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Calcium Polysulfides-Thiosulfate, Ammonium Thiosulfate, and NC-99 Blossom Thinners Impact Fruit Set of Apples, Peaches, and Plums

Esmaeil Fallahi*

Department of Plant Sciences, University of Idaho, USA

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***Corresponding author:** Esmaeil Fallahi, Department of Plant Sciences, University of Idaho, USA

Abstract

Crop load adjustment, using blossom and/or post-bloom thinners is a crucial practice to ensure production of commercially acceptable fruit size and yield efficiency in apples and stone fruit. In a study with two apple, one peach and one plum cultivars, application of calcium polysulfides and thiosulfate mixture (lime sulfur), ammonium thiosulfate (ATS), and NC-99 (Natural-cal), applied during bloom, reduced the fruit set of apples and/or certain stone fruit. In most cases, higher concentrations or double applications of a bloom thinner resulted in more blossom thinning which led into lower fruit set. Double applications of ATS at a rate of 15 mL.L-1 or a single application of this chemical at a rate of 25 mL.L-1 resulted in adequate levels of thinning in 'Fuji' apple. Double applications of ATS at a rate of 25 mL.L-1 resulted in excess thinning on 'Fuji' apple. In 'Gala' apple, a single application of NC-99 at 3% or 6%, with and without refined oil, or double applications of lime sulfur, each time at 5%, significantly reduced fruit set in 2013. In 'Jonathan' apple, applications of ATS at 25 mL.L-1 significantly reduced fruit set and increased fruit size. Application of lime sulfur at 6% with or without refined oil significantly reduced fruit set in 'Elberta' peach. In plums, application of lime sulfur at 6% with 1% refined oil significantly reduced fruit set, while application of this mixture at 3% lime sulfur (3% lime sulfur plus 1% oil) did not affect fruit set.

Keywords: Blossom Thinning; Crop Regulation; Fruit thinning; Stone Fruit; Regular Cropping

Introduction

proper balance between number and photosynthetic efficiency of source (leaf) and sink (fruit) is crucial for production of commercially acceptable fruit size and yield efficiency [1,2]. Early thinning of blossoms [3,4] and small fruits [5] will lead to a higher leaf-to-fruit ratio and ultimately larger fruit size. Blossom thinners have caustic effect, and reduce fruit set by damaging different flower parts, including anthers, stigmas, styles, and pollen tubes, and thus prevent fertilization [3,4].

Hydrogen cyanamide (Dormex, 50% a.i.) and some other chemicals were initially used to reduce chilling requirements of low-chill peaches grown in southwest Arizona, but when applied at "pink bloom" stage, reduced the number of open blossoms [6]. Based on that study, Dormex at 10 mL.L^{-1}, applied at full-bloom significantly reduced fruit set in 'Florda Prince' peach [6]. In later studies, Dormex was also found to be an effective blossom thinner for plums [7] and peaches [1] in Idaho. In wide-scale commercial trials, full-bloom applications of Dormex at 2.5 to 3.12 mL.L^{-1} significantly reduced fruit set in 'Flavorcrest' peach [8]. Dormex was a more consistent blossom thinner for apple and peach than monocarbamide dihydrogen sulfate or sulfcarbamide (Wilthin, 79%, a.i.), 7, oxybicylo(2,2,2) heptane-2-3 dicarboxcylic acid (Endothall, 0.5% a.i.; an aquatic herbicide), and pelargonic acid (Thinex) [1,2]. Endothall at a rate of 1.87 mL.L^{-1} formulation was found to effectively thin 'Redhaven' peach blossoms when applied at stages of 85%-90% open bloom [1]. In field trials in Washington, California, and Idaho, Endothall was an effective blossom thinner for apples and stone fruit [1,5]. However, Endothall was ineffective when applied at 100% bloom, when most flowers were already fertilized [1]. Wilthin has been used for blossom thinning in stone fruit, including peaches [5,9,10], and plums [9]. On 'Friar' plum, full-bloom application of Wilthin at 10 mL.L^{-1} plus polyoxyethylenepolypropoxypropanol (Regulaid with 90.6% a.i) at 1.25 mL.L^{-1}, using a hand-gun sprayer, increased fruit size [3]. In a comparison of ammonium thiosulfate (ATS), Wilthin, and Endothall, it was found that ATS was the best blossom thinner under Washington conditions [5]. Full-bloom application of the surfactant N, N-bis2-(omegahydroxypolyoxyethylenepolyoxypropylene) ethyl alkylamine (Armothin) at 30 $mL.L^{-1}$ or 5 $mL.L^{-1}$ reduced fruit set in 'Loadel' peach in California [11].

