Thinning ‘Fuji’ Apple Blossoms with Synthetic Auxins (MCPB-ethyl or NAA) and Ethephon with or without Postbloom Thinning with Carbaryl

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ADDITIONAL INDEX WORDS. *Malus sylvestris* var. *domestica*, ammonium thiosulphate, fruit set, return flowering, fruit quality, naphthaleneacetic acid

ABSTRACT. Three experiments were conducted at two locations, two at Summerland, British Columbia, Canada and one at Corvallis, Ore., to evaluate synthetic auxins (MCPB-ethyl or NAA) and ethephon as blossom thinners for ‘Fuji’ apple [*Malus sylvestris* (L.) Mill var. *domestica* (Borkh.) Mansf.]. These experiments also involved application of carbaryl at 1000 mg·L⁻¹ in the postbloom period. All blossom thinners were sprayed at 85% full bloom while carbaryl was applied at 11-mm fruit diameter. Within these experiments, MCPB-ethyl at up to 20 mg·L⁻¹ or NAA at up to 21 mg·L⁻¹ increased whole flower cluster removal linearly with rate; however, with the Corvallis experiment MCPB-ethyl failed to result in any thinning. Neither auxin treatment consistently reduced fruit set on the remaining clusters, resulting in “clustering”. Bloom-time application of ethephon at 100 mg·L⁻¹ with NAA further reduced crop load. Carbaryl reduced total crop load by increasing both whole cluster removal and number of sites with a single fruit. Return flowering was not improved by the auxin treatments except where there was very excessive crop reduction. Ethephon or carbaryl promoted return flowering with the carbaryl effect being more pronounced. However, this carbaryl effect was significantly countered by the bloom-time auxin whereas ethephon overcame the negative effects of the auxin treatments. The combined use of ethephon and carbaryl was effective in terms of both crop reduction and return flowering benefits. Chemical names used: 1-naphthyl N-methylcarbamate (carbaryl); 2-chloroethylphosphonic acid (ethephon); ethyl 4-(4-chloro-2-methylphenoxy) butanoate (MCPB-ethyl); and 2-(1-naphthyl) acetic acid (NAA).

‘Fuji’ apple (*Malus sylvestris* var. *domestica*) has a tendency to crop biennially which can seriously reduce profitability. One approach to overcoming this tendency is to aggressively reduce crop load in the heavy fruiting year with chemicals applied during and after the bloom period. Adequate return flowering of apple requires the presence of a substantial number of resting spurs completely free of fruit (Auchter, 1920) at the time of normal flower induction, i.e., during the first 4 to 6 weeks after flowering. Caustic agents like ammonium thiosulphate (ATS) and endothall are useful in this regard (Andrews and Collier, 1995; Balkhoven-Baart and Wertheim, 1997; Bound and Jones, 1997).

NAA and its amide salt, ethephon, and carbaryl have been used traditionally as postbloom thinners. Although not used as a blossom thinner for apple since the mid-1940s (Dennis, 2000), NAA has been recently evaluated again as a blossom thinning agent for new apple cultivars, including ‘Fuji’, often in combination with ethephon (Jones et al., 1994; Looney et al., 1997; Reginato and Whiting, 1999; Yokota et al., 1995). While thinning results with these chemicals are often variable and seriously influenced by spray volume and prevailing weather, the optimum time to thin red ‘Fuji’ was full bloom (FB) for NAA, and FB or earlier for ethephon (Jones et al., 1992). Satisfactory blossom thinning with the combined use of ethephon and NAA is reported by Basak et al. (1988) for ‘Golden Delicious’, and by Reginato and Whiting (1999) for ‘Fuji’. In contrast, Jones et al. (1994) reported that no additional thinning occurred on ‘Golden Delicious’ when NAA was combined with ethephon.

