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Bloom Thinning of 'Loadel' Cling Peach with a Surfactant: Effects of Concentration, Carrier Volume, and Differential Applications within the Canopy

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ADDITIONAL INDEX WORDS. *Prunus persica*, fruit thinning, fatty amine polymer, hand thinning, fruit set

SUMMARY. In 1994, we established that a surfactant, Armothin (AR), reduced fruit set when applied as 3% and 5% AR at 100 gal/acre with a Stihl mistblower to 'Loadel' clingstone peach [*Prunus persica* (L.) Batsch]. In 1995 we compared 3% AR at volumes of 100 and 200 gal/acre (935 and 1870 L·ha⁻¹, the volumes most commonly used by tree fruit growers in California) applied with commercial airblast sprayer; overthinning resulted with the latter. In 1996, we applied 3% AR at 100 gal/acre and 1% AR at 200 gal/acre. In 1995, differential applications of 3% AR at 100 gal/acre (two-thirds of the material applied to either the upper or lower canopy) reduced fruit

set in the upper canopy in proportion to the amount of chemical applied (twice as much fruit set reduction with twice as much chemical); fruit set in the lower canopy was reduced by an equal amount regardless of amount of chemical used. Salable yields, equivalent to those obtained by hand thinning, and improved fruit size were achieved with all treatments of 3% AR at 100 gal/acre in 1995 with a 76% reduction in hand thinning. Following a low-chill winter (1995-96) with a protracted bloom, flower bud density (return bloom) was significantly greater in 1995 AR-treated trees. In 1996, treatment with AR did not result in fruit set reduction due to the protracted bloom and poor weather conditions before and after bloom. Nonetheless, 1% AR at 200 gal/acre applied in 1996 increased salable yield and increased final fruit mass. Return bloom in 1997 was equal among 1996 treatments.

Thinning blossoms provides early adjustment of the fruit-to-leaf ratio (Havis, 1962), increasing fruit size, which is particularly desirable in early ripening peach cultivars (e.g., 'Loadel') that have a short fruit developmental period and fruit sizing problems (Southwick et al., 1996). Reducing flower buds by surfactants during the latter part of bloom resulted in improved fruit size at harvest in some treatments (Byers and Lyons, 1982, 1985). Under California conditions of low frost and generally good weather at bloom, cling peach fruit set is usually excessive, necessitating heavy thinning. Hand thinning is time-consuming and typically incurs costs in excess of \$283/acre (\$700/ha) in early maturing cling (and freestone) peaches (Southwick and Fritts, 1995). Although bloom thinning may cause overthinning in poor weather conditions at or shortly after bloom, the potential advantages of such a program and lack of suitable chemical thinning agents for small fruit removal warrant development of chemical alternatives to traditional hand thinning at reference date (pit hardening + 10 days). Work by Southwick et al. (1995) has led to the use of gibberellins for flower reduction, which reduces the need for hand thinning. However, growers are unsure of this practice and view it as risky. Initial work (Southwick et al., 1996) suggested that Armothin (AR) [(N,N-bis

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2-(omegahydroxypolyoxyethylene/polyoxypropylene) ethyl alkylamine]; AKZO-Nobel, Inc., Chicago) could be used at 3% and 100 gal/acre, but that work was done by hand (with backpack mistblower) on single trees. Larger trials with commercial equipment were needed to ensure consistent results under commercial conditions. Additionally, fruit tend to be smaller in lower tree canopy positions in *Prunus*, correlating with lower light interception (Southwick et al., 1990). By directing more spray volume to the lower canopy (differential application), we hoped to test improving the leaf-to-fruit ratio in those light-limited regions. AR probably thins flowers that are unfertilized at the time of application, as do other desiccating chemicals (Byers and Lyons, 1985; Fallahi, 1997), by drying petals, damaging the stigmatic surface, and reducing pollen germination and pollen tube growth (Costa et al., 1995).

Our objectives in 1995-1996 trials were to 1) establish safe, effective volume/rate applications under commercial conditions; 2) test the effects of differential application of thinning agent on the upper vs. lower canopy of the tree; and 3) detect effects on return bloom.

