Tergitol as a possible thinning agent for peach cv. Redhaven

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Abstract

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The effect of different blossom thinners ammonium thiosulfate (ATS) (1%, 2%), Armothin (1.5%), Tergitol-TMN-6 (0.5%, 1%), applied on peach cv. Redhaven at 50–60% full bloom was evaluated in thinning experiments in south-west Slovenia. The photosynthesis inhibitor metamitron (0.05%) applied at 8 mm fruit diameter was evaluated as fruitlet thinner as well. Application of 2% ATS resulted in excessive thinning. The thinning effect of 1% ATS was also too strong in two out of three thinning experiments. The use of 0.05% metamitron did not cause any thinning effect on peach trees and gave similar results as the non-treated control. The effective fruit set reduction and increase of average fruit weight was achieved with 0.5% and 1% Tergitol application. In three-year experiment both Tergitol applications reduced fruit set toward hand thinned level, but the share of fruit from bigger size class was only once enhanced to the level of hand thinned trees. No sign of phytotoxicity was noticed on fruits in all thinner application treatments.

Keywords: *Prunus persica*; blossom thinning; ammonium thiosulfate; Armothin; Tergitol-TMN-6; metamitron

Thinning of peach (*Prunus persica* [L.] Batch) is a necessary cultural practice to achieve larger fruit size and improve fruit quality. Thinning usually reduces total yield, but when properly carried out increases economic yield (Wertheim, Webster 2005). Peach thinning can be done as pre-bloom thinning (e.g. flower bud reduction), during the bloom (e.g. flower chemical thinning) or as post-bloom thinning (e.g. fruitlet hand thinning practice) (Reighard et al. 2006). Early thinning is important because of its impact on fruit size, although there is some reluctance by growers to eliminate a proportion of the flowers prior to ensuring adequate fruit set, especially in regions where spring frosts are common. However, in peaches the way to reduce fruit set chemically is to apply a caustic thinning agents during bloom, which interfere the fertilization by damaging different flower parts, while unfortunately all post-bloom hormone-type thinners are ineffective (Greene et al. 2001; Fallahi, Greene 2010). Thinning of fruit by hand is still the most common method of reducing crop load in peaches, which is usually carried out around 40–50 days after full bloom, but it is an expensive work as it requires significant labour (Byers et al. 2003). Chemical thinning of peach would be much less expensive than hand thinning, but it is not common in commercial orchards since it is considered risky due to inconsistent results (Osborne, Robinson 2008).

Numerous compounds were tried for peach blossom thinning including fertilizers like ammonium thiosulfate (ATS), surfactants like Armothin, Tergitol-TMN-6 and other caustic agents such as endothalic acid, pelargonic acid, hydrogen cyanamide, lime sulfur, different oils. Some of them demonstrated to be acceptable as blossom thinners for the cultivars studied in the investigated area (Southwick et al. 1996; Fallahi 1997; Fallahi et al. 1998, 2006; Ebel et al. 1999; Greene et al. 2001; Osborne et al. 2006; Miller, Tworkoski 2010). Since phytotoxicity may be caused using different agents, concentrations need to be determined for each cultivar at the given climatic conditions. It was reported that chemicals which suppress photosynthesis, including the herbicide terbacil or metamitron can induce fruit abscission in apples and peaches (Dennis 2000; Lafer 2010). However, none of the proposed agents has been included in the common peach thinning practice in Europe, yet.

The aim of this study was to evaluate the effectiveness of different agents used as blossom thinners (ATS, Armothin, Tergitol-TMN-6) or during the stage I of fruit development (metamitron) on fruit set and yield of cv. Redhaven in the conditions of southwestern Slovenia, under the Mediterranean climate.