Recently, MCPB-ethyl was evaluated as a blossom thinner on apple and shown to reduce fruit set of ‘Fuji’ (Looney et al., 1997; Yokota et al., 1995). This chemical, a synthetic auxin with an activity roughly comparable to that of NAA, is registered and used widely in Japan for use as a stop-drop agent on apple. The Japanese experiments indicated that MCPB-ethyl effectively thinned ‘Fuji’ flowers when applied just after full bloom of the king flowers (Yokota et al., 1995). In comparison, a study in the Pacific Northwest (Looney et al., 1997) showed that this chemical applied at 85% FB did not result in satisfactory thinning. The discrepancy in the results at two locations led us to retest this chemical as a blossom thinner, along with other bloom-time or postbloom thinners. Therefore, the objectives of this study were to 1) identify effective rates of MCPB-ethyl and NAA as blossom thinners for ‘Fuji’ apple; 2) evaluate auxin/ethephon combinations as blossom thinners; and 3) determine if the known effectiveness of carbaryl as a fruitlet thinner (Batjer and Westwood, 1960; Looney et al., 1997) is influenced by these bloom-time auxin treatments.

Materials and Methods

In 1998–99, three experiments involving ‘Fuji’ apple trees on Malling 9 (M.9) or M.26 rootstocks evaluated synthetic auxins MCPB-ethyl and NAA as blossom thinners in combination with other thinners, i.e., ethephon during bloom and carbaryl postbloom. All sprays were applied to run off to whole trees with a high pressure handgun sprayer.

EXPERIMENT 1: BLOOM-TIME MCPB-ETHYL OR NAA FOLLOWED BY CARBARYL. This experiment, initiated in April 1998 in a commercial orchard in Summerland, British Columbia, Canada, involved 5-year-old ‘Fuji’/M.9 slender spindle trees at a 1.5 × 4.5

Received for publication on 8 May 2001. Accepted for publication 1 Nov. 2001. Summerland contribution 2134. We thank the Washington Tree Fruit Research Commission for funding this study.

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m spacing. Trees were treated with MCPB-ethyl (Agro-Kanesho Co., Ltd., Tokyo, Japan) at 10, 15, or 20 mg·L⁻¹ a.i. or NAA (K-salt; Fruit Fix, AMVAC Chem. Corp., Los Angeles) at 5, 10, or 15 mg·L⁻¹ a.i. at 85% FB or at petal fall, followed by carbaryl (as Sevin XLR) at 0 or 1000 mg·L⁻¹ a.i. at 11-mm king fruit diameter.

EXPERIMENT 2: COMBINATION OF MCPB-ETHYL OR NAA WITH ETHEPHON, FOLLOWED BY CARBARYL. In April 1998, an experiment was conducted at the Lewis and Brown Farm, Oregon State University, Corvallis, with 6-year-old 'Fuji'/M.26 central leader trees at a 1.7 × 4.2 m spacing. Trees were treated at 85% FB with MCPB-ethyl or NAA at 4, 8, or 16 mg·L⁻¹ alone and in combination with ethephon at 100 mg·L⁻¹. Half of the trees received a follow-up spray of carbaryl at 1000 mg·L⁻¹ applied at 11-mm king fruit diameter.

EXPERIMENT 3: COMPARISON OF NAA AND ATS APPLIED AT BLOOM TIME. One experiment was conducted in April 1999 in the same orchard block as in Expt. 1 (now 6-year-old trees). NAA was compared with ATS as a blossom thinner. The trees were grouped into five blocks according to flowering intensity (number of flowers per cm² branch cross-sectional area) and treated with NAA (7, 14, or 21 mg·L⁻¹) or 1% a.i. ATS (AgriTec, Lake Country, British Columbia, Canada) at 85% FB, and later with either carbaryl at 1000 mg·L⁻¹ or carbaryl at 1000 mg·L⁻¹ plus NAA at 5 mg·L⁻¹ at 11-mm king fruit diameter.

MEASUREMENTS. Before treatment, all blossom clusters were counted on whole trees (Expt. 1), three midstem branches per tree (Expt. 2), and the top half of the tree (Expt. 3). Blossom intensity was expressed as the number of flower clusters per cm² trunk or branch cross-sectional area. Total fruit set was determined following the June drop and was expressed as the number of fruit per 100 counted flower clusters. The proportion of flower clusters that had been totally defruited by the treatments and the proportion of fruiting sites that set one, two, or equal to or greater than three fruit were also determined. Following these fruit set distribution determinations, the trees were hand-thinned to a commercial crop load.

