

Branched Secondary Alcohol Ethoxylate, Ammonium Thiosulfate, Calcium Polysulfides-Thiosulfate, and Fish Oil Effects on Blossom Thinning, Fruit Set and Quality of Peaches and Nectarines

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Abstract

Total crop load has an inverse relationship with fruit size, while larger fruit size is often demanded by the peach and nectarine markets. Hand-thinning is extremely expensive, and thus, crop load adjustment, using blossom thinners is a crucial practice to ensure production of commercially acceptable fruit size and yield efficiency in stone fruit. In this study, the influence of branched secondary alcohol ethoxylate (Tergitol TMN-6) and/or ammonium thiosulfate (ATS), Crocker Fish Oil (FO), and a mixture of calcium polysulfides and thiosulfate (lime sulfur) on fruit set and quality attributes in peaches (*Prunus persica*) and nectarines (*P. persica* var. *nectarina*) were studied. All blossom thinners reduced fruit set in “Summer Lady” peach in both 2016 and 2017. Fruit sets in “Summer Lady” peach trees with a double application of Tergitol TMN-6 at the rate of 7.5 or 10 mL·L⁻¹, each rate applied at 40% and 80% bloom, were lower than those receiving the same rates of this chemical only at 80% bloom, but they were similar to those receiving a single Tergitol TMN-6 spray at 15 mL·L⁻¹ at 80% or 100% bloom. “Summer Lady” peach trees receiving FO at 20 mL·L⁻¹ plus lime sulfur at 25 mL·L⁻¹, once at 40% bloom and again at 80% bloom had lower fruit set as compared to Untreated Control but the fruit set was higher than those with any Tergitol-TMN-6 spray. Tergitol TMN-6 at 12 mL·L⁻¹ at 100% bloom or 10 mL·L⁻¹ all stages of bloom reduced fruit set in “Zee Lady” and “Snow Giant” peaches. In “Snow Giant” peach, trees receiving Tergitol TMN-6 at all concentrations and blossom stages had

significantly higher fruit weight as compared to the trees of Un-treated Control. Applications of Tergitol TMN-6 at all concentrations at 80% bloom reduced fruit set in “Red Globe” and “Elberta” peaches in Utah. ATS and FO slightly reduced fruit set in peaches but they were less effective than Tergitol TMN-6 in all cases. Overall, it is concluded that efficacy of blossom thinners depends on the rate of thinners, temperature, cultivar and stage of bloom development.

Keywords

Bio-Regulator, Crop Regulation, Fruit Thinning, Stone Fruit, Regular Cropping, *Prunus persica*

1. Introduction

Hand-thinning is a critical cultural practice that increases the leaf-to-fruit ratio and leads to the production of larger fruit size in apples and peaches, as well as reduction of the biennial bearing in apples [1] [2] [3] [4]. Most blossom thinners are caustic and reduce fruit set by damaging different flower parts, including anthers, stigmas, styles, and pollen tubes, and thus prevent fertilization [4].

Hydrogen cyanamide (Dormex, 50% a.i.) was initially used to reduce dormancy requirement in “Florda Prince” peach [5]. In later studies, Dormex was also found to be an effective blossom thinner for plums [6] and peaches [2] in Idaho. Full-bloom applications of Dormex at 2.5 to 3.12 mL·L⁻¹ significantly reduced fruit set in “Flavorcrest” peach [7]. Comparing efficacy of blossom thinners revealed that Dormex was a more consistent blossom thinner for apple and peach than monocarbamide dihydrogen sulfate or sulfocarbamide (Wilthin, 79%, a.i.), 7, oxabicyclo(2,2,2) heptane-2-3 dicarboxylic acid (Endothall, 0.5% a.i.; an aquatic herbicide), and pelargonic acid (Thinex) [2] [3]. 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 [2]. In field trials in Washington, California, and Idaho, Endothall was an effective blossom thinner for apples and stone fruit [2] [8]. However, Endothall was ineffective when applied at 100% bloom, when most flowers were already fertilized [2]. Wilthin has been used for blossom thinning in stone fruit, including peaches [8] [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 the fruit size [4]. In a comparison of ammonium thiosulfate (ATS), Wilthin, and Endothall, ATS was proved to be the best blossom thinner under Washington conditions [8]. Full-bloom application of the surfactant N, N-bis2-(omegahydroxypolyoxyethylenepoly-oxypropylene) ethyl alkylamine (Armothin) at 30 mL·L⁻¹ or 5 mL·L⁻¹ reduced fruit set in “Loadel” peach in California [11].

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 [12]. In contrast to most other blossom thinners which are only toxic to pistils and/or stamens, Tergitol TMN-6 killed peach flowers by killing peduncles and pistils [12]. Fallahi *et al.* [13] reported that Tergitol TMN-6 at the rate of 5 mL·L⁻¹, applied at 75% to 85% bloom, reduced fruit set in peaches under conditions of southern Idaho, USA. Wilkins *et al.* [14] reported that Tergitol TMN-6 effectively reduced fruit set in “Fireprince” peach under climatic conditions of Clanton, Alabama. 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. Searching for new blossom thinners, 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.