MATERIAL AND METHODS

The thinning experiments were conducted in 2010, 2011 and 2012 in the experimental orchard of the Fruit Growing Centre at Bilje in south west Slovenia on cv. Redhaven, grafted on GF 677 rootstock (*Prunus amygdalus* × *P. persica*). Trees were planted in 2006 at a distance of 4 × 2 m and trained to a spindle form. Standard commercial practices were performed during the experiments. The trees selected for the experiment in each year were of similar growth vigour and bloom density. The thinning experiments were designed as a complete randomized block with seven replications and a single tree plot as a statistical unit each year. In the 2010 experiment non-thinned and hand thinned trees were compared with trees sprayed with chemical agents used as thinners: ammonium thiosulfate (ATS, 60% w/w, as product Ger-ATS LG, L. Gobbi, Brescia, Italy), surfactant Armothin (98% w/v fatty amine polymer; AKZO-Nobel, Amersfoort, The Netherlands) and surfactant Tergitol-TMN-6 (90% w/w, 2,6,8-trimethyl-4-nonyloxypolyethyleneoxyethanol; Dow Chemical Co., Midland, USA). The treatments were as follows: control (no thinning), hand thinned, 1% ATS, 2% ATS, 1.5% Armothin, 0.5% Tergitol and 1% Tergitol. In the experiments conducted in 2011 and 2012 all the treatments were the same, except the Armothin treatment; it was replaced by 0.05% metamitron using Goltix WG 90 (90% w/w, 3-methyl-4-amino-6-phenyl-1,2,4-triazin-5(4H)-one; Makhteshim Agan, Ashdod, Israel).

In all three years chemicals for blossom thinning (ATS, Armothin, Tergitol-TMN-6) were sprayed when 50–60% flowers were opened, with a knapsack sprayer to the drip point on the whole tree canopy. In 2011 and 2012 metamitron treatment was applied 20 and 30 days after full bloom (DAFB), respectively, when fruit diameter was 8 mm, to the whole tree canopy as well. In all thinning experiments performed in 2010, 2011 and 2012, fruits in the hand thinning treatment were hand thinned at 40 to 50 DAFB, by spacing them to about 12 cm apart, which is similar to current commercial practice. In treatments where chemical agents were applied, no supplemental hand thinning was performed. Before the applications all flowers were counted on each tree. At harvest, fruits from the whole tree were collected in one day, graded by diameter into two size classes (> 65 mm, < 65 mm), counted and weighted. Soluble solid content was measured each year on a sample of 8 fruits per tree using a digital refractometer (PAL-1; Atago Inc., Bellevue, USA), and in 2011 and 2012 titratable acidity was also measured by titration with 0.1N NaOH to pH 8.2. Data were statistically evaluated using the analysis of variance (ANOVA) followed by means separation using Duncan's multiple range test at $P = 0.05$. All calculations were performed using the statistical program Statgraphics 5.0 (STSC, Rockwille, USA). In 2011 and 2012, the phytotoxicity was estimated in chemical treatments on flowers, leaves or shoots within the scale 1–9 (1 = no phytotoxicity, 9 = total shoot burning).

RESULTS AND DISCUSSION

Experiment 2010

Blossom thinning with ATS at both concentrations (1% and 2%) and with the higher concentration of Tergitol (1%) significantly reduced fruit set and yield compared to control treatment (Table 1). The initial number of flowers per tree was moderate, indicating weak natural fruit set in 2010, so the crop load was small, which is evident from the number of fruit/tree and the yield/tree in a hand thinned treatment and in a control treatment. However, particularly 2% ATS caused excessive thinning since the yield was only 3.8 kg/tree. Thinning results obtained by Greene et al. (2001) on cvs Garnet Beauty and Redhaven showed that the use of ammonium thiosulfate (1.9–2.5% ATS with

Table 1. Effect of blossom thinners (ammonium thiosulfate – ATS, Armothin and Tergitol-TMN-6) on final fruit number, yield/tree and mean fruit weight of cv. Redhaven in 2010 thinning experiment

Treatment	No. flowers/tree	Fruit set (No. at harvest)				Yield (kg/tree)	Mean fruit weight (g)
		per tree	per 100 flowers	> 65 mm/tree	< 65 mm/tree		
Control	302^{ab}	107^{a}	34^{a}	24^{bc}	83^{a}	11.3^{a}	117^{c}
Hand thin	255^{b}	76^{abc}	30^{ab}	42^{a}	33^{bc}	10.7^{a}	152^{a}
ATS 1%	276^{ab}	47^{cd}	15^{de}	14^{c}	33^{bc}	5.5^{bc}	129^{bc}
ATS 2%	272^{ab}	25^{d}	9^{e}	15^{c}	10^{c}	3.8^{c}	155^{a}
Armothin 1.5%	302^{ab}	75^{abc}	23^{bcd}	25^{bc}	50^{abc}	8.9^{ab}	130^{bc}
Tergitol 0.5%	325^{a}	92^{ab}	28^{abc}	31^{b}	61^{ab}	11.3^{a}	140^{ab}
Tergitol 1%	268^{ab}	58^{bcd}	20^{cd}	17^{c}	41^{bc}	6.8^{bc}	131^{bc}

[a–e]mean separation within column by the Duncan's multiple range test, $P = 0.05$

935 l water/ha) can be applied to achieve effective thinning but no over-thinning. Weak natural fruit set and relative high temperature during the application can be the reason for over-thinning effect of 2% ATS in our experiment. Also, the application of 1% ATS and 1% Tergitol caused strong reduction of final fruit set and yield/tree.