Byers and Lyons [12] reported that Surfactant WK killed peach flowers by killing peduncles and pistils. Thus, the mode of action of this chemical is different than most other caustic thinners that are only toxic to pistils and/or stamens. Surfactant 2,6,8-trimethyl-4-nonyloxypolyethyleneoxyethanol (Tergitol) TMN-6 (90% aq.) was at least one of the putative active ingredients of Surfactant WK, a surfactant that was labeled by DOW Chemical Company. Wilkins et al. [13] reported that Tergitol-TMN-6 effectively reduced fruit set in 'Fireprince' peach under climatic conditions of Clanton, Alabama, USA. In that report, there was no difference in thinning response at full bloom or petal fall, suggesting a wide window of efficacy for this chemical. Fallahi et al. [14] reported that Terittol-TMN-6 at 5 $mL.L^{-1}$ rates, applied at 75% to 85% bloom, reduced fruit set in peaches. Miller and Tworkoski [15] reported that application of eugenol at 8% and 10% caused major caustic effects but application of this compound at 1% or 2% showed promising results on peach blossom thinning.

Sherif [16] reported that application of Rex lime sulfur (29% calcium polysulfide) at 3% plus 2% JMS stylet oil causes significant russeting and reduced pack out, whereas low rates (e.g. 1% lime sulfur and 1% JMS stylet oil) had no significant thinning effect in apples under conditions of West Virginia. Blossom thinning using 1.5-2% Rex lime sulfur and 2% oil showed acceptable thinning results and less fruit russeting in apples [16].

Despite considerable production of apples and stone fruit worldwide, it is a risky task to choose a reliable blossom thinner for these fruit crops. Growers spend between $1800 to 3400 per ha for hand thinning of stone fruit (personal knowledge). The increasing cost of fruit production and labor issues in the globally competitive fruit market mandates discovery of a reliable blossom thinner for pome and stone fruits. Thus, the goal of this study was to determine efficacy of lime sulfur, ammonium thiosulfate (ATS), and/or NC-99 on blossom thinning, fruit quality, and yield in three apple cultivars, one peach and one plum under conditions of southwest Idaho, USA.

Materials and Methods

Apple Experiments

General description for apple experimental orchards. Soil in all orchards was sandy loam with pH of approximately 7.3. Other than blossom and post-bloom thinning treatments, all cultural practices were performed according to the commercial orchard standards [17]. Air blast sprayers were used in all experiments throughout this study. After June drop, fruits in all treatment were counted for fruit set calculation and then hand thinned to maintain 13 to 15 cm spacing between fruits. Fruit set in apples was calculated as the number of fruits after June drop divided by number of mixed buds × 100.

The experimental design in all apple studies was randomized complete block design with three blocks. Each block consisted of two adjacent rows with 6 trees per treatment and thus a total of 36 data trees per experiment. Five buffer rows between adjacent blocks and eight guard trees between different plots of treatments within each block were used to prevent any cross contamination from the sprays. Yield was recoded and thirty fruits per tree were randomly sampled from each apple cultivar at harvest, and average fruit weight was calculated. Fruit russeting (marking) status was visually assessed, and the percentage of russeting was calculated. The amount of fruit surface covered with red was rated visually on a scale of 1 (least color) to 5 (most color). Fruit soluble solids concentration was measured using an Atago Hand-held refractometer.