Rex lime sulfur (29% calcium polysulfide) at 3% plus 2% JMS stylet oil caused significant russetting 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 [16]. In that report, spraying 1.5% - 2% Rex lime sulfur and 2% oil showed acceptable thinning results and less fruit russetting in apples [16].

Choosing a reliable blossom thinner for peaches and nectarines is a risky task. Based on author’s experience (Fallahi, unpublished data), three major risks are associated with blossom thinning of stone and pome fruits, including: 1) occurrence of severe frost after blossom thinning application; 2) over thinning due to high rates of blossom thinners and/or unfavorable temperature changes before, during and after applications of blossom thinners; 3) application in a season that bee activity is limited due to low temperatures and high wind, results in poor fruit set; 4) creation of “rough” fruit finish or russetting due to aggravation of the fruit cuticle by the blossom thinner and/or high temperatures and fast expansion of fruit surface. Despite these risks, fruit growers are increasingly forced to choose a method in addition to hand thinning to reduce the fruit load. The cost hand thinning is between \$1800 to \$3400 per ha and finding specialized fruit labor force is becoming extremely difficult. These issues would increase the cost of fruit production and marginalizes the net return. Therefore, the goal of this study was to determine efficacy of Tergitol TMN-6, lime sulfur, ammonium thiosulfate, and fish oil on blossom thinning, fruit quality, and yield in different peach and one nectarine cultivars under conditions of southwest, USA.

2. Materials and Methods

2.1. General Experimental Design, Orchard Conditions, and Methods for Stone Fruits

Blossom thinning studies were conducted on peaches [*Prunus persica* (L.) Batsch] in five orchards in 2016 (one at Symms Fruit Ranch in Sunny Slope, Idaho, two at the University of Idaho, Parma, Idaho, and two orchards near Og-

den, Utah). In Idaho, the same orchards were used in both 2016 and 2017. Blossom thinning was also conducted in one nectarine (*P. persica* var. *nectarina*) orchard at Williamson Orchards in Sunny Slope, Idaho in 2016. Air blast sprayers were used to deliver 1871 L·ha⁻¹ throughout this study.

Soil structure in all experimental orchards was sandy loam with a pH of about 7.5. Other than blossom thinning treatments, cultural practices in these orchards were generally similar to those recommended for the Pacific Northwest orchards, Washington State University [17].

The peach orchards at Symms Fruit Ranch Sunny Slope, Idaho, had seven-year-old trees of “Summer Lady” on Lovell rootstock, planted at 3.52 × 5.79 m spacing. Each of the two orchards used at the University of Idaho near Parma, Idaho was a five-year-old “Zee Lady” or “Snow Giant” peach on Lovell rootstock, and trees were planted at 2.44 × 5.03 m spacing. In Utah, five-year-old orchards of “Red Globe” and “Elberta” peaches on Lovell rootstock, each with a tree spacing of 3 × 4 m, were used for the blossom thinning experiment in 2016. Nectarine blossom thinning was conducted in a five-year-old orchard of “Diamond Ray” nectarine on Lovell rootstock with a 3 × 4.5 m tree spacing in 2016. Trees of “Zee Lady” and “Snow Giant” peaches were trained into a perpendicular V at 1.83 × 4.87 m. Other experimental trees were pruned as open vase shape with four to five main scaffolds.

On different sides of each tree, six fruit-bearing hangers or branches were randomly selected and tagged at their basal points. For fruit set measurement, number of flower buds on each of the selected hangers was counted about 5 - 7 days before bloom (before any treatment application). The total number of fruits on these tagged hangers or branches was counted after “June drop”, and percentage of fruit set was calculated as (fruit number/flower bud number) × 100. After counting fruit, crops in all treatments were hand thinned at the beginning of pit hardening to maintain about 17 cm spacing between fruits. **Figure 1** and **Figure 2** show peach trees in Un-treated Control treatment before and after hand thinning.

Approximately 40 peach or nectarine 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 red color).

The blossom thinning treatments were: 1) Surfactant 2,6,8-trimethyl-4-nonyloxypolyethyleneoxyethanol (Tergitol) TMN-6 (90% aq.), labeled and distributed by DOW Chemical Company; 2) Crocker’s Fish Oil, an organic, non-ionic, non-phytotoxic, sticker-spreader, registered by Crocker’s Fish Oil, LLC, Quincy, Washinton; 3) Lime-Sulfur, with 29.0% active ingredients of Calcium Polysulfide and 71% other ingredients, distributed by Miller Chemical & Fertilizer, LLC, Hanover, Pennsylvania.

For determining the bloom stage or blooming degree in the blossom thinning trails, percentages of open blooms in trees were visually estimated on a scale of



Figure 1. “Summer Lady” peach before hand-thinning in 2017.