Blossom thinning treatment with 1.5% Armothin caused significant reduction of fruit set expressed by the number of fruits/100 flowers as compared to the control treatment (Table 1). Costa and Vizzotto (2000) reported that the application of Armothin at 2–3% concentration when 70–80% of the flowers opened yielded interesting results in several climatic areas of cultivation and on different cultivars. On 1.5% Armothin and 0.5% Tergitol treated trees the number of fruit/tree and the yield/tree were similar to the hand thinned treatment, while the number of bigger fruits (> 65 mm) was significantly lower. The average fruit weight in 1.5% Armothin treatment was significantly lower compared to the hand thinned treatment. It should be mentioned that average fruit weight in the experiment is relatively small since the fruits were harvested in one picking. However the average fruit weight and the number of bigger fruits (> 65 mm) in hand thinned treatment were significantly higher than those in non-thinned control.

Experiment 2011

Application of ATS at 1% and 2% reduced fruit set and yield significantly compared to non-thinned control and to hand thinning treatment (Table 2). In 2011 2% ATS caused even stronger thinning effect than in 2010. It was observed that the number of fruit at harvest per 100 flowers was only 3 in 2% ATS treatment compared to the 23 fruit/100 flowers in hand thinned treatment. The over-thinning

Table 2. Effect of blossom thinners (ammonium thiosulfate – ATS, Tergitol-TMN-6 and metamitron) on final fruit number, yield/tree and mean fruit weight of cv. Redhaven in 2011 thinning experiment

Treatment	No. flowers/tree	Fruit set (No. at harvest)				Yield (kg/tree)	Mean fruit weight (g)
		per tree	per 100 flowers	> 65 mm/tree	< 65 mm/tree		
Control	750^{a}	305^{a}	41^{a}	63^{b}	242^{a}	33.7^{a}	112^{c}
Hand thin	748^{a}	170^{c}	23^{c}	111^{a}	59^{bc}	26.1^{c}	153^{b}
ATS 1%	742^{a}	101^{d}	14^{d}	61^{b}	40^{bc}	15.3^{d}	162^{ab}
ATS 2%	786^{a}	23^{e}	3^{e}	16^{c}	7^{c}	4.1^{e}	182^{a}
Metamitron 0.05%	794^{a}	308^{a}	38^{a}	60^{b}	248^{a}	32.7^{ab}	108^{c}
Tergitol 0.5%	782^{a}	240^{b}	30^{b}	54^{b}	186^{a}	26.7^{bc}	115^{c}
Tergitol 1%	793^{a}	156^{cd}	19^{cd}	73^{b}	83^{b}	23.0^{c}	152^{b}

[a–e]mean separation within column by the Duncan's multiple range test, $P = 0.05$

effect of 2% ATS is further evident by total yield, being only 4.1 kg/tree compared to 26.1 kg/tree on hand thinned trees where about optimal yield per tree was presented. 1% ATS also thinned too strong and did not enhance the number of bigger fruits as happened on hand thinned trees.

Spraying with surfactant Tergitol at either 0.5% or 1% significantly reduced fruit set and total yield compared to the control treatment. However, final fruit set reduction after 0.5% Tergitol application was not reduced enough to diminish the share of small fruits (< 65 mm) which stayed similar to non-thinned trees. The consequence was small average fruit weight which was similar to that of non-thinned control. Final fruit number after 1% Tergitol spraying was comparable to hand thinned trees. The share of small fruits (< 65 mm) was reduced to satisfactory level after 1% Tergitol application, but the share of bigger size fruits (> 65 mm) was not enhanced enough compared to hand thinning treatment. Promising results in the reduction of fruit set in peach were obtained with the application of Tergitol-TMN-6 at ranges of 0.5% to 1.25% sprayed at about 75% to 85% of full bloom, while applications of Tergitol at 2% or 3% excessively thinned peaches (Fallahi et al. 2006). Our results from 2011 experiment show somewhat better thinning of Tergitol 1% compared to Tergitol 0.5%, but contrary to our expectation, the enhancement of the yield of bigger size fruit did not follow fruit set reduction adequately.