'Fuji' and 'Jonathan' apple experiments in 2012. A 7-year-old 'BC-2 Fuji' on M.9 rootstock in an orchard planted with a 2 × 3.5 m tree spacing, near Wilder, Idaho and a 10-year-old 'Jonathan' on M.7 EMLA rootstock in an orchard, planted at 2.5 x 4 m tree spacing near Payette, Idaho, USA were selected for this study. Treatments on 'Fuji' trees were as follows: 1): Control + Hand, where trees received no thinning treatments, but received only a hand thinning; 2) ATS 15 $mL.L^{-1}$ once + PB (post-bloom thinner) +Hand, where trees received ammonium thiosulfate (ATS) at the rate of 15 $mL.L^{-1}$ once plus a post-bloom thinner (PB) plus hand thinning; 3) ATS 15 $mL.L^{-1}$ twice + PB +Hand, where trees received ATS at the rate of 15 $mL.L^{-1}$ twice plus a PB plus hand thinning; 4) ATS 25 $mL.L^{-1}$ once + PB +Hand, where trees received ATS at the rate of 25 $mL.L^{-1}$ once plus a PB plus hand thinning; 5) ATS 25 mL.L-1 twice + PB +Hand, where trees received ATS at the rate of 25 mL.L-1 twice plus a PB plus hand thinning; 6) ATS 30 $mL.L^{-1}$ once + PB +Hand, where trees received ATS at the rate of 30 $mL.L^{-1}$ once plus a PB plus hand thinning; 7) PB + Hand, where trees received only a mixture of post-bloom thinner. The stage of bloom and rate and frequencies of blossom thinning applications in 'Jonathan' apple was similar to those in 'Fuji', except that 'Jonathan' trees did not receive any ATS at the rate of 30 $mL.L^{-1}$.

Trees with either a single or double application of ATS treatments received one application in 'Fuji' on April 17, 2012 and in 'Jonathan' on April 20, 2012, when 87% of blooms (king bloom plus 1 or 2 side blooms; Figure 1) were open, and temperature during thinning applications was about 20 to 21^{o}C, reaching a maximum of 24^{o}C. Trees with double ATS treatments, received an additional ATS application in 'Fuji' on April 19, 2012 and in 'Jonathan' on April 21, 2012, when 100% of blooms (king plus at least 3 sides; Figure 2) were open and temperature during thinning applications was about 16 oC, reaching a maximum of 21 oC. The mixture of post-bloom thinner (PB) for 'Fuji' consisted of Sevin 4F at 1.25 $mL.L^{-1}$, Ethrel at 1.25 $mL.L^{-1}$, Amid Thin at 375 $mg.L^{-1}$, plus Regulaid at 1.25 mL.L-1 and was sprayed at petal fall on April 25, 2012, when temperature was about 18^{o}C, reaching to maximum of 21^{o}C. Sulfcarbamide (Wilthin®) at 2.5 $mL.L^{-1}$ was applied once as post-bloom thinner to 'Jonathan' on April 27, 2012. After June drop, fruits in all treatment were counted for fruit set calculation and then hand thinned to maintain 13 to 15 cm spacing between fruits.

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Figure 1: 'Fuji' apples in 87% bloom stage, when all king blooms and one or two side blooms were open. This was the stage when the first of two or the only spray of a blossom thinner was applied.

Figure 2: 'Fuji' apples in 100% bloom stage, when all king blooms and about two or three side blooms were open. This was the stage that the second of two spray of a blossom thinner was applied.

