

Tergitol-TMN-6 Surfactant Is an Effective Blossom Thinner for Stone Fruits

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Abstract. Effects of Tergitol-TMN-6 surfactant on blossom thinning (fruit set), fruit quality, and yield were studied in different cultivars of peach (*Prunus persica* [L.] Batsch) during 2003 to 2005, and in one cultivar of nectarine *Prunus persica* [L.] in one orchard and one cultivar of plum (*Prunus domestica* [L.]) in two orchards in 2004. In addition to Tergitol-TMN-6, effects of Crocker's fish oil (CFO) alone in three peach cultivars or in combination with lime sulfur in a nectarine cultivar were studied on fruit set, quality, and yield. Tergitol-TMN-6 at 5 mL·L⁻¹ or higher rates, applied at about 75% to 85% bloom, reduced fruit set without russetting peach fruit. Peach fruit size was often increased by Tergitol-TMN-6 treatment. Applications of Tergitol at 20 mL·L⁻¹ or 30 mL·L⁻¹ excessively thinned peaches. Tergitol-TMN-6 at all rates burned foliage, but the symptoms disappeared after a few weeks without any adverse effects on tree productivity. Tergitol-TMN-6 at 7.5 mL·L⁻¹ or 10 mL·L⁻¹, applied either once at about 80% to 85% bloom or twice at 35% bloom and again at 80% to 85% bloom, reduced fruit set without any fruit russetting in nectarine. Tergitol-TMN-6 at 7.5 mL·L⁻¹ to 12.5 mL·L⁻¹ reduced fruit set in 'Empress' plum. CFO at 30 mL·L⁻¹ was effective in blossom thinning of some peach cultivars. A combination of lime sulfur and CFO was not effective in blossom thinning of nectarine. Considering results from several orchards in different locations in the Pacific Northwest over 3 years, Tergitol-TMN-6 is an excellent blossom thinner for peach, nectarine, and plum at rates of 7.5 to 12.5 mL·L⁻¹, sprayed at a spray volume of 1870.8 L·ha⁻¹ when about 75% to 85% blooms are open.

Early thinning of stone fruit and apples is important because of its impact on fruit size (Fallahi, 1997; Fallahi et al., 1997). Many blossom thinners are caustic, and reduce fruit

set by damaging different flower parts, including anthers, stigmas, styles, and pollen tubes, and thus prevent fertilization (Fallahi and Willemsen, 2002; Hildebrand, 1944). Hydrogen cyanamide (Dormex, 50% a.i.) and some other chemicals were initially used to reduce chilling requirements of peaches grown in southwest Arizona, but when applied at "pink bloom," reduced the number of open blossoms (Fallahi et al., 1990). Based on this observation, Dormex was sprayed at different concentrations at prebloom and full bloom on 'Florda Prince' peach (Fallahi et al., 1990). Results indicated that Dormex at 10 mL·L⁻¹ applied at full bloom significantly reduced fruit set in 'Florda Prince' peach (Fallahi, unpublished data). In later studies, Dormex was also found to be an effective blossom thinner for plums (Fallahi et al., 1992) and peaches (Fallahi, 1997) in Idaho. In commercial-scale trials, full-bloom applications of Dormex at 2.5 to 3.12 mL·L⁻¹

significantly reduced fruit set in 'Flavorcrest' peach (Fallahi et al., 1998). Dormex was a more consistent blossom thinner for apple and peach than monocarbamide dihydrogen sulfate or sulcarbamide (Wilthin, 79% a.i.), 7, oxybicyclo(2,2,2) heptane-2-3 dicarboxylic acid (Endothall, 0.5% a.i.; an aquatic herbicide), and pelargonic acid (Thinex) (Fallahi, 1997; Fallahi et al., 1997). In field trials in Washington, California, and Idaho, Endothall was an effective blossom thinner for apples and stone fruit (Fallahi, 1997; Warner, 1998). Fallahi (1997) reported that Endothall effectively thinned 'Redhaven' peach blossoms at a rate of 1.87 mL·L⁻¹ formulation when 85% to 90% of blooms were open. However, Endothall was ineffective when applied at 100% bloom, when most flowers were already fertilized. Wilthin has been used for blossom thinning in stone fruit, including peaches (Fallahi, 1998; Greene et al., 2001; Warner, 1998) and plums (Fallahi, 1998). 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 (Fallahi and Willemsen, 2002). In a comparison of ammonium thio sulfate (ATS), Wilthin, and Endothall, it was found that ATS was the best blossom thinner under Washington conditions (Warner, 1998). In that report, however, fruits from ATS-treated trees remained small. Blossom thinning of sweet cherry (*Prunus avium* L.) with ATS and Crocker's fish oil (CFO) is becoming extremely important because newly developed dwarf rootstocks may result in smaller fruits if the crop is not thinned, and scientists in Washington are leading this field of research. Whiting and colleagues (2006) reported that a double application of ATS or CFO, once at 10% bloom and again at 90% bloom, significantly reduced fruit set on 'Bing' cherry in 2 years under conditions of central Washington. Full-bloom application of the surfactant N, N-bis(2-(omegahydroxypolyoxyethylenepolyoxypropylene) ethyl alkylamine (Armothin) at 30 mL·L⁻¹ or 5 mL·L⁻¹ reduced fruit set in 'Loadel' peach in California (Southwick et al., 1998).

