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Bloom Thinning 'Loadel' Cling Peach with a Surfactant

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***Abstract.* Hand thinning fruit is required every season to ensure large fruit size of 'Loadel' cling peach [*Prunus persica* (L.) Batsch] in California. Chemical thinning may lower costs of hand thinning. A surfactant, Armothin {[*N,N*-bis 2-(omega-hydroxypolyoxyethylene/polyoxypropylene) ethyl alkylamine]; AKZO-Nobel, Chicago; AR}, was sprayed at 80% of full bloom (FB), FB, and FB + 3 days. The spray volume was 935 liters/ha. Concentrations of AR were 1%, 3%, and 5% (v/v). An early hand thinning in late April, a normal hand thinning at 13 days before standard reference date (early May), and a nonthinned control were compared to bloom-thinned trees for set, yield, and fruit quality. AR resulted in no damage to fruit; however, slight leaf yellowing and burn and small shoot dieback were seen at the 5% concentration. Fruit set , and therefore, the number of fruit that had to be hand thinned, were reduced with 3% AR applied at 80% FB and 5% AR applied at all bloom phenophases (stages of bloom development). Thinning time was reduced by 37% (5% AR applied at 80% FB), 28% (5% applied at FB), and by 20% (3% applied at 80% of FB), compared to the normally hand-thinned control. Although AR resulted in early size (cross suture diameter and weight) advantages, at harvest there were no significant differences in fruit size among all AR treatments and the normally hand-thinned control. Total and salable yields of AR treatments and the normally hand-thinned control were equal. Armothin shows promise for chemical thinning of peach when used as a bloom thinner.**

Early fruit thinning (from bloom up to about 2 weeks before pit hardening) can reduce the percentage of small peach fruit at harvest (Farley, 1923; Shoemaker, 1933), increase total yield (Havis; 1962), and advance maturity (Havis, 1962), by reducing inter-fruit competition for scarce resources (Jackson, 1989). Chemical thinning at bloom may reduce the risk of foliage damage by caustic materials in varieties where leaves emerge after flowers and uneven absorption or transport through leaves, which may contribute to erratic results (Lilleland, 1965). Thinning of blossoms, rather than developing fruit maximizes the ability to adjust the fruit-to-leaf ratio, a method particularly desirable in early ripening peach cultivars with a short fruit developmental period and fruit sizing problems (Byers and Lyons, 1984; Havis, 1962). Success is predicated on the assumption that fruit set will be in excess of that needed for a satisfactory crop, and reduced June drop (Shoemaker, 1933; Weinberger, 1941) may offset the dangers of poor set or frost close to bloom. When frost is not a significant concern, such as in many peach-growing areas of California, peach trees generally set heavily due to self-fertility and good weather at bloom. 'Loadel' cling peach is an early-maturing variety, and therefore requires early season thinning to achieve market size by harvest (Havis, 1962; Weinberger, 1941). Hand thinning is time consuming and currently costs as much as $864.00/ha in early maturing cling and freestone peaches (Southwick and Fritts, 1995). Chemical thinning may reduce costs. Research with caustic or desiccating chemicals for bloom and postbloom thinning of peaches and related fruit has led to mixed results and no commercial use [monocarbamide dihydrogensulfate, Wilthin (Myers et al., 1993); dinitro-ortho-cresol, Elgetol (Hibbard and Murneek, 1950); urea (Di Marco et al., 1992; Zilkah et al., 1988); fertilizers (Byers and Lyons, 1983, 1984, 1985); and growth regulators (Beutel et al., 1969; Buchanan and Biggs, 1969; Byers, 1978)]. However, chemical thinning of stone fruit with gibberellins has been demonstrated (Southwick et al., 1995; Southwick and Fritts, 1995) and has become commercial practice in California.

Caustic bloom thinners that damage blossoms and pollen offer the advantage of early reallocation of limited photosynthates to fewer sinks. Preliminary trials on peach and 'French' prune (*Prunus domestica*) of monocarbamide dihydrogensulfate yielded poor results (S.M. Southwick, unpublished data). Preliminary results of experiments conducted in South Africa on plums (AKZO-Nobel, personal communication) suggested that the compound Armothin may be active for peach bloom thinning. We report here on effective fruit set reduction for 'Loadel' cling peach, an early maturing cultivar, by the surfactant Armothin.