'Gala' apple experiment in 2013. The orchard for this experiment was located near Roswell, Idaho, USA, where nine years old 'Gale Gala' trees on M.9 EMLA at panting space of 1.5 × 3.5 m were used. In this study, (NC-99, Genesis Agri-Products Inc., Union Gap, WA.), or lime sulfur at 5% were applied at the rate of at 1870 $L.ha^{-1}$ on April 26-27, 2013 as follows: 1) Un-treated Control; 2) NC-99 at 3% once on April 27, 2013, when king bloom and one side bloom were open; 3) NC-99 at 3% plus 1% refined oil once on April 27, 2013; 4) NC-99 at 6% on April 27, 2013; 5) lime sulfur at 5% once on April 27, 2013; 6) lime sulfur at 5% twice (on April 26, 2013 and April 27, 2013); 6) Lime sulfur once at 5% plus NC-99 at 3% once on April 27, 2013; 7) Lime sulfur at 5% three times plus NC-99 at 3% twice, on April 26 and April 27, 2013.

Temperature during blossom thinner applications on April 26, 2013 was about 21°C, and maximum for that day reached 30°C. During the second application on April 27, 2013, temperature was about 24 °C and maximum for that day reached 29°C. At each application in 2013, developmental stages of blossoms were similar to those described earlier for 'Fuji' experiment in 2012.

Stone Fruit Experiments

General experimental design, orchard conditions, and methods for stone fruits. The peach *[(Prunus persica (L.)* Batsch] blossom thinning was conducted in an 11-year old orchard of 'Elberta' on Lovell rootstock with a 2 × 4 m tree spacing in 2013. Also, plum [*Prunus salicina (L.)*] bloom thinning was studied in a nine-year old orchard of 'Empress' on Lovell rootstock, with a tree spacing of 4 × 4 m in 2013. Both peach and plum orchards were located near Fruitland, Idaho and had sandy loam soils with a pH of 7.3. The experimental design in both stone fruit experiments was

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randomized complete block design with four blocks. Each block consisted of two adjacent rows, each with 8 trees per treatment. To avoid contamination (border effect), four trees in the middle of that 8-tree segment per row were selected for sampling, although the entire eight trees received the same treatment. Also, five guard rows or buffers were put between the sets of adjacent experimental rows. Therefore, in each treatment, only a total of 16 trees were used for sampling. Air blast sprayers were used in all experiments throughout this study.

All trees were pruned as open vase shape with four to five main scaffolds. Other than blossom thinning treatments, all other cultural practices in these orchards were similar to those of commercial orchards [17].

On different sides of each tree, six fruit-bearing hangers or branches were randomly selected and tagged at their basal points. Fruit set was calculated by one or two of the following methods. Method 1): Total number of flower buds on each of the selected hangers was counted about 7 days before bloom (before any treatment application). The total number of fruits on the tagged hangers or branches was counted after "June drop". Fruit set in method 1 was calculated as fruit number/flower number × 100; Method 2): The diameter of each tagged hanger or branch at their basal points was measured, using a digital caliper (Digimatic Model CD-6, Mitutoyo, Tokyo, Japan), and cross sectional area of that basal point was calculated. The total number of fruits on the tagged hangers or branches was counted after "June drop", just before "pit hardening" stage. Fruit set in Method 2 was calculated as number of fruit/cross sectional area at the basal point. After counting fruits by either method, fruits in all treatments were hand thinned at the beginning of pit hardening to maintain about 17 cm spacing between fruits.

Approximately 40 peach per tree were sampled, cleaned, and evaluated for russeting (fruit marks). Thirty of these fruits were used for weight and color measurements. Fruit color was measured by giving a continuous ranking from 1 (green) progressively to 5 (fully developed color).

Apple and stone fruit experiments in 2014

In 2014, all studies of 2012 and 2013 were repeated, using limited rates and frequencies of the same blossom thinners. However, these blossom thinners were applied when pollination was complete, and some petals started to fall. Fruit set and other measurements in 2014 were exactly similar to those in 2012 and 2013.