Byers and Lyons (1985) reported that Surfactant WK killed peach flowers by killing peduncles and pistils. Thus, the mode of action of this chemical is different from most other caustic thinners that are only toxic to pistils or stamens. Surfactant 2,6,8-trimethyl-4-nonyloxypolyethyleneoxyethanol (Tergitol) TMN-6 (90% aq.) was at least one of the putative a.i. of Surfactant WK, a surfactant that was labeled by DOW Chemical Company and available during the 1980s. Wilkins and associates (2004) reported that Tergitol-TMN-6 effectively reduced fruit set in 'Fireprince' peach under climatic conditions of Clanton, Ala. 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.

Despite considerable production of stone fruit worldwide, there is no reliable blossom

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thinner available for these fruit crops. Growers spend between \$960 to \$2600 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 new and reliable blossom thinner for stone fruits. The goal of this study was to determine the efficacy of Tergitol-TMN-6 on blossom thinning, fruit quality, and yield in different cultivars of peaches and one cultivar of nectarine and plum. We have also studied the effects of CFO from Quincy, Wash., on the efficacy of thinning several cultivars of peach.

Materials and Methods

General experimental design, orchard conditions, and methods

Several experiments were conducted on peaches (*Prunus persica* [L.] Batsch) during 2003 through 2005, 'Empress' plum (*P. domestica* [L.]) in 2004, and 'July Red' nectarine in 2005. The experimental design in all experiments was a randomized complete block design with three blocks. Each block consisted of two adjacent rows, and each row had eight trees per treatment. To avoid contamination (border effect), four trees in the middle of the eight-tree segment per row were selected for sampling, although the entire eight trees received the same treatment. Also, at least two buffer rows were situated between the sets of adjacent experimental rows. Therefore, each treatment had eight trees per block, with total of 24 trees per experiment. Analysis of variance were computed using the statistical package by SAS (Raleigh, N.C.) for all experiments, and means were separated using LSD at the 5% level. A factorial arrangement and orthogonal contrast analysis were also used in a peach experiment in 2004 and a nectarine experiment in 2005, and is described later. Air blast sprayers were used in all experiments throughout this study. No surfactant was used in any of the experiments in this study.

The planting space and age of trees varied from experiment to experiment, but all trees were on Lovell peach rootstock. All experimental orchards had sandy loam soils with a pH of about 7.5. Other than the case for the 'Zee Lady' and 'Snow Giant' experiments in 2005, all trees were pruned to an 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.

On different sides of each tree, four fruit-bearing hangers or branches were randomly selected and tagged at their base. Fruit set was calculated by one or two of the following methods. For method 1, the 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 fruit on the tagged hangers or branches was counted after "June drop." Fruit set in method 1 was calculated as fruit number/flower number \times 100. For method 2,

the diameter of each tagged hanger or branch at its basal point was measured using a digital caliper (Digimatic model CD-6; Mitutoyo, Tokyo, Japan), and the cross-sectional area of that basal point was calculated. The total number of fruit on the tagged hangers or branches was counted after "June drop," just before the "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 13 to 15-cm spacing between fruits. Trees used for the "control" in all experiments did not receive any blossom thinner but received hand thinning as described earlier. These hand-thinned trees are referred to as "control" throughout the article and tables.

Yield per tree for all tested stone fruits was recorded. In all experiments, the final yield in the "control" trees should be considered the targeted crop load and be used for comparison with blossom thinners' responses, because hand thinning alone is currently the standard thinning practice in the stone fruit industry. About 50 fruit per tree were sampled at harvest, cleaned, visually evaluated for russeting (fruit marks), and percentage of fruit russeting was calculated. Thirty of these fruit 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). Fruit weight was used as the measure for fruit size.

Experiments in 2003

In 2003, three commercial orchards in Fruitland, Idaho, and two in Sunny Slope, Idaho, were used for blossom-thinning experiments. Each of these orchards had a different cultivar.

One of the two orchards in Sunny Slope was a 10-year-old 'Elberta' at 2.7×5.5 -m spacing and the other one was a 5-year-old 'August Lady' at 2.4×4.9 -m spacing. Both cultivars received the same treatments on 31 Mar. 2003, when trees of 'Elberta' peaches were in about 70% to 75% bloom and those in 'August Lady' were about 80% bloom. The treatments were control, CFO at $30 \text{ mL}\cdot\text{L}^{-1}$, Tergitol-TMN-6 (90% aq.) at $5 \text{ mL}\cdot\text{L}^{-1}$, and Tergitol-TMN-6 at 10, 20, or $30 \text{ mL}\cdot\text{L}^{-1}$. All applications were made at a spray volume of $1870.8 \text{ L}\cdot\text{ha}^{-1}$. Trees had no freeze damage before blossom thinning and had heavy bloom and moderately good pollination conditions. During treatment, the weather was calm, sunny, and air temperature was about $21.1 \text{ }^\circ\text{C}$ and reached a maximum of $23.8 \text{ }^\circ\text{C}$ during that day. Fruit set was calculated based on method 2 for 'Elberta' and 'August Lady' in 2003.