Figure 2. “Summer Lady” peach orchard floor after hand-thinning, 2017.

0%, where no bloom was open, progressively to 100%, where all blooms on the trees were open.

2.2. Blossom Thinning Treatments Were as Follows

A. Treatments in “Summer Lady” peach at Symms Fruit Ranch, near Caldwell, Idaho in 2016:

These trees received either a single or double application of Tergitol TMN-6. The single applications were made once at 40% bloom on April 12, 2016, when temperatures were 12.2°C to 18.9°C, or at 60% bloom on April 13, 2016 when temperatures were 18.3°C to 21.1°C, or at 80% bloom on April 14, 2016, when temperatures were 16.0°C to 17.5°C, or at 100% bloom on April 15, 2016, when temperatures were 16.7°C to 19.4°C. Trees with double applications received two of the above-mentioned treatments. The rates and times of applications were as follows:

1) Un-treated Control where trees did not receive any blossom thinner or hand thinning (**Figure 1**).

2) Terg 7.5 mL·L⁻¹ @ 80% Bl, where trees received Tergitol TMN-6 at the rate of 7.5 mL·L⁻¹ at 80% bloom.

3) Terg 7.5 mL·L⁻¹ @ 40% & 80% Bl, where trees received Tergitol TMN-6 at 40% bloom and again at 80% bloom, each time at the rate of 7.5 mL·L⁻¹.

4) Terg 10 mL·L⁻¹ @ 60% Bl, where trees received Tergitol TMN-6 at 60% bloom at the rate of 10 mL·L⁻¹ (**Figure 3**).

5) Terg 10 mL·L⁻¹ @ 80% Bl, where trees received Tergitol TMN-6 at 80% bloom at the rate of 10 mL·L⁻¹.

6) Terg 10 mL·L⁻¹ @ 40% & 80% Bl, where trees received Tergitol TMN-6 at 40% bloom and again at 80% bloom, each time at the rate of 10 mL·L⁻¹.

7) Terg 10 mL·L⁻¹ @ 100% Bl, where trees received Tergitol TMN-6 at 100% bloom at 10 mL·L⁻¹ (**Figure 4**).

8) Terg 15 mL·L⁻¹ @ 80% Bl., where trees received Tergitol TMN-6 at 80% bloom at 15 mL·L⁻¹.

9) Terg 15 mL·L⁻¹ @ 100% Bl, where trees received Tergitol TMN-6 at 100% bloom at 15 mL·L⁻¹.



Figure 3. Tergitol TMN-6 spray at 60% bloom in “Summer Lady” peach in Sunny Slope, Idaho in 2016.



Figure 4. Tergitol TMN-6 spray at 100% bloom in “Summer Lady” peach in Sunny Slope, Idaho in 2016.

B. Treatments on “Summer Lady” Peach at Symms Fruit Ranch in 2017:

These trees received either a single or double application of blossom thinners. First application was made on March 30, 2017, when 40% blooms were open, and temperatures were 15.0°C to 18.3°C. In treatments with a double application, in addition to the first treatment, trees also received a blossom thinner on March 31, 2017 when 80% blooms were open and temperatures were 7.2°C to 8.9°C. The rates and times of applications in 2017 were as follows:

- 1) Un-treated Control.
- 2) Terg 7.5 mL·L⁻¹ @ 80% Bl, where trees received Tergitol TMN-6 at 80% bloom at the rate of 7.5 mL·L⁻¹.
- 3) Terg 10 mL·L⁻¹ @ 80% Bl, where trees received Tergitol TMN-6 at 80% bloom at the rate of 10 mL·L⁻¹.
- 4) Terg 7.5 mL·L⁻¹ @ 40% & 80% Bl, where trees received Tergitol TMN-6 at 40% and again at 80% bloom at the rate 7.5 mL·L⁻¹.
- 5) Terg 10 mL·L⁻¹ @ 40% & 80% Bl, where trees received Tergitol TMN-6 at 40% and again at 80% bloom, each time at the rate of 10 mL·L⁻¹.
- 6) FO 20 mL·L⁻¹ Plus LS 25 mL·L⁻¹ @ 40% & 80% Bl, where trees received Crocker Fish Oil at 20 mL·L⁻¹ plus Lime sulfur at 25 mL·L⁻¹, applied at 40% and again at 80% bloom.
- 7) LS20 mL·L⁻¹ @ 40%&80% Bl, where trees received lime sulfur at 20mL·L⁻¹, applied at 40% and again at 80% bloom.