Results and Discussion

Experiments on apples. In 'Fuji' apples, all blossom thinning treatments, except ATS at 15 $mL.L^{-1}$ and post-bloom treatment, reduced fruit set as compared to untreated control in 2012 (Table 1). Compared with control, fruit weight of 'Fuji' apples was not affected by ATS treatments in 2012, because fruits of all treatments were hand thinned in June, providing sufficient leaf/fruit ratio in most treatments. 'Fuji' trees receiving a double application of ATS at 25 $mL.L^{-1}$ had smaller fruits than those receiving one application of this chemical at 15 $mL.L^{-1}$. Also, 'Fuji' trees receiving ATS at a single application of 30 $mL.L^{-1}$ or a double application at 15 or 25 $mL.L^{-1}$ had lower fruit color than control. 'In 2012, 'Fuji' trees that received double applications of ATS showed severe foliage burning that could have resulted in smaller fruit size and poorer color due to reduction of leaf surface/fruit ratio in some of these treatments.

'Fuji' apple in Untreated Control trees had relatively higher, while trees receiving 15 $mL.L^{-1}$ ATS showed lower percentage of fruit russeting than those with other treatments, although difference were not always significant (Table 1). Powdery mildew fungus *(Podosphaera leucotricha)* can create russeting in apples. Ammonium thiosulfate is a great fungicide and can reduced powdery mildew symptoms (personal experience). It is possible that ATS spray at 15 $mL.L^{-1}$ reduced russeting by reducing powdery mildew while applications of this chemical at higher rates or greater frequencies caused injury on the apple cuticle, leading to more russeting, and this area deserves further studies.

Table 1: Effect of chemical thinning treatments on 'Fuji' apple fruit set, weight, color, and russeting in 2012.

Treatment	Fruit set (Fruit/100 buds)[z]	Fruit weight (g)	Fruit color (1-5)[w]	Fruit russeting (%)
Control + Hand	133.2 a[x]	206.0 ab	3.39 a	23.3 a
ATSy 15 $mL.L^{-1}$ once+PBy + Hand	114.4 ab	229.0 a	2.91 ab	8.3 b
ATS 15 $mL.L^{-1}$ twice+PB + Hand	95.3 bc	198.4 ab	2.42 b	15.0 ab
ATS 25 $mL.L^{-1}$ once+PB + Hand	77.0 cd	215.2 ab	3.08 ab	18.3 ab
ATS 25 $mL.L^{-1}$ twice+PB + Hand	56.3 d	191.1 b	2.58 b	18.3 ab
ATS 30 $mL.L^{-1}$ once+PB + Hand	97.0 bc	220.6 ab	2.59 b	12.9 ab
PB + Hand	122.2 ab	204.0 ab	2.78 ab	-

[z]Fruit set = Number of fruit / 100 buds.
[y]ATS = ammonium thiosulfate; PB = Post bloom thinner.
[x]Mean separation within columns by LSD at $\alpha \leq 0.05$.
[w]Fruit color ranking: 1= least red progressively to 5= most red color.

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In 'Jonathan' apple, applications of ATS at 25 $mL.L^{-1}$, once or twice, significantly reduced fruit set and increased fruit size in 2012 (Table 2). Trees receiving an ATS blossom thinner at any rate or frequency had significantly larger fruit than those receiving Wilthin alone or Un-treated Control in 2012 (Table 2). This clearly indicates that application of Wilthin as a post-bloom thinner without any blossom thinning, under the full-crop condition of this study, is not sufficient. Thinning these trees to an optimum crop load with an acceptable and marketable fruit size requires extensive and expensive hand thinning and will result in reduction of profit to apple growers. Application of ATS at any rate or frequency reduced 'Jonathan' fruit russeting in 2012 (Table 2) because these treatments reduced the crop density and resulted in less fruit-to-fruit friction and contact. Fruit color in 'Jonathan' apple was not affected by any thinning treatments in 2012 (Table 2).

Table 2: Effect of chemical thinning on 'Jonathan' apple fruit set and quality attributes in 2012.