The three orchards in Fruitland were 6-year-old trees of 'Red Globe', 'Blazing Star', and 'Redhaven'. The tree spacing in each of these orchards was $2.4 \times 4.9 \text{ m}$. In each cultivar, treatments were control or Tergitol-TMN-6 at $10 \text{ mL}\cdot\text{L}^{-1}$ or $30 \text{ mL}\cdot\text{L}^{-1}$. In addition to these treatments, 'Red Globe'

received a fourth treatment of CFO at $30 \text{ mL}\cdot\text{L}^{-1}$. The experimental orchards in Fruitland were sprayed on 30 Mar. 2003 when trees in 'Red Globe' were at 83% bloom, 'Redhaven' were at 85% bloom, and 'Blazing Star' were at 90% bloom. Trees were sprayed at $1870.8 \text{ L}\cdot\text{ha}^{-1}$. Trees had no freeze damage before blossom thinning and had heavy bloom and excellent pollination and fertilization conditions. During the spray, it was calm, sunny, and air temperature was about $18.3 \text{ }^\circ\text{C}$ and reached maximum of $21.1 \text{ }^\circ\text{C}$ during that day.

Experiments in 2004

In 2004, two peach cultivars (in two different orchards) in the Sunny Slope area, and two different orchards of plums in Payette, Idaho, were selected. These orchards were a 6-year-old 'August Lady' at $2.4 \times 4.9 \text{ m}$; a 7-year-old 'Zee Lady' at 2.1×5.5 -m spacing; and two orchards, each with 14-year-old trees of 'Empress' plum on plum rootstock, planted at 2.4×4.9 -m spacing. The treatments for both peach orchards in 2004 were control and Tergitol-TMN-6 at $5 \text{ mL}\cdot\text{L}^{-1}$, $7.5 \text{ mL}\cdot\text{L}^{-1}$, or $10 \text{ mL}\cdot\text{L}^{-1}$. In the 'August Lady' orchard, each rate of Tergitol-TMN-6 was applied at a spray volume of either $935.4 \text{ L}\cdot\text{ha}^{-1}$ or $1870.8 \text{ L}\cdot\text{ha}^{-1}$. In the 'Zee lady' orchard, Tergitol-TMN-6 at each rate was sprayed at a spray volume of $1870.8 \text{ L}\cdot\text{ha}^{-1}$. Trees of 'August Lady' were in about 85% and those of 'Zee Lady' were in about 75% bloom at the time of treatment application. Both cultivars were sprayed on 4 Apr. 2004, and temperature at the time of application was about $22.8 \text{ }^\circ\text{C}$, reaching a maximum of $26.1 \text{ }^\circ\text{C}$, with excellent pollination and fertilization conditions before the blossom thinning. Treatments in 'Empress' plum trees in both orchards were control and Tergitol-TMN-6 at $7.5 \text{ mL}\cdot\text{L}^{-1}$, $10 \text{ mL}\cdot\text{L}^{-1}$, or $12.5 \text{ mL}\cdot\text{L}^{-1}$, with each concentration applied at a spray volume of $1870.8 \text{ L}\cdot\text{ha}^{-1}$. Plum trees were sprayed on 7 Apr. 2004, when trees were at about 75% to 80% bloom. Temperature at the time of application was about $21.8 \text{ }^\circ\text{C}$, reaching a maximum of $25.1 \text{ }^\circ\text{C}$, with good pollination and fertilization conditions before blossom thinning.

In 2004, the analysis of data in the 'August Lady' peach experiment was carried out in two ways. Once all treatments, including the control, were analyzed together and the means were separated by LSD. Then only data with three different rates of Tergitol-TMN-6 with two spray volumes ($935.4 \text{ L}\cdot\text{ha}^{-1}$ or $1870.8 \text{ L}\cdot\text{ha}^{-1}$) were analyzed in a 3×2 factorial arrangement and orthogonal contrast procedure, and the main effects (rate and spray volume) as well as interaction between rate and spray volume were computed using SAS packages.

Peach experiments in 2005

Two peach orchards for the 2005 experiments were located at the University of Idaho Parma Research and Extension Center near Parma, Idaho. The trees were planted at 1.8×5.0 -m spacing and trained to a Y-shape

system. Treatments for these experiments were control and Tergitol-TMN-6 at 7.5 mL·L⁻¹, 10 mL·L⁻¹, or 12.5 mL·L⁻¹, each applied at a spray volume of 1870.8 L·ha⁻¹ on 5 Apr. 2005. At the time of application, 'Zee Lady' was at 75% bloom and 'Snow Giant' was at 85% bloom. It was calm and sunny, with excellent bee activity during blossom thinning, and fertilization conditions were excellent before blossom-thinning application. The temperature during application was about 10.0 °C, and reached a maximum of 14.4 °C that day. In both 'Zee Lady' and 'Snow Giant' orchards, fruit set was measured based on method 2.