Materials and Methods

Plant material, experimental design, and treatments. Five-year-old 'Loadel' cling peach trees on 'Lovell' (*P. persica*) rootstock were selected from a uniform commercial orchard near Yuba City, in the Sacramento Valley of California. The soil was classified as a Columbia silty loam. Trees were planted at 6.1 × 6.1 m (269 trees/ha). The experiment was designed as a randomized complete block with five single tree replicates. A total of 12 treatments (60 trees) included applications at three bloom phenophases [8 Mar. 1994 = 80% full bloom (FB), 11 Mar. = FB, and 14 Mar. = 3 days post FB], three application rates of surfactant (1, 3, 5%), two hand-thinning treatments (early = 21 Apr., normal commercial = 5 May), and a nonthinned control. Sprays were applied to wetness with a hand-held Stihl SR 400 mist blower (Andreas Stihl, Waiblingen, Germany) at a volume of 935 liters/ha under clear, calm weather conditions. Treatment to reduce bloom consisted of a surfactant (fatty amine polymer), Armothin {[*N,N*-bis 2-(omega-hydroxypolyoxyethylene/polyoxypropylene) ethyl alkylamine]; AKZO-Nobel, Chicago; AR}, applied at a volume/volume dilution with water.

To time sprays accurately, bloom development (phenophase) was determined by counting the total number of flowers in FB and dividing that number by the total number of flowers present on each of two limbs on four trees. Average maximum and minimum

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temperatures and relative humidity (RH) throughout bloom ranged from about 3C (average minimum) to 22C (average maximum) and 20% to 95% RH, respectively.

Flowering, fruit set, fruit weight, and fruit thinning. To determine fruit set, at least 100 flowers were counted on two limbs (about 10 to 20 mm in circumference) randomly selected 2 to 2.5 m from the soil surface. The number of fruit that set on those same limbs was counted 21 Apr. 1994, and an early hand-thinning treatment by a commercial crew was made, thinning fruit to about 8 to 15 cm apart (<2000 fruit thinned per tree, on average). On 5 May (13 days before standard reference date; Davis, 1950; Proebsting, 1962) normal commercial hand thinning was performed so that fruit were spaced 12 to 18 cm apart; AR trees were also hand thinned to a similar spacing. Trees previously hand thinned on 21 Apr. were not rethinned. Two people worked to thin each tree, and the time needed to thin was recorded. Thinned fruit were collected and weighed. A random sample of 10 fruit was picked from each tree before thinning, weighed and measured for cross-suture diameter. Twenty thinned, fully developed fruit were collected and the number of fruit per kilogram was determined so that the number of fruit thinned from each tree could be calculated.

Harvest measurements. Fruit were hand-harvested on 18 July 1994 at minimum maturity (defined by no. 2 color disk, California Cling Peach Advisory Board). The undersized fruit (nonsalable) were removed by passing the fruit over a linked chain with screen size of 5.6 cm. Total yield and salable yield were measured for each replicate tree and total number of fruit per tree was calculated from the total yield weight and the mean fruit weight. Split-pit fruit were counted on a subsample of 25 fruit. Fruit firmness and soluble solids were determined on the other group of 25 fruit. Soluble solids were measured by randomly selecting peach halves, grinding them in a Wareing blender, and filtering the juice through cheesecloth onto a temperature-compensated hand-held refractometer Atago N1 (0% to 32%; Tokyo). Firmness was measured by removing a small exocarp section on one side with a sharp knife to expose the mesocarp (flesh). A Univ. of California fruit firmness tester equipped with a 7.93-mm tip was inserted into that fruit flesh point.

Statistical analyses. The effectiveness of the treatment was determined based on the following variables: percentage fruit set, thinning time, fruit thinned per tree, fruit size at normal thinning and at harvest (weight and diameter), trunk cross-sectional area (TCSA), total yield, salable yield, percentage undersized fruit, fruit firmness, soluble solids, and percentage split pits. Treatment means were separated for significance at $P = 0.05$ by Duncan's multiple range test and analyses of variance with contrast and trends were performed using SAS procedure GLM (SAS Institute, Cary, N.C.).

Results

Symptoms of phytotoxicity (slight leaf yellowing and burning and small twig dieback in the interior of the canopy) were noted with 5% AR sprays. However, tree growth measured by trunk cross-sectional area (TCSA) on 22 July 1994 was not different among treatments (data not shown). AR applications of 1% at all bloom phenophases and 3% AR at FB and FB + 3 days resulted in fruit set equivalent to that of unsprayed controls (Table 1). AR at 3% at 80% of FB and 5% AR at all phenophases affected sufficient numbers of flowers to reduce fruit set below that of controls. When percentages of fruit set for AR treatments (pooled across concentrations) were contrasted with the normally hand-thinned control, the reductions in set for treatments at 80% of FB, FB and at FB + 3 days were significant (Table 1, contrasts and trends). Fruit set was reduced linearly with respect to increasing concentration of AR within bloom phenophase application (i.e., at each treatment date, as AR concentration increased, fruit set decreased such that the

Table 1. Effect of Armothin (AR) sprays on fruit set, thinning, and thinning time in 'Loadel' cling peach in 1994.