Materials and methods

PLANT MATERIALS AND TREATMENTS,

1995. Nine-year-old 'Loadel' cling peaches on 'Lovell' rootstock were located near Marysville, Calif. (Yuba County). The soil was classified as a Columbia silty loam. Trees were planted at 20 × 18 feet; 121 trees/acre (6.1 × 5.5 m; 299 trees/ha). The

experiment was designed as a randomized complete block (RBC) with two trees per block and four blocks per treatment. Four bearing shoots were tagged in the upper and lower canopy sections in each of the two trees (two shoots in the upper and two in the lower) to evaluate treatment effects on fruit set, diameter, and mass. Three AR treatments were applied at ≈60% of full bloom (21 Feb.; Table 1), and an untreated control (normal hand thinning) was the fourth treatment. AR (3%, 100 or 200 gal/acre) was applied with an airblast sprayer (FMC 252; Food Machinery Corp., Jonesboro, Ark.), under clear and calm conditions [(temperature ≈68 °F (20 °C)]. Drying time was not recorded; however, spray applications of this type tend to dry in 1 h. For both application volumes, two-thirds of the material was applied to the upper half of the canopy and the remaining one-third to the lower half. At 100 gal/acre, application of two-thirds of the material to the lower canopy and one-third to the upper canopy was also tested.

PLANT MATERIALS AND TREATMENTS,

1996. Four-year-old 'Loadel' cling peaches growing on 'Lovell' rootstock were selected in an orchard similar to that used in 1995. The experiment was designed as a RCB with two spray treatments (3% AR at 100 gal/acre and 1% AR at 200 gal/acre) × two trees × four blocks. Four shoots were selected as before to evaluate fruit set. Spray treatments were applied at 50% of full bloom (8 Mar.); however, tree-to-tree bloom development was highly variable (14% to 78%) due to very low-chill hour accumulation. Sprays were

applied with a self-propelled, track-type grower-built air-blast sprayer at a volume of 100 or 200 gal/acre at ≈66 °F (19 °C) and calm, clear conditions. Differential applications done in 1995 were not repeated in 1996. Rainy, windy conditions before and after date of treatment were frequent and may have contributed to variability in results.

FRUIT SET, DIAMETER AND MASS, YIELD, TREE GROWTH (1995), AND RETURN BLOOM.

Flowers were counted on tagged branches and percentage set was counted at commercial thinning, when ≈1000 fruit were removed from each control tree to adjust the fruit number to the grower's knowledge of optimum bearing capacity for the orchard. In 1995, ≈100 fruit were removed from AR-treated trees (3%, 100 gal/acre) as a minimal thinning treatment to break up clustered fruit in the upper canopy; no thinning was done on trees treated with 200 gal/acre spray, as these were clearly overthinned. In 1996, fruit were hand thinned from treated trees to approximate the crop load on control trees; fruit removed were counted on the west half of the tree. Thinning time per tree was recorded for each treatment. Samples of 50 fruit (half each from upper and lower canopy) were taken from each treatment tree on 10 May 1995, and fruit mass and cross-suture diameter were measured. In 1996, 20 fruit per tree were sampled at thinning, 10 fruit from the upper and 10 from the lower canopy branches.

Fruit were harvested by hand on 12 July 1995 and by machine on 10 July 1996, when they reached mini-

Table 1. Effects of 3% Armothin (AR) sprays applied to 'Loadel' cling peach in 1995 at 60% of full bloom: fruit set, thinning time, mass, cross-suture diameter (at normal thinning 10 May and at harvest 12 July), vegetative growth [change in trunk cross-sectional area (TCSA), 1994-95], salable yield, and return bloom in 1996 (flower buds per inch shoot length).

Treatment (gal/acre)	AR distribution ^c in canopy (upper:lower)	Canopy location	Fruit set (%)	Time to thin (min)/ tree	At thinning (10 May)		At harvest (12 July)		Salable yield/tree (lb)	ΔTCSA (inches ²)	Flower buds/inch
					Mass/20 fruit (lb)	Fruit diam (inch)	Mass/10 fruit (lb)	Fruit diam (inch)			
AR, 100	1:2	Upper	30.0 b ^a	7 b	1.0 a	1.40 b	3.7 bc	2.6 bc	352.9 a	0.6 a	1.3 a
		Lower	1.9 d								
AR 100	2:1	Upper	16.6 c	7 b	1.0 a	1.45 a	4.0 b	2.8 ab	300.2 ab	0.6 a	1.5 a
		Lower	7.3 d								
AR 200	2:1	Upper	3.9 d	---	1.0 a	1.43 ab	4.8 a	2.9 a	108.5 c	0.8 a	1.5 a
		Lower	1.8 d								
Control ^a		Upper	37.7 a	30 a	0.8 b	1.30 c	3.2 c	2.5 c	370.9 a	0.6 a	1.0 b
		Lower	33.8 ab								

^aAR differential applications: two-thirds applied upper canopy; one-third applied lower canopy (2:1) or vice versa.