'July Red' nectarine experiments in 2005

The orchard was located at Sunny Slope, Idaho, and trees were planted at 3.0 × 5.5-m spacing. The treatments for this orchard were control; CFO at 20 mL·L⁻¹ mixed with lime sulfur at 20 mL·L⁻¹ applied twice; and Tergitol-TMN-6 at 7.5 mL·L⁻¹ or 10 mL·L⁻¹, each rate applied once or twice. Trees that received any blossom thinner treatment twice were sprayed once at 35% bloom and again at about 80% to 85% bloom. Trees receiving one treatment were sprayed when about 80% to 85% of blooms were open, with good pollination and fertilization conditions before the application of blossom thinners. The first applications were made when the temperature was about 15.6 °C, reaching a maximum of 17.8 °C on 2 Apr. 2005. The second applications were made when the temperature was about 13.9 °C, reaching a maximum of 14.4 °C on 5 Apr. 2005. During 2005, all applications were made at a spray volume of 1870.8 L·ha⁻¹.

Blossom buds were counted on 30 Mar. 2005 and fruit set was measured based on method 1, as described earlier. Fruits were sampled for quality evaluation on 23 Aug. 2005.

In 2005, the analysis of data in the 'July Red' nectarine experiment was carried out in two ways. Once all treatments, including control, were analyzed together and means were separated by LSD. Then, only data with two different rates of Tergitol-TMN-6 (7.5 mL·L⁻¹ or 10 mL·L⁻¹) with two frequency of sprays (at 80% to 85% bloom or both at 35% bloom and again at 80% to 85% bloom) were analyzed in a 2 × 2 factorial arrangement and orthogonal contrast procedure, and the main effects (rate and frequency of spray) as well as interaction between rate and frequency of spray were computed using SAS packages.

Peach experiments in Utah in 2005

Eight-year-old trees of 'O'Henry', 'John Henry', and 'Angelus' peaches, each in a different orchard, were selected in Utah during 2005. The tree spacing in all orchards was 2.4 × 4.9 m. The treatments for each cultivar were control and Tergitol-TMN-6 at 7.5 mL·L⁻¹, 10 mL·L⁻¹, or 12.5 mL·L⁻¹, applied when trees were at about 80% bloom at a spray volume of 1870.8 L·ha⁻¹. Temperature during application was about 21.1 °C and reached a maximum of 23.9 °C during that day, with good pollination and fertilization conditions before blossom-thinning application. Fruit set in all cultivars tested in Utah was calculated based on method 1 as described earlier.

Results and Discussion

Experiments in 2003

In Sunny Slope, Idaho, application of Tergitol-TMN-6 at 5 mL·L⁻¹ or higher significantly reduced fruit set in both 'Elberta' and 'August Lady' peaches (Table 1). Tergitol-TMN-6 at 10 mL·L⁻¹, 20 mL·L⁻¹, or 30 mL·L⁻¹ was excessive and resulted in severe foliar injury, overthinning, and lower yields, and the extent of the effects were proportional to the concentration of this chemical

(Table 1). Within about 2 h after application of Tergitol-TMN-6, flowers desiccated, turned dry, and wilted. Early-emerged leaves showed tip burning and turned brown. We observed some burning of the tender twigs in the trees receiving very high rates of Tergitol-TMN-6. Foliage and other injury symptoms recovered after about 4 to 6 weeks.

Application of Tergitol-TMN-6 at 10 mL·L⁻¹ or 20 mL·L⁻¹ increased fruit size in both 'Elberta' and 'August Lady' cultivars in 2003; nevertheless, the fruit size increase in these treatments did not bring their yields up to the level of the control trees that were only hand thinned (Table 1). Application of CFO reduced fruit set in 'Elberta' but not in 'August Lady' (Table 1). However, fruit size was unaffected by CFO in either cultivar. None of the treatments caused any symptoms of fruit russeting in either cultivar (Table 1).

In Fruitland, Idaho, Tergitol-TMN-6 at 10 mL·L⁻¹ or 30 mL·L⁻¹ reduced fruit set and yield but increased fruit size in 'Red Globe', 'Redhaven', and 'Blazing Star' (Table 2). For these parameters, Tergitol-TMN-6 at 30 mL·L⁻¹ was more effective than at 10 mL·L⁻¹, although differences were not always significant. In all cultivars in Fruitland, the yield of the trees treated with Tergitol-TMN-6 at 10 mL·L⁻¹ was closer to the targeted yield (yield of hand-thinned control trees) than that at Sunny Slope. One possible reason is that the trees at Sunny Slope were sprayed at an earlier stage of blossom, and fertilization conditions were not as favorable compared with those in Fruitland. However, similar to the study in the Sunny Slope orchards, applications at 30 mL·L⁻¹ caused overthinning. In Fruitland, CFO at 3% reduced fruit set in 'Red Globe' but had no effect on fruit size and yield, because all trees were hand-thinned at the time of pit hardening, and fruit-to-fruit competition was reduced.