Depending on the experiment, all or some of the following parameters were determined at harvest: total and mean fruit

weight, length (L) to diameter (D) ratio, percentage surface red color, firmness, total soluble solids concentration, titratable acidity, intensity of surface russet, and number of seeds per fruit. Fruit firmness and juice soluble solids and acidity were measured using a pressure tester (model EPT-1; Lake City Technical Products, Inc., British Columbia, Kelowna, Canada), a refractometer (model PR-101; Atago Co., Ltd, Tokyo, Japan), and a titrator (model 655 Dosimat; Metrohm Ltd., Herisau, Switzerland), respectively. Titratable acidity was determined by recording the amount of 0.1 N NaOH added to titrate 15 mL of juice to pH 8.1. Return flowering was measured on the part of the tree used for fruit set determination by counting all blossom clusters.

EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS. Experiments 1 and 3 were designed as a split plot with five blocks of single-tree plots; the main plots were the plus and minus postbloom carbaryl treatments, and the split plots were the bloom-time thinning treatments randomly allocated into the main plots. The design for Expt. 2 was a randomized complete block with five blocks of two-tree plots, one tree treated with postbloom carbaryl, the other nontreated. All data were subjected to analysis of variance with the SAS GLM procedure (SAS Inst., Inc. Cary, N.C.), with blossom intensity and mean fruit weight considered as covariates, depending on the data set. Orthogonal contrasts were used to test for a linear or quadratic relationship among bloom-time MCPB-ethyl or NAA rates in all experiments, and to assess differences between NAA at 14 or 21 mg·L⁻¹ and 1% ATS in Expt. 3.

Results

EXPERIMENT 1: BLOOM-TIME MCPB-ETHYL OR NAA FOLLOWED BY CARBARYL. Although flowering on 'Fuji'/M.9 trees was heavy in 1998, 43% of all flower clusters on nontreated trees failed to set even one fruit (Table 1). Nonetheless, both MCPB-ethyl and NAA applied at 85% FB defruited additional clusters depending on rates, with NAA being more effective than MCPB-ethyl compared at the same rates. NAA reduced the proportion of single fruit sites and increased the proportion of multiple fruit sites. Postbloom carbaryl application resulted in additional defruited

Table 1. Total fruit set, defruited cluster percentages, fruit set distribution, intensity of hand thin, mean fruit weight, and yield of 'Fuji'/M.9 apple trees treated with MCPB-ethyl or NAA at 85% FB, followed by carbaryl application at 1000 mg·L⁻¹ at 11-mm fruit diameter (Expt. 1; Summerland).

Treatment (1998)	Total fruit set ²	Defruited clusters (%)	Percentage fruiting sites with			Hand thin ²	Mean fruit wt (g)	Fruit yield (kg/tree)
			Single	Double	≥3			
Control	66	50	78	19	4	30	246	22.3
MCPB-ethyl 10 mg·L ⁻¹	69	47	77	19	4	27	240	23.5
MCPB-ethyl 15 mg·L ⁻¹	66	50	75	22	4	28	244	24.2
MCPB-ethyl 20 mg·L ⁻¹	56	58	75	19	6	20	253	23.1
NAA 5 mg·L ⁻¹	74	47	69	24	7	33	240	22.4
NAA 10 mg·L ⁻¹	58	62	65	25	11	24	251	22.3
NAA 15 mg·L ⁻¹	37	75	68	24	9	17	293	14.5
– Carbaryl	69	46	68	24	8	33	247	21.1
+ Carbaryl	53	61	77	19	4	18	257	22.4
Significance								
MCPB-ethyl	L*Q**	L***Q****	L**	NS	L*	L*	NS	NS
NAA	L***Q***	L***Q**	L***Q**	NS	L***Q**	L***	L***	L**Q*
Carbaryl	***	***	***	***	***	***	***	**

²Number of fruit per 100 flower clusters, determined after June drop (before hand thin).

²Number of fruit per 100 flower clusters, removed by hand thin after June drop.

NS, *, **, ***, **** Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.005, or 0.0001, respectively. L = linear; Q = quadratic. No interaction between MCPB-ethyl or NAA and carbaryl was found for any variable.

Table 2. Fruit firmness, soluble solids, titratable acidity, and return flowering of 'Fuji'/M.9 trees treated with MCPB-ethyl or NAA at 85% FB, followed by carbaryl at 1000 mg·L⁻¹ at 11-mm fruit diameter (Expt. 1; Summerland).