^bMean separation within columns by Duncan multiple range test, 5% level.

^cHand thinned.

mum maturity (defined by the no. 2 color disk California Cling Peach Advisory Board). Twenty fruit were picked randomly at harvest from each tree and their mass and diameters were measured before undersized fruit were removed [nonsalable, <2.24 inches (5.7 cm)]. Salable yield per tree was measured by total yield (weight) less the weight of the undersized fruit. Vegetative growth was measured at thinning and after harvest in 1995 at ≈ 18 inches (45 cm) from the soil surface, calculated as change in trunk cross-sectional area (TCSA).

Trees were evaluated in the year following treatment for effects on return bloom. Bloom density was measured on two branches, on a single sampled tree (not guard tree) in each block in 1995, one branch in the upper canopy and one branch in the lower canopy. Flower buds were counted on ≈ 39 inches (100 cm) of branch length, including laterals, and the mean number of flower buds per centimeter shoot length was calculated from the four branches (≈ 156 inches, 400 cm) per treatment, per location, pooled among blocks, but separated by canopy location. In 1996, return bloom was measured in a similar manner on two upper canopy branches per tree, on each of the two previously sampled trees in each block. Return bloom was not pooled among blocks in 1996.

STATISTICAL ANALYSES. The effectiveness of treatments was determined based on the following variables: percentage fruit set, minutes per tree needed for hand thinning, fruit mass and diameter at normal thinning and at harvest, TCSA (1995), number of fruit thinned (1996), and salable yield.

Data from the two sampled trees in each block were combined, as were data from branches on a single tree in similar locations, and block was the replication term. Treatment means were separated for significance at the 5% level by Duncan's multiple range tests using SAS's general linear models procedure (SAS Institute Inc., Cary, N.C.).

Results and discussion

Fruit set was reduced by all AR sprays in 1995 compared with no hand thinning (Table 1). One-third application of 3% AR at 100 gal/acre to the upper canopy reduced by 20% or 23% upper canopy set compared to the upper and lower canopy of untreated trees, respectively. Two-thirds application of 3% AR at 100 gal/acre to the upper canopy reduced upper canopy set by 56% to 57% compared to the untreated trees (upper and lower locations, respectively). Doubling the amount of chemical applied to the upper canopy nearly halved the amount of fruit set. Fruit set in the lower canopy of all treated trees was equivalent and much lower than that of any upper canopy treatment. Lower canopy fruit set of treated trees was $\approx 10\%$ that of the untreated controls (lower canopy).

As lower canopy fruit tend to be of lower quality (less color, smaller size; Marini et al., 1991), their preferential elimination by 90% in AR treatments was largely responsible for the reduction in the need to hand thin. Hand-thinning times for 3% AR, 100 gal/acre treatments were <25% of the controls. Application of 3% AR at 200 gal/acre resulted in overthinning and

no hand thinning was performed. Although rate of chemical was constant, change in carrier volume led to a substantial change in thinning response, unlike that reported in similar bloom-thinning trials with ammonium thiosulfate (Byers and Lyons, 1985). Fruit mass at thinning was increased by all AR treatments compared to the control, and diameter at thinning was greater with 3% AR at 100 gal/acre than in the control, reflecting reduced fruit set and subsequent reduction in interfruit competition for resources. Fruit mass and diameter were equivalent among the 100 gal/acre AR treatments and the 200 gal/acre AR treatment, although the 200 gal/acre AR trees were overthinned. There were no differences in fruit diameter or mass at thinning by canopy location (data not shown).

Phytotoxicity was not seen in any treatments at thinning or harvest; no scarring of fruit was found in any treatment. No treatment differences were found in vegetative growth in 1995, as measured by change in TCSA (Table 1). Fruit size differences due to treatment were established by the hand-thinning date such that AR thinning at bloom may have enhanced cell number or cell size by reducing initial fruit load, establishing by the hand-thinning date fruit size differences that were maintained through harvest. Fruit mass and diameter were not different between the top and bottom canopy positions within a given treatment at thinning, although fruit set differed by canopy location. Fruit mass and diameter at harvest was greatest and yield of salable fruit was lowest with 3% AR treatments at 200 gal/acre due to very

Table 2. Effects of Armothin (AR) sprays applied to 'Loadel' cling peach in 1996 at 50% of full bloom: fruit set, number of fruits thinned per half tree, thinning time per entire tree, and fruit diameter and mass at thinning and harvest, salable yield, and return bloom in 1997 (no. flowers/inch shoot length).