Applications of CFO or Tergitol-TMN-6 even at the highest rate (30 mL·L⁻¹), in either

Table 1. Effects of Tergitol-TMN-6 blossom thinner on fruit set, weight, russeting, and yield in 'Elberta' and 'August Lady' in Sunny Slope, Idaho, during the 2003 season.^{z,y,x}

Treatment	Fruit set, fruit/cm ²		Fruit weight, g		Fruit russeting, %		Yield (kg/tree)	
	Elberta	August Lady	Elberta	August Lady	Elberta	August Lady	Elberta	August Lady
Control	3.46 a	2.37 a	94.6 c	100.1 b	7.5 a	10.4 a	78.2 a	35.9 a
Tergitol 5 mL·L ⁻¹	2.12 b	1.39 b	108.3 c	93.6 b	5.8 a	10.0 a	69.3 a	27.8 ab
Tergitol 10 mL·L ⁻¹	0.46 c	0.27 c	129.5 b	128.8 a	6.4 a	5.0 a	38.3 b	11.0 cd
Tergitol 20 mL·L ⁻¹	0.01 d	0.05 c	153.8 a	151.0 a	16.2 a	16.7 a	2.3 c	0.67 d
Tergitol 30 mL·L ⁻¹	0.001 d	0.004 c	147.9 ab	100.1 b	5.0 a	11.1 a	0.63 c	0.20 d
Crocker's Fish Oil 30 mL·L ⁻¹	2.40 b	2.43 a	94.8 c	98.5 b	10.8 a	6.7 a	66.6 a	16.7 bc

^zMean separation within columns by LSD at 0.05. Each value is a mean of three blocks, each with eight trees.

^y'Elberta' peaches were at 70% to 75% bloom and those in 'August Lady' were at 80% bloom at the time of application.

^xAll applications were made at a rate of 1870.8 L·ha⁻¹.

Table 2. Effects of Tergitol-TMN-6 blossom thinner on fruit set, weight, yield, and russeting in different peach cultivars in commercial orchards in Fruitland, Idaho, during the 2003 season.^{z,y,x}

Treatment	Fruit set, fruit/cm ²			Fruit weight, g			Yield, kg/tree		
	Red Globe	Red Haven	Blazing Star	Red Globe	Red Haven	Blazing Star	Red Globe	Red Haven	Blazing Star
Control	2.84 a	2.20 a	2.88 a	147.5 b	170.5 c	159.9 a	43.5 a	21.8 a	23.2 a
Tergitol 10 mL·L ⁻¹	0.93 c	0.55 b	0.84 b	174.8 b	222.8 b	171.4 a	32.6 b	16.7 b	18.1 b
Tergitol 30 mL·L ⁻¹	0.24 c	0.02 b	0.16 c	239.0 a	261.3 a	185.0 a	13.1 c	2.61 c	5.1 c
Fish Oil 30 mL·L ⁻¹	1.85 b	—	—	178.0 b	—	—	40.6 ab	—	—

^zMean separation within columns by LSD at 0.05. Each value is the mean of three blocks, each with eight trees.

^yStages of bloom for each cultivar was 'Red Globe' at 83% bloom, 'Redhaven' at 85% bloom, and 'Blazing Star' at 90% bloom.

^xAll applications were made at a rate of 1870.8 L·ha⁻¹.

the Sunny Slope or Fruitland locations, did not have any adverse effects on fruit set or vegetative growth during the following year (data not shown).

Experiments in 2004

Tergitol-TMN-6 at 5 mL·L⁻¹ or more, applied at either 935.4 L·ha⁻¹ or 1870.8 L·ha⁻¹ spray volume, significantly reduced fruit set in 'August Lady' peach (Table 3). There was no difference in fruit set between Tergitol-TMN-6 at the 7.5 mL·L⁻¹ and 10 mL·L⁻¹ rates; however, both of these rates had significantly greater effect on reduction of fruit set in 'August Lady' peach than did 5 mL·L⁻¹. Orthogonal contrast analysis revealed that application of Tergitol-TMN-6 at a spray volume of 1870.8 L·ha⁻¹ was more effective in fruit set reduction of 'August Lady' peach than at 935.4 L·ha⁻¹. Fruit size and yield of 'August Lady' peach were unaffected by any of the treatments. There was no interaction between rate of Tergitol-TMN-6 and spray volume for any of the measurements. Tergitol-TMN-6 at 7.5 or 10

mL·L⁻¹ reduced fruit set, but had no effect on fruit size in 'Zee Lady' peach in 2004 (Table 3). Trees treated with Tergitol-TMN-6 at 10 mL·L⁻¹ had lower fruit set than those with 7.5 mL·L⁻¹.

Application of Tergitol-TMN-6 to 'Empress' plums at all rates reduced fruit set and increased fruit size in both orchard 1 (Table 4) and orchard 2 (data not shown). Application of Tergitol-TMN-6 at all rates also increased economic return of 'Empress' plum in orchard 2. No significant differences in blossom thinning were found among the different rates of Tergitol-TMN-6.