Treatment	Fruit set (Fruit/cm^2 branch) ^{z}	Fruit weight (g)	Fruit color (1-5)^w	Russeting rates (%)
Control	2.29 a^x	207.3 b	4.04 a	67.4a
ATSy 15 mL. L^{-1} once + PBy + Hand	1.62 abc	232.0a	4.08 a	48.5b
ATS 15 mL. L^{-1} twice + PB + Hand	1.86 abc	236.9a	4.25 a	48.1b
ATS 25 mL. L^{-1} once + PB + Hand	1.32 bc	221.1ab	4.04 a	50.6b
ATS 25 mL. L^{-1} twice + PB + Hand	1.26 c	228.4a	4.08 a	43.3b
Wilthin	1.97 ab	206.1b	3.96 a	53.3ab

^{z}Fruit set = Number of fruit / cm^2 branch).
^{y}ATS = ammonium thiosulfate; PB= Post bloom sprays.
^{x}Mean separation within columns by LSD at $\alpha \leq 0.05$.
^{w}Fruit color ranking: 1= least red progressively to 5= most red color.

In 'Gala' apple, a single application of NC-99 at 3%, with and without refined oil, or at 6%, or a double application of lime sulfur, each time at 5%, significantly reduced fruit set in 2013 (Table 3). A single application of lime sulfur at 5% was not sufficient to reduce the fruit set in 'Gala' apple. However, when one application of lime sulfur at 5% was accompanied with one application of NC-99 at 3%, fruit set was significantly reduced (Table 3). The lowest levels of fruit thinning in 'Gala' apple was achieved when trees receiving three applications of lime sulfur, each at 5% also received two applications of NC-99, each at 3% (Table 3). 'Gala' leaves from trees receiving a single application of NC-99 at 6% exhibited more severe burning than those receiving other rates or frequencies of thinners used in this study (Table 3).

Table 3: Effects of Natural-Cal (NC-99) and lime sulfur on 'Gala' apple fruit set and leaf burning in 2013.

Treatments	Fruit set (fruit no./100 buds)^z	Leaf burning Rate (%)
Control	61.8 a^y	0.01 e
3% NC-99 once	44.2 cd	2.8 de
3% NC-99 once + 1% oil once	51.5 bc	5.4 d
6% NC-99 once	35.6 de	30.0 a
5% lime sulfur once	54.7 ab	2.0 de
5% lime sulfur twice	37.2 de	2.5 de
5% lime sulfur once + 3% NC-99 once	49.0 bc	10.7 c
5% lime sulfur 3 times+ 3% NC-99 twice	33.8 e	17.0 b

^{z}Fruit set = (number of fruit/numbers of mixed buds) *100.
^{y}Mean separation within each treatment by LSD at $\alpha \leq 0.05$.

Experiments on Stone Fruit. Application of lime sulfur at 6% with or without refined oil significantly reduced fruit set and increased fruit weight at harvest in 'Elberta' peach (Table 4). Addition of refined oil to the 3% lime sulfur treatment significantly increased fruit weight, although had no effect on fruit set (Table 3). This observation suggests that the use of 3% lime sulfur plus 1% refined oil would have also reduced fruit set if measurements were made later. Application of this treatment should have resulted in weakening of the fruits, leading to their drop after the fruit set measurements were made. Addition of refined oil to the 6% lime sulfur treatment also resulted in slightly larger fruit, although the difference was not significant (Table 4).

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Table 4: Effects of blossom thinners on fruit set and quality attributes in 'Elberta' peach in 2013.

	Fruit set[y] (fruit no/100 flowers)	Avg. fruit weight (g)	Fruit color[w]	Fruit soluble solids (°Brix)	Fruit russet (%)
Control	69.11 a	221.7 b	3.7 a	10.05 a	16.72 ab
3% Lime sulfur	62.72 a	215.6 b	2.9 a	9.60 a	19.22 ab
3% Lime sulfur + 1% refined oil	65.36 a	231.2 a	2.9 a	9.90 a	11.67 b
6% Lime sulfur	46.74 b	241.8 a	2.6 a	9.55 a	13.14 b
6% Lime sulfur + 1% refined oil	46.24 b	249.2 a	3.2 a	10.3 a	22.95 a

[z]Fruit set = (number of fruit/numbers of flowers) *100.
[y]Mean separation within columns of each treatment by LSD at $\alpha \leq 0.05$.
[w]Fruit color ranking: 1= least red progressively to 5= most red color.