First results of metamitron application on peach trees in 2011 at the concentration 0.05% show that crop load (fruit No./100 flowers, total yield/tree) and average fruit weight were similar to the untreated, control trees (Table 2), indicating that metamitron spraying at the time when fruit diameter was around 8 mm (20 DAFB) had no thinning effect on cv. Redhaven in this thinning experiment. Byers et al. (1986) reported that the application of terbacil (photosynthetic inhibitor as well) at 300 ppm (0.03%) to cv. Redhaven 35 days after full bloom reduced the crop load to approximately the desired fruit density and that lower rates were ineffective. Field studies on 20 to 25-year-old peach trees of cv. Madison showed the effectiveness of terbacil in increasing fruit abscission and that the 1,000 ppm treatment resulted in fruit size similar to that on hand thinned trees (DelValle et al. 1985). Thinning experiments performed on apples with metamitron at 350 ppm showed different thinning efficacy, depended upon the time of application, and inconsistent thinning results among years were also observed (Lafer 2010; Basak 2011).

Experiment 2012

As in the experiments of previous years, in 2012 ATS treatment at 2% resulted in excessive thinning, causing too big reduction of crop load (Table 3). Application of 1% ATS did not thin significantly compared to control (non-thinned) treatment in 2012, which is rather different than it was in the 2010 and 2011 experiments, and shows inconsistent thinning effect obtained by ATS. Like in the previous year 0.05% metamitron application had no thinning effect, since the crop load, total yield/tree and average fruit weight were similar to the non-thinned control. In contrast, a thinning effect was observed at both applications of Tergitol. Tergitol (0.5% and 1%) application reduced fruit number/tree at harvest and increased

Table 3. Effect of blossom thinners (ammonium thiosulfate – ATS, Tergitol-TMN-6 and metamitron) on final fruit number, yield per tree and mean fruit weight of cv. Redhaven in 2012 thinning experiment

Treatment	No. flowers/tree	Fruit set (No. at harvest)				Yield (kg/tree)	Mean fruit weight (g)
		per tree	per 100 flowers	> 65 mm/tree	< 65 mm/tree		
Control	760^{a}	242^{a}	33^{a}	67^{ab}	175^{a}	26.9^{a}	112^{c}
Hand thin	706^{a}	145^{cde}	20^{cd}	97^{a}	48^{c}	22.1^{ab}	157^{a}
ATS 1%	737^{a}	201^{abc}	27^{abc}	82^{ab}	120^{ab}	25.4^{a}	130^{bc}
ATS 2%	721^{a}	95^{e}	12^{e}	51^{b}	44^{c}	13.6^{c}	161^{a}
Metamitron 0.05%	751^{a}	221^{ab}	29^{ab}	51^{b}	170^{a}	22.3^{ab}	108^{c}
Tergitol 0.5%	770^{a}	162^{bcd}	22^{bcd}	80^{ab}	83^{bc}	23.4^{ab}	145^{ab}
Tergitol 1%	735^{a}	136^{de}	19^{de}	65^{ab}	71^{bc}	17.9^{bc}	139^{ab}

$^{a-e}$mean separation within column by the Duncan's multiple range test, $P = 0.05$

average fruit weight significantly compared to control treatment. There was no significant difference in crop load, total yield/tree and the average fruit weight in comparison with the hand-thinned treatment. Also the number of bigger fruits from both Tergitol treatments was not significantly different regarding the hand-thinned treatment. However in 2012, the number of bigger fruits from 0.5% Tergitol treated trees was higher than in 1% Tergitol treatment.

Analyses of soluble solid and titratable acids content in fruit flesh performed in 2011 showed no significant differences among treatments (Table 4). In 2012 only fruit sample of 2% ATS showed higher content of soluble solids than control treatment; the difference was small, but statistically significant. Regarding the titratable acids measured, significantly less acids were found in fruits from metamitron treated trees than in fruits from ATS or hand thinned trees. However, none of thinning treatments differed significantly from control regarding fruit acidity.