Experiments in 2005

Tergitol-TMN-6 at 7.5 mL·L⁻¹, 10 mL·L⁻¹, or 12.5 mL·L⁻¹ reduced fruit set and increased fruit size (Table 5), but had no effect on fruit color and russetting in 'Zee Lady' peach (data not shown). 'Zee Lady' peach trees treated with Tergitol-TMN-6 at 12.5 mL·L⁻¹ had lower fruit set than all other treatments and had lower yield than control trees and those treated with Tergitol at 10

mL·L⁻¹. In 'Snow Giant' peach, Tergitol-TMN-6 at 12.5 mL·L⁻¹ was the only rate that reduced fruit set and yield. Other rates of Tergitol-TMN-6 were ineffective in reducing fruit set in 'Snow Giant', perhaps because this cultivar was sprayed when blooms were in a more advanced stage (85% bloom) and were more fertilized compared with 'Zee Lady', which was at 75% at the time of application. Fruit color and rate of russetting were unaffected by any rate of Tergitol-TMN-6 in 'Snow Giant' peach (data not shown).

Tergitol-TMN-6 at 7.5 mL·L⁻¹ or 10 mL·L⁻¹, applied either once at about 80% to 85% bloom or twice—once at 35% bloom and again at 80% to 85% bloom—reduced fruit set in 'July Red' nectarine in 2005 (Table 6). However, analysis of all treatments (including control) together or in an orthogonal contrast analysis of just Tergitol-TMN-6 treatments as a factorial arrangement revealed that double applications of Tergitol-TMN-6 at either 7.5 mL·L⁻¹ or 10 mL·L⁻¹ resulted in significantly lower fruit set compared with a single application in 'July Red' nectarine. A double application of CFO and lime sulfur did not affect fruit set. In this nectarine, fruit size increased proportionally to the rate and frequency of Tergitol-TMN-6 applications. Yield (Table 6) and fruit color (data not shown) were unaffected by any of the blossom-thinning treatments in 'July Red' nectarine. This is because all trees were hand thinned at the beginning of pit hardening, and the increase in the fruit size between the times of bloom and hand thinning compensated for the reduction in the number of fruits in the trees treated with Tergitol-TMN-6. Tergitol-TMN-6 treatments did not increase severity of nectarine fruit russetting, while reducing the fruit set (Table 6) and needs for hand thinning and labor cost (data not shown). This is an extremely important finding for the nectarine fruit industry, because nectarine fruits are readily russeted by a large number of chemicals, insects, and environmental factors. There was no interaction

Table 3. Effects of Tergitol-TMN-6 blossom thinner on fruit set, weight, and yield of 'August Lady' and 'Zee Lady' peaches in Sunny Slope, Idaho, in 2004.^{zy}

Analysis of treatments	Fruit set, fruit/cm ²		Fruit weight, g		Yield, kg/tree	
	August Lady	Zee Lady	August Lady	Zee Lady	August Lady	Zee Lady
Treatments						
Control	54.3 a	43.6 a	146.2 a	142.9 a	74.2 a	63.7 ab
Tergitol 5 mL·L ⁻¹ at 1870.8 L·ha ⁻¹	40.4 b	37.0 ab	160.5 a	152.9 a	61.3 a	80.8 a
Tergitol 7.5 mL·L ⁻¹ at 1870.8 L·ha ⁻¹	26.6 c	31.1 b	163.6 a	156.9 a	57.6 a	63.5 ab
Tergitol 10 mL·L ⁻¹ at 1870.8 L·ha ⁻¹	25.4 c	23.2 c	163.5 a	144.3 a	57.7 a	48.4 b
Tergitol 5 mL·L ⁻¹ at 935.4 L·ha ⁻¹	42.7 b	—	137.9 a	—	48.2 a	—
Tergitol 7.5 mL·L ⁻¹ at 935.4 L·ha ⁻¹	31.9 c	—	150.5 a	—	62.6 a	—
Tergitol 10 mL·L ⁻¹ at 935.4 L·ha ⁻¹	29.4 c	—	139.4 a	—	64.8 a	—
Factorial arrangement, orthogonal contrast						
5 mL·L ⁻¹ vs. 7.5 mL·L ⁻¹ Tergitol rate	**	—	NS	—	NS	—
5 mL·L ⁻¹ vs. 1 mL·L ⁻¹ Tergitol rate	**	—	NS	—	NS	—
7.5 mL·L ⁻¹ vs. 1 mL·L ⁻¹ Tergitol rate	NS	—	NS	—	NS	—
935.4 L·ha ⁻¹ vs. 1870.8 L·ha ⁻¹ spray volume	*	—	NS	—	NS	—
Interaction						
Tergitol rate × spray volume	NS	—	NS	—	NS	—

^zMean separation within columns by LSD at 0.05.

^yTrees were at 85% bloom in 'August Lady' and in 75% bloom in 'Zee Lady' at the time of application.

^xNSNonsignificant at 0.05 level. Each value is the mean of three blocks, each with eight trees.