This observation suggests that crop load management in peaches can be decided based on a number of factors including temperatures during application, efficiency of pollination and levels of fertilized fruit. When the conditions are in favor of heavy fruit set, a 6% lime sulfur without oil would be beneficial. However, when the chance of pollination and fruit set is likely but uncertain, and there is a risk of moderate frost injury during pollination and after fruit set, an application of 3% lime sulfur plus 1% refined oil may be enough.

In plums, application of lime sulfur at 6% with 1% refined oil significantly reduced fruit set, while application of this mixture at 3% lime sulfur (3% lime sulfur plus 1% oil) did not affect fruit set (Table 5). Based on author's personal experience, 'Empress' plus is a hard-to-thin cultivar. Hand thinning of this cultivar is extremely time consuming and would cost between $3000 to over $4500 per hectare. Fine-tuning and a timely application of lime sulfur at 6% can be economically sound. However, early applications of this chemical, before sufficient pollination an fertilization may lead to major losses. Results on apples and stone fruit in 2014. No significant difference was found in the fruit set or quality attributes among treatments (data not shown). This finding was expected as we intentionally applied the blossom thinners too late, when blossoms were well pollinated and fertilized and thus, could not be thinned with the selected chemicals that were applied.

Table 5: Effects of lime sulfur on blossom thinning in 'Empress' plum in 2013[z].

Treatment	Fruit set (fruit/branch cross sectional area)
Orchard 1	
Control	3.87 a
3% Lime sulfur + 1% refined oil	4.91 a
Orchard 2	
Control	11.62 a
6% Lime sulfur + 1% refined oil	2.01 b

[z]Mean separation the column of each orchard by LSD at 5%.

[x]Fruit set = number of fruit/branch cross-sectional area (cm^2).

General conclusions and assessment in blossom thinners. This study demonstrated that ATS, NC-99, and lime sulfur blossom thinners effectively reduced the fruit set of apples and/or certain stone fruit. In most cases, higher concentrations or double application of a bloom thinner resulted in more blossom thinning which led into lower fruit set. Double application of ATS at a rate of 15 $mL.L^{-1}$ or a single application of this chemical at a rate of 25 mL. L^{-1} resulted in adequate levels of thinning in 'Fuji' apple. Double application of ATS at a rate of 25 mL. L^{-1} resulted in excess thinning on 'Fuji' apple. Application of ATS at 15 $mL.L^{-1}$ reduced russeting of 'Fuji' apple fruits. Considering all of our results from different years, it is concluded that although double application of most blossom thinners may have been more effective than a single application, double application may pose a number of problems and risks. The first potential problem is over-thinning as enough flowers may not have been fertilized at the times of application. The second problem is that because the time period for application of any blossom thinner is very limited, it may not always be feasible to apply them twice in a timely manner, particularly in the large fruit operations with multiple orchards. Temperature, bee activity,

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time of application, bloom developing stages, varietal differences, tree vigor, and spray volume are among factors influencing the effectiveness of blossom thinning in apples and stone fruit [3]. Temperature affects bee activity and thus, the number of fertilized flowers.

Lack of significant effects of blossom thinners in 2014 was a clear indication that times of applications for all chemicals and fruit types were too late. Thus, efficacy of any blossom thinner largely depends on the physiological stage of blooms and pollen tube grow, and this fact should be carefully taken into account when managing crop load adjustment. One should be cautious about fruit marking and leaf burning with the application of blossom thinners. Although most of these blossom thinners induced varying degrees of leaf and foliage burning in apples in our study, some of these symptoms disappeared after a few weeks and did not cause any adverse effect. Additional blossom thinning research is also needed to determine a method for a quick determination of the proper blossom stage based on physiological development of pollen tube and/or fertilization of the ovules.

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