Treatment (1998)	Firmness (N)	Soluble solids (%Brix)	Titratable acidity ^z	Return bloom ^y (1999)
Control	74.9	16.2	7.5	2.2
MCPB-ethyl 10 mg·L ⁻¹	75.6	16.2	6.9	1.2
MCPB-ethyl 15 mg·L ⁻¹	74.6	16.4	7.2	1.5
MCPB-ethyl 20 mg·L ⁻¹	75.5	16.4	7.1	2.0
NAA 5 mg·L ⁻¹	75.3	16.0	6.7	1.3
NAA 10 mg·L ⁻¹	75.0	15.9	6.4	2.1
NAA 15 mg·L ⁻¹	77.6	16.3	6.4	3.9
– Carbaryl	75.1	16.2	6.9	1.5
+ Carbaryl	75.8	16.2	6.8	2.5
Significance				
MCPB-ethyl	NS	NS	NS	Q**
NAA	Q*	NS	L****	L*Q****
Carbaryl	NS	NS	NS	****

^zThe mL of 0.1 N NaOH used to titrate 15 mL of juice to pH 8.1.

^yNumber of flower clusters per cm² trunk cross-sectional area.

NS,*,**,**** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively. L = linear; Q = quadratic. No interaction between MCPB-ethyl or NAA and carbaryl was found for any variable.

clusters while increasing the proportion of fruiting sites with a single fruit. All chemical treatments reduced the hand thinning requirement with carbaryl having a very substantial effect.

Despite its positive effect on fruit thinning, the highest rate of MCPB-ethyl (20 mg·L⁻¹) did not increase mean fruit weight (Table 1). On the other hand, NAA treatments at 10 or 15 mg·L⁻¹ increased mean fruit weight (259 and 290 g, respectively, compared to 239 g for control). Yield was substantially reduced by NAA at 15 mg·L⁻¹ (≈34%). Carbaryl improved both mean fruit weight and yield in most combination treatments. Fruit firmness seemed to be increased by NAA (especially when not followed by carbaryl). Total soluble solids concentration was decreased slightly by carbaryl, while juice acidity was decreased by NAA (Table 2). Neither auxin treatment influenced fruit shape, surface red color, intensity of surface russet, and seed number (data not presented).

Although flowering on 'Fuji'/M.9 trees was light in 1999, without postbloom carbaryl treatment return flowering was reduced by all rates of MCPB-ethyl or the lowest rate of NAA (Table 2). While NAA at 15 mg·L⁻¹ increased return bloom, this treatment reduced crop load excessively (Table 1). Postbloom carbaryl application increased flowering with the highest value coming from the combination of the highest rate of NAA and carbaryl. However, this carbaryl effect was reduced in combination with the lower rates of these auxins. The later application of MCPB-ethyl or NAA, i.e., at petal fall, was less effective than at 85% FB in increasing thinning, fruit size, and return flowering (data not presented).

EXPERIMENT 2: COMBINATION OF MCPB-ETHYL OR NAA WITH ETHEPHON, FOLLOWED BY CARBARYL. Because MCPB-ethyl in this experiment proved ineffective in reducing fruit set and improving return flowering, only results of NAA alone and in combination with ethephon and carbaryl are reported. NAA, applied at 85% FB, increased whole cluster removal and reduced fruit set linearly with rate (Table 3). The highest rate of NAA (16 mg·L⁻¹) completely defruited 34% of initial flower clusters, resulting in about 27% reduction in total fruit set compared to the control. Lower rates showed only slight effects. None of the NAA treatments increased the proportion of fruiting sites with one or two fruit (Table 3).

Bloom-time ethephon at 100 mg·L⁻¹ significantly removed whole flower clusters and also reduced fruit set within clusters (Table 3). Although ethephon alone seemed to decrease the proportion of fruiting sites with three or more fruit, this effect was countered by NAA ($P < 0.05$ for NAA × ethephon). Carbaryl proved effective in reducing total fruit set, both by increasing total cluster removal and by reducing the proportion of fruiting sites with three or more fruit (Table 3). Interestingly, the proportion of fruiting sites with a single fruit was slightly but significantly reduced by carbaryl while that with two fruit was substantially increased.