Bloom phenophase (full bloom = FB)	AR concn (%)	Fruit set (%)	Thinning time/person (min)	No. fruit thinned/tree (5 May)
80 % FB	1	63.7 bcd[z]	11.5 ab	4182 bc
	3	53.3 cde	7.9 cd	3378 d
	5	41.7 ef	6.2 d	2248 e
FB	1	65.3 bcd	10.1 bc	3625 cd
	3	65.1 bcd	9.1 bcd	4246 b
	5	29.1 f	7.1 cd	1736 e
FB + 3 days	1	67.4 bc	11.6 ab	3256 d
	3	63.2 bcd	13.4 a	5058 a
	5	51.3 de	9.1 bcd	3614 cd
Hand thinned 5 May (normal)		73.2 ab	9.9 bc	4748 ab
Hand thinned 21 Apr. (early)		76.3 ab		1969 e[y]
No hand thinning		81.8 a		

Contrasts and trends		Mean sum of squares: Fruit set (%)	Thinning time/ person (min)	No. fruit thinned/ tree
5 May hand thinned control vs.	80% FB	2446.72***	5.33	6,555,846.58**
	FB	2403.40***	3.52	7,163,330.88**
	FB + 3 days	956.91*	6.75	1,786,439.20
Linear trend	80% FB	1947.02***	55.12***	7,475,065.79**
Linear trend	FB	5231.63***	18.00*	7,133,166.66**
Linear trend	FB + 3 days	988.47*	12.50	255,626.80

[z]Mean separation within columns by Duncan's multiple range test, $P = 0.05$.
[y]Fruit were thinned 21 Apr. 1995.
*,**,***Significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

linear relationship was negative). Linear trends were significant for the applications of AR at all phenophases of bloom (Table 1).

The number of fruit thinned by hand per tree on 5 May was reduced in several AR treatments as a result of reduced fruit set (Table 1). A highly significant decrease in the number of fruit thinned in contrast to the 5 May control was found for AR treatments at 80% of FB and FB, when all AR concentrations were grouped (Table 1). No significant reduction in number of fruit thinned after AR treatment was found at FB + 3 days when similarly contrasted. The numbers of fruit thinned for AR treatments at the first phenophase of bloom decreased linearly with increasing concentration of AR (Table 1). Although fruit set and number of fruit thinned were significantly reduced by several AR treatments compared to the 5 May control, thinning time per tree was equivalent to the control in most AR treatments due to an increased production of 'nubbin' fruit in AR-treated groups that required extra care in thinning. Thinning time was reduced by 37% (5% AR applied at 80% FB), 28% (5% applied at FB), and 20% (3% applied at 80% of FB), compared to the normally hand-thinned control. Thinning time for AR treatments was not significantly different from the 5 May hand thinning control when pooled AR concentrations within each phenophase application date were contrasted with the control. Lack of significance of pooled AR treatments with respect to reduction in thinning time was due to 'averaging' of reduced times for some AR treatments with increased times for others.

Fruit weight measured on 5 May was greatest in the group treated with 5% AR at 80% FB, followed by 5% AR at FB and 3% AR at 80% FB, the early hand thinning treatment, and 3% AR applied at FB (Table 2). All other AR treatments produced fruit with weight equivalent to that of the normally hand-thinned fruit or the unthinned fruit. Comparisons of fruit weight (measured on 5 May) among AR treatments applied at 80% FB and at FB with normally hand-thinned fruit showed significant increases due to AR treatments. AR treatments applied at 80% FB improved fruit weight most effectively on 5 May. A linear relationship with respect to increase in AR concentration and increasing weight of fruit at thinning was found for AR treatments applied at 80% of FB and at FB. Fruit diameter (Table 2) was greatest for trees treated with 5% AR applied at 80% FB (Table 2). Contrasts showed that combined AR treatments at 80% of FB and at FB improved fruit diameter compared with 5 May hand thinning. By 18 July harvest, however, the increases in fruit weight and diameter for AR treatments was no longer apparent. Fruit from all AR treatment groups were of equivalent weight and diameter to the normally hand-thinned fruit and of greater weight and diameter than fruit from either early- or nonthinned trees. Fruit from the early hand-thinned control were smaller in diameter than AR treatment fruit or normally hand-thinned fruit, and the early thinned fruit were equivalent in diameter to the unthinned fruit.