Table 4. Effect of Tergitol-TMN-6 on fruit set and return in 'Empress' plum in 2004.^{zy}

Treatment	Orchard 1 fruit set, fruit/cm ²	Orchard 1 fruit weight, g	Orchard 2 US no. 1, %	Orchard 2 return, \$US/bin
Control	28.9 a	156.7 b	14.6	163.73
Tergitol 7.5 mL·L ⁻¹ at 1870.8 L·ha ⁻¹	11.7 b	155.5 b	36.6	211.90
Tergitol 10 mL·L ⁻¹ at 1870.8 L·ha ⁻¹	7.5 b	207.1 a	44.7	233.77
Tergitol 12.5 mL·L ⁻¹ at 1870.8 L·ha ⁻¹	7.2 b	192.7 a	41.1	223.23

^zMean separation within columns by LSD at 0.05. Each value is the mean of three blocks, each with eight trees.

^yTrees were at 75% to 80% bloom at the time of applications. US no. 1 refers to high-quality fruits. Each bin of plum is about 400 kg. \$US/bin is the net amount per bin that was paid to the grower by the packing house.

Table 5. Effect of Tergitol-TMN-6 application on fruit set, weight, and yield of 'Zee Lady' and 'Snow Giant' peaches at the University of Idaho Pomology orchards in 2005.^{zyx}

Treatment	Fruit set, fruit/cm ²		Fruit weight, g		Yield, kg/tree	
	Zee Lady	Snow Giant	Zee Lady	Snow Giant	Zee Lady	Snow Giant
Control ^z	36.7 a	29.9 a	189.1 b	289.0 a	17.4 a	14.9 a
Tergitol 7.5 mL·L ⁻¹	22.0 b	29.5 a	209.2 a	273.2 a	14.6 ab	14.5 a
Tergitol 10 mL·L ⁻¹	22.5 b	29.8 a	210.3 a	286.1 a	15.6 a	14.9 a
Tergitol 12.5 mL·L ⁻¹	13.2 c	18.3 b	211.1 a	277.9 a	11.7 b	11.2 b

^zMean separation within columns by LSD at 0.05. Trees in all treatments, including control, were hand thinned after fruit set calculation. Trees in 'Zee Lady' were at 75% bloom and those in 'Snow Giant' were in 85% bloom at the time of application.

^yAll applications were made at a rate of 1870.8 L·ha⁻¹.

^x'Zee Lady' was at 75% bloom and 'Snow Giant' was at 85% bloom at the time of application.

Table 6. Effects of Tergitol on 'July Red' nectarine fruit set, weight, russetting, and yield in 2005.^{zy}

Analysis of treatments	Fruit set, %	Fruit weight, g	Russetting, %	Yield, kg/tree
Treatment				
Control ^z	45.6 a	147.5 c	10.1 a	99.9 a
Tergitol 7.5 mL·L ⁻¹ once at 80% to 85% bloom	29.8 b	195.7 ab	14.8 a	75.7 a
Tergitol 10 mL·L ⁻¹ once at 80% to 85% bloom	30.9 b	173.5 b	9.7 a	82.4 a
Tergitol 7.5 mL·L ⁻¹ at 35% and 80% to 85% bloom	15.5 c	206.9 a	14.9 a	72.4 a
Tergitol 10 mL·L ⁻¹ at 35% and 80% to 85% bloom	12.3 c	206.0 a	14.6 a	91.3 a
20 mL·L ⁻¹ lime sulfur and 20 mL·L ⁻¹ CFO at 35% and 80% to 85% bloom	50.4 a	174.0 b	9.6 a	98.4 a
Factorial arrangement, orthogonal contrast				
Tergitol 7.5 mL·L ⁻¹ vs. 10 mL·L ⁻¹	NS	NS	NS	NS
Frequency of application (once vs. twice)	**	*	NS	NS
Interaction				
Tergitol rate × frequency of application	NS	NS	NS	NS

^zMean separation within columns by LSD at 0.05.

^yAll applications were made at a rate of 1870.8 L·ha⁻¹.

^{NS}Nonsignificant at 0.05. Trees in all treatments, including control, were hand thinned after fruit set calculation. CFO, Crocker's fish oil.

between rate and frequency of application of Tergitol-TMN-6 for fruit set, quality, or yield in nectarine (Table 6).

In Utah orchards, application of Tergitol-TMN-6 at 10 mL·L⁻¹ or 12.5 mL·L⁻¹ reduced fruit set in 'John Henry', 'O'Henry', and 'Angelus' cultivars (Table 7). Although fruit set was reduced proportionally to the Tergitol-TMN-6 concentrations, fruit reduction with 7.5 mL·L⁻¹ was not significantly different from the control. None of Tergitol-TMN-6 treatments in the Utah orchards resulted in reduction of yield compared with control trees.