C. Treatments at the University of Idaho, Parma, Idaho “Zee Lady” and “Snow Giant” Peaches in 2016:

These trees received blossom thinners on April 13, 2016, when blooms were at about 60% open and temperatures were 16.0°C to 18.3°C, or on April 15, 2016, when about 80% blooms were open and temperatures were 17.0°C to 18.6°C, or on April 16, 2016, when about 100% blooms were open and temperatures were 17.1°C to 18.2°C. The rates and times of applications in 2016 were as follows:

- 1) Un-treated Control.
- 2) Terg 10 mL·L⁻¹ @ 60% Bl, where trees received Tergitol TMN-6 at 60% bloom in “Zee Lady” and “Snow Giant” at the rate of 10 mL·L⁻¹.
- 3) Terg 10 mL·L⁻¹ @ 80% Bl, where trees received Tergitol TMN-6 at 80% bloom in “Zee Lady” and “Snow Giant” (Figure 5) at the rate of 10 mL·L⁻¹.
- 4) Terg 10 mL·L⁻¹ @ 100% Bl, where trees received Tergitol TMN-6 at 100% bloom in “Zee Lady” and “Snow Giant” at the rate of 10 mL·L⁻¹.
- 5) Terg 12 mL·L⁻¹ @ 100% Bl, where trees received Tergitol TMN-6 at 100% bloom in “Zee Lady” and “Snow Giant” at the rate of 12 mL·L⁻¹.

D. Treatments at the University of Idaho, Parma, Idaho “Zee Lady” and “Snow Giant” Peaches in 2017:

These trees received blossom thinners on March 31, 2017, when blooms were at about 40% open and temperatures were 15.0°C to 17.3°C, or at 80% open on April 3, 2017, and temperatures were 17.0°C to 18.7°C. The rates and times of applications in 2017 were as follows:



Figure 5. “Snow Giant” peaches at the University of Idaho Orchards at 80% bloom stage in 2016.

1) Un-treated Control.

2) Terg 10 mL·L⁻¹ @ 70% or 85% Bl, where trees received Tergitol TMN-6 at 70% bloom in “Zee Lady” and 85% bloom in “Snow Giant” at the rate of 10 mL·L⁻¹.

3) Terg 12.5 mL·L⁻¹ @ 70% or 85% Bl, where trees received Tergitol TMN-6 at 70% bloom in “Zee Lady” and 85% bloom in “Snow Giant” at the rate of 12.5 mL·L⁻¹.

4) FO 20 mL·L⁻¹ plus LS25 mL·L⁻¹ @ 70% Bloom for “Zee Lady” and 80% Bl, where trees received Crocker Fish Oil at the rate of 20 mL·L⁻¹ and lime sulfur at the rate of 25 mL·L⁻¹ at 70% bloom in “Zee Lady” and 85% bloom in “Snow Giant”.

5) ATS 20 mL·L⁻¹ @ 70% bloom in “Zee Lady” and 85% bloom in “Snow Giant” at the rate of 20 mL·L⁻¹.

Treatments on “Red Globe” and “Elberta” Peaches in Utah, 2016:

These trees received blossom thinners on April 15, 2016, when blooms were at about 80% open and temperatures were 15.0°C to 17.3°C, or on April 17, 2016, when about 100% blooms were open and temperatures were 17.1°C to 18.0°C. The rates and times of applications in 2016 were as follows:

1) Un-treated Control.

2) Terg 7.5 mL·L⁻¹ @ 80% Bl, where trees received Tergitol TMN-6 at 80% bloom at the rate of 7.5 mL·L⁻¹.

3) Terg 10 mL·L⁻¹ @ 80% Bl, where trees received Tergitol TMN-6 at 80% bloom at the rate of 10 mL·L⁻¹.

4) Terg 12 mL·L⁻¹ @ 100% Bl, where trees received Tergitol TMN-6 at 100% bloom at the rate of 12 mL·L⁻¹.

E. Treatments on “Diamond Ray” Nectarine at Williamson Orchards, 2016:

These trees received either a single or double application of Tergitol TMN-6. The single applications were made once at 40% bloom on April 14, 2016, when temperatures were 16.6°C to 18.3°C, or at 80% bloom on April 15, 2016 when temperatures were 16.6°C to 17.8°C, or at 100% bloom on April 18, 2016, when

temperatures were 6.7°C to 18.9°C. Trees with double applications received two of the above-mentioned treatments. The rates and times of applications were as follows:

- 1) Un-treated Control.
- 2) Terg 7.5 mL·L⁻¹ once @ 80% Bl, where trees received Tergitol TMN-6 at 80% bloom at the rate of 7.5 mL·L⁻¹.
- 3) Terg 7.5 mL·L⁻¹ @ 40% & 80% Bl, where trees received Tergitol TMN-6 at 40% and again at 80% bloom, each time at the rate of 7.5 mL·L⁻¹.
- 4) Terg 10 mL·L⁻¹ @ 80% Bl, where trees received Tergitol TMN-6 at 80% bloom, at the rate of 10 mL·L⁻¹.
- 5) Terg 10 mL·L⁻¹ @ 40% & 80% Bl, where trees received Tergitol TMN-6 at 40% and again at 80% bloom, each time at the rate of 10 mL·L⁻¹.
- 6) Terg 15 mL·L⁻¹ @ 100% Bl, where trees received Tergitol TMN-6 at 100% bloom (**Figure 6**), at the rate of 15 mL·L⁻¹ Tergitol TMN-6.