Fruit flesh firmness of normally hand-thinned fruit was lowest among all treatments (Table 3), but statistically equal to that of all AR-treated fruit except those treated with 1% AR at FB. Fruit from early hand-thinned and unthinned controls were the firmest, but also statistically equal in firmness to all AR-treated fruit except those treated with 1% AR at FB + 3 days. Soluble solids were equivalent among all treatments (Table 3), as were split-pits (data not shown; numbers negligible). Total yield was equivalent among AR treatments and the normally hand-thinned control, and lower than the nonthinned and early thinned controls (Table 3). The calculated total number of fruit per tree was not statistically different among treatments (data not shown). The yield of marketable fruit was equivalent among the hand-thinned controls and AR treatments, with the exception of a slightly reduced, but not significantly different, marketable yield from 5% AR applied at FB + 3 days (Table 3). Undersized fruit (Table 3) were most numerous in nonthinned and early thinned controls, followed by AR treatments of 3% and 5% at 80% of FB and 5% at FB. All other AR treatments produced undersized fruit proportionately to the normally hand-thinned treatment. Contrasts between the normally hand-thinned control and AR treatments at 80% of FB and FB showed highly significant and significant increases, respectively,

Table 2. Effect of Armothin (AR) sprays on fruit weight and cross suture diameter in 'Loadel' cling peach in 1994.

Bloom phenophase	AR concn	5 May 1994 (before thinning)		18 July 1994 (at harvest)	
(full bloom = FB)	(%)	Fruit wt (g)	Fruit diam (mm)	Fruit wt (g)	Fruit diam (mm)
80% FB	1	17.3 de[z]	33.1 c	147.4 a	66.6 a
	3	19.2 b	34.0 b	138.6 a	66.2 a
	5	21.5 a	35.1 a	137.2 a	65.6 a
FB	1	17.2 de	33.0 c	141.8 a	66.7 a
	3	18.3 c	33.2 c	153.5 a	67.8 a
	5	19.9 b	34.3 b	141.5 a	65.1 ab
FB + 3 days	1	16.8 ef	32.4 d	153.5 a	67.4 a
	3	16.4 ef	32.1 de	143.6 a	65.7 a
	5	16.0 ef	32.0 de	140.2 a	65.4 a
Hand thinned 5 May (normal)		16.4 ef	31.7 e	143.6 a	66.9 a
Hand thinned 21 Apr. (early)		19.6 b	34.2 b	110.7 b	61.9 bc
No hand thinning		18.0 cd	33.2 b	98.0 b	59.1 c
Contrasts and trends					
5 May hand-thinned	80% FB	25.55***	17.39***	18.68	1.76
control vs.	FB	12.22*	9.82***	12.48	0.38
	FB + 3 days	0.005	0.71	14.41	1.51
Linear trend	80% FB	35.20***	8.26**	208.28	2.20
Linear trend	FB	14.18**	3.21*	0.10	5.61
Linear trend	FB + 3 days	1.10	0.34	358.05	7.80

[z]Mean separation within columns by Duncan's multiple range test, $P = 0.05$.

*,**,***Significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 3. Effect of Armothin (AR) sprays on fruit firmness, soluble solids, total yield, marketable yield, and undersized fruits of 'Loadel' cling peach in 1994.