Treatment	Canopy location	Fruit set (%)	Fruit thinned/half tree (no.)	Thinning time/tree (min)	At thinning (15 May)		At harvest (10 July)		Salable yield/tree (lb)	Flower buds/inch
					Mass/20 fruit (lb)	Fruit diam (inches)	Mass/10 fruit (lb)	Fruit diam (inches)		
AR 3%, 100 gal/acre	Upper	28.8 ab ²	394.0 b	27.8 b	0.77 a	1.3 a	3.3 a	2.4 a	303.3 ab	0.8 a
	Lower	18.4 c								
AR 1%, 200 gal/acre	Upper	34.4 a	476.6 ab	29.8 ab	0.75 ab	1.3 a	3.2 ab	2.5 a	334.6 a	0.7 a
	Lower	23.6 bc								
Control (untreated)	Upper	30.6 ab	526.2 a	30.8 a	0.716 b	1.2 a	3.1 b	2.4 a	276.6 b	0.8 a
	Lower	16.3 c								

²Mean separation within columns by Duncan multiple range test, 5% level.

light cropping. AR treatments of 100 gal/acre had salable yields that were equivalent to that of normal hand thinning, with substantially reduced hand-thinning times. Return bloom in 1996 was improved 11% to 23% by reduced cropping due to bloom thinning but was not statistically different from controls.

There were no treatment effects on fruit set in 1996, although set by canopy location was different (Table 2). When the 200-gal/acre carrier volume, common to California cling peach growers' management practices, was used with 1% AR in 1996, fruit set was not reduced below acceptable levels, unlike in 1995 when 3% AR at 200 gal/acre resulted in overthinning. Treatment 1 (3% AR, 100 gal/acre) resulted in 25% fewer fruits thinned per half tree compared to the control (Table 2). There was no significant difference among treatments with regard to fruit diameter at thinning or harvest in 1996 (Table 2). Fruit mass at thinning and harvest in 1996 was improved by AR treatment at 3% (100 gal/acre) compared to the control, but not by the 1% AR treatment. Total yields were not different among treatments in 1996 (data not shown). An increase in salable yield (total yield – undersized, unsalable fruit) was found in 1996, with Treatment 2 (1% AR, 200 gal/acre) significantly increasing salable yield compared to that of the control.

Bloom thinning substantially reduced fruit set in 1 out of 2 years, thereby reducing hand thinning. For AR to be effective, buds must have broken and flowers must be at an advanced stage of anthesis, with the greatest effectiveness achieved when a maximum number of flowers are at the same advanced bloom stage (Byers and Lyons, 1982). Under typical California climatic conditions at bloom, fruit set tends to be very heavy in cling peaches pruned to produce for the canning industry, and a well-managed bloom thinner would not tend to overthin. Lack of fruit clustering and lower return bloom in 1996 did not allow the same thinning strategy as was used in 1995. Clustering in most years contributes greatly to the perceived need-to-thin in cling peaches, and AR bloom thinning in 1995 should be

more representative of expected results in normal-chill years by California standards. Under climatic conditions such as very low chill hour accumulation, use of AR may not be desirable. However, a single application of 3% AR at 100 gal/acre with commercial equipment at 50% to 60% full bloom will work in most years and not overthin in low-chill and long-bloom years. At higher volumes (200 gal/acre) lower concentrations of AR per acre should be used.

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Evaluation of ethylene inhibitors for postharvest treatment of *Gypsophila paniculata* L.

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ADDITIONAL INDEX WORDS. silver thiosulfate, STS, flower opening, flower senescence, 1-methylcyclopropene, baby's breath

SUMMARY. Commercial floral products with claimed anti-ethylene effects were evaluated for their efficacy in promoting postharvest longevity of gypsophila ('Perfecta', 'Gilboa', and 'Golan' baby's breath, *Gypsophila paniculata* L.). These products were applied according to label directions and compared to a laboratory preparation of silver thiosulfate (STS) prepared as a short pulse treatment and as an overnight treatment; they were also compared to the new anti-ethylene gas, 1-methylcyclopropene (1-MCP). After these pretreatments, the flowers were exposed to ambient air or to 0.7 ppm ethylene gas for 36 hours; other flowers received a simulated shipping treatment. Products containing adequate concentrations of silver consistently extended the display life of gypsophila. Products with low concentrations of silver (<10 ppm) or containing aminoethoxyvinylglycine (AVG)

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