General comments

Considering all our results from different regions and different years, we can conclude that the effective rates for Tergitol-TMN-6 for stone fruit blossom thinning is between 5 mL·L⁻¹ and 12.5 mL·L⁻¹. It also appears that a spray volume of either 1870.8 L·ha⁻¹ or 935.4 L·ha⁻¹ is effective in blossom thinning of peach when using Tergitol-TMN-6, although 1870.8 L·ha⁻¹ seems to be more effective. Spray volume of blossom thinners can affect fruit set. Time, temperature, bloom developing stages, and varietal differences are very important factors influencing the effectiveness of blossom thinning in peaches. It is essential that blossom thinners be applied when some, but not all, fertilization has taken place. Also, the severity of frost damage must be considered before determining rates of any blossom thinner. In apples, the best time to spray to thin blossoms is when the king bloom is open and fertilized, and only one side bloom is open but not fertilized (Fallahi and Willemsen, 2002). At this stage, the other side blooms are at the "popcorn" stage or

slightly (but not completely) open, and not fertilized. However, because stone fruits do not have king blooms, an arbitrary percentage of blooms should be used as a gauge for timing blossom-thinning applications in these fruits. Based on our experiments, it seems that when about 75% to 80% of blooms are open, and when reasonably good pollination and fertilization conditions exist before application, this is an optimum stage for spraying Tergitol-TMN-6. It also seems that higher concentrations of Tergitol-TMN-6 are needed when the percentage of open blooms is higher (i.e., 85%–100%). However, we note that the actual degree of fertilization may vary from orchard to orchard, even if both orchards are at an identical stage of bloom. Therefore, temperature and bee activity should be closely observed and taken into account for timing of blossom-thinning spray. Temperature affects bee activity and subsequently the number of fertilized flowers. Temperature also affects the chemical characteristics and the effectiveness of blossom thinners. Further research is needed to find a better method for a quick determination of the proper stage based on physiological development of pollen tube or fertilization of the ovules.

A double application of Tergitol-TMN-6 (~35% and 80% to 85% open bloom) was also effective in thinning and seemed to be slightly better than a single application. However, a double application may pose a number of problems and risks. The first potential problem is overthinning, because a sufficient number of flowers may not have been fertilized at the times of application. The second problem is that the span of time for the application of any blossom thinner is

very limited and it may not be always feasible to apply the thinner twice, particularly in a large commercial setting when several hectares of orchards should be sprayed within a limited time window. Mode of action in some blossom thinners could be more than just being caustic, and each variety could react differently to blossom thinners in each region. For example, Wilkins and associates (2004) reported that the application of Tergitol-TMN-6 from popcorn to shuck-off stages resulted in good thinning in 'Fireprince' peach, and the efficacy of the chemical applied at full bloom was similar to that at petal fall in Alabama. Certainly at shuck-off, whatever fertilization that is to take place will have taken place. Perhaps, as observed in the study by Byers and Lyons (1985), it was the killing of the peduncle and some other tissue that gave this chemical such a wide window of efficacy in the study by Wilkins and colleagues (2004). However, in our study we noticed that application of Tergitol-TMN-6 at an earlier stage of bloom (i.e., less percentage of blooms open) was more effective than late application. This contradiction suggests that the mode of action of Tergitol-TMN-6 could interact with varietal and environmental factors.

One should be cautious about fruit marking and leaf burning with the application of any blossom thinner. Slow drying conditions, as well as late applications, increase the possibility of fruit marking and leaf burning. However, in our study, fruit marking was not observed in any location or at any concentration of Tergitol-TMN-6 in stone fruit. Leaf burning is often associated with blossom-thinning applications (Fallahi and Willemsen, 2002). Although Tergitol-TMN-6 induced varying degrees of leaf and foliage burning, even the most severe symptoms disappeared after a few weeks, and did not cause any adverse effect on the following year's crop. Also, because fruit size at harvest was not adversely affected with the application of Tergitol-TMN-6 in the range of 5 to 12.5 mL·L⁻¹, it is doubtful if the overall photosynthetic capacity of the whole tree is diminished over a long time with this chemical.

Because trees in all treatments were hand thinned after fruits were counted for fruit set calculations, yield and quality differences at harvest were not always significant. However, the earlier thinning of flowers resulted in production of larger fruits in some Tergitol-TMN-6 treatments. That is because fruit-to-fruit competition in the trees receiving some Tergitol-TMN-6 treatments was reduced several weeks before the time that the control trees were thinned. Thus, in addition to the major reduction in the cost of hand thinning, fruit size at harvest, in some cases, may increase with the use of Tergitol-TMN-6. The larger fruit size in these cases often compensated for the fewer fruits, resulting in a similar yield to the control trees that had only hand thinning several weeks after bloom.

Currently we are cooperating with several researchers on evaluating Tergitol-TMN-6 in

Table 7. Effects of Tergitol on fruit set in different cultivars of peaches in Utah in 2005.^{zy}

Treatment	Fruit set, %		
	John Henry	O'Henry	Angelus
Control	68.0 a	83.3 a	56.2 a
Tergitol 7.5 mL·L ⁻¹ once at 80% bloom	66.8 a	79.5 ab	53.1 ab
Tergitol 10 mL·L ⁻¹ once at 80% bloom	56.0 b	72.7 b	41.9 b
Tergitol 12.5 mL·L ⁻¹ once at 80% bloom	50.1 b	71.8 b	39.5 b

^zMeans within columns are separated by LSD at 0.05.

^yAll applications were made at a rate of 1870.8 L·ha⁻¹.

different states and regions. The results presented here have been a valuable basis for these studies, and we think that Tergitol-TMN-6 may have the potential to become a reliable blossom thinner for stone fruits after more regional tests and registration.

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