In all three years, the phytotoxicity was followed up to 5 weeks after blossom thinner application. Blossom thinners were applied when around 50–60% flowers were opened, so they affected the open flowers. The injury to flowers estimated three days after application was the most evident at higher (2%) dose of ATS, where around 80% flowers/petals were damaged, had brownish appearance. Less damage to flowers was observed at 1% ATS and 1% Tergitol applications, where around 40–50% flowers showed brownish appearance. At 0.5% Tergitol, the evidence of flower damage was the least expressed. In case of ATS, the concentration at 2% affected also leaf development, which was seen as less developed leaf foliage and was observed up to three weeks after treatment. After that, this effect disappeared. Additionally, some burned shoots (2–5 shoots/tree) were also observed after the application of 2% ATS. Other blossom thinner treatments (1% ATS and both Tergitol concentrations) did not affect leaf development. The metamitron treatment after bloom, when the fruit size was around 8 mm caused light yellow discoloration between the veins and slight necrosis on the edge of the leaf, which was visible one week after application but could not be seen few weeks later. No signs of phytotoxicity were noticed on fruits in either thinner application treatment.

Results obtained from 2010 to 2012 thinning experiments show that ATS at 2% caused excessive thinning of cv. Redhaven with too strong yield reduction, which is undesirable, although in this treatment the mean fruit weight was increased the most. Osborne and Robinson (2008) for cv. Rising star reported that the severe over-thinning occurred at ATS 5%, while ATS 3.5% thin effectively with reduced crop load and improved total crop value. In this report ATS treatments were applied by air-blast sprayers at spray volume of 935 l/ha, which is similar water consumption as in our experiments. The thinning effect of ATS at 1% was also too strong in our experiments in years 2010 and 2011, while in 2012 it did not show significant thinning effect compared to the untreated control, which indicated inconsistent ATS performance. Inconsistent thinning response obtained by ATS application in peach and apple was reported also by Miller and Tworkoski (2010). In both years of our study, the 0.05% metamitron post bloom application, at the stage when fruit diameter was around 8 mm, demonstrated the lack of thinning, since the final fruit set, the fruit number in both size classes, yield per tree and the average fruit weight were similar to the non-thinned control. Over the three years of our study the application of

Table 4. Soluble solids content and titratable acids of cv. Redhaven in 2011 and 2012 thinning experiment

Treatment	2011		2012	
	soluble solids (°Brix)	titr. acids (mg/100 g)	soluble solids (°Brix)	titr. acids (mg/100 g)
Control	9.4[a]	6.16[a]	9.7[b]	7.44[abc]
Hand thin	9.6[a]	5.97[a]	10.1[ab]	7.84[ab]
ATS 1%	9.8[a]	6.10[a]	10.0[ab]	8.16[a]
ATS 2%	9.9[a]	5.96[a]	10.4[a]	7.73[ab]
Metamitron 0.05%	9.9[a]	5.86[a]	10.3[ab]	6.70[c]
Tergitol 0.5%	9.9[a]	5.95[a]	10.2[ab]	7.12[bc]
Tergitol 1%	9.7[a]	6.19[a]	10.0[ab]	7.43[abc]

[a–c]mean separation within column by the Duncan's multiple range test, $P = 0.05$

Tergitol gave promising thinning results, which is in accordance with reports from literature (Fallahi et al. 2006). Although the results have been variable from year to year in our experiments, it can be concluded that good thinning effect was obtained by applying Tergitol at 0.5%. In this treatment the crop load was reduced compared to non-thinned control, and the average fruit weight was increased. In comparison to control trees the 0.5% Tergitol application significantly reduced final fruit number twice in the three-year experiment. Twice, the final fruit number was comparable to the hand thinned treatment. On the other hand, it should be noted that Tergitol application (especially at higher concentration) did not enhance the yield of bigger size class fruit adequately, as normally occurred on hand thinned trees. However, there is an indication that for the cultivar studied, the application of Tergitol 0.5% at blossom, supplemented with additional fruit hand thinning can be a good and safe approach toward reducing hand thinning expenses and achieving good fruit quality results. Also, no sign of Tergitol-induced phytotoxicity was visible on leaves and shoots after application even at the higher rate (1%) and no phytotoxicity was noticed on fruits.

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