Return flowering was not improved by NAA despite its effect on crop reduction (Fig. 1). Carbaryl substantially improved return flowering but this effect significantly declined when combined with NAA. Bloom-time ethephon alone also increased return flowering and overcame the negative effects of NAA in the NAA + carbaryl treatments. Similar results were obtained with MCPB-ethyl (data not presented).

EXPERIMENT 3: COMPARISON OF NAA AND ATS APPLIED AT BLOOM TIME. With this experiment, where all bloom-time NAA and ATS treatments were followed by postbloom carbaryl or carbaryl plus NAA at 5 mg·L⁻¹, bloom-time NAA increased whole flower cluster removal and reduced total fruit set linearly with rates (Table 4). The highest rate of NAA (21 mg·L⁻¹) proved excessive, with 85% of the flower clusters removed. NAA at 14 mg·L⁻¹ resulted in a moderate level of cluster removal, similar to that of the ATS treatment. However, NAA at 14 mg·L⁻¹ did not reduce multiple fruit clusters as efficiently as ATS, resulting in a much higher hand thinning requirement (Table 4). Adding NAA at 5 mg·L⁻¹ to carbaryl in the postbloom spray significantly increased the proportion of fruiting sites with a single fruit, possibly reduced the proportion of fruiting sites with three or more fruit ($P = 0.08$), and significantly reduced final fruit set (Table 4). This resulted in a significant reduction in the hand thinning requirement.

Mean fruit weight at harvest increased as total fruit set decreased following the thinning treatments (Table 4). The highest rate of NAA resulted in the largest fruit but yield was reduced

Table 3. Total fruit set, defruited cluster percentages, and fruit set distribution of 'Fuji'/M.26 apple trees treated with NAA and ethephon at 85% FB, alone and tank-mixed, followed by carbaryl at 1000 mg·L⁻¹ at 11-mm fruit diameter (Expt. 2; Corvallis).

Treatment (1998)	Total fruit set ²	Defruited clusters (%)	Percentage fruiting sites with		
			Single	Double	≥3
NAA 0 mg·L ⁻¹	130	24	29	54	21
NAA 4 mg·L ⁻¹	138	27	31	46	26
NAA 8 mg·L ⁻¹	121	35	33	47	19
NAA 16 mg·L ⁻¹	101	43	29	49	20
NAA 0 + Ethephon 100 mg·L ⁻¹	---	---	---	---	13
NAA 4 + Ethephon 100 mg·L ⁻¹	---	---	---	---	20
NAA 8 + Ethephon 100 mg·L ⁻¹	---	---	---	---	22
NAA 16 + Ethephon 100 mg·L ⁻¹	---	---	---	---	24
- Ethephon	135	25	28	51	---
+ Ethephon	110	39	33	47	---
- Carbaryl	142	29	32	40	28
+ Carbaryl	103	35	29	58	13
Significance					- Ethephon + Ethephon
NAA (Linear)	****	****	NS	NS	NS ****
Ethephon	****	****	***	NS	NS
NAA × ethephon	NS	NS	NS	NS	*
Carbaryl	****	***	*	****	****

²Number of fruit per 100 flower clusters.

NS,*,***,**** Nonsignificant or significant at $P \leq 0.05$, 0.001, or 0.0001, respectively. No interactions between NAA and carbaryl, between ethephon and carbaryl, and among NAA, ethephon, and carbaryl were found for any variable.

substantially to about half that of the ATS treatment. NAA at 14 mg·L⁻¹ resulted in fruit size and yield values similar to those following ATS treatment. The combined use of carbaryl and NAA in the postbloom spray seemed to increase mean fruit weight compared to carbaryl alone, without affecting yield.

Interestingly, despite larger fruit size, the highest rate of NAA increased fruit firmness at harvest relative to the ATS treatment (Table 5). Both juice soluble solids and acidity increased linearly with bloom-time NAA rate (Table 5).

Return flowering was satisfactory across all thinning treatments. The overall NAA effect on flowering was not statistically significant even though the highest rate appeared to promote flowering (Table 5). Addition of NAA to the postbloom carbaryl spray tended to increase flowering.