The experimental design in stone fruit experiments was 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, four guard rows or buffers were put between the sets of adjacent experimental rows. Therefore, in each treatment, a total of 16 trees were used for sampling.

3. Results and Discussion

Symptoms of Tergitol TMN-6 Applications. General symptoms of Tergitol TMN-6 sprays in nectarine and peaches were similar. All petals or portions of petals were burned and became pale (**Figure 7**). The paleness and degree of petal burning varied depending on the petal color and rate of Tergitol TMN-6, and stage of blooms at the time of application.



Figure 6. Stage of 100% bloom for blossom thinning study in nectarine.



Figure 7. Caustic symptom of Tergitol TMN-6 applications after 24 - 36 hours in peaches.

3.1. Experiments on “Summer Lady” Peach in Sunny Slope

Application of all blossom thinners treatments significantly reduced fruit set in the “Summer Lady” peaches in both 2016 and 2017 (**Table 1**). In 2016 and 2017, fruit set reduction in “Summer Lady” peach trees with a double application of Tergitol TMN-6 at the rate of $7.5 \text{ mL}\cdot\text{L}^{-1}$ or $10 \text{ mL}\cdot\text{L}^{-1}$, each rate at 40% and 80% bloom, were similar to those receiving a single Tergitol-TMN spray at $15 \text{ mL}\cdot\text{L}^{-1}$ at 80% or 100% bloom (**Table 1**). However, trees of the above-mentioned applications had significantly lower fruit set than those receiving a single application (**Table 1**).

Trees receiving Fish Oil at $20 \text{ mL}\cdot\text{L}^{-1}$ plus lime sulfur at $25 \text{ mL}\cdot\text{L}^{-1}$, once at 40% bloom and again at 80% bloom reduced fruit set as compared to Un-treated Control but, the fruit set was higher than those with any Tergitol-TMN-6 spray in 2017 (**Table 1**).

Fruit weight was often proportional to the severity of thinning (**Table 1**). Trees in Un-treated Control had the highest number of fruit but lowest fruit weight (**Table 1**). Application of Tergitol at $10 \text{ mL}\cdot\text{L}^{-1}$ at 40% and 80% bloom caused overthinning in both 2016 and 2017 and resulted in production of largest fruit but lower number of fruit and yield per tree in 2016 (**Table 1**). Thus, this rate and frequency is not recommended for “Summer Lady” peach blossom thinning. Based on our experience (not published) and another report [18], a marketable medium-large “Summer Lady” peach fruit would weigh about 166 - 176 grams. Trees receiving Terg $10 \text{ mL}\cdot\text{L}^{-1}$ @ 100% Bl, Terg $15 \text{ mL}\cdot\text{L}^{-1}$ @ 80% Bl, and Terg $15 \text{ mL}\cdot\text{L}^{-1}$ @ 100% Bl had average fruit weight above 166 g and yield above 72 kg/tree, without any adverse effects on fruit color or russetting in 2016 (**Table 1, Figure 8**), and can be considered optimum rates and bloom stage for Tergitol TMN-6 sprays. However, If the market demands for smaller fruit size with the same yield threshold (*i.e.* fruit size of above 156 g and yield of above 72 kg/tree), application of Terg $7.5 \text{ mL}\cdot\text{L}^{-1}$ @ 80% Bl, Terg $10 \text{ mL}\cdot\text{L}^{-1}$ @ 60% Bl, and

Table 1. Effect of blossom thinners on “Summer Lady” peach fruit set in 2016 and 2017 and yield and fruit quality attributes at harvest in 2016.

Blossom Thinner & Bloom Stage	Fruit set (No/100 flowers)		2016 Yield (kg/tree)	2016 Avg. Fruit weight (g)	2016 Fruit no (per tree)	2016 Fruit color (1 - 5) ^y	2016 Fruit russet (%)
	2016	2017					
Un-treated Control	68.67 a ^z	41.63 a	77.91 a	141.19 d	552 a	2.70 c	5.36 a
Terg 7.5 mL·L ⁻¹ @ 80% Bl	38.97 bc	2.49 c	77.56 a	157.17 c	493 a	3.28 b	2.58 a
Terg 7.5 mL·L ⁻¹ @ 40% & 80% Bl	19.65 d	0.47 d	56.44 bc	180.11 ab	313 bc	3.60 ab	5.91 a
Terg 10 mL·L ⁻¹ @ 60% Bl	42.70 b	-	72.29 ab	157.52 c	446 ab	3.83 a	7.50 a
Terg 10 mL·L ⁻¹ @ 80% Bl	37.44 bc	4.51 c	76.18 a	156.91 c	486 a	3.98 a	3.33 a
Terg 10 mL·L ⁻¹ @ 40% & 80% Bl	14.22 d	0.02 d	52.43 c	190.09 a	276 c	4.04 a	6.06 a
Terg 10 mL·L ⁻¹ @ 100% Bl	34.60 c	-	84.49 a	166.04 bc	509 a	3.65 ab	4.17 a
Terg 15 mL·L ⁻¹ @ 80% Bl	16.64 d	-	76.87 a	181.43 ab	424 ab	3.93 a	7.50 a
Terg 15 mL·L ⁻¹ @ 100% Bl	17.44 d	-	72.72 ab	182.93 a	398 b	3.92 a	5.13 a
FO 20 mL·L ⁻¹ & LS25 mL·L ⁻¹ @ 40% & 80% Bl	-	8.61 b	-	-	-	-	-
ATS LS 20 mL·L ⁻¹ @ 40% & 80% Bl	-	8.45 b	-	-	-	-	-