Bloom phenophase (full bloom = FB)	AR concn (%)	Fruit firmness (N)	Soluble solids (%)	Total yield (kg)	Marketable yield (kg)	Undersized fruit (%)
80 % FB	1	34.4 abc[z]	9.2 a	145.3 cd	121.6 a	16.5 cde
	3	35.3 abc	9.2 a	171.2 bc	130.9 a	23.2 c
	5	33.7 abc	8.1 a	150.8 cd	116.6 ab	22.6 cd
FB	1	36.2 ab	8.8 a	154.3 cd	128.2 a	16.6 cde
	3	33.9 abc	9.4 a	134.3 d	111.2 ab	17.0 cde
	5	33.4 abc	9.6 a	145.8 cd	112.3 ab	22.5 cd
FB + 3 days	1	31.6 c	9.0 a	139.8 cd	118.0 ab	15.8 de
	3	34.4 abc	9.6 a	148.6 cd	120.1 a	19.3 cde
	5	32.8 bc	9.6 a	118.6 d	95.1 bc	19.3 cde
Hand thin 5 May (normal)		31.7 c	9.2 a	150.4 cd	128.4 a	14.6 e
Hand thin 21 April (early)		37.6 a	8.6 a	198.3 ab	118.8 ab	40.1 b
No hand thinning		36.9 ab	9.2 a	214.9 a	79.1 c	62.6 a
Contrasts and trends				Mean sum of squares		
5 May hand thinned control vs.	80% FB	22.94	0.30	85.65	86.83	112.12**
	FB	23.37	0.04	95.48	374.64	49.69*
	FB + 3 days	4.51	0.16	654.53	903.07	36.02
Linear trend	80% FB	0.98	2.42	59.40	50.05	75.83**
Linear trend	FB	15.57	1.12	145.35	506.26	69.27*
Linear trend	FB + 3 days	2.99	0.84	893.59	1043.10	25.49

[z]Mean separation within columns by Duncan's multiple range test, $P = 0.05$.

*,**,***Significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

in undersized fruit. A positive linear relationship existed between increasing AR concentration and percentage undersized fruit with AR applications at 80% of FB and FB. Increased concentrations of AR, when applied at the two early phenophases of bloom , produced higher percentages of 'nubbin' fruit that did not substantially affect the marketable yield, as these fruit were exceedingly small and low weight. The 'nubbin' fruit, therefore, did not contribute greatly to undersized volume or weight, but only to percentages of undersized fruit and increased thinning times.

Discussion

Early-maturing peaches in the eastern United States ('Early Hiley', 'Redhaven') have responded well to bloom thinning by hand with increased return bloom and no adverse effects on tree or shoot growth, fruit size, and quality (Havis, 1962; Weinberger, 1941). Promising results in frost prone areas have been achieved by some researchers, demonstrating that bloom thinning in peach can successfully regulate cropping without excessive loss to frost and that removal of blossoms may render the next season's floral buds more frost hardy (Byers and Marini, 1994; Chandler, 1907; Corgan and Widmoyer, 1971; Proebsting and Mills, 1964), actually decreasing the danger of loss due to frost. Bloom thinning of 'Loadel' cling peach showed good response with respect to fruit and vegetative growth and fruit quality. Bloom thinning in combination with early hand thinning should allow the grower to remove fewer fruit, thereby increasing yield without reducing fruit size. In our work with early hand thinning we attempted to remove fewer fruit (saving time and money), expecting to achieve yield and fruit size similar to normal hand thinning. To achieve the desired results we should have removed more fruit at early hand thinning. Effective methods to assess the amount of early hand thinning required should be developed before the practice can be used across a wide range of orchards.

The reduction in fruit set resulting from Armothin application demonstrated this surfactant's potential to substitute, at least in part, for normal hand thinning. Although some phytotoxicity symptoms (slight leaf yellowing and burning and young shoot dieback in canopy interior) were observed in the 5% AR, these were minor and did not affect the yield or fruit quality, and AR application was not detrimental to whole tree growth. Size and weight of fruit in AR treatment groups at harvest were equivalent to those of normally hand-thinned fruit and proved to be superior to those obtained with an early hand thinning treatment, confirming that bloom thinning can maximize the tree's capacity to allocate sufficient resources to fruit when the leaf-to-fruit ratio is increased early in the growing season. Relatively high percentages of undersized fruit ('nubbin' fruit) resulting from application of 3% AR at 80% of FB, and 5% AR at 80% FB and FB may have been due to leaf and shoot damage incurred by AR use (resulting in an adverse and direct effect on the very young fruit at fertilization and set). 'Nubbin' fruit were not problematic to marketable yield, but did necessitate additional attention by the thinners. As reduction in thinning time (by reduction in initial set) is a goal for chemical bloom thinning, the production of 'nubbin' fruit and the extra time needed to thin them is of concern to the goals of this research, however, management of either the surfactant treatment or the thinning crews may alleviate these effects, thereby reducing the time required to thin and, consequently, thinning costs. Ongoing experiments in 1995 with commercial sprayers showed no excessive nubbin fruit (Southwick, Weis, and Yeager, unpublished data). Armothin proved to be an effective bloom thinner at identifiable bloom phenophases (80% of FB and FB) for the early ripening cling peach cultivar, 'Loadel', and has potential application as a commercial substitute, at least in part, for hand thinning in California. An experimental use permit was issued for its use in stone fruit thinning in California during 1996.

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