Discussion

The thinning effects of bloom-time MCPB-ethyl or NAA treatments appear to be confined mostly to whole flower cluster removal. Neither chemical reduced fruit set within clusters as efficiently as carbaryl, ethephon (Tables 1 and 3), or ATS (Table 4). For example, in Expt. 3 where all trees received a postbloom carbaryl spray, ATS resulted in more than 68% of fruiting sites with a single fruit compared to 35% for NAA at 14 mg·L⁻¹. Thus, the significantly higher fruit set on the remaining clusters required a substantial amount of hand thinning.

Furthermore, neither MCPB-ethyl nor NAA had the desired effect of stimulating return flowering. Although return flowering was improved by some treatments, this occurred at the expense of excessive crop reduction (e.g., NAA at 15 and 21 mg·L⁻¹ in Expts. 1 and 3, respectively). In some other cases, return flowering was suppressed by these auxin treatments (Fig. 1A), even though they substantially removed whole flower clusters and thus reduced crop load (Fig. 1B). Similar results

were obtained in the first Summerland experiment where MCPB-ethyl at 20 mg·L⁻¹ was compared with carbaryl only for their effects on thinning and return flowering (Table 1). This lack of return flowering response to bloom-time NAA treatments was also noted by Meland (1998) who reported that increasing NAA concentrations to 30 mg·L⁻¹ failed to promote return flowering of 'Summerred' and 'Gravenstein' apples, even though there was a linear reduction of crop load, including excessive crop reduction, for both cultivars.

Thus, it appears that bloom-time auxins (at least for MCPB-ethyl and NAA) are capable of suppressing flower induction. Clearly, the enhanced flowering one would expect from such whole cluster removal failed to materialize. It could be that there are some residual effects of the applied auxin on development of the terminal meristem (where flower induction occurs for the following season) and/or there is an imbalance between flower promoting and flower inhibiting hormones during the critical phase of flower induction (Callejas and Bangerth, 1997). Further research is required to validate these possible explanations.

In contrast, postbloom carbaryl treatment improved return flowering in all experiments. This is consistent with earlier reports (Batjer and Westwood, 1960; Looney et al., 1997; McArtney et al., 1995; Williams, 1993). As a thinner, carbaryl reduced both the number of fruiting sites and the number of fruit per cluster. Since it has been reported that spurs that support two fruit until about 2 months after flowering are substantially less likely to flower than totally defruited spurs (Looney et al., 1997; McArtney et al., 1995), the carbaryl effect on thinning likely explains the return flowering benefit. However, other effects of carbaryl such as increased leaf size and specific leaf weight (Looney, 2000) may also contribute to this return flowering effect.

In the Corvallis experiment, it was evident that the beneficial effect of carbaryl on flowering was specifically countered by the bloom-time auxin treatments (e.g., Fig. 1A for NAA). Since

Fig. 1. (A) Return flowering of 'Fuji'/M.26 trees treated with NAA and ethephon at 85% FB, followed by postbloom carbaryl (1000 mg·L⁻¹), alone and in combination, and (B) the relationship between return flowering and final fruit set. Values in A are means $\pm$ SE of five replications. In B, the values by the symbols represent NAA concentrations and the treatments receiving NAA at 0 mg·L⁻¹ are circled. A regression line was drawn using all data points.

addition of ethephon generally reversed this negative auxin effect on flowering while showing only a slight effect on reducing fruit set (e.g., Fig. 1A and B for NAA), one could speculate that ethylene may affect the residual activity of the auxin and/or possibly retard shoot growth sufficiently to increase flower initiation.

The joint use of ethephon and NAA as blossom thinners caused more 'clustering' than ethephon alone whereas the combination of ethephon and postbloom carbaryl looked promising for overall crop reduction as well as for obtaining more singles and higher return flowering. Although some previous studies have shown positive effects of the joint use of ethephon and NAA on thinning and flowering in apples (Basak et al, 1988; Reginato and Whiting, 1999), we would not recommend this practice under our conditions. Because of clustering, the hand thinning requirement proved excessive. Thus, results herein are similar to those of Jones et al. (1994) and Meland (1998) who found the combined use of ethephon and NAA at bloom to be ineffective.