^zMean separation within each column by LSD at 5% level. ^yFruit color ranking: 1 = green, progressively to 5 = uniform red.



Figure 8. Harvest time picture of a “Summer Lady” peach tree, receiving a perfect blossom thinning followed by a hand thinning in 2016.

Terg 10 mL·L⁻¹ @ 80% Bl would be suitable. In these cases, the numbers of fruit per tree were between 398 and 509 (Table 1). Based on this study, double applications of Terg 7.5 mL·L⁻¹ or higher resulted in larger fruit size but drastically reduced yield. Thus, a double application should either be avoided or only be applied when the market demands and justifies for larger fruits with lower yield.

In general, the results of Tergitol TMN-6 on peach thinning in this study agreed with our previous report [13] and that of Wilikins *et al.* [14] with different groups of peach cultivars.

3.2. Experiments on “Zee Lady” and “Snow Giant” Peaches at the University of Idaho

Comparing to trees of Un-treated Control, trees receiving Tergitol TMN-6 at 12.5 mL·L⁻¹ at 100% bloom or 10 mL·L⁻¹ at all bloom stages of bloom in 2016 (Terg 10 mL·L⁻¹ @ 60% Bl, Terg 10 mL·L⁻¹ @ 80% Bl, Terg 10 mL·L⁻¹ @ 100% Bl, Terg 12.5 mL·L⁻¹ @ 100% Bl) and Tergitol at 10 mL·L⁻¹ or 12.5 mL·L⁻¹; **Table 2** and **Table 3**) and at 70% or 80% bloom in 2017 (**Table 4**) significantly reduced fruit set in “Zee Lady” and “Snow Giant” peaches. In “Zee Lady”, the percentages of fruit dropped on the ground (PFDG) in each treatment approximately mirrored its fruit set percentage in 2016. Thus, trees in Un-treated Control had significantly higher PFDG than all other treatments (**Table 2**).

It is noteworthy that in “Zee Lady” peach, applications of Tergitol at 60% or 100% bloom (Terg 10 mL·L⁻¹ @ 60% Bl or Terg 10 mL·L⁻¹ @ 100% Bl) were less effective on fruit set education than the sprays of Terg 10 mL·L⁻¹ @ 80% Bl or Terg 12.5 mL·L⁻¹ @ 100% Bl in 2016 (**Table 2**). This result implies that a single application of at Tergitol TMN-6 to “Zee Lady” peach at 10 mL·L⁻¹ at 60% bloom is too early, as blooms are not sufficiently open and pollinized. Also, application of Tergitol TMN-6 to “Zee Lady” peach at 10 mL·L⁻¹ at 100% bloom is too late as most flowers are already fertilized and they cannot be sufficiently thinned at this rate. Nevertheless, when the rate was increased to 12.5 mL·L⁻¹, this chemical significantly reduced fruit set of “Zee Lady” peach even at 100% bloom in 2016. However, when “Snow Giant” trees were at 100% bloom stage, application of Tergitol TMN-6 at 12.5 mL·L⁻¹ resulted in significantly lower fruit set as compared to all other treatments in 2016 (**Table 3**). Also, application of Tergitol at 10.0 mL·L⁻¹ at 100% bloom effectively reduced fruit set in “Snow Giant”. This comparison reveals that “Snow Giant” peach is more sensitive than “Zee Lady” to the same stage of bloom and concentrations of Tergitol TMN-6. Therefore, response of cultivar, concentration of blossom thinner and stage of blooms are all crucial in the success or failure of blossom thinning.

In “Zee Lady”, trees receiving Tergitol TMN-6 at 12.5 mL·L⁻¹ at 100% bloom had smaller fruit in 2016 (**Table 2**), perhaps because this rate resulted in minor leaf burning, reducing carbohydrate deposit into the fruit tissues. Nevertheless,

Table 2. Effect of Tergitol TMN-6 on fruit set, yield, and fruit quality in “Zee Lady” peach in 2016.

