth by Ethrel even for the early maturing peach 'Empress'. Although Ethrel is not currently labeled for delaying bloom of peaches, it would provide the significant benefits of increasing cold hardiness and delaying bloom without reducing fruit weight at harvest when trees are thinned to proper croploads.

Literature cited

Coston, D.C., G.W. Krewer, T.E. Elkner, J.G. Williamson, and E.T. Sims, Jr. 1986. Chemical treatments to delay bloom in peach. *J. Amer. Soc. Hort. Sci.* 110:874-877.

Crisosto, C.H., S.L. Cid, P.B. Lombard, K. Tanino, and R. Harber. 1989. Effect of ethephon application on bud and stem hardiness and bloom delay of 'Redhaven' peach trees. *Adv. Hort. Sci.* 3:21-23.

Crisosto, C.H., A.N. Miller, P.B. Lombard, and S. Robbins. Effect of fall Ethephon

applications on bloom delay, flowering, and fruiting of peach and prune. *HortScience* 25:426-428.

Dennis, F.G. 1976. Trials of Ethephon and other growth regulators for delaying bloom in tree fruits. *J. Amer. Soc. Hort. Sci.* 101:241-245.

Durner, E.F. and T.J. Gianfagna. 1988. Fall Ethephon application increases peach flower bud resistance to low-temperature stress. *J. Amer. Soc. Hort. Sci.* 113:404-406.

Durner, E.F. and T.J. Gianfagna. 1991. Ethephon prolongs dormancy and enhances supercooling in peach flower buds. *J. Amer. Soc. Hort. Sci.* 116:500-506.

Funt, R.C. and D.C. Ferree. 1986. Ethephon induced bloom delay of peach trees, Ohio, USA. *Acta Hort.* 179:163-169.

Gianfagna, T.J., R. Marini, and S. Rachmiel. 1986. Effect of Ethephon and GA₃ on time of flowering in peach. *HortScience*: 21:69-70.

Sloan, R.C. and F.B. Matta. 1996. Peach bloom delay and tree responses to fall applications of Ethephon. *Miss. Agr. For. Expt. Sta. Bul.* 1055.

Stembridge, G.E. and C.E. Gambrell, Jr. 1974. Measuring peach thinning and maturation responses. *HortScience* 9:29-30.

Williams, K.M. 1989. Peach bloom delay using fall applications of Ethrel and Pro-Gibb. *Acta Hort.* 254:151-154.