In conclusion, whole cluster removal with bloom-time MCPB-ethyl or NAA spray does not appear to be a viable chemical thinning strategy for 'Fuji' apple in the Pacific Northwest. We observed overset on the remaining clusters, over thinning and leaf epinasty at higher rates, inconsistent thinning from year to year, and suppressed return flowering. Thus, while this procedure may have value in Japan where the aim is to reduce fruit set much more drastically (Yokota et al., 1995), we see no place for it in 'Fuji' orchards in the Pacific Northwest. In contrast, carbaryl applied at 11-mm king fruit diameter was the only effective treatment, in terms of both its commercial thinning and return flowering benefits.

Table 4. Total fruit set, defruited cluster percentages, fruit set distribution, intensity of hand thin, mean fruit weight, and yield of 'Fuji'/M.9 trees treated with NAA or ATS at 85% FB, followed by postbloom carbaryl application (1000 mg·L⁻¹) with or without NAA at 5 mg·L⁻¹ (Expt. 3; Summerland).

Treatment (1999)	Total fruit set ²	Defruited clusters (%)	Percentage fruiting sites with			Hand thin ³	Mean fruit wt (g)	Fruit yield (kg/tree)
			Single	Double	≥ 3			
NAA 0 mg·L ⁻¹	129	22	57	29	15	59	172	16.8
NAA 7 mg·L ⁻¹	113	32	54	31	15	49	182	16.1
NAA 14 mg·L ⁻¹	111	45	38	36	27	50	197	15.4
NAA 21 mg·L ⁻¹	28	84	50	36	14	8	248	7.4
ATS 1.0% a.i.	69	49	74	19	7	16	217	15.0
Nonsprayed control	183	14	36	31	33	95	155	19.8
Carbaryl only (postbloom)	97	45	50	32	18	42	201	14.0
Carbaryl + NAA (postbloom)	82	48	59	28	13	31	205	14.3
Significance								
Bloom-time NAA	L****Q***	L****Q**	Q*	L**	Q*	L****Q**	L****Q*	L****Q**
Postbloom NAA	*	NS	*	NS	NS	**	NS	NS
NAA 14 mg·L ⁻¹ vs. ATS 1.0%	****	NS	****	****	****	****	*	NS
NAA 21 mg·L ⁻¹ vs. ATS 1.0%	****	****	***	****	NS	NS	***	****

²Number of fruit per 100 flower clusters, determined after June drop (before hand thin).

³Number of fruit per 100 flower clusters, removed by hand thin after June drop.

NS, *, **, ***, **** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.005, \text{ or } 0.0001$, respectively. L = linear; Q = quadratic. No interaction between bloom-time NAA and postbloom NAA was found for any variable.

Table 5. Fruit firmness, soluble solids, titratable acidity, and return flowering of 'Fuji'/M.9 apple trees treated with NAA or ATS at 85% FB, followed by postbloom carbaryl application (1000 mg·L⁻¹) with or without NAA at 5 mg·L⁻¹ (Expt. 3; Summerland).

Treatment (1999)	Firmness (N)	Soluble solids (%Brix)	Titratable acidity ^z	Return bloom ^y (2000)
NAA 0 mg·L ⁻¹	76.8	14.1	6.6	16.6
NAA 7 mg·L ⁻¹	76.7	13.7	6.2	14.7
NAA 14 mg·L ⁻¹	77.0	14.4	7.0	18.7
NAA 21 mg·L ⁻¹	80.3	14.9	7.8	21.9
ATS 1.0% a.i.	76.1	14.5	6.8	21.6
Nonsprayed control	78.1	13.9	6.4	5.5
Carbaryl only (postbloom)	77.3	14.3	6.7	17.0
Carbaryl + NAA (postbloom)	77.4	14.3	7.0	20.3
Significance				
Bloom-time NAA	L**	L****	L****	NS
Postbloom NAA	NS	NS	NS	NS
NAA 14 mg·L ⁻¹ vs. ATS 1.0%	NS	NS	NS	NS
NAA 21 mg·L ⁻¹ vs. ATS 1.0%	**	NS	**	NS

^zThe mL of 0.1 N NaOH used to titrate 15 mL of juice to pH 8.1.

^yNumber of flower clusters per cm² branch cross-sectional area.

NS, **, **** Nonsignificant or significant at $P \leq 0.01$ or 0.0001, respectively. L = linear. No interaction between bloom-time NAA and postbloom NAA was found for any variable.

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