Treatment	Thinned fruit on ground (%)	Fruit set (Fruit no/100 flowers)	Yield (kg/tree)	Fruit russet (%)	Avg. fruit weight (g)	Fruit number (No/tree)	Fruit color (1 - 5) ^y	Fruit russet (%)
Un-treated Control	81.00 a ^z	43.58 a	23.12 a	2.14 a	191.5 ab aab	121 a	3.38 a	2.14 a
Terg 10 mL·L ⁻¹ @ 60 Bl	50.3 b	26.10 b	30.36 a	1.43 a	19.86 a	153 a	3.50 a	1.43 a
Terg 10 mL·L ⁻¹ @ 80 Bl	42.67 c	16.25 c	24.84 a	0.01 a	194.81 a	128 a	3.60 a	0.01 a
Terg 10 mL·L ⁻¹ @ 100 Bl	48.33 bc	26.00 b	23.46 a	0.00 a	199.93 a	117 a	3.30 a	0.01 a
Terg 12.5 mL·L ⁻¹ @ 100 Bl	52.80 b	15.99 c	23.46 a	1.43 a	186.80 b	126 a	3.65 a	1.43 a

^zMean separation within each column by LSD at 5% level. ^yFruit color ranking: 1 = green, progressively to 5 = uniform red. ^zFruit color ranking: 1 = green, progressively to 5 = uniform red.

Table 3. Effect of Tergitol TMN-6 on fruit set, yield, and fruit quality at harvest in “Snow Giant” peach in 2016.

Treatment	Fruit set (No./100 flowers)	Yield (kg/tree)	Fruit weight (g)	Color (1 - 5) ^z	Russet (%)
Un-treated Control	67.67 a ^y	23.22 a	216.85 b	2.28 a	1.39 b
Terg 10 mL·L ⁻¹ @ 60 Bl	57.55 b	23.33 a	243.92 a	2.39 a	4.72 ab
Terg 10 mL·L ⁻¹ @ 80 Bl	54.79 bc	23.39 a	236.11 a	2.33 a	5.84 a
Terg 10 mL·L ⁻¹ @ 100 Bl	49.97 c	23.45 a	242.03 a	2.41 a	3.95 ab
Terg 12.5 mL·L ⁻¹ @ 100 Bl	43.18 d	22.05 a	242.51 a	2.43 a	6.95 a

^zFruit color ranking: 1 = green, progressively to 5 = uniform red. ^yMean separation within each column by LSD at 5% level.

Table 4. Effect of fish oil, ammonium thiosulfate, and Tergitol TMN-6 on fruit set in “Zee Lady” peach at 70% bloom and “Snow Giant” peaches at 85% bloom in 2017.

Treatment	Fruit set in “Zee Lady” at 70% bloom (Fruit/100 flower)	Fruit set in “Snow Giant” at 85% bloom (Fruit/100 flower)
Un-treated Control	41.57 a ^z	45.50 a
FO 20 mL·L ⁻¹ plus LS25 mL·L ⁻¹ @ 70% Bl ZL 80% Bl SG	36.23 a	41.84 ab
ATS 20 mL·L ⁻¹ @ 70% Bl ZL 80% Bl SG	33.40 ab	37.21 b
Terg 10 mL·L ⁻¹ @ 70 Bl ZL 80% SG	25.80 bc	19.18 c
Terg 12.5 mL·L ⁻¹ @ 70 Bl ZL 80% SG	21.33 c	17.37 c

^zMean separation within each column by LSD at 5% level.

in “Snow Giant”, trees receiving Tergitol TMN-6 at all concentrations and blossom stages had significantly higher fruit weight as compared to the trees of Un-treated Control in 2016 (**Table 3**). Application of Tergitol TMN-6 in 2016 did not affect fruit russetting in “Zee Lady” in (**Table 2**) while tended to increase russetting in “Snow Giant” fruit (**Table 3**). This observation is particularly important when “Snow Giant” white-fleshed peach is produced for the Asian market. This market usually mandates blemish-free or fruit with minimum russet.

Yield and fruit color were not influenced by Tergitol TMN-6 application at any rate or blossom stage in either “Zee Lady” (**Table 2**) or “Snow Giant” peach (**Table 3**) in 2016 because fruits in all trees in this study were hand-thinned to establish a uniform crop with 15 - 18 cm spacing between fruits.

Blossom thinning study in 2017 revealed that application of FO plus LS did not reduce peach fruit set in either “Zee Lady” or “Snow Giant”, while application of ATS at 20 mL·L⁻¹ at 80% bloom reduced fruit set in “Snow Giant” peach (**Table 4**). However, a single application of Tergitol TMN-6 at the rate of either 10 mL·L⁻¹ or 12.5 mL·L⁻¹ on “Zee Lady” at 70% bloom or “Snow Giant” at 80% bloom significantly reduced fruit set in 2017 (**Table 4**). In a previous report, ammonium thiosulfate (ATS, 55%) was also an effective blossom thinner and reduced set in “Garnet Beauty” and “Redhaven” peaches over 3 years [10]. Nevertheless, based on our experience, ATS effects could fluctuate from place to place and year to year, depending on the temperature, and may occasionally

cause fruit russetting.

3.3. The Experiment on “Red Globe” and “Elberta” Peaches, Utah

Comparing with untreated -control, applications of Tergitol TMN-6 at all concentrations at 80% bloom significantly reduced fruit set (**Table 5**) and increased fruit weight but did not affect yield in “Red Globe” and “Elberta” peaches in Utah (data not shown). The fruit set reduction was inversely proportional to the rate of application in these cultivars in 2016 (**Table 5**).

3.4. The Experiment on “Diamond Ray” Nectarine

Application of Tergitol TMN-6 at all rates and bloom stages significantly reduced fruit set and yield but increased fruit weight, color, and russet in “Diamond Ray” nectarine in 2016, although differences were not always significant (**Table 6**). Production of russet-free fruit in nectarines is extremely critical for export market but this practice is one of the most difficult tasks facing fruit growers. Application of Tergitol TMN-6 at 7.5 mL·L⁻¹, either once at 80% bloom or twice, at 40% and again at 80%, produced relatively large fruit size and high yields, while had lower fruit russet than other rates (20.83% and 21.49%, respectively; **Table 6**). Thus, if low levels of russetting could be tolerated in this nectarine, Tergitol TMN-6 at 7.5 mL·L⁻¹ can be used to reduce the fruit set and cost of production and increase the net return.

Table 5. Effect of Tergitol TMN-6 on fruit set of “Red Globe” and “Elberta” in peaches in Utah, 2016.

Treat	Red Globe fruit set (Fruit no./100 flowers)	Elberta unit set (Fruit no./100 flowers)
Un-treated Control	65.49 a ^z	50.26 a
Terg 7.5 mL·L ⁻¹ @ 80% Bl	46.81 b	33.48 b
Terg 10 mL·L ⁻¹ @ 80% Bl	43.23 bc	32.76 b
Terg 12.5 mL·L ⁻¹ @ 80% Bl	35.57 c	27.39 b

^zMean separation within each column by LSD at 5% level.

Table 6. Effect of Tergitol TMN-6 on fruit set, yield, and fruit quality in “Diamond Ray” nectarine at harvest, 2016.

Treat	Fruit Set (Fruit no./100 flowers)	Yield (kg/tree)	Avg. Fruit weight (g)	Color (1 - 5) ^z	Russet (%)
Un-treated Control	50.87a ^y	43.71 a	136.06 c	2.50 c	9.87 c
Terg 7.5 mL·L ⁻¹ @ 80% Bl	14.40 b	29.17 b	156.67 ab	2.75 abc	20.83 b
Terg 7.5 mL·L ⁻¹ @ 40% & 80% Bl	10.86 bc	28.47 b	149.04 ab	2.92 abc	21.49 b
Terg 10 mL·L ⁻¹ 80% Bl	9.82 bc	22.91 bc	145.98 b	2.64 bc	22.99 b
Terg 10 mL·L ⁻¹ @ 40% & 80% Bl	8.49 bc	16.65 c	159.05 a	3.00 ab	32.57 a
Terg 15 mL·L ⁻¹ @ 100% Bl	5.39 c	21.53 bc	151.44 ab	3.16 a	24.61 ab

^zFruit color ranking: 1 = green, progressively to 5 = uniform red. ^yMean separation within each column by LSD at 5% level.

4. General Remarks and Conclusions

Stage of bloom, temperature, bee activity, varietal differences, wind, tree vigor, and spray volume are among factors influencing the effectiveness of blossom thinning in apples and stone fruit [4]. Temperature affects bee activity and thus, the number of fertilized flowers. In this study, when the conditions are in favor of heavy fruit set, it seemed that applications of Tergitol TMN-6 at $10 \text{ mL}\cdot\text{L}^{-1}$ at 80% bloom or $12.5 \text{ mL}\cdot\text{L}^{-1}$ at 100% bloom, led to optimum thinning. 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 lime sulfur at $25 \text{ mL}\cdot\text{L}^{-1}$ at 70% to 85% bloom may be enough. One should be cautious about fruit marking and leaf burning with the application of blossom thinners.

Fine-tuning and a timely application of Tergitol TMN-6 can be economically sound. However, early applications of this chemical, before enough pollination and fertilization may lead to major losses. Additional research on blossom thinning is also warranted to discover a quick method that can determine a proper blossom stage based on physiological development of pollen tube and/or fertilization of the ovules.

The limitation of our study is similar to those of any other regional plant bio-regulator study. In any study involving a plant bio-regulator, including blossom thinner, the interaction of that chemical and the environmental and climatic factors needs to be carefully investigated for each region. Then results need to be compared in various regions to have a more comprehensive knowledge about the impact of that blossom thinner in different areas.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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